CONGO GREEN CORRIDOR

DEMOCRATIC REPUBLIC OF CONGO

ECONOMIC DEVELOPMENT STUDY FOR
THE GREEN CORRIDOR IN DRC

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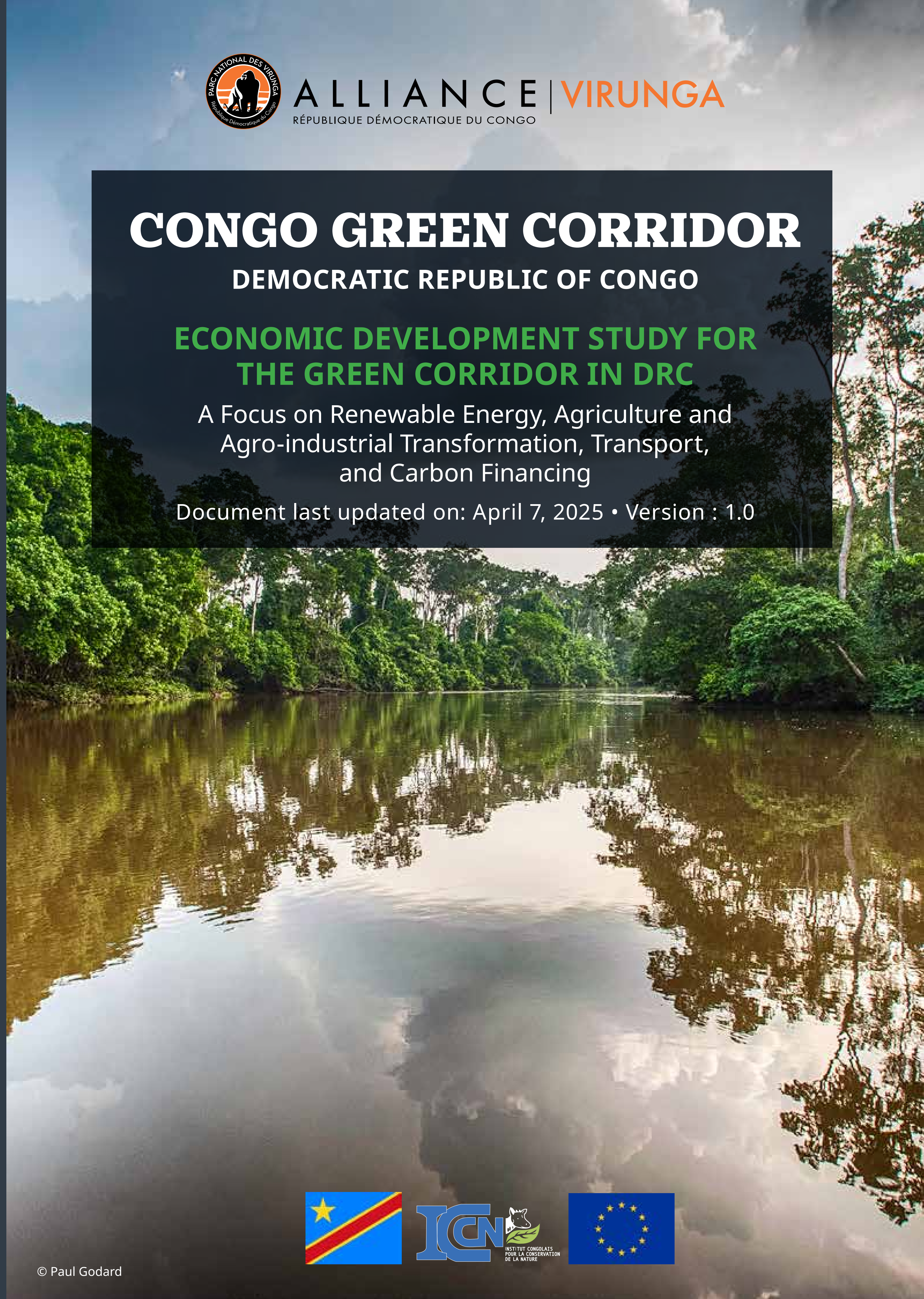

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CONGO GREEN CORRIDOR

DEMOCRATIC REPUBLIC OF CONGO

ECONOMIC DEVELOPMENT STUDY FOR THE GREEN CORRIDOR IN DRC

A Focus on Renewable Energy, Agriculture and Agro-industrial Transformation, Transport, and Carbon Financing

Document last updated on: April 7, 2025 • Version : 1.0

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EXECUTIVE SUMMARY

The Kivu-Kinshasa Green Corridor is an ambitious initiative aimed at fostering sustainable economic development, biodiversity conservation, peacebuilding, and climate action across over 500,000 km² of the Democratic Republic of Congo (DRC). Spanning from the Kivus to Kinshasa, it encompasses 285 000 km² of tropical moist forests and 60 000 km² of peatland ecosystems. It directly benefits approximately 31.5 million inhabitants who live within its perimeter, 80% of which live in 6 key cities : Kinshasa, Kisangani, Goma, Butembo, Beni and Mbandaka.

This study aims to provide a high-level analysis of the economic development potential of the Green Corridor along 4 key sectors

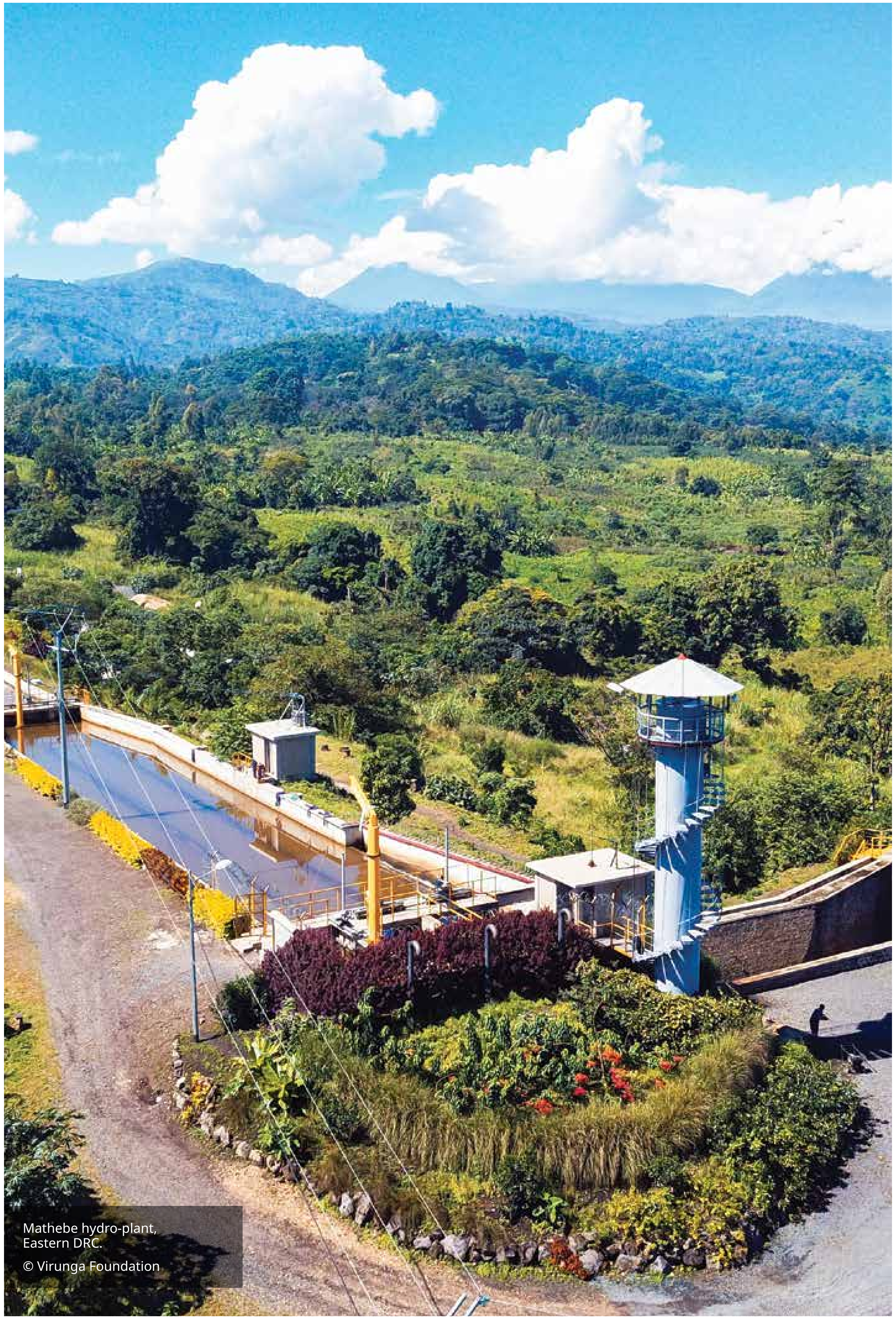
RENEWABLE ENERGY

AGRICULTURE AND AGRO-INDUSTRIAL TRANSFORMATION

CLEAN TRANSPORT

CARBON FINANCING

The study also aims to describe what the economic development potential would mean in financial terms, should it be adopted and executed following a 'private-market' approach. Results provided in this study are exploratory and would require, each, in-depth analysis at a later stage.



Mathebe hydro-plant,
Eastern DRC.

Renewable energy

There are 129 settlements within the Green Corridor, with a population of > 5 000 inhabitants. Those settlements represent ~25.5 million inhabitants, 80% of which are concentrated in 6 cities.

Electrification of those 129 settlements relies on a dual strategy :

1. Prioritization of run-of-the-river hydropower in the 6 key cities of Kinshasa, Kisangani, Goma, Butembo, Beni Mbandadue to its competitive cost at a somewhat larger scale.
2. Mini-grid photovoltaic systems with battery storage for the other 117 settlements (NB : 6 settlements are already electrified by Virunga Energies SAU) due to its flexibility, smaller fixed costs and ease of maintenance.

Improving access to electricity of the 6 key cities, based on either internal figures or established literature (e.g., World Bank), would represent the following results:

1. 14.1 mn inhabitants with access to electricity
2. $675 million invested in rehabilitating or developing new generation, transmission and distribution assets
3. $1.5 bn in yearly revenues ; $228 million if excluding Kinshasa from the scope of the study
4. $748 million in yearly profits ; $31 million (excl. Kinshasa).

Key major cities face unique challenges: Kinshasa alone requires $450 million to renovate its grid. Kisangani would require $80–100 million to rehabilitate its existing hydropower station and grid. Goma would require $20–40 million to expand the grid and reach more customers while Beni and Butembo need approximately $65–$80 million to enhance access through existing hydropower assets. Mbandaka would require $40–60 million to build generation assets and grid from scratch.

Total electrification of the 117 smaller towns and villages, reaching 3.1 million inhabitants, will require an estimated investment of $551 million, installing 112 MWp of solar capacity and 451 MWh of battery storage. However, the profitability of such venture remains highly uncertain, the average town and village turning an expected annual profit of $85 thousand and -$24 thousand respectively.

Electrification of the Green Corridor will bring additional co-benefits by deploying innovative climate solutions at scale : e-cooking and e-mobility

The city of Goma at night,
Eastern DRC
Image source: Google

- e-cooking : potential of 2-4 million tons of CO_2 avoided annually by converting up to 2 million households to electric cooking. It represents an energy demand upside of 365 GWh per year, while saving 20-40% of household expenditures for cooking.
- e-mobility : potential of 0.3-0.4 million tons of CO_2 avoided annually by converting up to 119 000 motorbikes to electricity. It represents a demand upside of 152 GWh per year, while increasing the net income of taxi men by 40%.

It is concluded that electrifying the Green Corridor has huge potential, both in terms of social impact and financial returns. However, the profitability of the electrification plan within the Green Corridor is highly dependent on Kinshasa and the 5 other key cities.

Agriculture

Agriculture holds significant potential, with **~3 million hectares currently under cultivation within the Corridor**, producing **~13 million tons per year of agricultural produce**. Key crops in the Corridor are : manioc (primarily in the west), cocoa, palm oil, coffee, banana, rice and maize.

Virunga proposes to leverage the diversity of crops within the Corridor to kickstart an large-scale agro-industrial transformation centered along three key elements:

1. **Decentralized industrial hubs**, mainly in eastern DRC, including a cocoa fermentation center, a palm oil press and between 10 - 40 eco rangers. Those hubs are meant to be self-financing, via revenues from the palm oil press and cocoa fermentation center, while offering protection against armed groups to local communities and ensuring the protection of forests.
2. **Special economic zones** that would benefit from an attractive fiscal status, offering all required services for industrials (clean energy, water, road access, ...) and attracting other private companies / investors.
3. **Key crop processing facilities**, located within the special economic zones, and focused on transforming locally harvested crops into added-value products (mainly flour). Each zone would have one or more processing plants focused on a specific crop, depending on the specificities of the zone.

Investing in agro-industrial transformation within the Green Corridor along this strategy would represent the following.

1. **Nineteen (19) industrial hubs** deployed primarily along the Beni - Kisangani road section for a total investment of $37.8 million. The hubs would be able to process 78 615 tons per year, while generating revenues of $48.9 million per year and profits of $1.4 million per year in aggregate.
2. **Six special economic zones** developed or extended around the 6 key cities of the Corridor. 80 hectares of land would be developed for a total investment of $34.2 - 48.8 million investment, and an EBITDA of $2.7 million per year.
3. **Key crop processing facilities** for maize, rice, manioc, banana, palm oil, cocoa and coffee, able to process 634 000 tons for a total investment of $159.6 million (including investing in structuring key agricultural value chains) and an EBITDA of $70.5 million.

Transport

Transportation infrastructure is critical yet underdeveloped, comprising key roads (notably RN2 and RN4) and river navigation along the Congo River. Significant rehabilitation investments are required, exemplified by the World Bank and Chinese-backed projects on RN2, yet implementation remains partial and inconsistent. Almost all roads can be considered severely degraded. River transport, essential for internal connectivity, also faces severe infrastructure constraints. Rehabilitating such infrastructure would require significant commitment from the government and mobilization of external funding.

Transport was treated, as part of this study, as a means to export the transformed products to the main markets and would represent a ~$301 million opportunity.

Exporting all products to Kinshasa would represent

- 36 365 40-feet containers.
- 51 boats required to ferry products all year round, with a transport capacity of 1250T each.

Developing the necessary fleet of barges would entail the following financial implications:

1. **CAPEX required**: $304 million invested in new barges (excluding the cost of 40-feet containers)
2. **Potential revenues**: $119 million per year (excluding road transport, and additional revenue streams such as container handling, customs clearance, etc.)
3. **EBITDA**: ~$35 million per year

Carbon financing

Deforestation and forest degradation in the Green Corridor, mainly due to wood fuel needs and subsistence agriculture, is already sizable, estimated at 2 500 - 4 000 km^2 per year. It represents typical annual emissions of 30-50 million tons of CO_2. Only 70% of forests in DRC are considered intact, down from 78% a couple of years ago.

In that context, carbon financing presents a clear opportunity and imperative, linked closely to forest and peatland preservation within the corridor. With 285,000 km^2 of tropical moist forests and over 60,000 km^2 of peatlands, the Green Corridor is strategically positioned to leverage global carbon markets, as a tool to finance its economic development and conservation plan.

The Green Corridor is estimated to hold **40 – 42 gigatons of CO_2** stock split as follows:

1. 19 – 21GtCO2 in 285 000 km^2 of tropical moist forests
2. 22 GtCO2 in 60 000 km^2 of peatland

However deforestation and forest degradation within the basin are resulting in significant CO_2 emissions, a trend which the corridor aims to reduce and halt over time. Based on the current forest loss and associated emissions rate, we estimate the carbon finance potential within the corridor to be as follows:

- With average emissions from forest loss and degradation at **30–50 million tCO_2/year**, by targeting a 50% reduction in these, the Green Corridor could credibly avoid **up to 25 million tCO_2/year**.
- Over a 5-year crediting period, this equates to **125 million tonnes of avoided CO_2 emissions**, with potential issuance of **80–100 million jurisdictional credits** after accounting for uncertainty, leakage, and permanence buffers.
- At an average carbon price of **$10–15 per tonne**, this could represent **$800 million to $1.5 billion in potential revenue from sales of the credits**, if implemented with high environmental and social integrity under standards like ART-TREES.
- Such a revenue could represent a **significant** and sustainable **funding mechanism for i)** the **conservation** activities within the corridor, **ii)** investment budget for **sustainable development** activities within the corridor's local communities **and iii) government budget for country-level sustainable development activities**. Enabling ongoing preservation of the Corridor's forested areas in perpetuity and enabling a real Green Economy within the DRC.

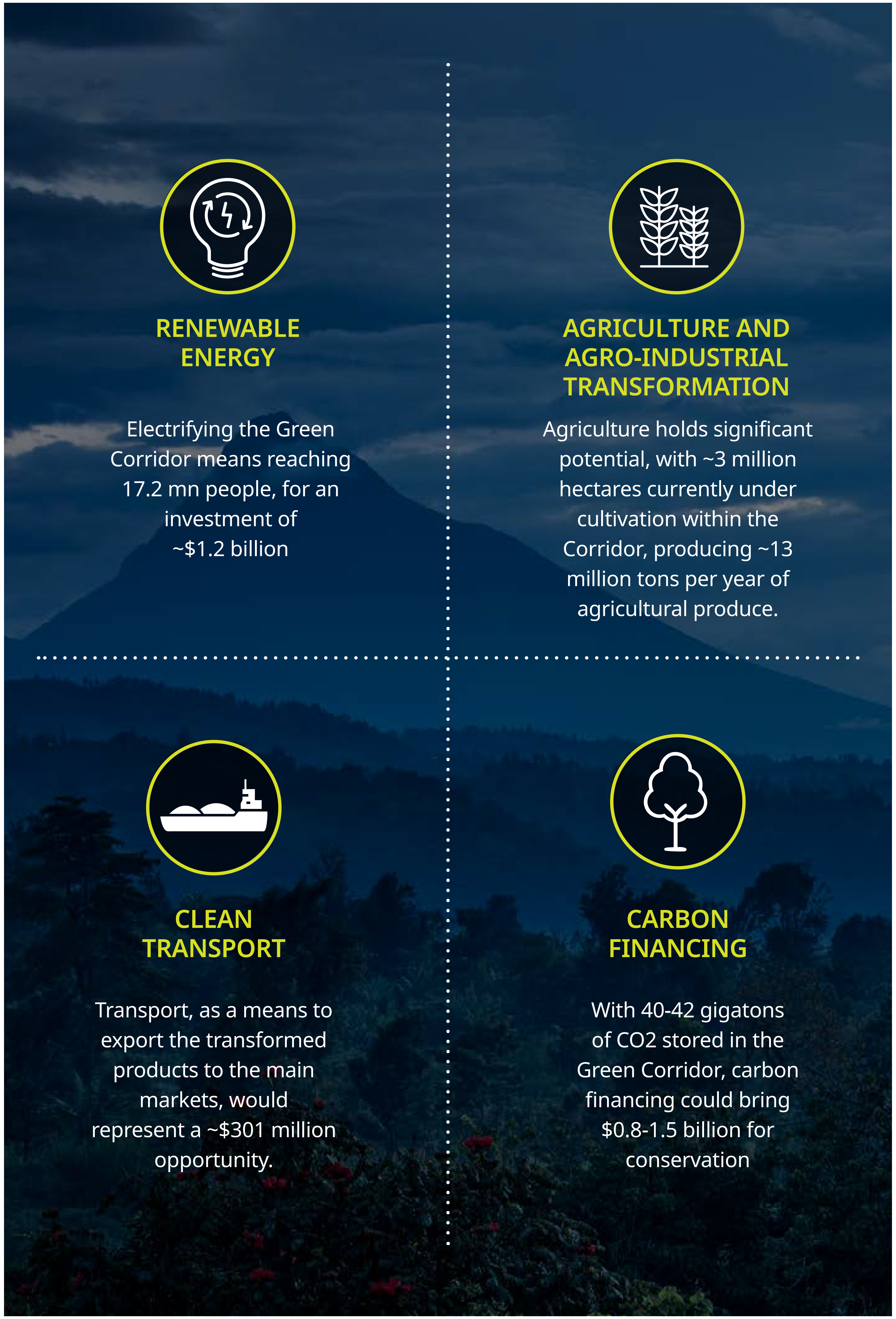
To successfully implement a program of this scale, key elements must be brought together:

Programme design and objectives:

- **Baselining of emissions** from the jurisdictional area (we have provided an estimate of this in the previous section)
- **Projecting Business-As-Usual (BAU) trends** for 2024–2030; The emissions baseline should be spatialized and projected forward to support dynamic scenario modeling
- Development of a set of **actions and initiatives to reduce the BAU** forest loss (spanning policy and on-the ground initiatives), and estimation of an associated expected reduction in forest loss (and hence emissions)

Operationalising and implementing the program:

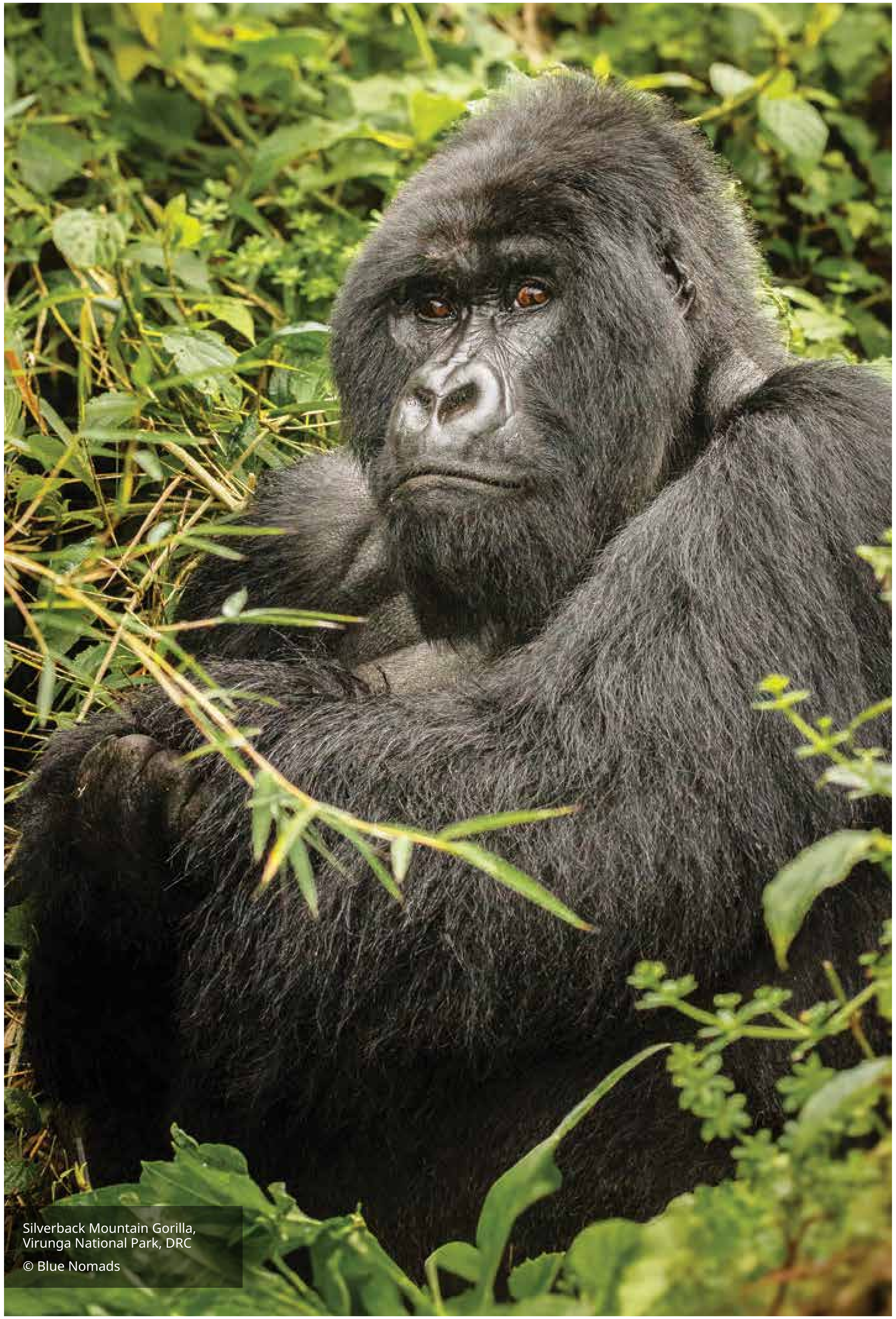
- Identification and mandating of key legal and administrative functions: identifying the entity responsible for the programme overall, establishment of local governance bodies with IPLC representation at the provincial level and identification of implementing agencies.
- The development of a dynamic **MRV platform** - key for ART-TREES eligibility;
- Delineation of **benefit-sharing, nesting, and grievance mechanisms**.



INTRODUCTION

ECONOMIC DEVELOPMENT STUDY FOR THE GREEN CORRIDOR IN DRC

Ivango Hydro Plant, DRC.
© Brent Stirton/Getty Images



Silverback Mountain Gorilla,
Virunga National Park, DRC

Introduction and objectives of document

The **Kivu-Kinshasa Green Corridor** is a unique-in-its-kind community-managed protected area spanning over **500,000 km²**, an area approximately the size of France, linking the eastern and western regions of the Democratic Republic of Congo (DRC), from the Kivus to Kinshasa. This protected area will benefit more than **31.5 million people living within its boundaries** and encompasses around **285,000 km² of primary forests** and **60,000 km² of peatlands**, representing **67% of the total peatlands in the DRC**.

Fig 1 : The Green Corridor in the Democratic Republic of Congo

The main objectives of the Green Corridor are:

- **Sustainable economic development** primarily through renewable energy, ecological agriculture and industrial transformation, green transport, and carbon financing.
- **Biodiversity conservation**, ensuring ecological connectivity to protect emblematic species such as bonobos, mountain gorillas, and okapis.
- **Peace building**, offering the means to the Congolese communities to live in peace, especially in war-torn eastern DRC
- **Climate action** by protecting over **100,000 km² of primary forests** currently not protected and **60,000 km² of peatlands**, crucial for their role as carbon sinks.

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CONGO GREEN CORRIDOR

The primary objective of this study is to develop a high-level roadmap for economic development projects within the Green Corridor, strategically structured around four key sectors: renewable energy, agriculture, transport, and carbon financing. This roadmap aims to outline feasible, high-impact initiatives that leverage sustainable practices to stimulate regional economic growth and environmental protection. Additionally, the study will assess financial requirements and potential revenue streams associated with these projects, providing actionable insights into funding strategies and economic viability to attract investment and ensure long-term sustainability.

All results presented in this study are meant to be high-level and directional. Each project will require an in-depth further analysis should it go to the development stage.

RENEWABLE ENERGY

Progress in creating electricity access to rural regions around Goma, DRC.

Progress in creating electricity access to rural regions around Goma, DRC.
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Renewable Energy

The current section on renewable energy builds and expands on the cornerstone study conducted by the World Bank in 2020[1]. While we provide a high-level estimate of the opportunity, based on data and sound modelling, for all major settlements along the Congo River, it is important to note that each city will require a dedicated feasibility study at the time of project development to optimize electricity access and associated costs.

Data used

The study focused on the urban center[2], defined in *Appendix 4*, of 129 villages and towns located inside the Green Corridor, representing a total population of 25 million inhabitants. The median population in urban centers is 26 214 inhabitants per village / town[3], with the following 6 cities accounting for ~80% of the total population contained in urban centers across the Green Corridor:

1. KINSHASA 15.50 mn inhabitants	**2. KISANGANI** 1.30 mn inhabitants	**3. GOMA** 1.05 mn inhabitants
4. BUTEMBO 0.95 mn inhabitants	**5. BENI** 0.75 mn inhabitants	**6. MBANDAKA** 0.55 mn inhabitants

[1] World Bank. 2020. Increasing access to electricity in the Democratic Republic of Congo. Opportunities and challenges. Washington, DC: World Bank.
[2] The notion of urban centers has been introduced in this study as a means to optimize capital expenditures and business profitability. Transport and distribution of electricity account for a significant share of capital expenditure and depend primarily on km2 to be electrified while revenues are primarily dependent on density of people within a specified area. The notion of urban center allows to define a minimum people density threshold above which it makes business sense to electrify an area.
[3] To be compared to an estimated 31.5 mn people living within the boundaries of the Green Corridor

To develop an electrification strategy, the study focuses on settlements with over 5 000 inhabitants.

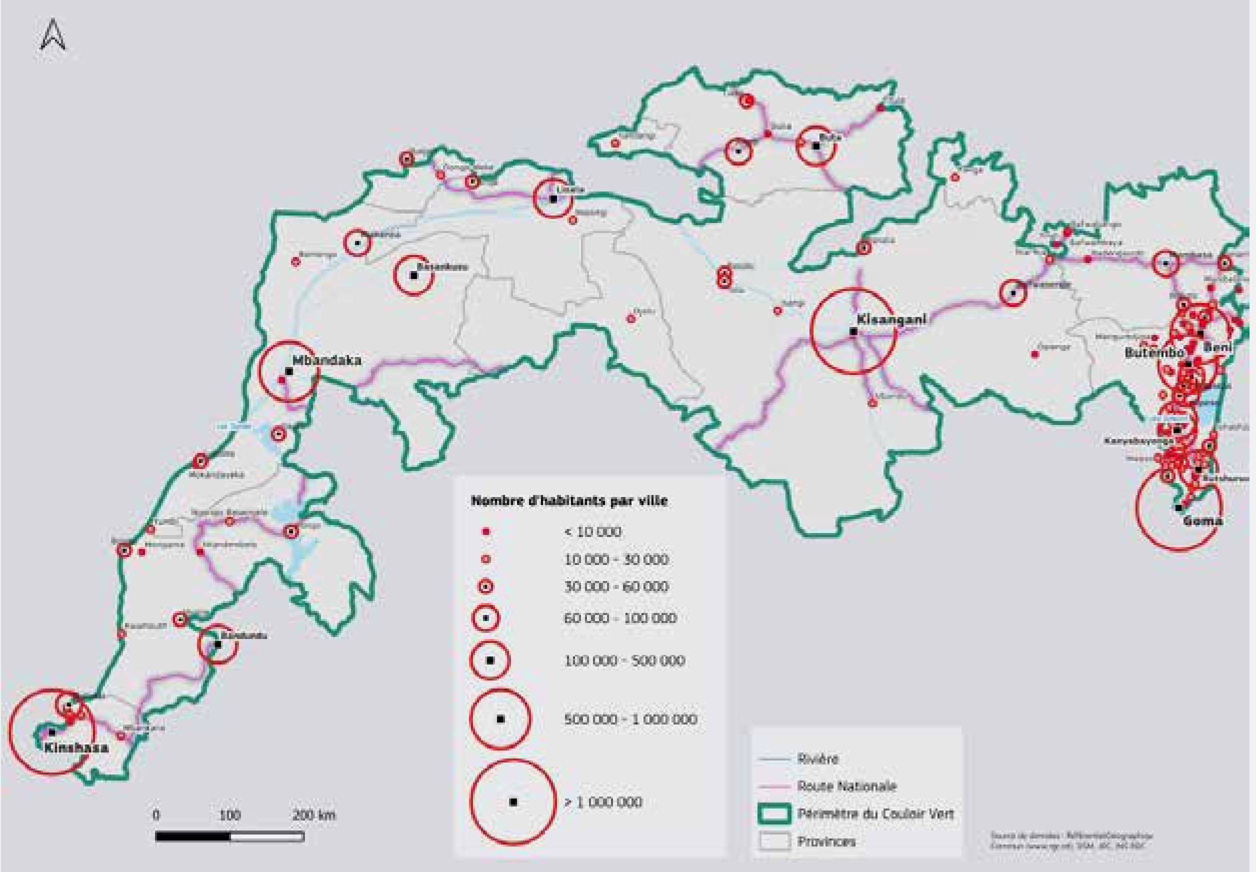


Fig 2 : Settlements with > 5 000 inhabitants within the Green Corridor

Baseline strategy

The electrification strategy in the Green Corridor prioritizes run-of-the-river **hydropower** as the primary energy source, given its lower **Levelized Cost of Electricity (LCOE)** (typically **$0.02–0.05/kWh**) and higher reliability and availability compared to solar power (LCOE typically **$0.04–0.08/kWh**, but reaching up to $1/kWh for off-grid, rural solar farms). However, because hydropower requires significant initial capital investment, it is often economically unsuitable for small-scale village electrification. In such scenarios, **solar energy** becomes the preferred solution due to its lower upfront capex, scalability, flexibility, and suitability for lower-capacity installations.

Therefore, as part of the electrification of the Green Corridor, the following baseline strategy is proposed:

1. For large cities with populations exceeding **500,000 inhabitants**, and a sizable hydropower (typically > 5 MW) source nearby (typically less than 60 km, hydropower is the technology of choice to generate electricity for the urban centers).
2. For all other cities and villages, solar (photovoltaic coupled with batteries) is used to electrify the urban centers.

Electrification of large cities

In this section, we provide an overview of the opportunities for electrification of large cities - based on GIS and urban centre analysis carried out for this study and existing estimates from literature (e.g. World Bank). As mentioned above, such results will need to be validated and reviewed in detail during feasibility studies and after possible authorization. It is important to note that the current study might not include or consider all ongoing electrification projects.

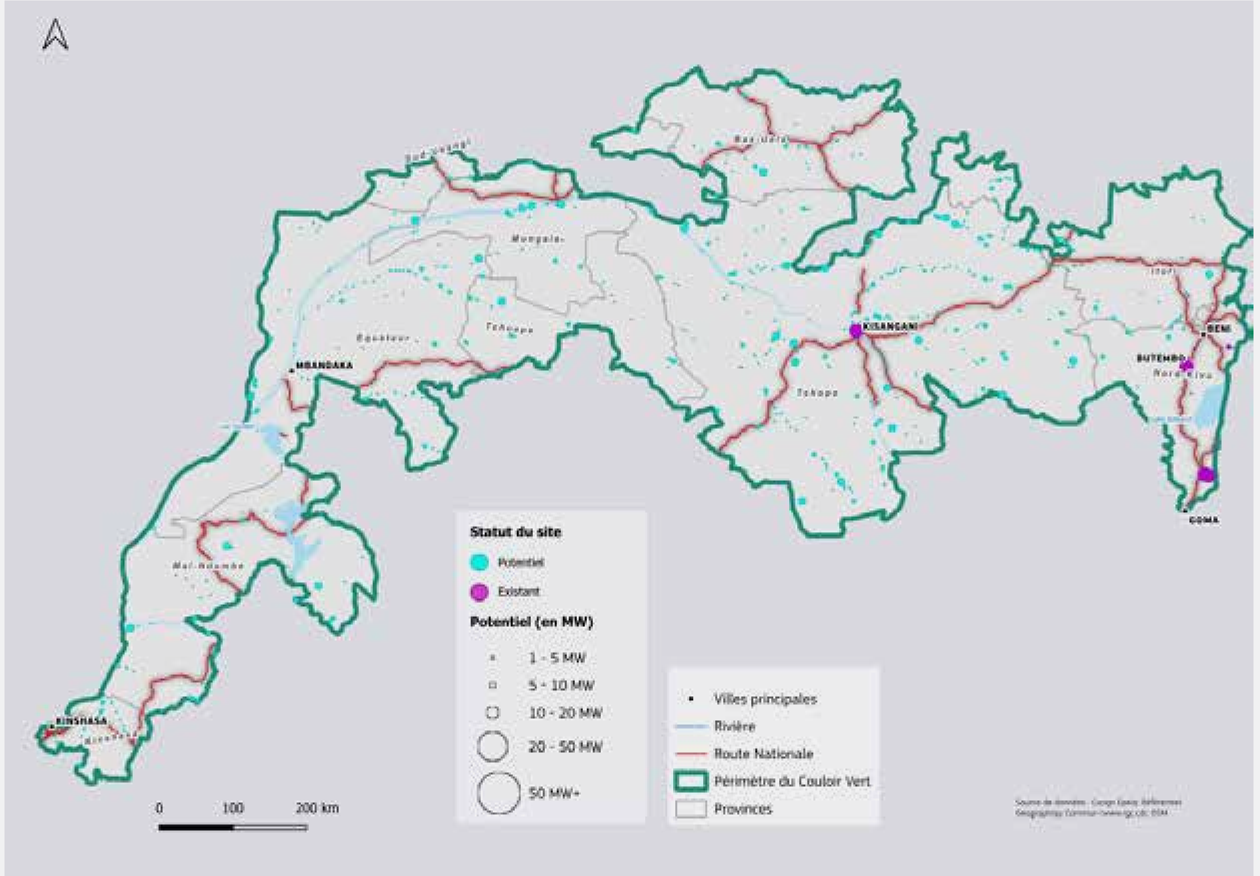


Fig 3 : overview of hydrological potential and existing sites

Kinshasa

Kinshasa, the capital of the Democratic Republic of Congo (DRC), faces significant challenges in its electrification landscape despite an electrification rate estimated at 97% by Resource Matters[4], an NGO.

Kinshasa's electricity grid is characterized by a combination of significant potential and persistent challenges. The city relies heavily on hydropower, with the Inga I and II dams on the Congo River supplying approximately 90% of its electricity. Despite this, the grid infrastructure remains underdeveloped, leading to frequent power outages that disrupt daily life and hinder economic activities. Recent efforts to modernize the system include the rehabilitation of a major substation for the Inga dams aiming to stabilize and enhance the efficiency of electricity transmission and distribution. The development of the Kinsuka power station aims at reducing load shedding. However, to fully harness the city's hydropower potential and ensure a reliable electricity supply, further investments in infrastructure and maintenance are essential.

[4] https://congoepela.resourcematters.org/en/data#loc=12.25/-4.3603/15.23409

Access to electricity allows a broad range of co-benefits, such as e-cookers.

E-cooker being used in a domestic setting, Goma, DRC.
© Brent Stirton/Getty Images

The World Bank estimates that the cost of renovating the low voltage network alone of Kinshasa would represent ~450 million. Priority projects, as mentioned by the World Bank are:

- Construction of 2 power stations 200 kV/400 kV in Inga and 400kV/200kV in Kinshasa to use the full dispatch capacities of the last 2 HV lines Inga-Kinshasa
- Construction of the 220 kV lines between Zongo 2 and Kinshasa to dispatch the full capacity of Zongo 2 + Zongo 1
- Rehabilitation and maintenance of the existing grid (i.e. lines, HV/HV substations)
- Rehabilitation, densification and extension of the distribution grid (i.e. MV and LV lines, substations, transformers)

Virunga currently does not hold any formal role in the improvement of electricity access in Kinshasa but is prepared to contribute to it should it appear that it can add value to the process.

Beni & Butembo

Beni and Butembo, located in the North Kivu province of the Democratic Republic of Congo, face significant challenges in electricity access. The region encompassing Beni and Butembo has one of the lowest electricity access rates in the country, with respectively 38% and 34% of the population connected to a power grid according to Resource Matters. Private operators, such as ENK and Nuru have developed generation assets in recent years, such as the Talihya Nord I Hydropower (~10 MW). Despite these recent developments, many homes in Beni and Butembo still lack access to electricity, and those connected often experience frequent power outages, impacting daily life and economic activities, due to a lack of both generation and high-quality transmission assets.

A possible short-term solution for the lack of energy in those cities lies in the provision of electricity by the Luviro hydropower plant (14.6 MW) operated by Virunga Energies SAU, located in Ivingu and the grid of which lies at the outskirt of Butembo by

1. Selling directly its electricity in newly attributed concession zones, not yet developed by existing power providers
2. Interconnecting the Luviro powerplant with existing power providers for concession zones already developed by them.

Preliminary studies have estimated the investment required for such a solution at around $65 - 80 million, which would allow to supply electricity to an additional 800 000 people. Such plans would require legal authorization and a review of existing concessions for both cities.

In the medium-term, the development of Talihya Sud hydropower (around 10 MW) would supply additional energy to Beni and Butembo. Such a project would represent an additional investment of $20 – 30 million.

Kisangani

Kisangani, the capital of Tshopo Province in the Democratic Republic of Congo (DRC), faces significant challenges in providing reliable electricity access to its residents. The city's primary power source, the Tshopo Hydroelectric Plant, has experienced frequent operational disruptions over the years. Originally inaugurated in 1955 with an installed capacity of 12.5 MW, the plant underwent expansion to reach 19.6 MW. However, due to technical issues and aging infrastructure, its current output has dwindled to approximately 2 MW, which is insufficient to meet the city's estimated demand of 50 MW. [5] Furthermore, SNEL's grid is in a poor state and requires significant rehabilitation.

In 2018, Kisangani endured a near-total power shutdown lasting two months, highlighting the city's vulnerability to electricity shortages. To address these challenges, several initiatives have been proposed. One such project is the Kisangani Solar Power Station, a planned 40 MW solar photovoltaic plant located near the city. Despite its potential, the project has faced delays, particularly due to the COVID-19 pandemic, and its current status remains uncertain.

Additionally, plans have been made to construct an 80 MW hydroelectric power plant at Babeba on the Tshopo River, approximately 260 km northeast of Kisangani. This project aims to significantly bolster the region's power supply[6].

Despite these proposed developments, the majority of Kisangani's population continues to rely on traditional energy sources, such as charcoal and fuelwood, due to the unreliable electricity supply.

Preliminary internal studies have estimated the capital investment required for rehabilitating both the power station and the local grid to be $80 – 100 million and would enable the supply of electricity to an additional 900 000 people.

Goma

Goma, the capital of North Kivu province in the Democratic Republic of Congo (DRC), stands as one of the cities with the best electrification rate. A study by the Anjou University revealed that approximately 83.03% of households in Goma have some form of electricity access (86% according to Resource Matters), surpassing the urban average in the DRC.

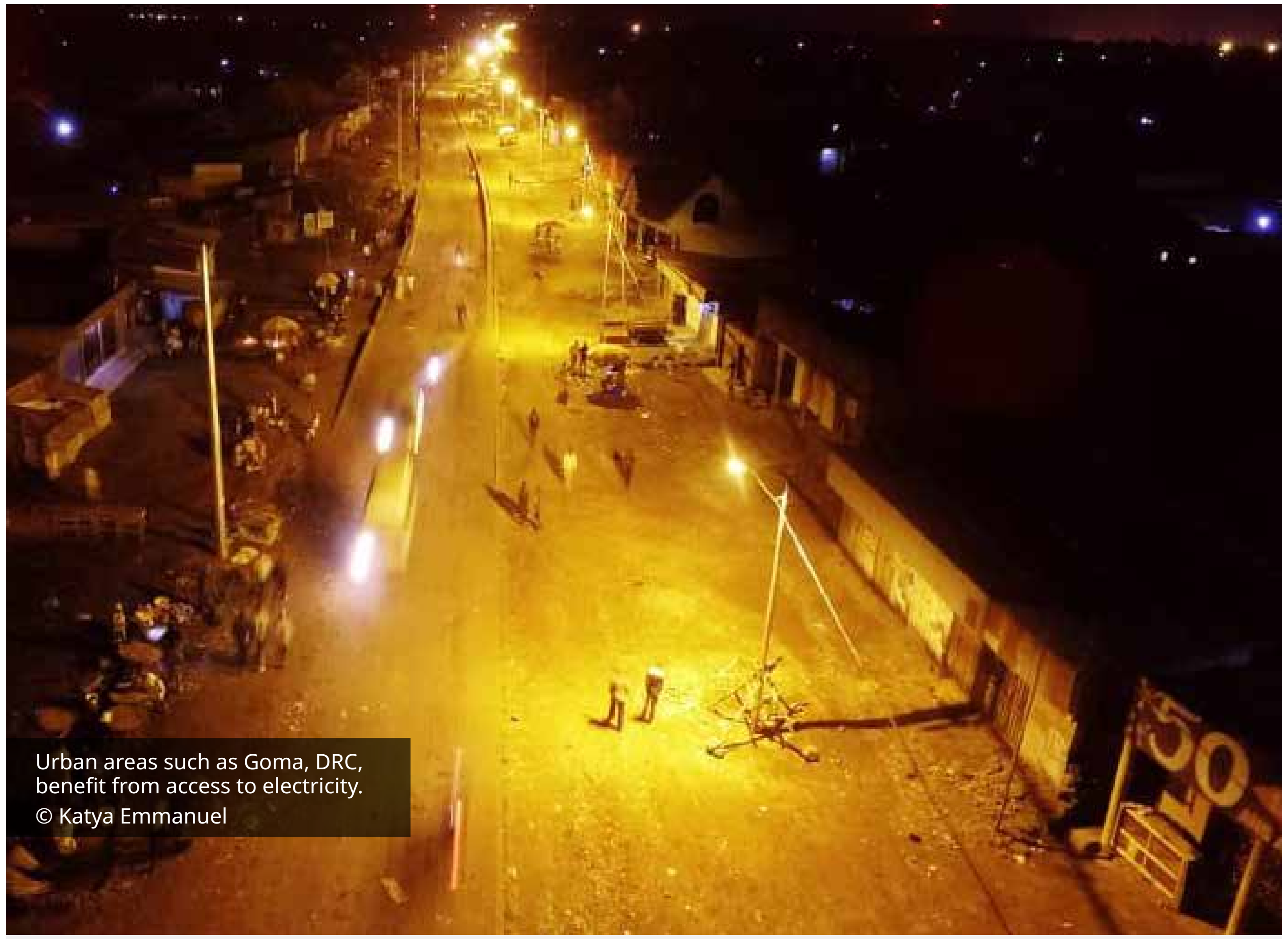
Despite this relatively high access rate, the quality and reliability of electricity supply remain concerns. Many households experience limited availability, with power often accessible only during late-night hours, especially among poorer households in SNEL's distribution concessions. Voltage fluctuations and frequent outages further compromise the dependability of the service. These issues have led to widespread dissatisfaction among residents, with approximately 34.98% expressing dissatisfaction with the current electricity services. [7]

The electricity market in Goma is characterized by the presence of multiple suppliers, including private companies such as Virunga Energies, SOCODEE, Nuru and the national utility, Société Nationale d'Électricité (SNEL).

Energy demand in Goma is estimated at 60 MW (by SNEL) – 80 MW (by the provincial government). Currently, it is estimated that actors supply:

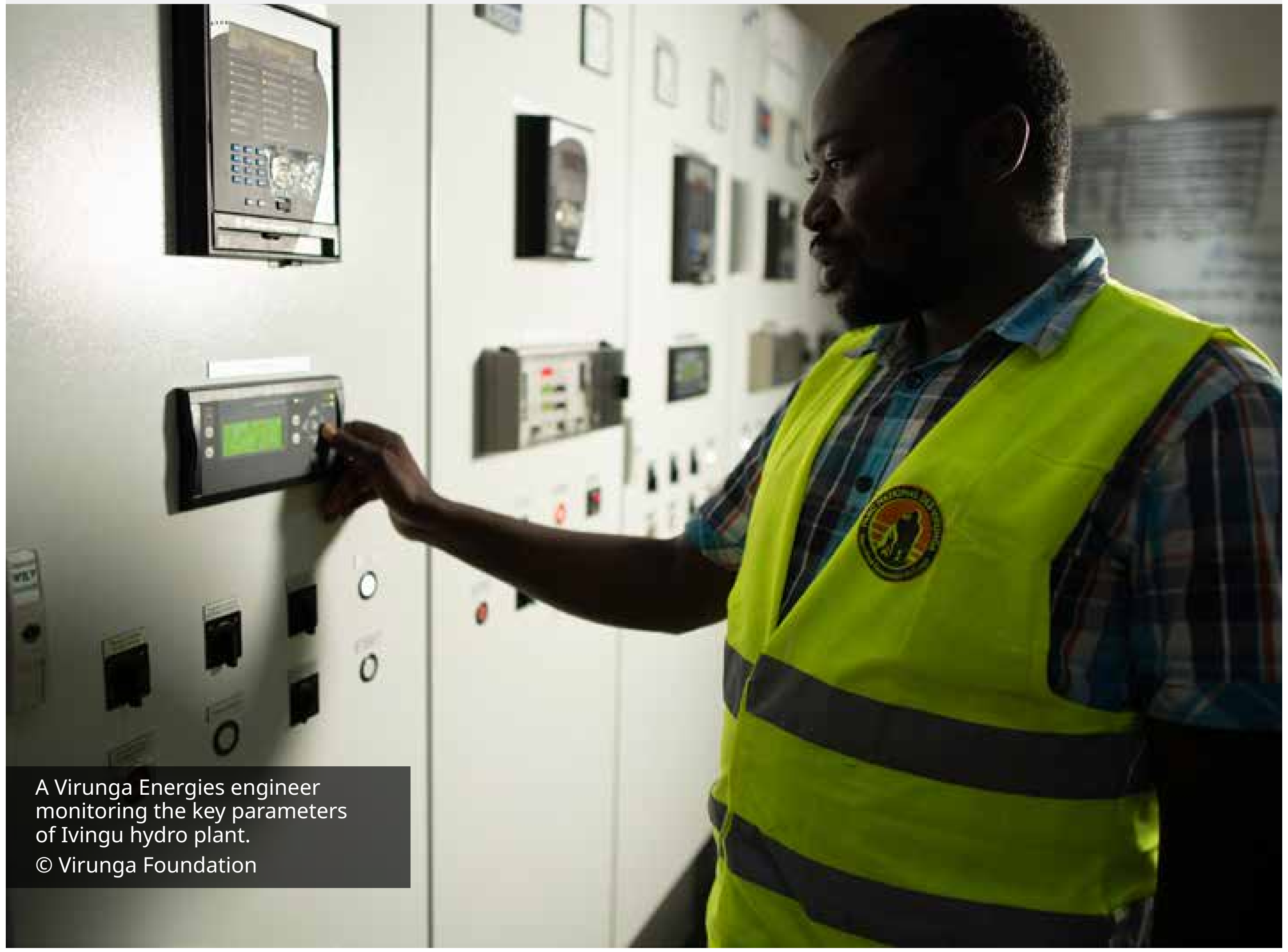
1. SNEL : 4 MW (World Bank, 2020)
2. Virunga Energies : 30 MW, with ongoing construction of a further 14 MW

[5] https://fr.wikipedia.org/wiki/Barrage_de_la_Tshopo
[6] https://africa-energy-portal.org/news/dr-congo-solar-and-hydroelectric-power-investment-planned-kisangani
[7] https://sun-connect.org/wpcont/uploads/5402-13087-1-PB.pdf

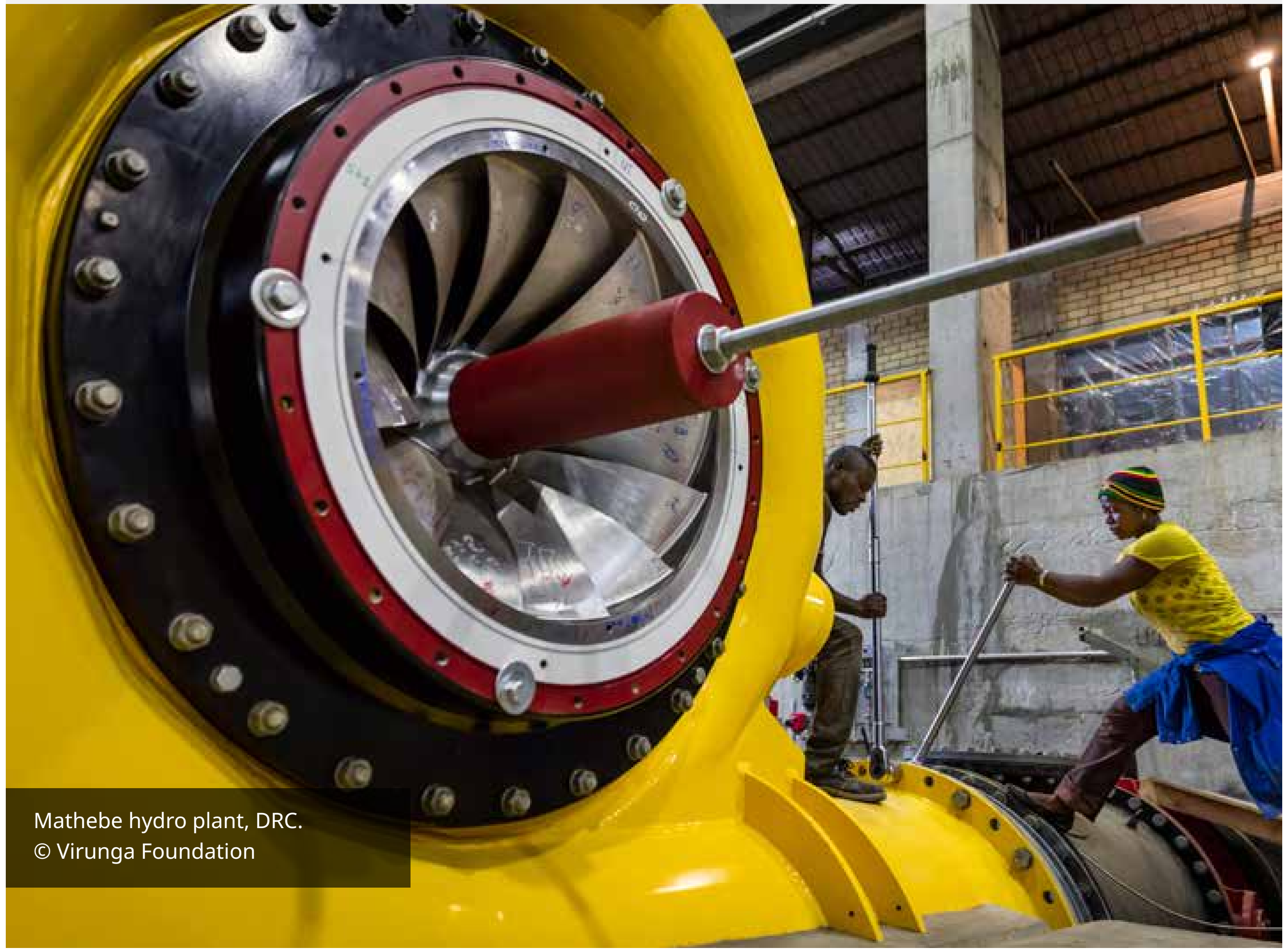


Urban areas such as Goma, DRC, benefit from access to electricity.
© Katya Emmanuel

A newly erected pylon which is part of a broader network supplying electicity to Goma and surroundings.
© Brent Stirton/Getty Images



A Virunga Energies engineer monitoring the key parameters of Ivingu hydro plant.
© Virunga Foundation



Mathebe hydro plant, DRC.
© Virunga Foundation

3. Nuru : 1.3 MWp (solar), with ongoing construction of a new ~5 MWp solar plant. Nuru is currently connected to Virunga's grid to supply its clients with electricity during night time / off-peak hours and displace their previously-used diesel generator
4. SOCODEE : 0 MW (it purchases electricity from Virunga Energies and redistributes it in its concession, without producing any of its own electricity)

Further increasing access to electricity would mainly consist of expanding existing grids in the concessions of SOCODEE and Nuru. Internal estimates suggest an investment of 20 - 40 million.

Mbandaka

Mbandaka is the capital of Équateur Province in the Democratic Republic of Congo (DRC). Historically, the city benefited from consistent electricity and running water until the 1970s. However, in the following decades, infrastructure deteriorated, leading to widespread lack of electricity and other essential services.[8]

According to Resource Matters, an NGO, only 8% of the population of Mbandaka has access to electricity in one form or another while there are two unexploited hydropower sites, Eala and Ruki, respectively 12 MW (~6km from the city center) and 114 MW (~43 km from the city center). Furthermore, Mbandaka has significant solar potential close to the city.

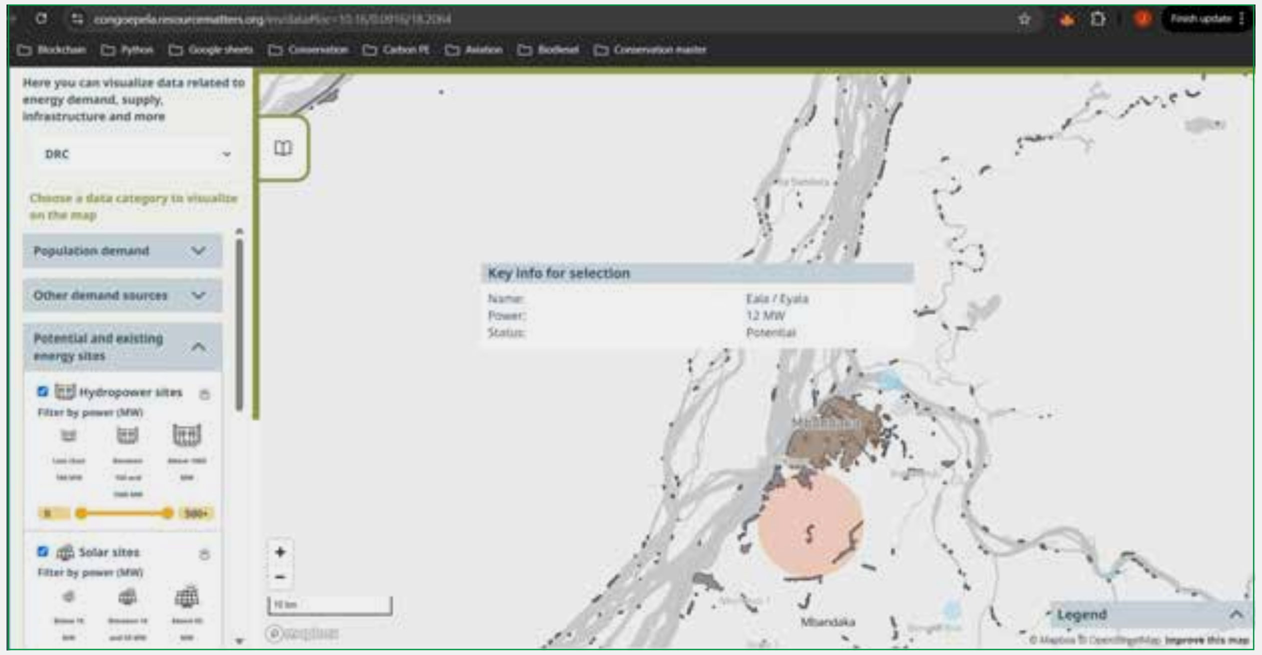


Fig 4 : Eala site potential close to Mbandaka

Preliminary internal studies have estimated the investment required for developing the 12-MW hydropower station and the grid to $40 – 60 million and would enable it to supply electricity to an additional 385 000 people.

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[8] https://www.theguardian.com/cities/2018/jun/27/mbandaka-in-the-spotlight-fought-off-ebola-but-can-the-drc-equator-city-recover?utm_source=chatgpt.com

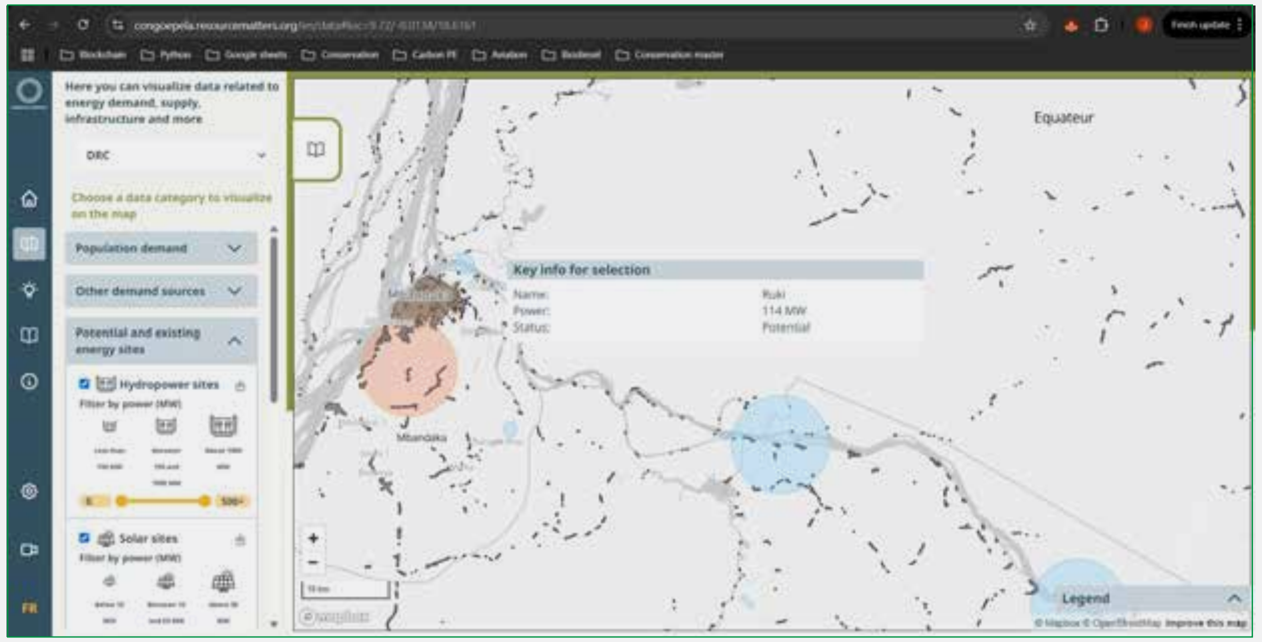


Fig 5 : Ruki site potential a bit farther away from Mbandaka

Electrification of other cities and towns

A different approach was followed to electrify the other 123 villages within the Green Corridor. Given their limited size, reduced population, and demand for energy per capita, it is suggested to electrify such cities and towns with optimized decentralized solar farms, the vast majority of which have no access to electricity beyond household-level solar panels.

Out of 123 villages within the Corridor, 6 are already electrified by Virunga Energies (Rutshuru, Kimbulu, Lubero, Musienene, Rumangabo, Mutwanga).

Electrifying the remaining 117 villages would represent the following results and implications (full detailed results are available in Appendix 3):

1. **Demand for energy**: 164 832 MWh per year
2. **Installed capacity**: 112 MWp of solar panels and 451 MWh of batteries
3. **Investment required**: $551 million
4. **Potential revenues**: $72 million per year (exclusive of VAT)
5. **Taxes for the government**: $21 million per year
6. **Increase in access to electricity**: 432 917 connections, representing 3 030 419 inhabitants, assuming 7 people per household on average

The following results were obtained by modelling the demand, based on historical data from Virunga Energies, and the required installed solar capacity, based on the mean solar irradiance across the corridor. Revenues and other financials were obtained using data from, among others, the World Bank, varying tariffs depending on the size of each solar farm ($0.6 / kWh for households of the smallest solar farms and $0.5 / kWh for the rest), and historical data from Virunga Energies.

Co-benefits of electrification: e-cookers and e-mobility

e-Cookers

The introduction of electric cooking (e-cookers) in the Green Corridor holds significant promise for improving household incomes, environmental sustainability, and local energy markets. Currently, most households across major cities in the Green Corridor—such as Kinshasa, Goma, Beni, Butembo, Kisangani, and Mbandaka—rely heavily on charcoal and fuelwood for cooking, contributing substantially to deforestation, indoor air pollution, and greenhouse gas emissions. By transitioning to e-cookers, households can achieve considerable savings, typically reducing cooking energy expenditures by 20-40% compared to charcoal-based cooking. For an average household spending around $20 monthly on charcoal, this translates into annual savings of approximately $50–100 per household.

Environmentally, shifting to e-cookers drastically reduces both local air pollution and carbon emissions. Charcoal and firewood cooking contribute significantly to household air pollution, a major cause of respiratory diseases. Electric cooking eliminates this pollution at the household level, immediately improving indoor air quality and public health outcomes. Moreover, a typical household switching to electric cooking from charcoal can avoid roughly 1–2 tonnes of CO_2 emissions annually. With approximately two million households potentially transitioning across the Green Corridor cities, this could mean annual CO_2 reductions of up to 2–4 million tonnes.

Adopting e-cookers would notably increase electricity demand, creating incentives for further investments in renewable energy infrastructure. On average, electric cooking adds about 0.5 kWh per day per household, or approximately 182.5 kWh per year. Across a hypothetical scenario involving two million households transitioning to electric cooking, total annual electricity consumption would increase by about 365 GWh. This additional demand presents a significant opportunity for scaling renewable energy projects, especially hydroelectric and solar energy, enhancing the region's sustainable energy landscape.

Critically, transitioning to e-cookers significantly reduces pressure on forests, as charcoal production drives substantial deforestation across the DRC. Replacing charcoal cooking with electric cooking can help mitigate deforestation rates in the Congo Basin, preserving biodiversity, ecosystems, and carbon storage capacity. Collectively, the widespread adoption of e-cookers represents a transformative opportunity for households, the environment, and the energy sector within the Green Corridor.

Metric	Estimated Annual Impact (70% adoption)
Households converted	~2 million households
Economic Savings (Fuel expenditures)	$100–$200 million saved per year
CO_2 Emissions Avoided	2–4 million tonnes CO_2 avoided per year
Increased Electricity Demand	~365 GWh of additional electricity per year
Reduced Deforestation (Wood Saved)	12–24 million tonnes of wood saved per year

Domestic e-cooker use, Goma, DRC
© Brent Stirton/Getty Images

e-Mobility

The adoption of **electric mobility (e-mobility)**, particularly through **e-motorbikes**, represents a substantial opportunity to transform transportation along the Green Corridor. In countries such as Rwanda, Kenya, and Uganda, motorbikes—commonly known as "boda-bodas"—are essential for affordable urban mobility, with tens of thousands in use across major cities. Transitioning to electric motorbikes has significant economic, environmental, and social benefits:

Economically, switching to e-motorbikes substantially increases profitability for taxi drivers by reducing fuel and maintenance expenses. For instance, in Rwanda, studies by Ampersand (a prominent e-mobility company in Kigali) indicate that taxi drivers switching from petrol to electric motorcycles can see their **net income increase by approximately 30-50%** due to lower operating costs. Similarly, Kenya-based company Roam estimates that e-motorbikes can lower operational expenses by up to 60%, significantly enhancing livelihoods.

Environmentally, the shift toward e-mobility drastically reduces local air pollution and greenhouse gas emissions. Considering a typical petrol-powered motorbike emits about 2.5 to 3 tonnes of CO_2 annually, electrifying even 10,000 motorbikes could potentially eliminate up to **30,000 tonnes of CO_2 emissions per year**. In urban areas, where air pollution often exceeds World Health Organization limits, replacing combustion engines with electric motors significantly improves air quality and public health outcomes.

From an energy perspective, widespread adoption of e-motorbikes could stimulate local electricity demand, creating opportunities for investment in renewable energy sources such as solar and hydroelectric power. Estimates suggest that each e-motorbike requires around **3-4 kWh of electricity daily**, translating into an increased annual demand of approximately **1,000-1,500 kWh per motorbike**. Aggregated over thousands of motorcycles, this additional demand can support grid stability and encourage renewable energy development.

Based on rough calculations for the six main cities (Kinshasa, Kisangani, Goma, Butembo, Beni, Mbandaka), and accounting for the greater scale of motorbike usage in Kinshasa—estimated to be approximately twelve times higher than in Goma—the potential impact of transitioning to electric motorcycles (e-motorbikes) across the Green Corridor cities is significant. With roughly 120,000 motorbikes operating in Kinshasa alone, and approximately 10,000 motorbikes in each of the five other targeted cities (Goma, Beni, Butembo, Kisangani, Mbandaka), the total estimated fleet size reaches around 170,000 motorcycles. Assuming a conversion rate of 70% to electric motorcycles, this implies electrifying about 119,000 motorbikes. Economically, this transition could substantially improve the livelihoods of taxi operators, who typically experience a 40% net income increase after switching from petrol to electric due to reduced operating costs (fuel and maintenance). Assuming a conservative baseline annual revenue of $2,400 per motorbike taxi, drivers could see additional annual earnings of approximately $960 per vehicle, representing a collective increase of about $114.2 million annually across the six cities.


e-motorbikes in Goma, DRC
© Jérôme Gabriel


e-motorbikes in Goma, DRC
© Jérôme Gabriel

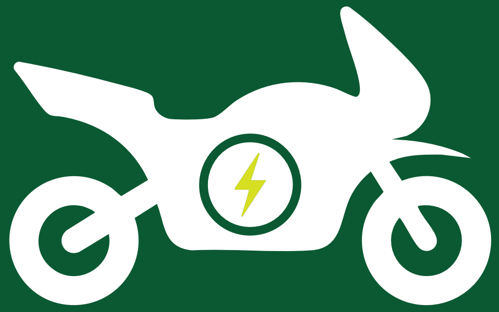
From an environmental perspective, each conventional petrol-powered motorbike emits roughly 3 tonnes of CO_2 per year. Converting 119,000 motorbikes to electric would thus eliminate approximately 357,000 tonnes of CO_2 annually. This significant reduction in emissions would markedly improve air quality, reducing local pollution and enhancing public health outcomes. In terms of energy demand, the introduction of these electric motorcycles would increase electricity consumption, with each motorbike requiring an estimated 3.5 kWh daily (approximately 1,277 kWh per year). Consequently, the entire fleet of 119,000 electric motorbikes would consume roughly 152 GWh annually, creating substantial opportunities for further investment and development in renewable energy sources, such as hydro and solar power, to sustainably meet this increased demand. Overall, transitioning to e-mobility in these major urban centers of the Green Corridor holds transformative potential—driving economic growth, reducing environmental impacts, and supporting the sustainable development of local energy infrastructure.

Metric	Estimated Annual Impact
Total Motorbike Fleet	170,000 motorbikes
Converted to Electric (70%)	119,000 e-motorbikes
Economic Impact	
Additional Revenue per Motorbike Driver	~$960 per year
Total Additional Revenue	**~$114.2 million per year**
Environmental Impact	
CO_2 Emission Reduction	**~357,000 tonnes CO_2 per year**
Energy Impact	
Increased Electricity Demand	**~152 GWh per year**

Table 2 : Potential impact of e-Mobility

e-cookers

The introduction of electric cooking (e-cookers) in the Green Corridor holds significant promise for improving household incomes, environmental sustainability, and local energy markets.



e-mobility

The adoption of electric mobility (e-mobility), particularly through e-motorbikes, represents a substantial opportunity to transform transportation along the Green Corridor.

Agriculture and Agro-industrial Transformation

Chia fields, Beni, DRC.
© Guerchom Ndebo

Cocoa farmer, Beni, DRC.
© Guerchom Ndebo

Agriculture and Agro-industrial Transformation

Challenges of the agricultural sector in the Green Corridor

The **Kivu-Kinshasa Green Corridor** extends over approximately 2,400 km, connecting the Virunga National Park in the east and the Yangambi (Tshopo) National Park in the west, in order to protect at least **100 000 km^2** of primary forests in the Congo Basin.

Beyond the ecological objective, the project seeks to transform areas weakened by **decades of conflict** into poles of economic growth and stability. Agriculture occupies a central place in this vision: the Green Corridor should make it possible to transfer **one million tonnes of food** each year from the Kivus to Kinshasa, thanks to investments in sustainable agriculture, value chains and innovative transport infrastructure (for example, hydrogen-powered river barges on the Congo).

This corridor crosses regions with varied agro-ecological conditions (the Kivu mountains, the rainforests of the central basin, the savannahs around the forests, the areas along the Congo River), offering **enormous agricultural potential**. The DRC already has nearly **80 million hectares of arable land**, of which barely **10% is cultivated**.

Historically, agriculture was a pillar of the economy: at independence, it contributed 43% of export earnings, making the Belgian Congo the world's *second largest* producer of palm oil (after Nigeria). Even today, more than **70% of the working population lives off family farming**.

The Green Corridor covers some of the most fertile land in the DRC and includes a variety of crops ranging from **cash crops** (cocoa, coffee, oil palm, rubber, etc.) to **food crops** (cassava, plantain, maize, rice, etc.). For example, the Kivus and Tshopo produce organic quality cocoa, which is in demand on the international market while the central basin is home to old oil palm and rubber plantations from the colonial era that are now under-exploited.

In addition, the corridor's population is highly dependent on **cassava** and **plantain** – the DRC is the world's third largest producer of cassava (around 30 million tonnes in 2018) and the world's largest producer of plantain (4.7 million tonnes). This agricultural potential is crucial for national **food security** and offers significant **investment** opportunities (agro-industries, exports, biofuels, etc.).

However, the stakes are high. The agricultural sector in these regions faces chronic underinvestment (only ~3% of the national budget in recent years), a lack of infrastructure and the consequences of instability. Recurring **armed conflicts** in the east have disrupted the sectors (displacement of agricultural populations, insecurity hindering the collection and transport of crops, etc.), and have even caused migration of farmers to safer forest areas such as Tshopo – contributing to deforestation through the anarchic expansion of crops such as cocoa.

Furthermore, the lack of passable roads and reliable means of transport makes it very difficult to get products to market: for example, the RN4 Beni–Kisangani is a strategic road but has long been in a poor state of repair, and the current cost of river transport on the Congo is high, limiting the disposal of agricultural surpluses. As the President pointed out, the deficient road network *'complicates travel and increases transport costs'* of rural production.

The **environmental challenges** are also significant: the Congo Basin is suffering from the effects of climate change and the pressure of shifting agriculture based on slash-and-burn. Without planning, the expansion of **mono-specific plantations** or the opening up of new agricultural land risks further fragmenting the forest.

This substantial gap presents significant opportunities: improving agricultural productivity through modern techniques, better seeds, fertilizers, and infrastructure could transform agriculture into a key driver of economic growth. The Green Corridor aims to provide an integrated response to these issues, combining conservation and development. The **methodological challenge** is therefore to arrive at a rigorous estimate of the current agricultural areas by crop in this corridor, in order to orient public decisions and private investments towards a model of **sustainable and resilient agriculture** that reconciles food security, farmers' incomes and forest preservation.

Agricultural potential in the Green Corridor

The Kivu-Kinshasa Green Corridor is home to **significant areas of crops**: the total agricultural area within the Green Corridor (by summing the individual areas) is **approximately 3 million hectares**, of which we assume 15% to be in fallow or uncultivated. Therefore, It can be estimated that by 2025 approximately **240,000 hectares** of the corridor will be planted with cocoa, coffee, oil palm or rubber (about half of which will be cocoa). These areas represent significant **opportunities for local development**. Their distribution along the corridor means that it is feasible to develop **centres for local processing** at different stages: for example, **an artisanal chocolate factory** in Beni to add value to the cocoa from the east, **community oil mills** towards Mbandaka for palm oil, a **rubber factory** in Gemena for rubber, or **coffee washing stations** in Kivu. This would create local added value instead of only exporting raw materials.

In this section, we briefly present results of our internal estimation of cash and food crops areas within the Green Corridor. The full methodology, results and details are available in *Appendix 5*.

Artisanal chocolate factory,
Mutwanga, Eastern DRC
© Brent Stirton/Getty Images

Cash crop areas

The following **orders of magnitude** have been estimated for the "cash crop" cultivated areas by sector in the Kivu-Kinshasa Green Corridor:

Summary table

Cocoa ≈ 110,000 ha (mostly smallholders) Mainly North Kivu/Ituri and Équateur/Ubangi. Strong recent expansion following the decline of coffee.

Oil palm ≈ 65,000 ha (60,000–70,000 ha depending on the area considered). Includes ~21,000 ha of industrial plantations (PHC) and ~15–20,000 ha of village plantations. Large concessions available for expansion.

Hevea (rubber) ≈ 10,000 ha currently exploited (potential > 20,000 ha) Essentially Miluna plantation (5,000 ha). Other projects in the pipeline (Tshopo, etc.) not yet productive.

Coffee (arabica+robusta) ≈ 60,000 ha in production (70,000+ ha of existing coffee trees) Historically in sharp decline. Eastern arabica (Kivu) ~20k ha; north/western robusta ~20k ha. Significant rehabilitation potential.

(NB: All these values are rounded and are intended to give an order of magnitude, not absolute precision.)

An illustrative example is the *Miluna* concession (South Ubangi province) which combines **5,000 ha of rubber trees, 1,000 ha of oil palms, 500 ha of cocoa and 100 ha of coffee** on the same farm. This shows that, at the local level, these crops coexist and that multi-purpose processing units (oil mills, cocoa dryers, rubber factories, etc.) could benefit from diversified supplies.

1. Cocoa

Cocoa is a crop that has recently emerged as an export sector in the DRC, particularly in the east and north of the country. **Introduced during the colonial period** (1930s) at a few sites along the Congo and to the east, the cocoa tree had never reached the scale it has in West Africa. In recent decades, in the face of growing global demand and as a profitable alternative to coffee, cocoa has been booming in the corridor. The provinces of **Kivu, Ituri and Tshopo** are now the main producers of Congolese cocoa. It is estimated that there are around **65,000 cocoa farmers** in North and South Kivu alone, often smallholders with plots of 0.5 to 2 ha integrated into the forest (agroforestry system). The quality of Congolese cocoa is recognised as exceptional – fine, organic and from ancient varieties – which gives it significant economic interest in niche markets.

In the Green Corridor, the **key cocoa production areas** include: the territories of **Beni** and **Lubero** (North Kivu) where local cooperatives were formed after the partial pacification of these areas, the territory of **Mambasa** (Ituri) on the outskirts of the Okapi Reserve, and increasingly the **Yangambi sector** in Tshopo (around Yanonge, Isangi). The latter has seen an influx of planters from Kivu, fleeing the conflicts, who are clearing the forest to establish new cocoa plantations. This migration of Nande

COCOA

Cocoa farmer, Beni, Eastern DRC
© Guerchom Ndebo

HEVEA

Rubber plant harvesting
© Jcomp

PALM OIL

Palm processing, Beni, Eastern DRC
© Guerchom Ndebo

COFFEE

Coffee farmer, Beni, Eastern DRC
© Guerchom Ndebo

farmers to Tshopo contributed to the increase in deforestation locally in 2020-2021, revealing the importance of better planning this expansion (for example, through agroforestry rather than monoculture).

2. Oil palm

The oil palm is of historical and strategic importance in the DRC. It was one of the flagship crops of the colonial era: as early as 1911, the industrialist William Lever established vast plantations in the Belgian Congo to supply European soap factories. At its peak, the DRC (Zaire) was the world's second largest producer of palm oil. Current oil palm cultivation in the DRC presents a very different profile, with on the one hand former industrial plantations inherited from colonisation, and on the other a myriad of scattered village palm groves. Historically, the country had **147,000 ha of palm trees planted in 1958**. However, since the 1960s, national production has collapsed, falling from ~220,000 t in 1960 to around **150,000 t in recent years**, far below domestic demand (estimated at 500,000 t), resulting in a deficit of ~350,000 t that is being filled by massive imports. This decline is due to a lack of maintenance of the palm groves, the abandonment of many plantations, and a lack of investment.

The **Green Corridor** includes most of the DRC's main palm areas, as these are located along the Congo River and in the northeast: the **PHC (Plantations et Huileries du Congo)** plantations of **Lokutu** (Tshopo), **Yaligimba** (Mongala) and **Boteka** (Équateur) are located there, totalling more than 100,000 ha of concessions (of which about 20,000 ha are currently cultivated). These sites, formerly managed by Unilever and then the Canadian company Feronia, have suffered from financial difficulties and recent labour disputes, but have enormous potential for recovery. In addition to these industrial complexes, there are many scattered **village palm groves**: around Yangambi (Tshopo), in **Mai-Ndombe** (Mbandaka-Kinshasa axes), in **Tshuapa** (Ikela territory, etc.), as well as on the outskirts of old industrial sites (local populations continue to harvest palm bunches on the abandoned or fallow land of former plantations). In the east, palm cultivation is more limited by the mountain climate, but there are some palm groves in the lowlands of **North Kivu** (Lubero, Beni) and **Maniema** (Pangi), generally to produce artisanal red oil for local use.

3. Hevea (natural rubber)

The rubber tree (Hevea brasiliensis) also has a long history in the Congo. At the beginning of the 20th century, before the introduction of plantations, rubber was harvested by exploiting wild lianas (the *'rubber boom'* having left a dark legacy). Subsequently, **rubber plantations** were established during the colonial period - first on an experimental basis in Yangambi and Ecuador, then on a larger scale in the 1940s and 50s. In 1925, there were already around 4,000 hectares of rubber trees planted in the Belgian Congo, an area that increased after the war. The main rubber-growing areas were the same as for oil palms: the **Yangambi** region (INÉRA developed rubber plantations there), the **Mongala and Équateur** basin (around Bokungu, Befale, etc.), and certain areas of **Eastern Kasai** (Lodja, Lomela) at the southern end of the corridor. Under the Mobutu regime, several of these plantations were abandoned (due to lack of maintenance after Zairianisation).

Today, rubber production in the DRC is almost non-existent - around **14,000 tonnes in 2018** - and comes mainly from a few *village rubber trees* or abandoned plantations where latex is still harvested by hand. For example, in the territory of **Opala** (Tshopo), there are reportedly *'around twenty thousand hectares of rubber plantations invaded by the bush'* inherited from colonisation, some of which are occasionally exploited by the villagers (for the production of artisanal rubber).

The **Green Corridor** includes precisely these areas: Yangambi–Isangi, Opala–Yahuma, as well as the former plantations of **Sankuru** (Lodja) on the southern edge

4. Coffee (arabica and robusta)

Coffee was for a long time the DRC's main cash crop. There is **Arabica coffee** (mountain coffee, top of the range) grown mainly in the east, and **Robusta coffee** (lowland coffee, more productive) dominant in the west and north. Historically, the Congolese coffee industry was flourishing: during the 1980s, the country produced between 80,000 and 120,000 tonnes of coffee per year, making it one of the main African exporters. **Robusta coffee** from eastern Congo expanded dramatically during colonisation, going from almost nothing to **51,000 tonnes in 1959** following the establishment of vast smallholder coffee plantations in the former Orientale Province. However, successive shocks (falling prices, looting during the wars, plant diseases such as tracheomycosis of the robusta coffee tree) led to a collapse. In 2018, production was only about **29,000 tonnes** of all coffees combined.

In the Green Corridor, there are two types of coffee cultivation:

- In the east, the highlands of **Kivu** (North and South Kivu) produce high-quality **arabica** coffee. Around Lake Kivu and the volcanoes, tens of thousands of small farms grow high-altitude arabica (often <1 ha each). Although affected by disease, cultivation persists thanks to cooperatives and replanting projects (e.g. ICO/NCO project targeting 46,000 ha rehabilitated in post-conflict zones).
- In the north and centre of the country, the plains of the **Cuvette Centrale** (former Equateur and Orientale provinces) were the domain of **robusta** coffee. Industrial plantations and vast peasant estates existed: in the 1930s, there were already 56,000 ha of coffee trees in the Belgian Congo, and in the 1980s the Haut-Uele region alone had a total of 27,000 ha of coffee trees in production. With the unrest, these figures have fallen, but many coffee trees remain in a semi-abandoned state in villages along the river and its tributaries. For example, the province of **Tshuapa** or **Mongala** still has robusta coffee trees among elderly farmers, even if marketing is sporadic.

Food crop areas

The following **orders of magnitude** have been estimated for the "food crop" cultivated areas by sector in the Kivu-Kinshasa Green Corridor:

Summary table

Cassava ≈ 1,300,000 ha (mostly smallholders) across the Green Corridor.

Maize ≈ 400,000 ha (mostly smallholders) across the Green Corridor.

Plantain banana ≈ 200,000 ha primarily along the RN4 (the Nande and Mbuti peoples have been growing plantain in Ituri and North Kivu for generations), and the entire central basin where bananas are often grown in cottage gardens.

Leguminous plants ≈ 100,000 ha. The (common) **bean** is more common in the East (Kivu, Maniema)

1. Cassava

In the Green Corridor, cassava is grown by almost every rural household on small, scattered plots. It is often cultivated in association – for example, cassava + maize or cassava + groundnut/cowpea. After 1 to 2 years of growth, it is harvested and the plot is either left fallow or replanted. The cycles are therefore staggered, making precise monitoring difficult. The corridor does not include large single-species cassava plantations (with the exception of recent projects such as an initiative to plant 1,400 ha of industrial cassava in Kongo Central for bread flour, outside the corridor zone). It is a very fragmented mosaic.

Estimated area in the Green Corridor: Based on production data and a modest average productivity (~8 to 10 t/ha of fresh roots, given extensive cultivation practices), we estimate that approximately **1.3 to 1.4 million hectares** are devoted to cassava in the Green Corridor.

2. Maize

Maize is strategic because Kinshasa and urban centres consume large quantities of it. In 2017-2018, faced with a local shortage, the DRC had to import maize from Zambia and South Africa to feed Kinshasa and Lubumbashi. Developing maize in the Green Corridor could reduce this dependence. Nevertheless, this crop requires more inputs than cassava (seeds selected each season, soil fertility) and suffers from the poor condition of the roads when it comes to exporting the harvest - surplus maize from Nord-Ubangi or Tshopo has difficulty reaching consumers due to the lack of inexpensive transport.

Estimated area in the Green Corridor: Based on an annual production of around 600,000 tonnes of grain maize in the provinces crossed by the corridor (out of ~2 million nationally) and an average yield of around 1.5 t/ha, we estimate that at least **400,000 hectares** of maize are in the Green Corridor. However, these are largely associated or temporary crops: rarely large continuous monocultures. If we consider the area *mainly dedicated* to corn (pure crop), it would be more like around 200,000 ha, the rest being shared with other food crops. The highest densities of maize in the corridor are found around the major populated axes (Kisangani-Banalia axis, Befale basin, etc.). This figure is consistent with the total cultivated area (maize occupies about 10-15% of the agricultural area of the corridor, which corresponds to the practices observed).

3. Rice

Rice in the DRC is a growing crop, driven by strong urban demand. The country imports a large proportion of the rice it consumes, due to insufficient local production. Nevertheless, certain regions of the Green Corridor offer favourable conditions for rainfed rice (plateau cultivation) or irrigated rice in the marshes. Traditionally, rice was cultivated in the marshy savannah areas of the former Équateur and in the valleys of the former Kivu.

Areas in the Green Corridor: The **Ruzizi** plain (South Kivu) can be cited – although geographically to the east of the main corridor, it is part of the East-West dynamic – where irrigation schemes have existed since the 1950s. More directly in the corridor: the rice paddies of the **Tshuapa** basins (Boende territory in particular), the **Lomami** valley and some tributaries of the Congo. For example, the province of Tshopo has encouraged rice around Yangambi (INERA was conducting varietal trials there). In **Bas-Uele**/Ituri too, upland rice is cultivated by people from South Sudan. National paddy rice production was around **990,000 tonnes in 2018**, most of which was consumed directly or husked locally. In the corridor, it can be estimated that perhaps 30% of this volume is produced there (i.e. 300,000 tonnes of paddy rice), mainly in Orientale and Équateur provinces.

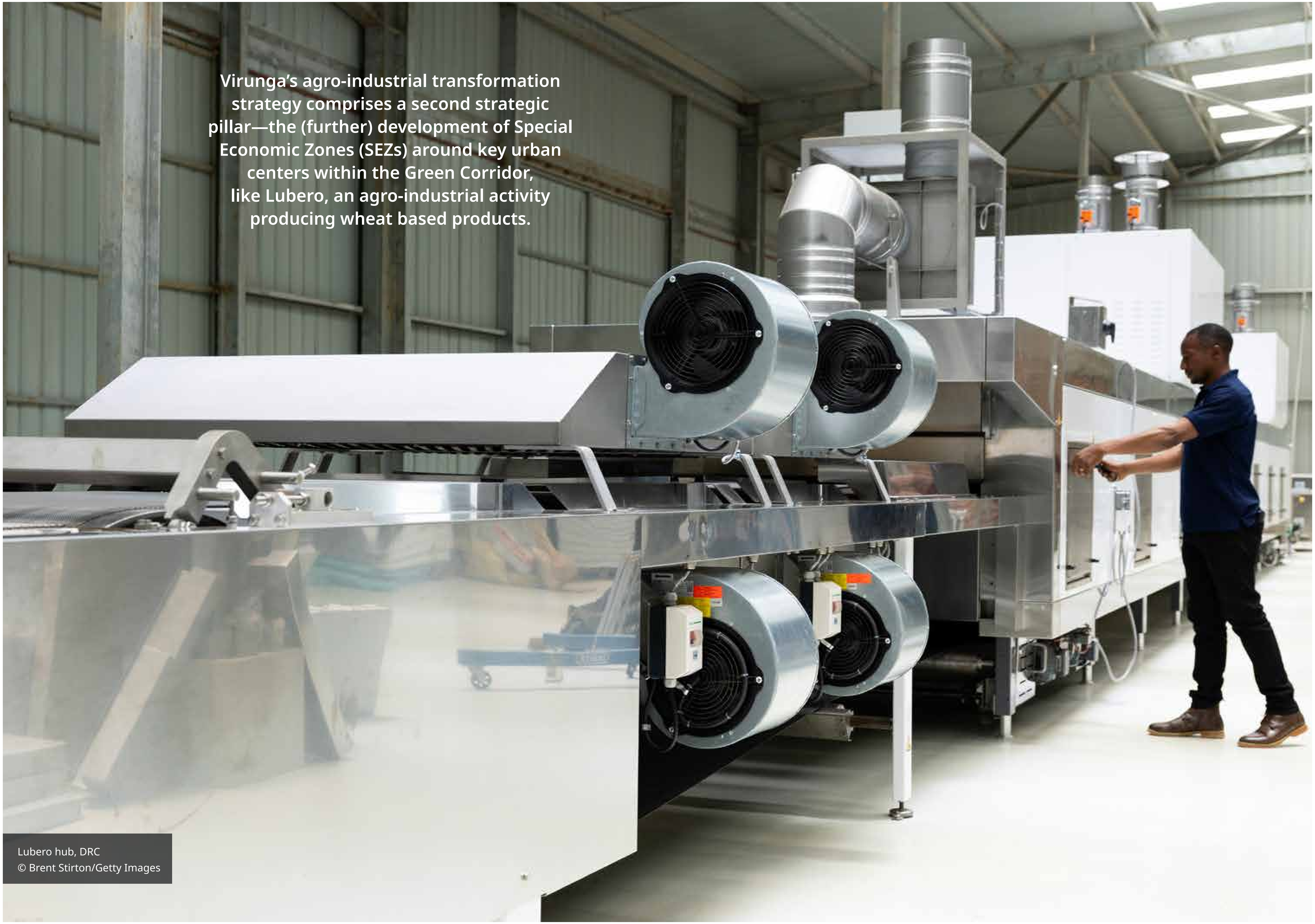
Estimated surface area in the Green Corridor: Based on a low average yield (1.0–1.5 t/ha), the surface area cultivated with rice in the Green Corridor is estimated at between **200,000 and 300,000 hectares**.

4. Other food crops (plantain, groundnut, etc.)

Finally, the Green Corridor is home to a multitude of other food crops that are considered secondary but are crucial to local diets and incomes: **plantain bananas** (and sweet bananas), **legumes** (common beans, cowpeas/peas, peanuts), **tubers** (sweet potatoes, taro), as well as various vegetables and fruits (pineapples, citrus fruits, mangoes, etc.). Taken individually, each of these crops occupies smaller areas than cassava or corn, but collectively they mobilise a significant portion of the land cultivated in a polyculture system.

The **plantain banana** deserves a special mention: the DRC is the world's leading producer with 4.7 million tonnes, mainly in the humid forest regions. The Green Corridor, which crosses the forest belt, includes large areas of plantain, for example: along the RN4 (the Nande and Mbuti peoples have been growing plantain in Ituri and North Kivu for generations), and the entire central basin where bananas are often grown in cottage gardens. We estimate that there are around **200,000 hectares** of plantain banana trees in the corridor

Leguminous plants (peanuts, beans, soya) are commonly intercropped with cassava or maize. For example, the **peanut** is widespread in the province of Équateur – it is sown at the same time as maize



Virunga's agro-industrial transformation strategy comprises a second strategic pillar—the (further) development of Special Economic Zones (SEZs) around key urban centers within the Green Corridor, like Lubero, an agro-industrial activity producing wheat based products.

Lubero hub, DRC
© Brent Stirton/Getty Images

or cassava, and it covers the soil by fixing nitrogen. Its surface area in the Green Corridor can be estimated at ~100,000 ha (often mixed with other crops). The (common) **bean** is more common in the East (Kivu, Maniema) on perhaps 50,000 ha in the corridor, particularly in rotation after maize or between young cassava plants.

Summary table of all crops

Province	Cassava	Maize	Rice	Plantain	Other food crops	Cocoa	Coffee	Oil palm	Rubber	Total cultivated
Bas-Uele	84 512	33 805	17 841	25 353	16 905	0	2 000	2 000	1 000	**183 416**
Équateur	23 954	9 581	5 057	7 186	4 793	0	3 000	11 000	1 000	**65 571**
Ituri	46 963	18 785	9 914	14 089	9 394	4 000	3 000	3 000	0	**109 145**
Kinshasa	27 054	10 821	5 711	8 116	5 413	0	0	0	0	**57 115**
Maï-Ndombe	32 730	13 092	6 909	9 819	6 547	0	1 000	5 000	0	**75 097**
Mongala	87 031	34 812	18 373	26 109	17 409	0	3 000	16 000	1 000	**203 734**
Nord-Kivu	403 406	161 362	85 163	121 021	80 683	8 000	8 000	2 000	0	**869 635**
Sud-Ubangi	36 674	14 669	7 742	11 002	7 337	0	1 000	5 000	0	**83 424**
Tshopo	382 736	153 094	80 799	114 820	76 550	3 000	3 000	19 000	1 000	**834 999**
Tshuapa	37 635	15 054	7 945	11 290	7 529	0	1 000	5 000	1 000	**86 453**
Total	**1 162 695**	**465 075**	**245 454**	**348 805**	**232 560**	**15 000**	**25 000**	**68 000**	**5 000**	**2 567 589**

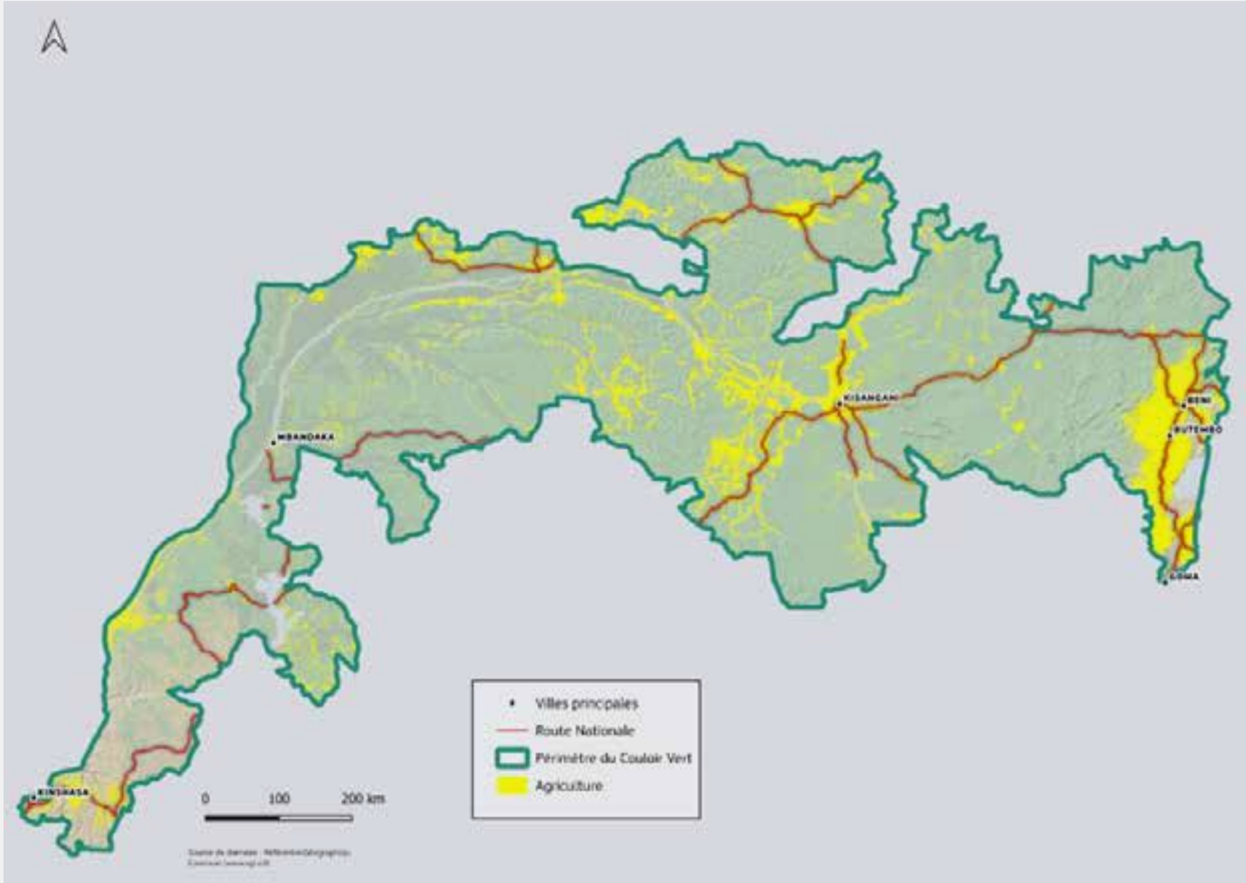


Fig 6 : overview of agricultural areas within the Green Corridor

Agro-industrial transformation strategy

FOBs and industrial hubs to foster peace, economic development and conservation

Virunga National Park has pioneered an innovative model combining conservation, security, and economic development, known as "industrial hubs." These hubs integrate three critical elements:

1. **Conservation and Security**: Each hub features a Forward Operating Base (FOB) staffed by ICCN eco-rangers. These rangers are tasked not only with protecting wildlife and natural resources within the park but also with enforcing peace and providing security against armed groups operating in the region.
2. **Economic Development**: The industrial hubs include value-added agricultural processing facilities, specifically a cocoa fermentation center and a palm oil press (typically able to process 1 ton per hour of fresh palm fruits). These facilities empower local communities by creating jobs, stimulating economic activity, and enhancing market access for agricultural products.
3. **Community Impact**: By coupling security provision with tangible economic opportunities, Virunga's industrial hubs address the root causes of insecurity and deforestation—poverty and lack of livelihoods—thus fostering lasting peace and sustainable development.

Virunga National Park has pioneered an innovative model combining conservation, security, and economic development, known as “industrial hubs”, like Mangina. These hubs serve as crucial points for initial processing (cocoa fermentation and palm oil pressing) before products are exported.

Mangina Industrial hub Beni,
Eastern DRC
© Brent Stirton/Getty Images

Fig 7 : Example of an industrial hub in Mangina

Virunga's agro-industrial transformation strategy aims to foster sustainable economic growth, enhance security, and promote conservation by adapting solutions to specific regional contexts. In the **eastern region (from Beni to Kisangani)**, the strategy emphasizes the deployment of decentralized **industrial hubs**, combining ICCN-managed forward operating bases staffed by eco-rangers with agricultural processing units, specifically targeting areas suitable for **cocoa and palm oil** production. Given the challenging security environment, these hubs serve as crucial points for initial processing (cocoa fermentation and palm oil pressing) before products are exported to major economic centers along the corridor, such as **Kinshasa, Beni, Butembo, Goma, Kisangani, and Mbandaka**. In contrast, the approach in the **central and western regions** focuses on enhancing value chains for locally dominant crops—including **rice, maize, manioc (cassava), and bananas**—leveraging existing agricultural strengths. By tailoring interventions to regional conditions and crops, Virunga's strategy seeks to maximize local impact, stabilize communities, and sustainably unlock the economic potential of agriculture across the DRC.

Nineteen (19) priority sites have been identified for the deployment of industrial hubs, combined with a FOB, primarily in the area of Beni - Kisangani (see appendix 4 for a detailed list of results) , where most of palm oil and cocoa production and insecurity lie.

Preliminary results indicate that deploying 19 industrial hubs would represent the following results:

1. Transformation capacity (into palm oil) : 78 615 tons / year of palm oil
2. CAPEX required: $37.8 million
3. Revenues generated: $48.9 million / year
4. Profits from industrial hubs (excluding peace building and conservation activities): $6.3 million / year
5. Profits (including peace building and conservation activities): $1.4 million / year

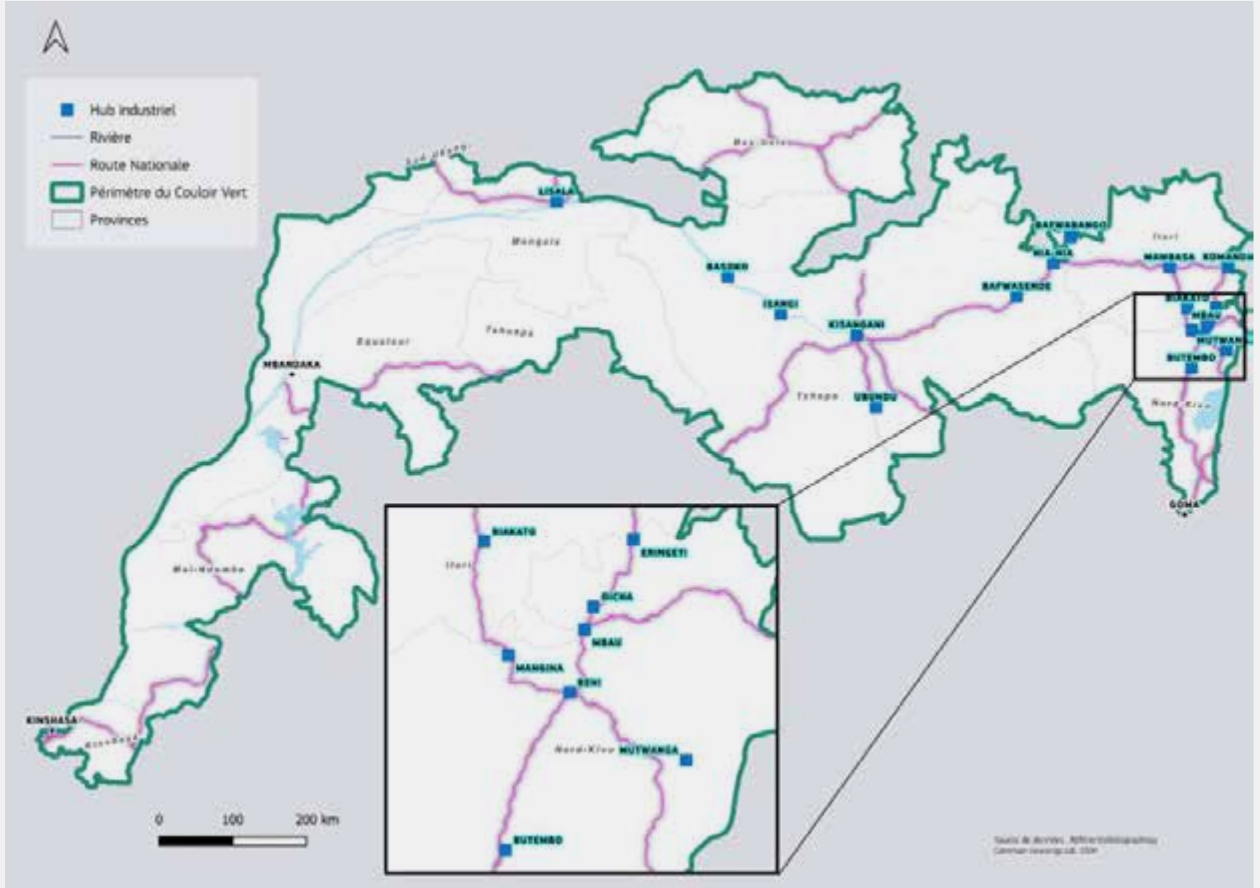


Fig 8 : Location of the 19 industrial hubs

In aggregate, the deployment of 19 industrial hubs is profitable and can pay for itself, assuming a cost of capital of 0% (money is lent at a 0% interest rate). However, the aggregate hides significant disparities in the profitability at the unit-level, with larger palm oil presses (six in total) being significantly more profitable than smaller palm oil presses, which are unprofitable if required to finance the conservation and peace building activities.The table below provide an overview of profitability depending on the size of each industrial hub, the insecurity level within the region and whether it is an optimal location for palm fruit and cocoa harvesting.

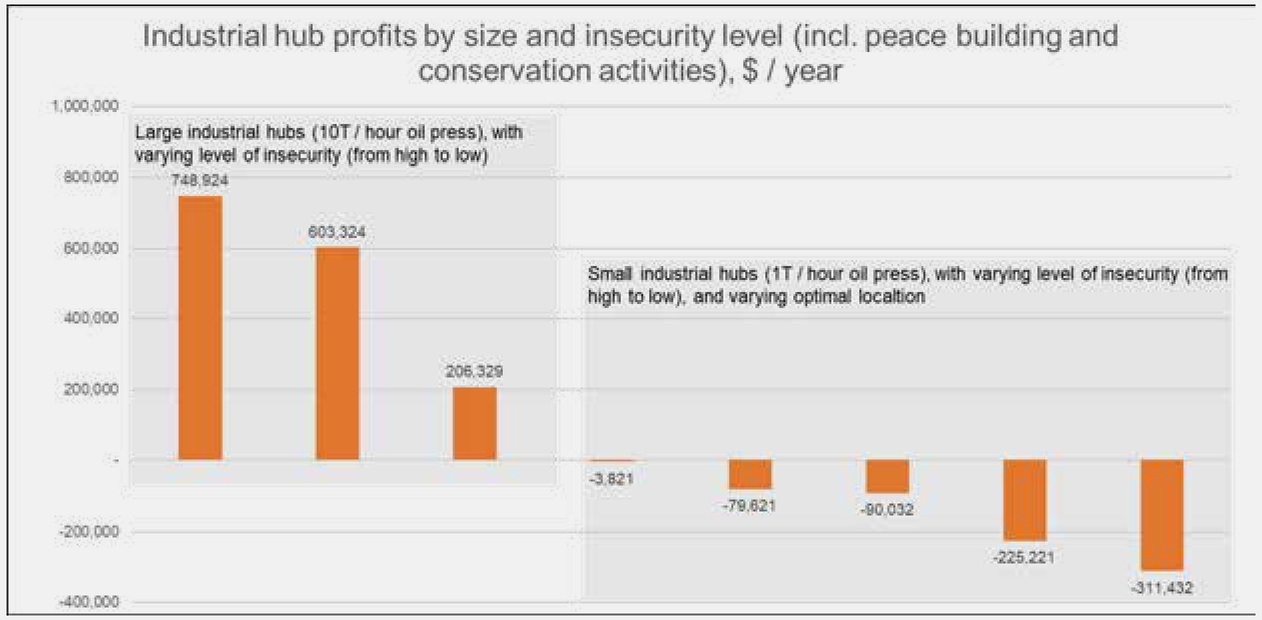


Fig 9 : Profitability of the different archetypes of industrial hubs

Industrial hub type	Transformation capacity, tons / year	CAPEX, $	Revenues, $ / year	Profits, $ / year	Cashflow hub + FOB, $ / year
10T - Medium insecurity - Expected	11,488	3,216,667	7,218,649	955,791	748,924
10T - High insecurity - Expected	11,488	3,316,667	7,218,649	955,791	603,324
10T - High insecurity - Actual	8,297	3,316,667	4,812,433	558,795	206,329
1T - Low insecurity - Expected	1,352	1,321,167	905,870	127,245	-3,821
1T - Medium insecurity - Expected	1,352	1,371,167	905,870	127,245	-79,621
1T - Low insecurity - Actual	976	1,321,167	566,169	41,035	-90,032
1T - High insecurity - Expected	1,352	1,471,167	905,870	127,245	-225,221
1T - High insecurity - Actual	976	1,471,167	566,169	41,035	-311,432

Fig 10 : table of profitability and cashflow (incl. peace building and conservation) by industrial hub size and insecurity level[9]

Special Economic Zones in key cities for a second layer of agro-transformation

Virunga's agro-industrial transformation strategy comprises a second strategic pillar—**the (further) development of Special Economic Zones (SEZs)** around key urban centers within the Green Corridor.

Special Economic Zones (SEZs) represent a critical component of the agro-industrial transformation strategy due to their ability to offer a solution to structural challenges inherent to the Congolese business environment. In a country characterized by high fiscal pressure, administrative complexity, and infrastructure deficits, SEZs offer an advantageous fiscal framework—including significant tax exemptions and reduced customs duties—that can attract investors who might otherwise hesitate due to operational risks and costs. Furthermore, by concentrating value-added agro-industrial activities within clearly defined geographic areas, SEZs facilitate powerful synergies between processing industries, logistics providers, and renewable energy developers, improving overall operational efficiency and cost-effectiveness. This concentration also supports large-scale investments and economies of scale, centralizing processing activities to enhance productivity, increase market competitiveness, and ultimately accelerate broader economic growth and employment creation within the region. Virunga aims to position itself as the **first investor and "first risk taker"** within the Special Economic Zones (SEZs), thereby igniting the essential initial spark of economic activity. By taking on this anchor investor role, Virunga hopes to demonstrate confidence in the viability and potential of these zones, significantly reducing the perceived risk for subsequent private sector entrants. This strategic positioning is expected to attract new private - high-profile- companies, who can leverage the infrastructure, services, and economic dynamism initiated by Virunga to establish their own independent ventures within the SEZs. Through this catalytic approach, Virunga seeks not only to foster a diverse and thriving ecosystem of businesses but also to ensure sustained green economic growth, job creation, and regional development.

Six SEZs are envisioned to serve as hubs of economic growth a in strategic locations near the six key cities of the Green Corridor:

- **Maluku** (serving Kinshasa, already established formally by an independent actor),
- **Nyiragongo** (serving Goma, already established by Virunga but without the official ZES status),
- **Mutwanga** (serving Beni and Butembo, already established by Virunga but without the official ZES status),
- **Lubero** (serving Beni and Butembo, already established by Virunga but without the official ZES status).
- **Kisangani**, and
- **Mbandaka**.

[9] See methodology section for further details.

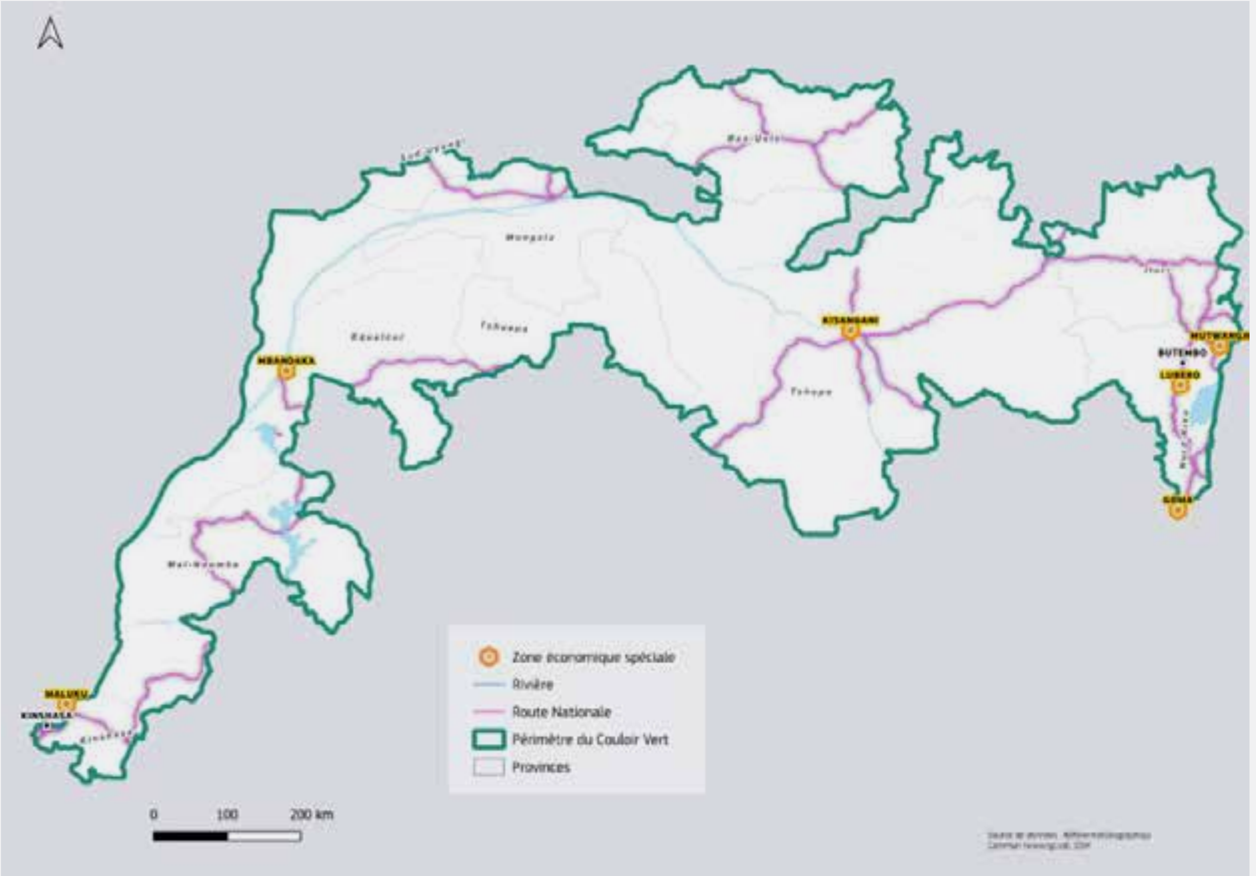


Fig 11 : overview of proposed special economic zones

These zones are strategically positioned near major cities and are specifically designed to host advanced agro-processing facilities for locally abundant crops such as maize, manioc, and wheat. Additionally, these SEZs provide the **second-tier transformation stage** for commodities like cocoa and palm oil, initially processed at decentralized industrial hubs. By enabling further value addition, products from these zones—such as flour, refined palm oil, cocoa derivatives, and packaged foods—can significantly increase market value, profitability, and competitiveness. Once processed, these high-value products are transported to major urban markets using river and road transport networks, facilitating greater market integration, stimulating local economic development, and enhancing overall food security and economic resilience in the region.

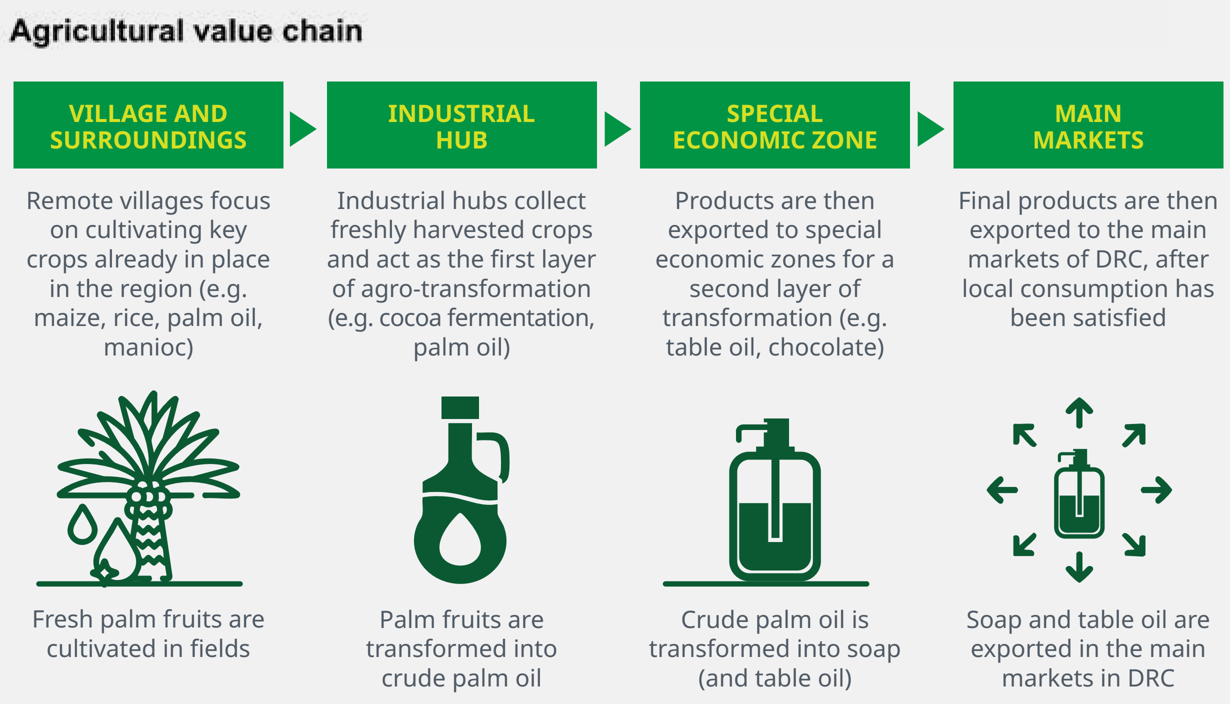


Fig 12 : envisioned agricultural value chain within the Green Corridor

As part of this preliminary study, it has been assumed that Virunga would contribute to the development of each special economic zone to a certain extent, as described hereunder.

In aggregate, in addition to existing area developed (e.g., in Goma, Lubero, Mutwanga and Maluku), Virunga could develop a further 80ha across the 6 different SEZ:

1. **Investment required** : ~$34.2 - 48.8 million ; this would include developing access to electricity, water, basic roads within the zone and a percentage of pre-built hangars on the land area. The investment cost was estimated based on Virunga's previous experiences in developing industrial zones in North-Kivu (for an approximate cost of ~ $0.6 million per ha)
2. **Revenues** : $3.4 million per year ; this is based on existing pricing applied in Virunga's industrial zones
3. **EBITDA**: $2.7 million per year ;

Industrial hubs collect freshly harvested crops and act as the first layer of agro-transformation

Palm oil processing.
Beni, Eastern DRC
© Guerchom Ndebo

The investment in the special economic zones should be break-even from an operational point of view but would act mainly as a catalytic investment. Hectares to be developed and the exact cost per SEZ would need to be further analyzed in subsequent studies.

ZES	Kisangani	Goma	Mbandaka	Maluku	Mutwanga	Lubero	Total
Hectares to be developed	50	10	10	0	10	0	**80**
Cost without hangar	21,346,154	4,269,231	4,269,231	-	4,269,231	-	**34,153,846**
Cost with 10% of land with hangars	30,480,769	6,096,154	6,096,154	-	6,096,154	-	**48,769,231**
Revenues per ZES	2,100,000	420,000	420,000	-	420,000	-	**3,360,000**
EBITDA	1,680,000	336,000	336,000	-	336,000	-	**2,688,000**

Fig 13 : what a further investment in SEZ could look like across the 6 key cities

Key crops processing facilities

Each special economic zone would act as the center of processing facilities for each key crop present around the 6 key cities. In this section, we provide a high level overview of what it could look like in the medium term. It incorporates both existing plans from Virunga (already ongoing in eastern DRC) and new - potential - developments.

Each special economic zone would be equipped with a biodiesel production plant, to ensure the decarbonization of transport, while reducing the cost of fuel by ~10%. Western SEZ would process mainly manioc (cassava), while eastern SEZ would be more diversified, owing to North-Kivu highly fertile and diversified agriculture.

1. Kisangani : rice, banana, manioc in addition to palm oil
2. Mutwanga : cocoa, palm oil and coffee
3. Lubero : wheat
4. Goma : maize

Hereunder, we provide a summary table of what processing facilities could look like in the 6 special economic zones, along with their respective proposed transformation capacity.

ZES transformation capacity	Rice	Maize	Manioc	Coffee	Cocoa	Banana	Wheat	Refinery + soap	Biodiesel
Kisangani	100 t / day		100 t / day			50 t / day			10m3 / day
Goma		500 t / day							10m3 / day
Mbandaka			100 t / day						10m3 / day
Maluku			100 t / day			50 t / day			10m3 / day
Mutwanga				1000 t / year	200 t / day + 30 t / month			300 t / day + 800 t / month	10m3 / day
Lubero							200 t / day		10m3 / day

Fig 14 : what processing facilities could look like in the 6 special economic zones

Developing such processing facilities could yield the following results in the long term (highly preliminary):

1. **Transformation capacity** : 634 000 tons of agricultural produce transformed each year into added value products
2. **Investment required** : $159.6 million of CAPEX into setting up the new processing facilities ; including significant investment in the upstream value chain (improving yields and farmers' best practices)
3. **Revenues** : $596.7 million of yearly revenues
4. **EBITDA** : $70.5 million of yearly EBITDA

The results presented in this section should be considered exploratory, given their high dependency on several key underlying assumptions, especially in the context of the Democratic Republic of Congo, where the prevailing security environment and complex fiscal landscape can significantly affect the financial performance and profitability of agro-industrial ventures. Fluctuations in security conditions can impact operational continuity, supply chains, and logistics, while variations or uncertainties in the fiscal regime—such as changes in taxation policies or regulatory frameworks—can alter cost structures and revenue forecasts substantially. Therefore, while the presented outcomes provide valuable insights into potential scenarios, they must be interpreted with caution.


Cocoa processing, Mutwanga, Eastern DRC © Virunga Origins

TRANSPORT

Concept for transportation on key rivers within the Congo Basin

Robust vehicles are needed to navigate degraded roads.
© Brent Stirton/Getty Images

Transport

State of transport infrastructure

Infrastructure along the Green Corridor—including roads, airports, river transport, and ports—faces significant challenges, constraining economic growth and regional integration in the Democratic Republic of Congo (DRC). **Road networks** are overall in poor condition, with extensive degradation and limited paved sections, leading to long transit times, high costs, and isolation of many communities. **Airports**, while numerous, often have limited capacity and aging facilities, hindering their reliability and operational safety. **River transport** on the Congo River, the world's second-largest river by discharge, remains severely underutilized due to inadequate dredging, lack of navigation aids, outdated vessels, and insufficient maintenance. This drastically limits the potential for cost-effective inland transportation. Similarly, **port infrastructure**—critical for handling goods along the river—is mostly dilapidated (see additional details in *Appendix 1 - "deep dive reports - transport"*), lacking modern handling equipment, storage facilities, and proper quay infrastructure, resulting in congestion, inefficiencies, and delays. Despite these considerable constraints, strategic investments in infrastructure rehabilitation and modernization hold significant potential to unlock economic development, enhance regional trade, and improve livelihoods along this essential transport corridor.

Roads

Existing data sets on the state of road infrastructure are mainly outdated and generally overestimate the state of infrastructure (e.g., some roads, known to be severely degraded are still reported as paved). Therefore, we limit ourselves to present a general overview of roads within the Green Corridor. Some additional details may be found in *Appendix 6 - Matrix of distances between cities.*

The **Green Corridor** in the Democratic Republic of Congo (DRC) encompasses key urban centers such as **Kinshasa**, **Goma**, **Beni**, **Butembo**, **Kisangani**, and **Mbandaka**. The road infrastructure connecting these cities is vital for economic activities, yet it faces significant challenges. It can be assumed that a car or truck travels, on a degraded road, at a speed of 5 - 10 km / hour.

- **Kinshasa to Mbandaka**: The only road linking Kinshasa directly to Mbandaka goes via Kananga and follows portions of the RN1, RN7 and RN8 along a 2 500+km journey. The only credible option for travel between the two cities is the Congo River.
- **Mbandaka to Kisangani**: Mbandaka is linked to Kisangani either via the Congo River or a ~1 200km road journey following the RN7 and RN8.
- **Goma to Kisangani**: There are two options, both with degraded road conditions, for travelling from Goma to Kisangani via road:
    - A 1 000 km journey following the RN2 (north), then RN4 (west), passing through Beni and Butembo.
    - A 800 km journey following the RN3 (north-west) passing through Walikale.

It is worth noting that building upon earlier efforts, in November 2019, the DRC government signed a memorandum of understanding with China Communications Construction Company (CCCC) for the asphalting of a 670-kilometer stretch of the N4 road, connecting Kisangani, Bafwasende, Niania, Mambasa, and Beni. This project aimed to improve transportation between these key towns, particularly addressing challenges posed during the rainy season when the road often became impassable. This new development could change the transport dynamic between eastern DRC and Kisangani should it materialize.

Hereunder, we provide an overview of existing roads within the Green Corridor, split by type : (1) national roads in red, and (2) provincial roads in yellow.

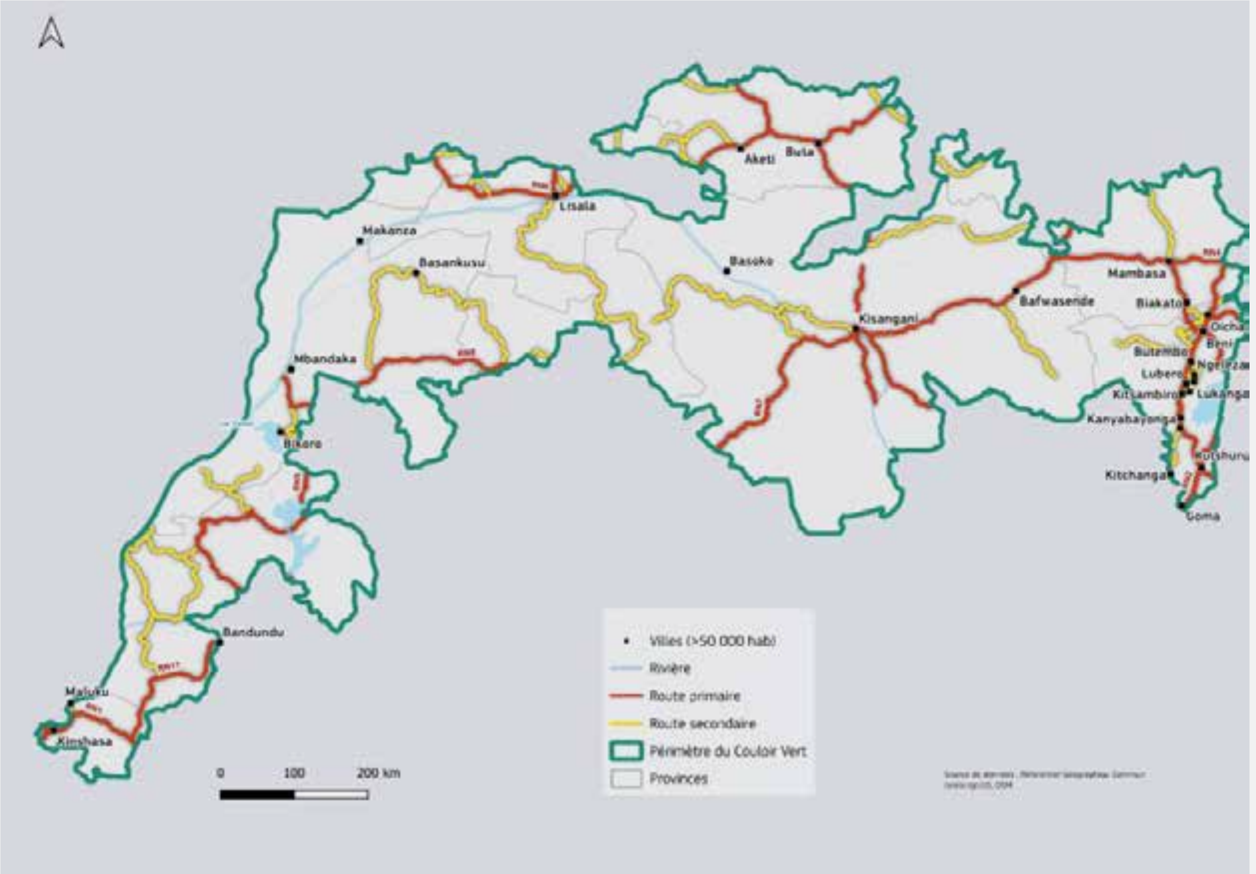


Fig 15 : overview of existing provincial and national roads within the Green Corridor

Rivers and ports

As for roads, the state of river infrastructure in DRC is severely limited.

The condition of port facilities along the Congo River is a critical factor in transport efficiency. **Kisangani, Mbandaka, and Kinshasa** are three key river ports, and all have suffered from years of underinvestment and war damage:

- **Kisangani:** This upstream river port (the terminus of navigability) has very **dilapidated facilities**. Warehouses and quays are in poor repair, and handling equipment is scarce or old. On the opposite bank, an SNCC rail-port is *"almost abandoned"*. Efforts to rehabilitate the main port have begun – the government estimated **$5 million** is required to fix erosion damage, rebuild the **container terminal**, repair warehouses, and purchase new cranes and forklifts. In 2013, some rehabilitation of the Kisangani port did start, but much remains to be done. A **modest new crane** was installed with donor support, which has slightly improved loading productivity. Overall, capacity is limited and large vessels must queue to unload during peak seasons. On the ground reports mention that cranes are limited to weights below 14 tons.

- **Mbandaka:** The mid-stream port at Mbandaka (Equateur Province) has very basic infrastructure. It primarily serves as a refueling and transshipment point. Years of neglect mean **dockside storage** is minimal and many vessels simply beach on the riverbank to load/unload. There is little mechanized equipment – cargo is often manhandled. Despite these constraints, Mbandaka remains an important stop, but it exemplifies the **"severe maintenance problems"** along the river. Significant investment would be needed to build proper jetties and warehouses at Mbandaka.
- **Kinshasa:** The capital's river port is the gateway to the interior, handling incoming barges from Kisangani, Kasai River, and Ubangi River. The port infrastructure in Kinshasa is aging and congested. According to the IFC, the port's quays and cranes are *"dilapidated or nonoperational"*, which *"reduces productivity"*. Maintenance has been spotty – for example, the main gantry cranes frequently break down, slowing container handling. In recent years, a private concession at the nearby Matadi seaport invested in equipment, but Kinshasa's fluvial port under SCTP has lagged. Dredging is also an issue; sediment buildup at the Beach Ngobila passenger port and the freight port limits draft. Overall, Kinshasa's river port can no longer efficiently handle the volume of traffic, resulting in delays and higher costs. The current state of disrepair at Kinshasa and other river ports remains a *"serious drawback"* to efficient transport. Private ports have popped up across Kinshasa to offer a much better alternative and cater to private companies' needs but remain limited in scope.

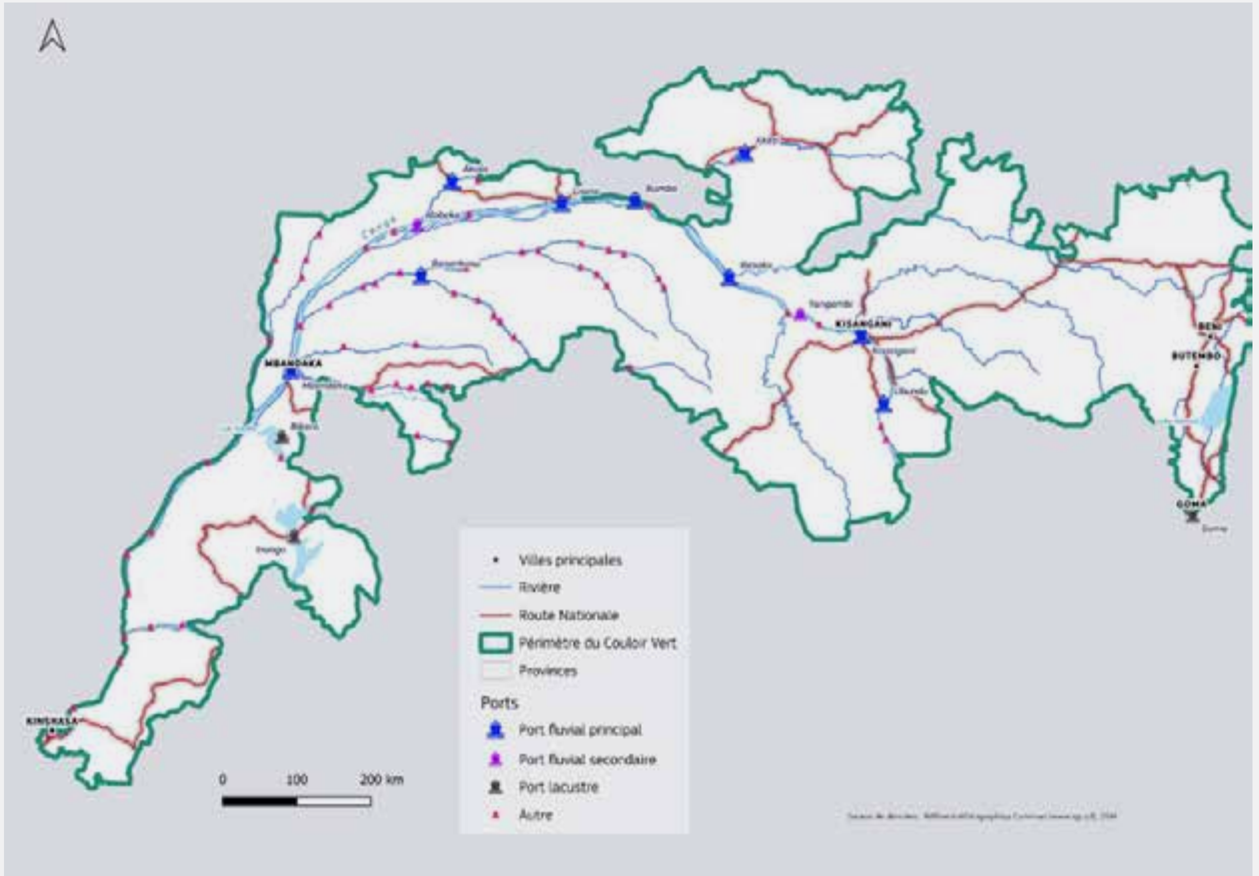


Fig 16 : overview of existing ports within the Green Corridor

Landing strip development,
Eastern DRC.
© Virunga Foundation

Airports

The Green Corridor has a multitude of private and public airstrips within its perimeter. However, very much like for roads and ports, most of the airstrips are in a poor state, rendering them unusable for commercial travel. It is worth noting that the key cities are usually decently served by commercial airlines.

Despite its high cost, currently, most of the transport of goods from eastern DRC to western DRC happens by air due to the limited availability or credibility of other options like road and river transport, especially for the transport of fresh produce.

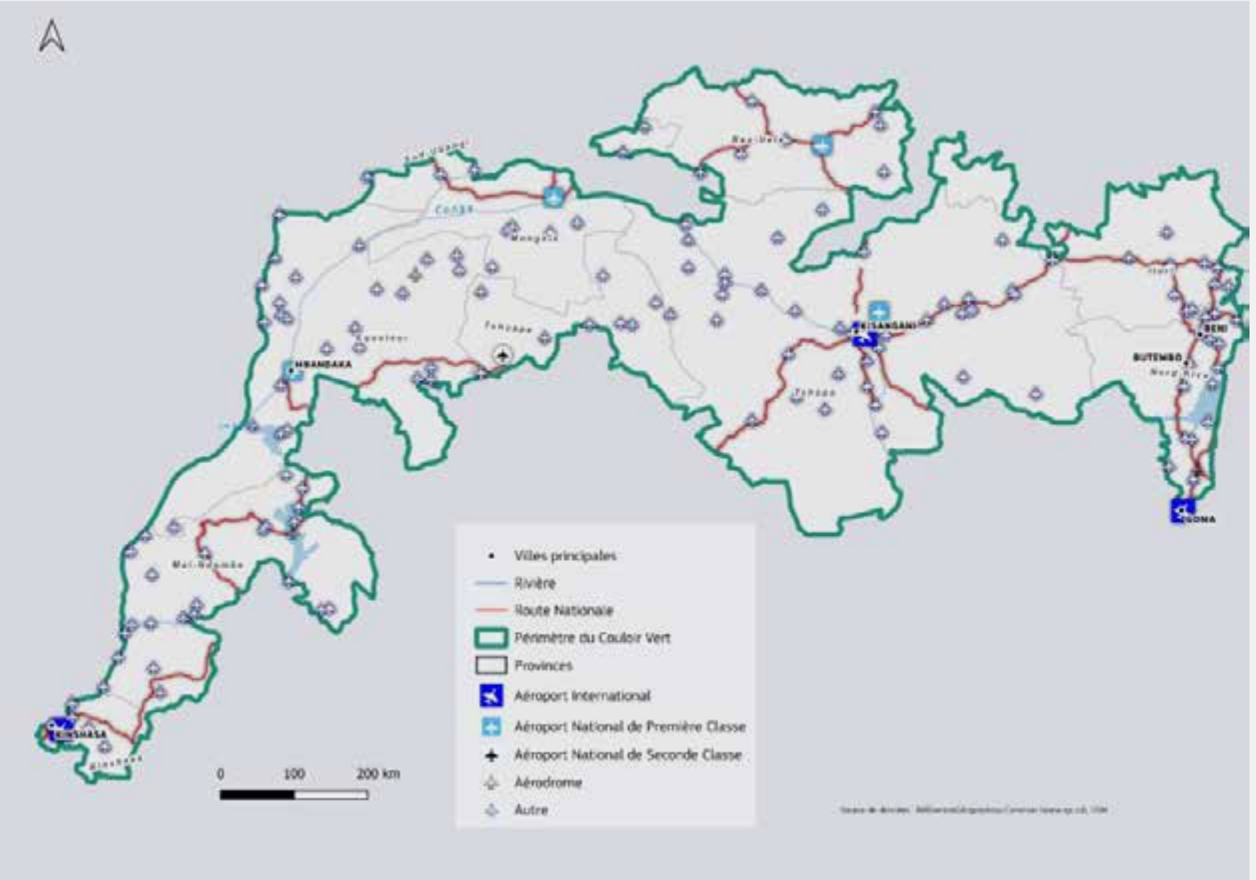


Fig 17 : overview of existing airstrips within the Green Corridor

Opportunities for improvement

Transport is a key component of this development study and is the missing link between production and consumption in DRC. While most of the agricultural production and planned transformation will happen in eastern DRC, the main market remains Kinshasa. It is therefore critical to factor into account the modalities of transport of those products, with the objectives of exporting up to 1 million tons, to Kinshasa - or any of the key cities within the Green Corridor.

In this section, we mention a couple of elements acting as barriers to the transportation of significant quantities of agricultural produce within the Green Corridor. A detailed study would be required to estimate the cost of investments required to fix these barriers and is not included as part of the scope of this document.

As mentioned above, there are two critical transport links within the Green Corridor:

1. The road section from Goma to Kisangani (RN2 / RN4 or RN3)
2. The river section from Kisangani to Kinshasa

The road section (~670 km), currently unpaved and almost impracticable during the rainy season, should be rehabilitated and paved by a Chinese company in the coming years. Works seem to be under way. The rehabilitation of that road section would represent a significant improvement in the connectivity of eastern DRC with Kisangani and Kinshasa.

The river section primarily supports **informal and semi-formal trade**, facilitated largely by privately-owned or informally operated barges and smaller boats known as **baleinières**. Barges often travel in large convoys, carrying a range of cargo including agricultural produce (manioc, maize, rice), timber, fuel, construction materials, and consumer goods. Passengers are also commonly transported, frequently under precarious conditions due to inadequate safety measures and overcrowding.

Operationally, the river transport system is characterized by **aging and poorly maintained vessels**, resulting in slow, inefficient voyages. Journeys between major ports such as Kisangani and Kinshasa (~1,750 km by river) frequently last from **three weeks to several months**, depending on water levels, the condition of vessels, and availability of cargo. Due to poor navigational infrastructure—limited dredging, absence of reliable navigation aids, and the seasonal fluctuations of water levels—navigation remains difficult, particularly during the dry season.

The **port infrastructure** along the river is generally outdated and severely limited. Major ports, including Kisangani, Mbandaka, and Kinshasa, suffer from insufficient dock capacity, deteriorated storage facilities, outdated loading equipment (e.g., max 14 tons per container in Kisangani), and chronic congestion. Furthermore, river transport faces **informal checkpoints and frequent administrative bottlenecks**, leading to unpredictable delays and higher transaction costs.

In addition to significant investment in the rehabilitation of infrastructure, there exists an opportunity to further develop the business of transportation along the Congo River. There are no existing private or public companies offering proper transportation for fresh agricultural produce (or any good which would require attentive care). There is a clear opportunity for a private actor to play a major role in improving the quantity and quality of transportation services by offering, e.g., refrigerated cargo, containerized transport and predictable deliveries.

Potential opportunities for businesses

As mentioned earlier, there is an opportunity for private businesses to play an increasingly important role in the transport sector on the Congo River. In this section, we tentatively provide a sizing of what the development of a serious private transportation actor would require in terms of financial resources and returns in the context of Virunga's ambitions to transform up to 1 million tons of agricultural produce[10]. It is worth noting that this does not include investments in port or road infrastructure which are assumed to be handled by the government.

Current transportation cost

While underdeveloped, it is still possible to export products from eastern DRC to Kinshasa. There are two primary options:

1. By air travel : fast and expensive
2. By road and river : slow but less expensive

Currently, approximate costs are the following for a kg of goods. Air travel costs ~1.80$ / kg while a combination of road and river costs between ~0.28 - 0.42 $ / kg but will take months before arriving at the destination.

Transport section	Travel type	Cost ($ / kg)
Goma -> Beni	Road	0.14
Beni -> Kisangani	Road	0.20
Kisangani -> Kinshasa	River	0.08
Goma -> Kinshasa	Air	1.80

Fig 18 : overview of transport cost options from eastern DRC to Kinshasa

Assuming that 100% of all agricultural produce, as calculated in the 'Agriculture' section of this report, is exported from Goma to Kinshasa, it represents a sizable market opportunity of

1. ~$301 million by road and river
2. ~$1 283 million by air

Preliminary results

Exporting all products to Kinshasa would represent[11]

- 36 365 40-feet containers, assuming a max load of 28 tons per container and an average load of containers of 70%.
- 51 barges required to ferry products all year round, assuming an effective transport capacity per boat of 1250 T, and ~11 trips per boat per year.

Developing the necessary fleet of barges would entail the following financial implications:

4. **CAPEX required**: $304 million invested in new barges (excluding the cost of 40-feet containers)

[10] A more detailed study is under development but is not available at the date of closing the current report. In this section, to provide initial estimates, it will be assumed that all agricultural produce from industrial hubs (78,615 tons) and key processing facilities (634,144 tons) are exported from Goma to Kinshasa. In reality, a sizable proportion of agricultural produce will either be consumed locally or in other main markets (e.g., the other key cities of the Green Corridor) or to international markets (e.g., for chocolate).

[11] Hypothesis are based on preliminary research into the market but also assume a certain gain in efficiency compared to existing operations along the Congo River (e.g., in handling time at port facilities, in optimization of load per container, etc.)

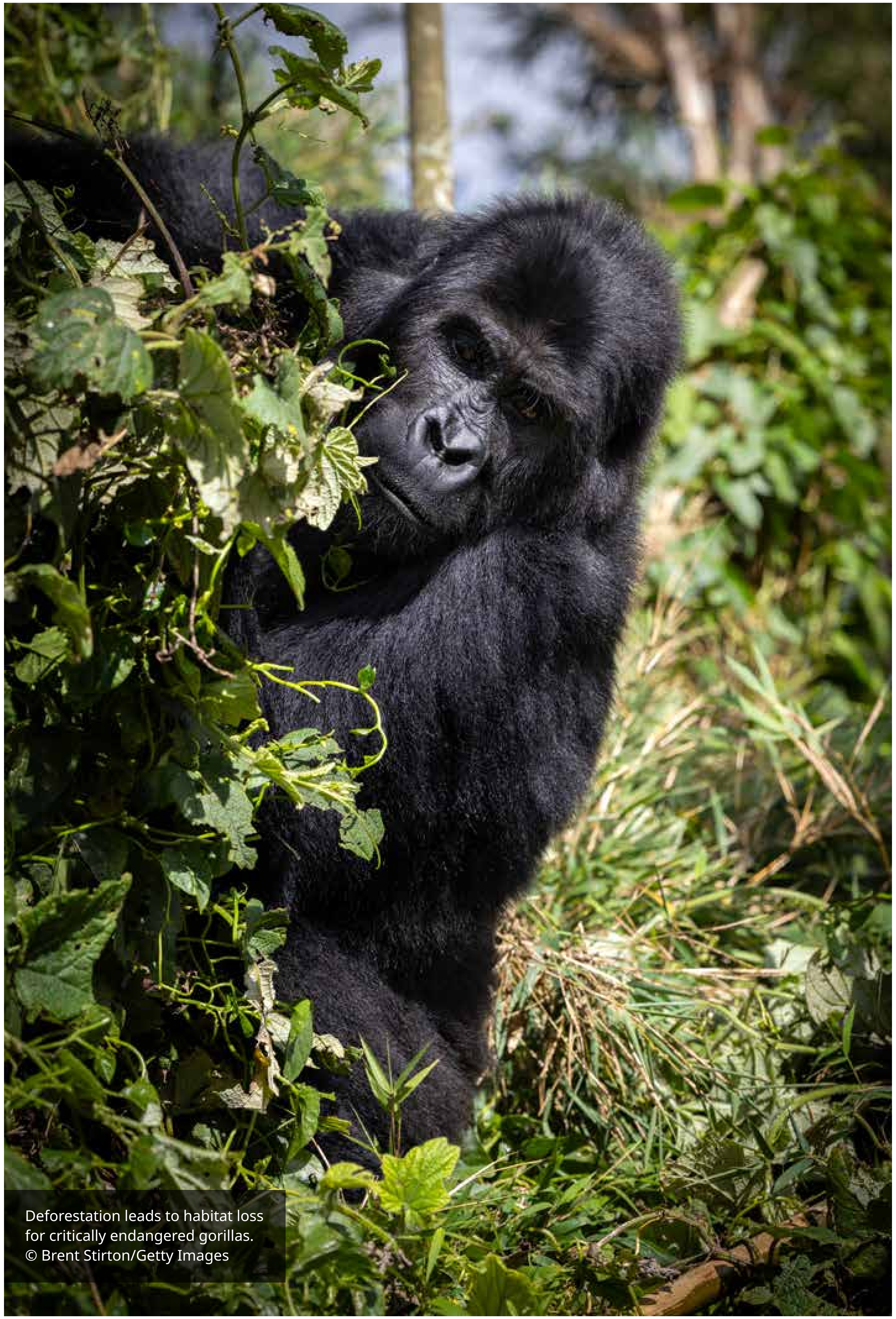
5. **Potential revenues**: $119 million per year (excluding road transport, and additional revenue streams such as container handling, customs clearance, etc.)
6. **EBITDA**: ~$35 million per year

However, our research indicates that, due to the deflated price per t-km of river transport, breaking even would represent a challenge. Additional revenue streams - or a higher pricing power - would be required to make river transportation profitable and be able to compete with informal actors.

Congo River, Eastern DRC
© Brent Stirton/Getty Images

CARBON FINANCE

Tropical Forests, Eastern DRC
© Brent Stirton/Getty Images



Deforestation leads to habitat loss for critically endangered gorillas.
© Brent Stirton/Getty Images

Carbon finance

Introduction: Global Carbon Finance and Tropical Forests

Tropical forests play a pivotal role in the global climate equation. Tree cover loss in tropical regions currently contributes roughly 8% of worldwide greenhouse gas emissions, yet protecting and restoring these forests could provide **23% of the cost-effective climate mitigation** needed by 2030 . This represents a major opportunity for carbon finance – the flow of funds in exchange for measured climate benefits (like avoided deforestation or carbon sequestration). In recent years, governments, donors, and private companies have mobilized significant resources to incentivize forest conservation. For example, the LEAF Coalition (Lowering Emissions by Accelerating Forest Finance) announced at COP26 that it had raised **$1 billion for tropical forest protection**, with 23 tropical jurisdictions proposing programs that together could safeguard half a billion hectares of forest. This surge of interest underscores how carbon finance can channel unprecedented funds into forest-rich regions – especially in tropical countries – in return for verifiable emissions reductions.

Carbon credits are an opportunity to generate cashflows from conservation, restoration and sustainable development activities, which can then be re-invested in the corridor to support the implementation and ongoing expenses of those or other conservation and development projects. These activities (renewable energy development, improved agricultural practices) and outcomes (reduced deforestation) are highly aligned with what the Corridor is aiming to achieve within its boundaries, presenting a highly synergistic approach to financing the activities to be implemented within the Corridor itself.

Carbon Markets: Voluntary vs. Jurisdictional

Carbon credits can be generated in different ways and from different activities which are expected to take place within the corridor, there are two main approaches to carbon credit generation from nature-based solutions, such as conservation, restoration and reduction in deforestation:

Privately developed carbon projects:

- **Ownership and implementation:** These are projects managed by a private entity, typically either a commercial carbon project developer or an NGO and they are carried out on land which is either owned by the implementing entity or leased from third parties (land-owners, communities). The credits are typically issued by aligning with a methodology published by an international standard such as Verra, Gold Standard or CORSIA, and the projects must be verified by an entity accredited by the relevant standard setter in order for the resulting credits to be issued, registered and traded.
- **MRV and accounting:** There are different methodologies which can be used to account for and measure and report on the emissions reductions generated by a given project, and verification has not always been robust - leading to many private projects, especially in forest carbon - to being widely discredited as “over-issuing” or not delivering on their project targets despite the issuance of credits. Measurement, Reporting and Verification (MRV) is a key element of carbon credit projects, and having a robust, transparent approach based on verifiable data is key to achieving “high-integrity” credits.

- **Issuance and sale:** credits from private developers or NGOs can be sold to buyers directly or through intermediaries who will place credits with corporates or individuals looking to reduce their net emissions by offsetting them using carbon credits. Credits issued under a standard are registered with that standard such that they can be retired and to avoid double counting and selling to multiple entities, however these registries are not yet as robust as would be desirable and there are many weaker projects still operating globally. Large, sophisticated buyers will have in-house teams with a strong understanding of project quality, and the integrity of the project, alongside things like permanence of the carbon emissions avoided or removed, will drive the price of a given project's credits.
- **Proceeds:** proceeds from the sale of credits generated by private developers or NGOs are typically split between the developer, the land owner (if applicable) and the local community (if applicable), with the bulk of the credits going to the developer. There has been much criticism of projects where insufficient credits were apportioned to local communities and this has become a key area of focus for standards agencies and for rating agencies (which rate projects on a scale of A to E)

Jurisdictional REDD+ Programmes:

- **Ownership and implementation:** these programmes span much larger areas, typically entire provinces or even countries, and the project proponent is typically the national or local government. Projects span public and private land, hence the project proponent must have jurisdictional authority over the relevant project area to enact project activities - which usually span policy changes and on-the-ground initiatives, often working together with private sector or civil society implementers. There are significant benefits to taking a Jurisdictional approach to REDD+ programmes including: reduced risk of **leakage** (i.e. where deforestation is reduced in a particular area, but simply shifts to somewhere nearby - in private projects this is accounted for by discounting the number of credits issued amongst other mitigation activities), enabling greater consistency in accounting methods by encompassing a larger area, and aligning climate finance with national targets. However, given the scale of these programmes, a robust, transparent and functional governance and administrative framework is fundamental to the programme's credibility and its ability to issue and sell credits.
- **MRV and accounting**: jurisdictional REDD+ programmes have made significant improvements on accounting and integrity of credits, with standards like **ART-TREES** (Architecture for REDD+ Transactions' The REDD+ Environmental Excellence Standard) emerging to certify jurisdictional programs, providing a rigorous framework for measuring impact and issuing credits at jurisdictional level. Jurisdictional programmes are large and hence the "project boundary" often encompasses public and private land, and requires a varied approach to reaching the desired deforestation reduction - this means that often private projects can exist within jurisdictional project boundaries - when this is the case the private project should be **"nested"** within the broader jurisdictional programme and accounted for to avoid double counting of outcomes from that project.
- **Issuance and sale:** jurisdictional credits can be used by the issuing government to meet its own NDCs (Nationally determined Contributions) or can be sold to buyers, which can be large programmes from e.g. the World Bank or a specific foreign Government looking to offset against their own emissions, or multi-buyer coalitions which can include both Governments and private sector corporations (for example LEAF coalition which includes 4 governments and more than twenty corporate buyers of jurisdictional REDD+ credits).

- **Proceeds:** proceeds from the sale of jurisdictional credits are typically split in line with the national government's carbon credit regulation and usually include a portion to government (local or national depending on the structure of the project) which is typically re-invested in climate and development budgets in full or in part, a portion to the implementing entity which could be a parastatal or an NGO or private sector entity (where applicable), and a portion to the local communities where the activities are taking place.

For tropical forest jurisdictions like the Democratic Republic of Congo (DRC), this evolving carbon finance landscape presents both an opportunity and a challenge. On one hand, DRC's vast forests – about 152 million hectares, the largest in Africa – position it as a prime supplier of forest-based carbon credits. On the other hand, harnessing this opportunity requires strong governance, careful implementation and alignment with international standards to ensure credibility. The **Green Corridor Kivu–Kinshasa** initiative in DRC is a case in point: it aims to leverage the jurisdictional approach to protect forests and drive green development and could be an excellent candidate for jurisdictional REDD+. In the sections that follow, we examine how the Green Corridor can capitalize on carbon finance by learning from past experiences, addressing key barriers, and charting a clear roadmap to participate in high-integrity carbon market mechanisms.

Carbon Stocks, Emissions and Mitigation Potential of the Green Corridor Kivu–Kinshasa

The Green Corridor Kivu-Kinshasa spans a significant portion of the Democratic Republic of Congo (DRC), encompassing areas of high ecological value and substantial carbon stocks.

The Green Corridor Kivu–Kinshasa encompasses an **exceptional diversity of forest ecosystems** ranging from lowland moist tropical forests to swamp forests and peatlands, each contributing to significant biomass and carbon storage. One of the key aims of the Corridor is the conservation of at least an additional 100,00 0km2 of undisturbed forest. In carbon terms, this area is equivalent to a stock of 6.6 - 7.3 billion tCO2e if we assume it all to be dense moist forest, demonstrating the significant value of preserving these forests in the long term. This estimate accounts only for above-land biomass, so including below-ground biomass (additional 25% of carbon), and if the area in question were to encompass peatlands from the Cuvette Centrale (peat stored > 1,000 tC/ha of carbon compared with moist dense forest which stores 130 - 250 tC/ha), this number could increase substantially.

Recent remote sensing analyses have underscored increasing threats to forest integrity in the Congo Basin, driven primarily by small-scale agriculture expansion, infrastructure development (particularly road construction linked to logging), and selective logging activities.

According to Shapiro et al. (2021), approximately **70% of forests in the Congo Basin remain fully intact**, marking a notable decline from 78% in 2000. Their innovative Forest Condition (FC) metric, combining forest fragmentation, canopy cover, and biomass losses, demonstrates a consistent deterioration of ecological integrity, emphasizing that around **20% of the Congo Basin ecosystems are now classified as threatened**, directly impacting biodiversity and carbon storage capacity.

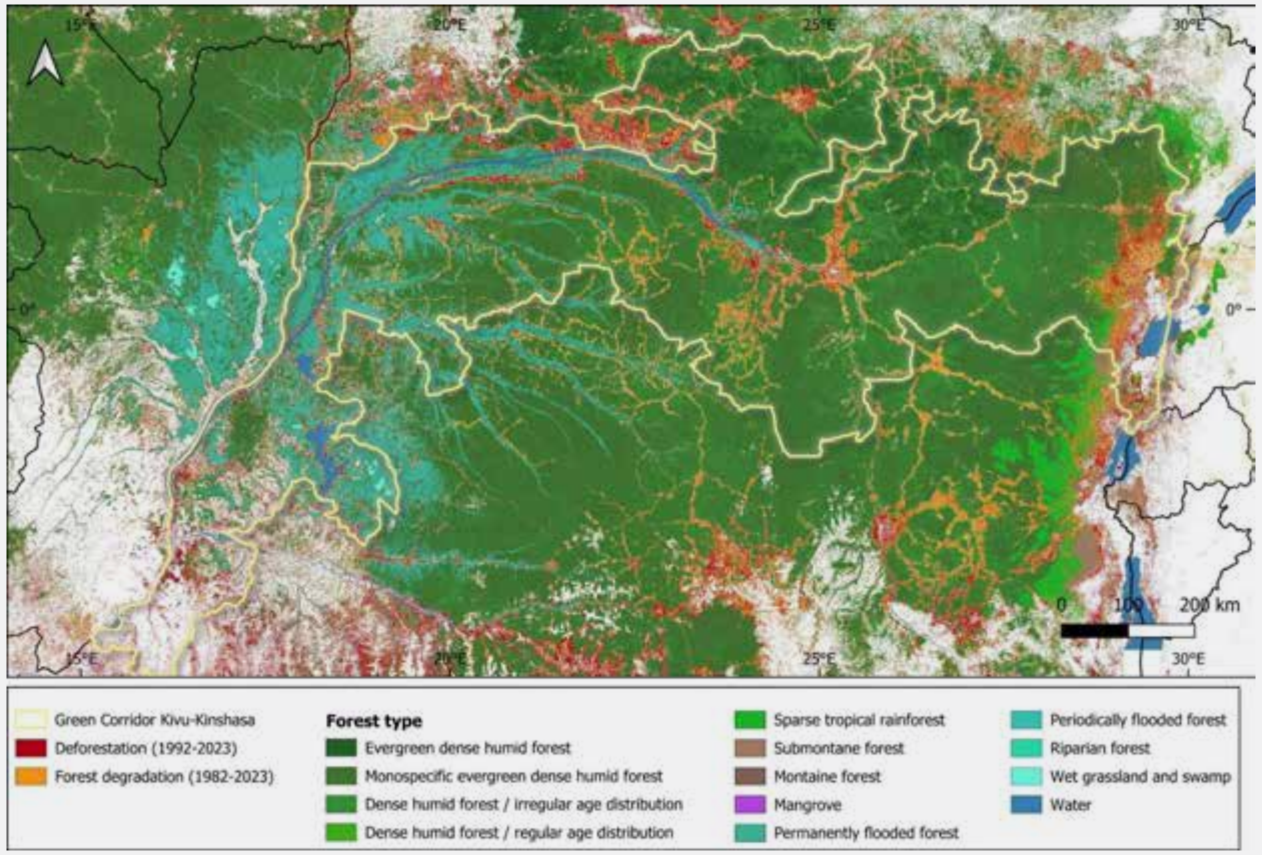


Fig 19 : overview of forest types within the Green Corridor

Deforestation and forest degradation in the Green Corridor

Forest emissions in the Green Corridor Kivu–Kinshasa are driven by a combination of **deforestation (complete removal of forest cover)** and **degradation (partial canopy disturbance, often due to selective logging or shifting cultivation)**. Both processes release significant quantities of greenhouse gases, with degradation often under-reported despite its growing contribution to forest carbon loss in Central Africa.

Forest emissions are driven by deforestation, DRC.
© Brent Stirton/Getty Images

According to the compiled remote sensing data done in this study by VisioTerra, deforestation and degradation have remained substantial over the past two decades, though fluctuating between periods:

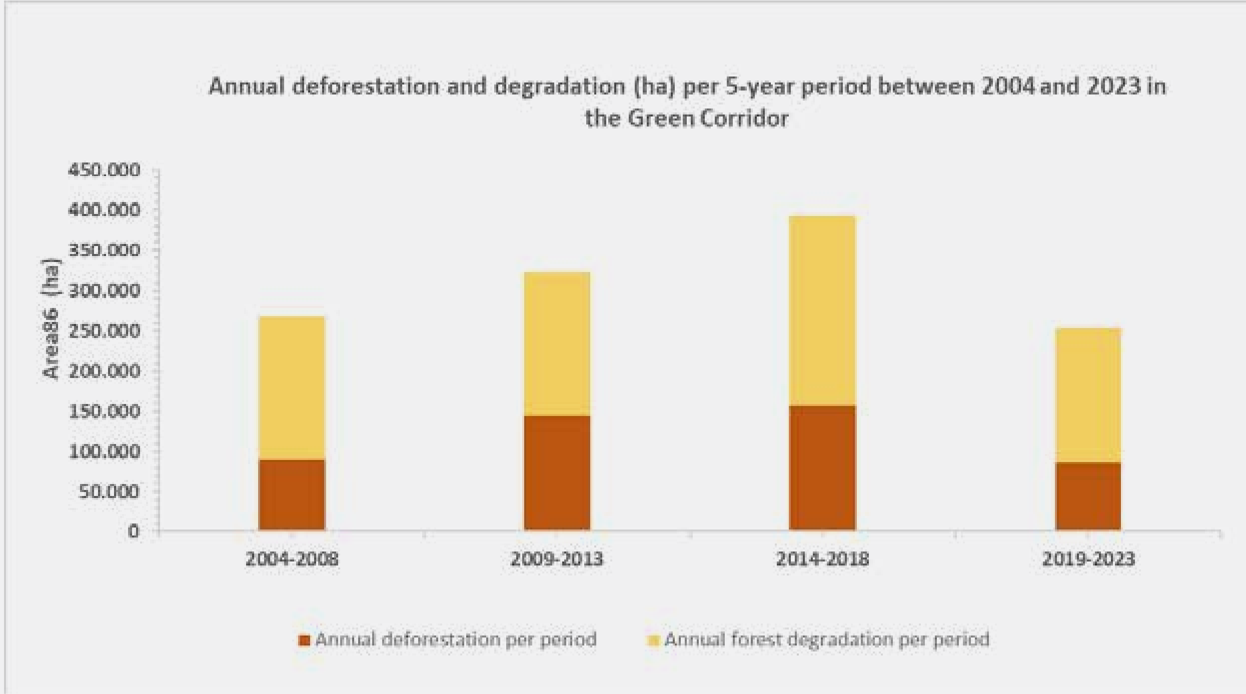


Fig 20 : deforestation and degradation over 2004 - 2023 period

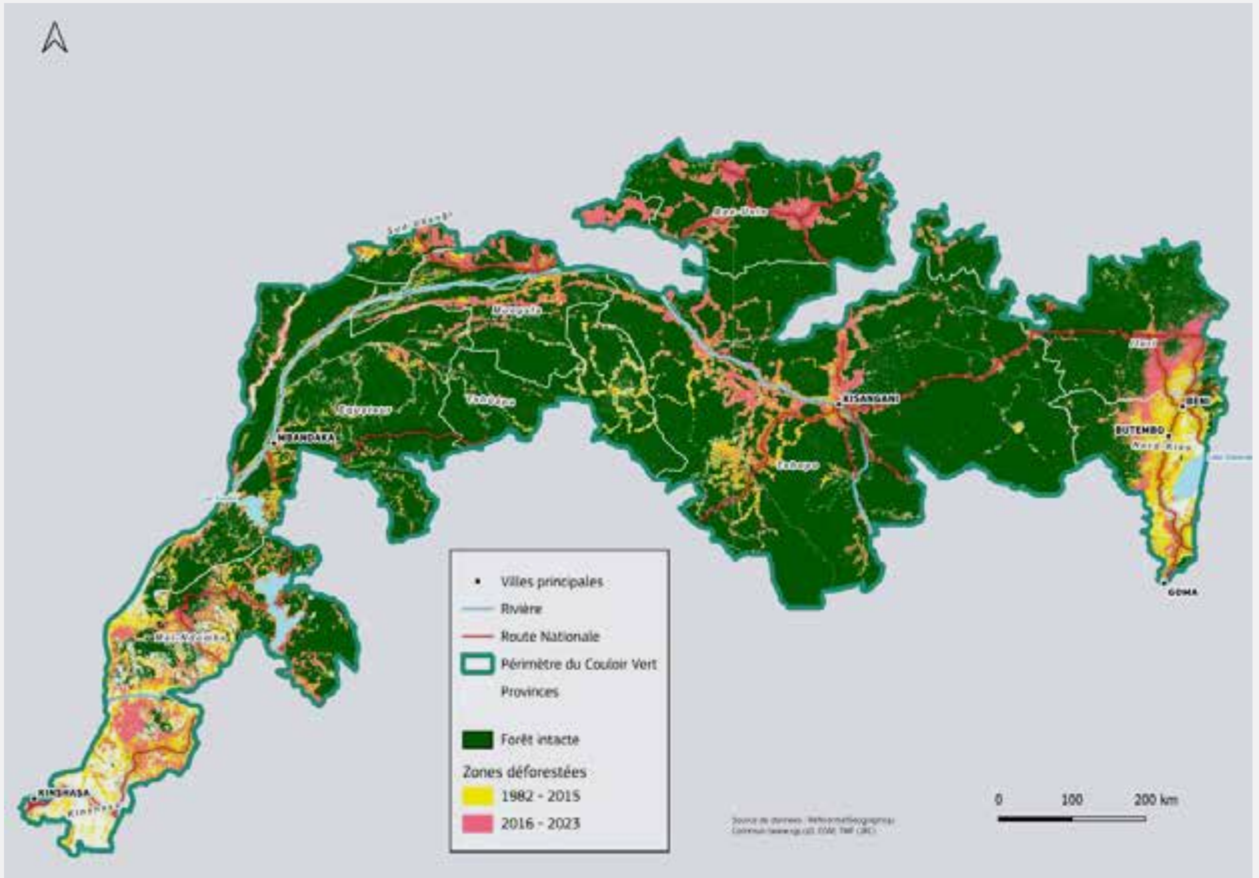


Fig 21 : deforestation over 1982 - 2023 period

Deforestation around Eastern DRC.
© Brent Stirton/Getty Images

While deforestation slightly declined in the most recent period (2019–2023), degradation remains persistent and significant. These figures indicate a transition in land-use dynamics, with **more subtle but widespread disturbances becoming a dominant driver of emissions**.

Emissions Calculations

Over the past two decades, the Green Corridor Kivu–Kinshasa has experienced sustained forest disturbance from both deforestation (permanent conversion of forests) and degradation (temporary or partial biomass loss). These changes are now well quantified thanks to the latest multi-source remote sensing datasets covering the period **2004 to 2023**, disaggregated by province and disturbance type.

To estimate greenhouse gas emissions, the following standard conversion factors were applied:

- **Deforestation**: 220 tCO_2/ha
  (based on aboveground biomass and typical carbon densities in Congo Basin humid forests)
- **Degradation**: 65 tCO_2/ha
  (averaged from regional studies on selective logging, light disturbance, and shifting agriculture)

We estimate the total average annual emissions for each 5-year period as follows:

Period	Annual deforestation per period (ha)	Annual forest degradation per year (ha)	Total Annual Emissions (tCO_2/year)
2004-2008	89.645	177.264	31.244.060
2009-2013	144.520	178.463	43.394.495
2014-2018	157.396	235.117	49.909.725
2019-2023	86.042	167.770	29.834.290

The peak observed during **2014–2018**, with nearly **50 million tCO_2/year emitted as a result of forest loss and degradation**, underscores the critical importance of intervention. The subsequent reduction in 2019–2023 may be linked to forest cover saturation in frontier zones, governance improvements, or under-detection of degradation — highlighting the importance of high-resolution MRV systems for future REDD+ crediting.

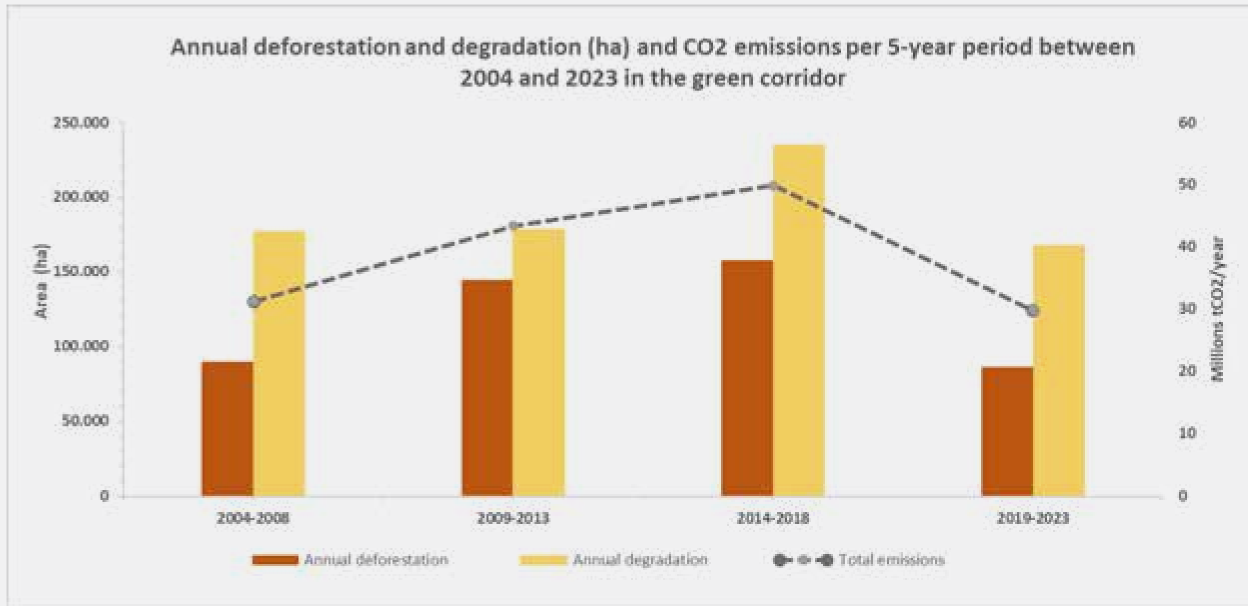


Fig 22 : emissions linked to deforestation and degradation

Provincial Patterns of Emissions[12]

Emission volumes vary widely by province, reflecting ecological heterogeneity and pressure intensity (see figures below). Across all periods:

- **Maï-Ndombe, Tshopo, Mongala, and Bas-Uele** consistently rank among the top emitters due to the higher land-use change rate.
- **Maï-Ndombe alone accounted for over 11 million tCO_2/year during 2009–2013**, positioning it as a prime target for REDD+ finance as shown in this study.

[12] Maps of deforestation at provincial level are available in *Appendix 10*

- Provinces like **Kinshasa and Tshuapa** exhibit lower emission volumes but still present high relative rates in terms of disturbance per unit forest area.

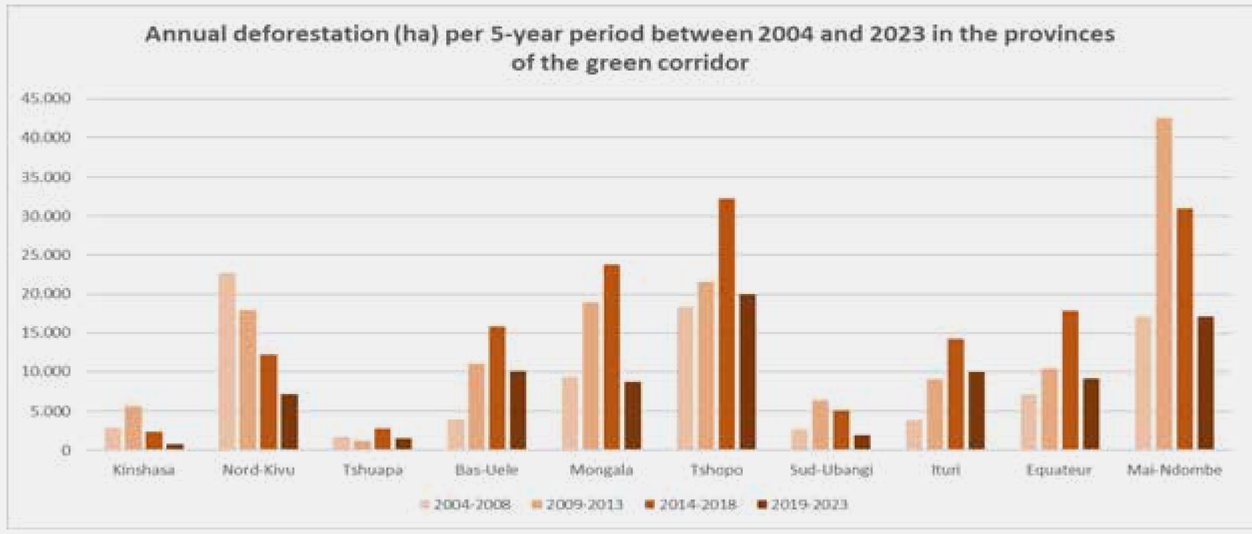


Fig 23 : deforestation by province

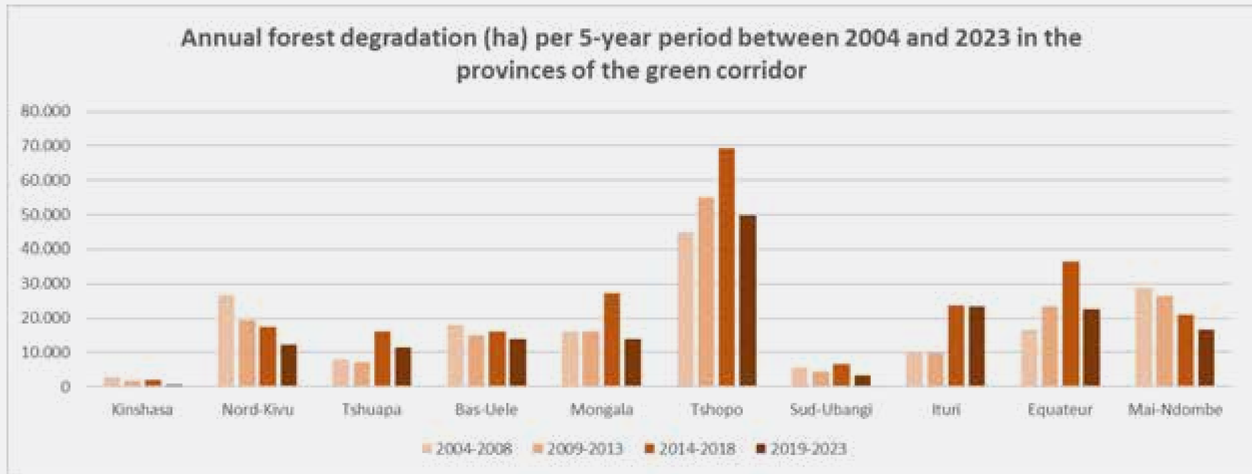


Fig 24 : forest degradation by province

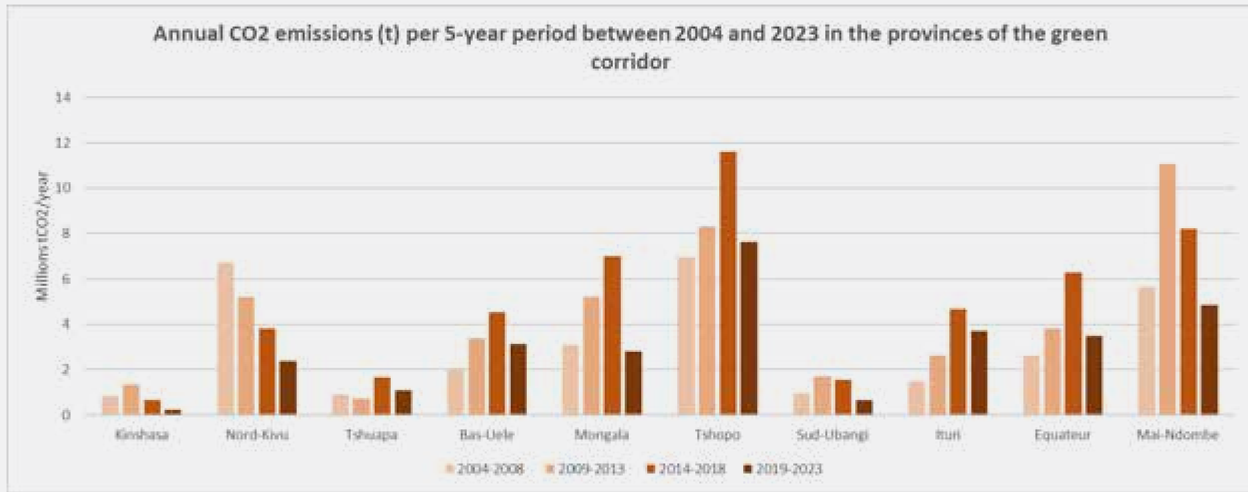


Fig 25 : emissions by province

The Carbon Finance Opportunity

The revised emissions baseline is highly relevant for understanding the potential impact of implementing a REDD+ programme in the Corridor:

- With average emissions from forest loss and degradation at **30–50 million tCO_2/year**, by targeting a 50% reduction in these, the Green Corridor could credibly avoid **up to 25 million tCO_2/year**.

- Over a 5-year crediting period, this equates to **125 million tonnes of avoided CO_2 emissions**, with potential issuance of **80–100 million jurisdictional credits** after accounting for uncertainty, leakage, and permanence buffers.

- At an average carbon price of **$10–15 per tonne**, this could represent **$800 million to $1.5 billion in potential revenue**, if implemented with high environmental and social integrity under standards like ART-TREES.

Implementing a jurisdictional REDD+ program in the Green Corridor

To implement a jurisdictional REDD+ program in the Corridor, several elements must be brought together, both in terms of analysis and project design, but also in terms of governance and systems and process implementation:

Programme design and objectives:

- **Baselining of emissions** from the jurisdictional area (we have provided an estimate of this in the previous section)
- **Projecting Business-As-Usual (BAU) trends** for 2024–2030; The emissions baseline should be spatialized and projected forward to support dynamic scenario modeling

THE CARBON FINANCE OPPORTUNITY

With average emissions from forest loss and degradation at 30–50 million tCO_2/year, by targeting a 50% reduction in these, the Green Corridor could credibly avoid up to 25 million tCO_2/year.

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- Development of a set of **actions and initiatives to reduce the BAU** forest loss (spanning policy and on-the ground initiatives), and estimation of an associated expected reduction in forest loss (and hence emissions)

Operationalising and implementing the program:

- Identification and mandating of key **legal and administrative functions**: identifying the entity responsible for the programme overall, establishment of local governance bodies with IPLC representation at the provincial level and identification of implementing agencies.
- The development of a dynamic **MRV platform** - key for ART-TREES eligibility and hence to enter purchase programs such as the LEAF coalition's;
- Delineation of **benefit-sharing, nesting, and grievance mechanisms**.

Specifically, these latter three warrant a closer study.

Eligibility Barriers and Enabling Conditions for Carbon Crediting

To unlock carbon finance at the jurisdictional level, the Green Corridor must satisfy a number of eligibility criteria and enabling conditions commonly required by international standards and financing initiatives. These conditions act as **gateways** – without them, the Corridor program might struggle to attract credible buyers or get approval under programs like ART-TREES or the LEAF Coalition. Below we outline the key barriers and the steps needed to overcome them:

Policy and Regulatory Framework:

The Democratic Republic of Congo (DRC) has recently strengthened its policy foundation for jurisdictional carbon finance. In September 2023, the government adopted an inter-ministerial decree (*Arrêté interministériel* du 15 septembre 2023) on carbon revenue sharing. This decree provides, for the first time, a legal basis for allocating carbon credit revenues among the central State, provincial authorities, decentralized local entities, and local communities. It stipulates how the **State's share** of carbon sale proceeds is distributed: **50%** to the national public treasury, **15%** to the province where the emissions reductions occur, **10%** to the local territory (entité territoriale décentralisée) of origin, and **25%** to environmental funds (including a 5% allocation to the national REDD+ fund).

Through this mechanism, communities are assured an indirect stake in carbon benefits via the 10% channeled to their local entities. By clearly defining benefit-sharing across levels of government, the 2023 decree greatly improves the enabling environment for jurisdictional programs such as the Green Corridor Kivu–Kinshasa. It aligns incentives for provinces and communities to support REDD+ activities and provides much-needed clarity and certainty to investors and donors, replacing the previous ad-hoc taxation approach with a transparent revenue-sharing framework. **This clarity is expected to unlock innovative finance** and bolster stakeholder buy-in, as noted by partners observing that the new revenue-sharing rules help "mobilize non-domestic resources" and ensure a portion of carbon revenues reach local communities

Despite this progress, **important gaps** remain in DRC's carbon finance policy framework that need to be addressed to fully operationalize jurisdictional programs and attract investment:

- **Nesting rules:** Detailed rules for **nesting** private or local carbon projects within larger jurisdictional REDD+ programs have yet to be developed. DRC has adopted a hybrid approach allowing both national and project-level crediting, but **guidelines on how projects align with provincial/national baselines and accounting** (to avoid double counting of emission reductions and ensure consistency with the country's NDC targets) are still missing. Clear nesting protocols will be critical to integrate standalone projects into the Green Corridor program and future jurisdictional schemes.

- **Project registration and oversight:** The **modalities for registering and approving carbon projects** under the new framework remain to be clarified. DRC established a Carbon Market Regulatory Authority (**ARMCA**) in June 2023 to oversee the carbon market, including maintaining a national carbon credit registry. However, the **specific procedures for project/program registration, approval, and coordination** under ARMCA are not yet fully defined or operational. Streamlined registration processes and a functional national REDD+ registry will be needed to improve transparency and investor confidence.

- **Benefit-sharing implementation:** Under current Congolese law, specifically the **Interministerial Decree of 15 September 2023 on carbon revenue management** and the decree establishing the Carbon Market Regulatory Authority (**ARMCA**, June 2023), the carbon stored in forests (carbon stocks) is explicitly recognized as a national asset under state authority, managed by the Ministry of Environment. However, once carbon credits are officially validated, issued, and registered through ARMCA, these credits are legally owned by the officially registered project holder or jurisdictional management entity, which could be a public, private, or community entity formally designated through regulatory procedures.

  The primary outstanding challenge is thus not the definition of ownership per se, but rather negotiating the detailed benefit-sharing arrangements among the state, provinces, local governments (ETDs), communities, and private project developers. The 2023 Decree provides a general framework for revenue sharing (e.g., fixed percentages allocated to provinces, local governments, and the national REDD+ fund, FONAREDD), but the exact implementation mechanisms—particularly for jurisdictional REDD+ programs like the Green Corridor—will require further negotiation, stakeholder consultation, and formal agreements to ensure clarity, equity, and effectiveness in benefit allocation.

By addressing these gaps – establishing nesting and registration rules, and detailing benefit-sharing operations – DRC can further strengthen its policy framework. This will give government agencies, donors, and investors greater confidence that jurisdictional initiatives like the Green Corridor Kivu–Kinshasa can deliver verified emission reductions *and* equitably share the benefits, thereby making the carbon business model sustainable for all stakeholders.

Meeting International Standard Requirements:

Each high-quality standard or program has its **eligibility requirements**. For ART-TREES, the jurisdiction must, inter alia, demonstrate a **Forest Reference Emission Level (FREL)** or baseline for deforestation emissions, a system for tracking reversals (to ensure permanence of emissions reductions), and implementation of social and environmental safeguards consistent with the Cancun REDD+ safeguards.

The Green Corridor will need to compile a TREES Concept note showing that it meets these requirements. Potential barriers here include the technical complexity of establishing a FREL for such a large, varied region and proving the ability to reduce emissions beyond what national policies alone would achieve. Enabling conditions would be to use DRC's already-submitted national FREL (to the UNFCCC) and National Forest Inventory (NFI) supported by FAO, as a basis, and to refine it for the Corridor region. Similarly, DRC's Safeguard Information System (SIS) and existing laws on community consultation can be cited as evidence of safeguard implementation, but these may need updating to cover the specific context of the Corridor (such as addressing conflict-related risks or community consent in new protected areas). In short, **leveraging existing national REDD+ readiness work** will be crucial to meet standards criteria without starting from scratch.

Institutional Capacity and Political Stability:

A less formal but very real eligibility factor is demonstrating that the program can be effectively implemented. **Early dialogues with initiatives like LEAF** have shown that proponents must convince funders of their capacity to deliver results. For the Corridor, the **current security situation** in parts of Eastern DRC could be seen as a barrier – if large areas are inaccessible due to conflict or lawlessness, it may hinder implementation and monitoring, thus discouraging investment. Tackling this means highlighting enabling factors such as the Congolese government's commitment (the fact that this is a Presidential priority is a strong signal), any improvements in security due to the Corridor (e.g. the plan includes community-based security efforts), and partnerships with experienced organizations. In practice, aligning with international partners (UN-REDD, World Bank, conservation NGOs) during preparation can shore up the program's credibility. High-level political support must trickle down to **administrative readiness** – e.g. having a designated team or task force working on the carbon component, budget allocated for preparatory studies, and clear endorsement that the emissions reductions from the Corridor will not be counted toward DRC's own NDC (Nationally Determined Contribution) if they are sold internationally (to avoid double claiming).

Alignment of Projects and Programs (Nesting):

As mentioned, a pre-condition for many jurisdictional programs is resolving overlaps with existing voluntary carbon projects. If any REDD+ projects are already in operation within the Corridor's boundaries (or if new projects are proposed by private developers), the program must define how these will be **nested**.

A barrier can arise if project developers fear losing their investments or credits; conversely, if not addressed, a jurisdiction could be deemed ineligible due to double-counted emissions. DRC's approach, as learned in Mai-Ndombe, is to integrate projects via a national registry (the **REDD+ National Registry** tracks all carbon initiatives) and to potentially deduct project-issued credits from the jurisdiction's results.

The enabling condition here is to have a functioning registry and legal mandate that all carbon projects in the Corridor register and align with the Corridor's accounting. Encouragingly, DRC approved several new REDD+ projects through FONAREDD in December 2023, indicating that a framework for governing projects exists. The Corridor program can build on this by formalizing collaboration agreements with any project operators so that everyone works toward the overall emissions reduction goal (with projects perhaps continuing but with adjustments to credit volumes or revenue-sharing with the government).

Finance for Readiness:

Preparing a jurisdictional program to the point of submission and validation requires upfront investment – for stakeholder consultations, technical studies, and institution-building. A potential barrier is securing this **readiness finance**. However, various enabling options are available: the Central African Forest Initiative (**CAFI**) has been a key donor for DRC's REDD+ (and could be approached to support the Corridor's development), and the **World Bank** has launched a new $300 million program to protect forests and savannas in DRC, which might provide funding or technical assistance. Additionally, the **Green Climate Fund or bilateral donors** (Norway, Germany, etc.) could be tapped specifically to back this high-profile Corridor initiative. Demonstrating early political commitment (which DRC has) and a clear workplan (to be outlined in a roadmap) will help unlock these preparation funds.

In summary, the **barriers** to eligibility – legal clarity, meeting standard criteria, capacity gaps, project overlaps, and funding needs – can be overcome by **leveraging DRC's existing REDD+ architecture and actively engaging supporters.** The Green Corridor starts with some strong enabling conditions: it has top-level political sponsorship and a clear conservation mandate, and it builds on a decade of national REDD+ experience. By addressing the remaining gaps (technical documentation, on-ground capacity, and alignment with standards), the Corridor can position itself as a credible candidate for programs like ART-TREES and initiatives like LEAF. The next subsection examines a relevant example from Colombia that offers additional insights on making a jurisdictional approach work in practice.

Case Study 1: Lessons learned from Mai-Ndombe REDD+ Experience

Mai-Ndombe province in DRC offers a valuable precedent for jurisdictional REDD+. Mai-Ndombe was the pilot province for DRC's first large-scale emission reduction program, initiated in the mid-2010s under the World Bank's Forest Carbon Partnership Facility (FCPF). Over the years, multiple REDD+ projects and readiness efforts were implemented in Mai-Ndombe, including private conservation projects and government-led integrated programs. For example, one high-profile REDD+ project in Mai-Ndombe protects 300,000 hectares of critical bonobo and forest elephant habitat by converting former logging concessions into community-managed conservation zones financed through carbon credits. That project, managed by a private company (ERA/Wildlife Works) in partnership with communities and the government, demonstrated the potential to channel carbon revenue into protecting forests and providing benefits to local communities (such as schools and livelihood support). Mai-Ndombe also attracted significant donor support – including at least $90 million in REDD+-linked investments over a decade and a $50 million performance-based payment under the FCPF Carbon Fund for reducing deforestation via issuance of credits.

Despite these efforts, the Mai-Ndombe experience highlights critical challenges that the Green Corridor must learn from:

Independent evaluations by Rainforest Foundations UK highlighted potential issues with the level of community engagement and the flow of benefits to local communities. After more than ten years of REDD+ interventions, there has been *"little improvement to land tenure [and] few benefits [have] trickled down to local communities,"* whilst deforestation and forest degradation continued. In some areas, local communities became disillusioned when promised benefits (like new schools or wells) were delayed or delivered at a smaller scale than expected, leading to conflict and loss of trust.

The demand for charcoal leads to llegal deforestation in protected forest areas in Eastern DRC.

Deforestation around Eastern DRC.
© Brent Stirton/Getty Images

The governance of the program also proved complex: overlapping claims and unclear land rights were not fully resolved, and the mechanism for sharing carbon revenues was slow to operationalize. Additionally, Mai-Ndombe's provincial program had to navigate the **"nesting" issue** – i.e. how to account for and integrate existing standalone carbon projects within the broader province-wide accounting. Early on, a lack of clarity on this front caused tension between project developers and the government, as both needed to avoid double-counting the same emission reductions.

Several **lessons** emerge from the Mai-Ndombe experience which are applicable to the Green Corridor:

- **Robust and Documented Community Engagement:** Mai-Ndombe showed that without genuine Free, Prior, and Informed Consent (FPIC) and ongoing community participation, local support for a carbon program can erode quickly. The Green Corridor should ensure communities are co-designers of initiatives and have effective grievance redress mechanisms from the start. Benefits must be tangible, fairly shared, and timely to maintain trust.

- **Clear Land Tenure and Rights:** Unresolved land tenure issues undermined Mai-Ndombe's interventions. In the Corridor, the new status as a community reserve offers a chance to formalize land-use rights and responsibilities (e.g. through community forests or co-management areas) in a way that communities feel secure and invested in conservation.

- **Strong Governance & Transparency:** Mai-Ndombe's experience underlines the importance of transparent governance, including how decisions are made and how funds are allocated. A multi-stakeholder steering committee for the Corridor's carbon program – including local leaders, civil society, and provincial officials – could improve oversight. Moreover, publishing benefit-sharing agreements and financial reports would increase transparency.

- **Realistic Baselines and Targets:** One technical lesson is to set achievable deforestation reduction targets. Mai-Ndombe's reference level (baseline) and assumed emission reductions may have been too optimistic, given rising pressure from in-migration and agriculture. The Green Corridor should use the latest data and science to establish baselines that reflect on-the-ground realities, ensuring that performance-based payments are attainable and not based on overly optimistic scenarios.

- **Integration of Projects (Nesting):** DRC is now developing a national nesting framework so that project-level activities align with provincial/national accounting. For the Corridor, this means any existing or future REDD+ projects inside its boundaries should be coordinated under the jurisdictional program's umbrella. Clear rules must define how project credits are adjusted or deducted from the jurisdiction's results to prevent double issuance. Learning from Mai-Ndombe, where this clarity came late, the Corridor should establish nesting guidelines early on.

In summary, Mai-Ndombe's REDD+ journey illustrates both the possibilities of carbon finance in DRC and the pitfalls to avoid. It reinforces that a jurisdictional program must be **people-centered, well-governed, and technically rigorous** to succeed. The Green Corridor, benefiting from a fresh legal framework and high-level political will, can build on these lessons to chart a more inclusive and effective course.

Case Study 2: Lessons from Orinoquía, Colombia: A comparable jurisdictional case

The Orinoquía region of Colombia, a vast area of savannas and forests in the eastern part of the country, provides a useful comparison for the Green Corridor. Like the Kivu–Kinshasa Corridor, Orinoquía is a large landscape (covering about 25% of Colombia's land area) with a mix of ecosystems, significant carbon stocks, and a developing frontier of agriculture and extractive activities. Colombia selected Orinoquía for a jurisdictional sustainable landscape program in recent years, aiming to curb deforestation and promote low-carbon development.

The Orinoquía region is included in Colombia's national REDD+ submissions. Colombia has developed a national Forest Reference Emission Level (FREL) that encompasses all its continental biomes, including the Orinoquía region. This national FREL serves as a benchmark for assessing the country's performance in reducing emissions from deforestation.

Additionally, this was supported in part by the World Bank's BioCarbon Fund under its Initiative for Sustainable Forest Landscapes (ISFL), which, similar to ART/LEAF, supports jurisdiction-scale emission reductions programs. The ISFL aims to promote sustainable land use practices and reduce deforestation through jurisdictional approaches, aligning with Colombia's National REDD+ Strategy.

While the Orinoquía region is integrated into these national and international frameworks, the implementation of jurisdictional REDD+ programs that generate and sell carbon credits is still in progress. The focus remains on developing the necessary policies, strategies, and capacities to enable effective emission reductions and the eventual issuance of carbon credits within the region.

Integrated Land-Use Planning: One lesson from Orinoquía is the importance of embedding the carbon program in a broader land-use plan. The Orinoquía initiative was not only about carbon credits, but also about directing agricultural expansion to lower-carbon areas, strengthening protected area networks, and fostering sustainable livelihoods (like cattle ranching on improved pastures, agroforestry, and bioeconomy products) in order to reduce pressure on forests. The Green Corridor shares this philosophy – it is conceived as a "green development corridor" balancing conservation with sustainable economic growth. The takeaway is that a jurisdictional carbon program should avoid being a standalone silo; instead, it should align with regional planning. In practical terms, the Corridor's carbon strategy could be integrated into DRC's land-use plans for the involved provinces and into sectoral programs (e.g. an agricultural development plan that emphasizes productivity on existing cleared land to avoid new deforestation). This alignment ensures that emission reduction efforts have local co-benefits and political buy-in.

Institutional Coordination and Capacity: Orinoquía's program highlighted the need for strong institutional arrangements, especially since multiple departments (sub-national units) were involved. Colombia created a special coordination body for Orinoquía and leveraged its regional environmental authorities. They also developed a detailed **jurisdictional REDD+ program document (ERPD)** that outlined roles at national vs. regional levels. During a World Bank preassessment mission for the Orinoquía program in mid-2023, it was noted that further guidance was needed on implementation arrangements and technical methodologies. In response, the Colombian team prepared technical manuals and clarified benefit-sharing mechanisms. For the DRC Corridor, a similar level of detailed preparation will be needed. It may be beneficial to develop an **operational manual** for the Corridor's carbon program, specifying how activities will be implemented across different zones, how data will be collected, and how benefits will flow to local communities. Additionally, investing in local technical teams (possibly in partnership with universities or NGOs) can mirror Colombia's approach of building regional capacity to run the program day-to-day.

Baseline and Credit Calculations: The Orinoquía case also offers insight into setting baselines and managing expectations on credit volume. Colombia had to reconcile its national forest reference baseline with the specific circumstances of Orinoquía. The analysis indicated that, due to certain adjustments (like excluding areas overlapping with existing projects and applying discounts for uncertainty and risk), the final volume of credits Orinoquía could generate might be significantly lower than the theoretical maximum. In fact, studies suggested that various deductions (for uncertainty, leakage, buffers, etc.) could reduce the credited emission reductions by up to ~25% from the raw calculations. This underscores a lesson: **be conservative and transparent in estimating emission reductions**. For the Green Corridor, expectations should be managed that not every ton of CO_2 avoided will translate into a sellable credit – some portion will be set aside as buffers or to account for national accounting alignment. Knowing this, the financial projections for the Corridor should use prudent assumptions (e.g. credit price and volume) to ensure the viability of the business model. It's better to over-deliver than to over-promise in carbon finance.

Safeguards and Social Inclusion: Both Colombia and DRC place a high value on social safeguards given the presence of indigenous peoples and local communities. In Orinoquía, stakeholder engagement (including with indigenous groups and campesino organizations) was conducted, and safeguard plans were prepared as part of the program design. One comparable element is that Orinoquía, like the Green Corridor, is not as heavily forested as an Amazon rainforest region – it includes savannah and wetlands used by ranchers and farmers. Thus, the social context involves working with productive sectors rather than primarily forest-dwelling communities. The Green Corridor will similarly need to engage farmers, fishers, and possibly artisanal miners alongside indigenous groups. A lesson from Orinoquía is to tailor community benefit programs to these groups – for instance, offering sustainable cattle ranching techniques in Colombia provided economic incentives to ranchers to avoid clearing new land. In DRC's Corridor, programs for s**ustainable agriculture** (e.g. intensification and agroforestry for staple crops) **or alternative livelihoods** for those in mining could be part of the carbon strategy, ensuring that emissions reductions efforts go hand-in-hand with local development priorities.

Access to Markets and Finance: Finally, Orinoquía's participation in international initiatives (World Bank ISFL, and being part of Colombia's national REDD+ submissions) positioned it to potentially sell credits to buyers like LEAF or CORSIA down the line. However, progress can be slow – it takes years to move from concept to a signed Emission Reductions Purchase Agreement (ERPA). For instance, by 2023 Colombia was still in the process of negotiating an ERPA price for Orinoquía's emissions reductions. The **lesson for DRC** is to maintain momentum and political support through what can be a lengthy process. Diversifying potential funding sources can help; while waiting for carbon credit transactions, the Corridor can seek interim funding (grants or upfront finance) to start implementation. It's also worthwhile to engage early with platforms like Emergent (which intermediates LEAF deals) to signal the Corridor's potential supply of credits. The more the Corridor's profile is raised internationally as a credible, high-integrity program, the easier it will be to attract buyers once credits are issued.

In summary, Orinoquía's experience reinforces many similar themes – the need for integrated planning, strong institutions, realistic accounting, and patience in securing finance. The Green Corridor can apply these insights by ensuring its carbon program is embedded in a holistic development approach, by drafting detailed program documentation with stakeholder input, and by proactively managing the technical and financial dimensions of the program. Doing so will increase the confidence of both national stakeholders and international partners in the Corridor's success.

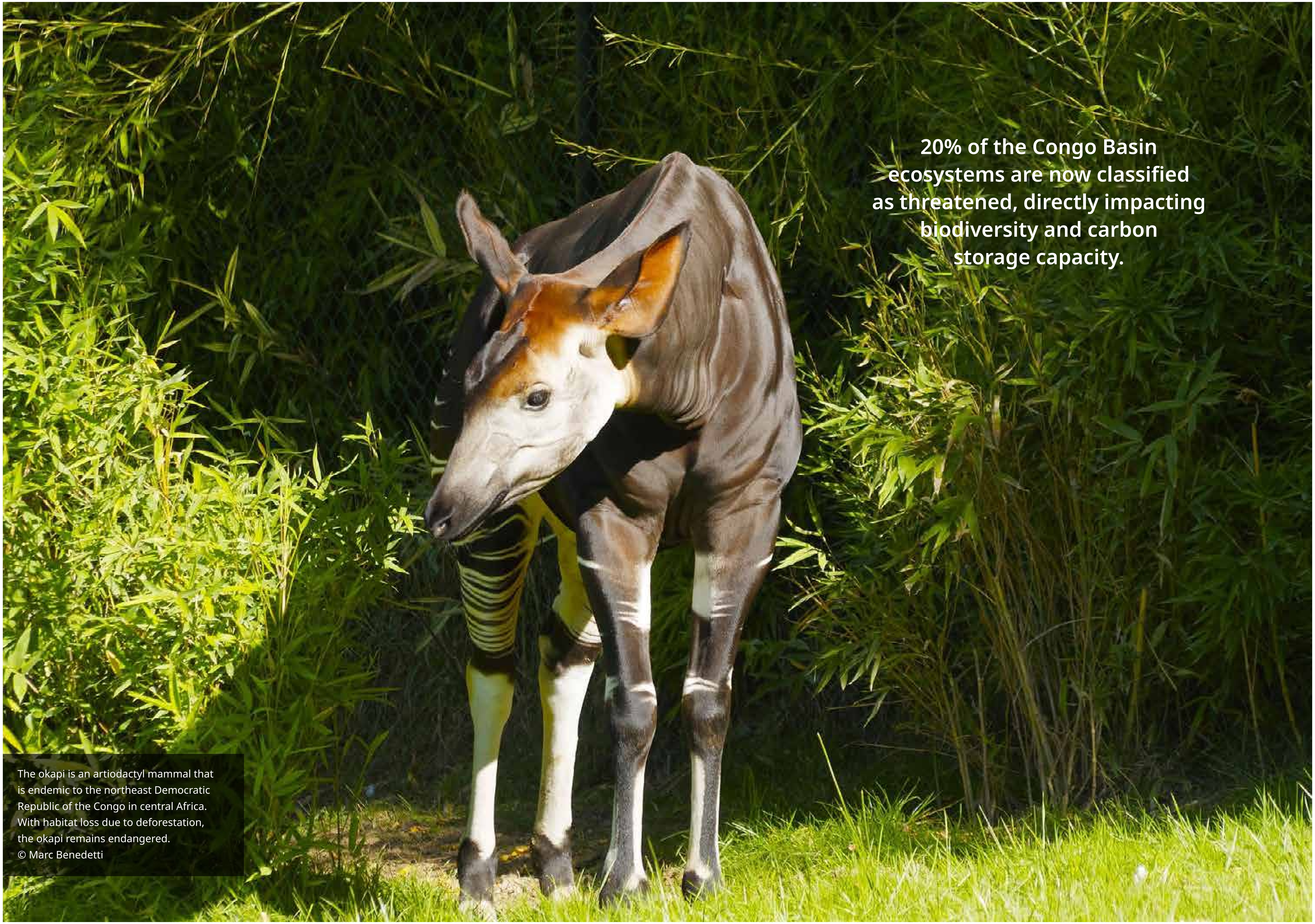
Aligning with ART-TREES, LEAF, and other standards

To maximize credibility and financial return, the Green Corridor's carbon program should align with **globally recognized standards and initiatives**. Chief among these are the **ART-TREES standard** and the **LEAF Coalition** - a key buyer of jurisdictional credits, which have become the de facto benchmarks for high-integrity jurisdictional REDD+ programs. Alignment with such standards and eligibility for LEAF will signal to donors and private investors that the Corridor's emissions reductions are real, additional, and meet the highest environmental and social safeguards.

ART-TREES (Architecture for REDD+ Transactions – TREES): ART-TREES is a leading standard specifically designed for jurisdictional REDD+ crediting. It provides a rigorous methodology for estimating and subsequently measuring emission reductions from deforestation and forest degradation at national or subnational scale, including accounting rules to prevent double counting and ensure permanence. Aligning the Green Corridor program with TREES would involve several steps: preparing a TREES Concept note, followed by a full TREES program submission. The **TREES Concept** is effectively a pre-screening; as seen with other jurisdictions (e.g. Colombia, Costa Rica, and provinces in Brazil), ART must approve this concept before a program can proceed to full registration. The Corridor's concept would need to outline the proposed boundaries, forest cover, reference period for emissions, and key policies to reduce deforestation. One advantage the Corridor has is scale – with over 285,000 km^2 of primary forest, it easily meets ART's minimum forest cover requirement and indeed represents a globally significant carbon sink.

In aligning with TREES, the Corridor must also commit to ART's monitoring and reporting cadence (likely on a 5-year crediting cycle) and its buffer pool contributions (a percentage of credits goes into a shared pool as insurance against reversals). Additionally, ART-TREES requires demonstration of adherence to the Cancun Safeguards and stakeholder consultations. The Corridor's community-centered design and the legal mandate for community involvement will serve it well here, as it can showcase how indigenous and local communities are integral to the program's governance and benefit from it. By hewing to the TREES requirements, the Corridor program will produce **TREES Credits**, which are considered high-quality and are eligible for purchase by the LEAF Coalition and potentially for compliance markets (with host country authorization) under Article 6.2 of the Paris Agreement.

LEAF Coalition: LEAF is a coalition of governments and major companies committed to purchasing jurisdictional REDD+ credits that meet high standards (in practice, LEAF requires ART-TREES or an equivalent standard). By aligning with ART-TREES, the Corridor would by extension be positioning



20% of the Congo Basin ecosystems are now classified as threatened, directly impacting biodiversity and carbon storage capacity.

The okapi is an artiodactyl mammal that is endemic to the northeast Democratic Republic of the Congo in central Africa. With habitat loss due to deforestation, the okapi remains endangered.
© Marc Benedetti

itself to attract LEAF funding. The LEAF Coalition has already signed letters of intent with several countries (e.g. Ghana, Ecuador, Vietnam) to buy emissions reductions at $10 per ton for the 2022-26 period, and has green-lit proposals from jurisdictions like the state of Chocó in Colombia and Bolivia. To join these ranks, DRC could submit the Green Corridor as a candidate in future LEAF calls for proposals. One critical point is that LEAF – and ART – will require the DRC government to commit that any credits sold to LEAF will receive a **"corresponding adjustment."** This means DRC would adjust its greenhouse gas inventory/NDC accounting to ensure those emissions reductions are not counted toward its own Paris Agreement targets (so that the buyer can claim them). DRC has signaled willingness to participate in such arrangements as part of being a "solution country" to climate change. Early dialogue with LEAF/Emergent can clarify this process. Aligning with LEAF could bring sizable finance: for example, Guyana's recent ART-TREES credits (the first ever issued at national scale) led to a deal of **$750 million** with a private company over several years – a scale of funding that, if achieved for the Corridor, could be transformative for green development in DRC.

Other Credible Standards/Initiatives: While ART-TREES is prominent, the Corridor can also remain open to other opportunities. The **REDD+ Early Movers (REM)** program (funded by Germany/Norway) is one example that has provided payments to jurisdictions (it has supported states in Brazil and provinces in Ecuador, for instance). If REM or similar bilateral results-based payments are revived, the Corridor could be a candidate by demonstrating early emission reductions even before full credit issuance.

Additionally, the **Voluntary Carbon Market** via Verra's Jurisdictional and Nested REDD+ (JNR) framework is another pathway. Verra is in the process of updating its JNR standard to align more with emerging best practices. DRC could consider a dual approach: primarily pursuing ART/LEAF, but also ensuring that any smaller-scale project activities within the Corridor use methodologies that are consistent with a future national system (so that if Verra credits are issued at project level, they can be reconciled). However, pursuing multiple standards can be labor-intensive; focusing on ART-TREES (which is widely accepted by buyers) may yield the most streamlined path to market.

Another initiative of note is Article 6 of the Paris Agreement – specifically, **bilateral cooperation under Article 6.2**. Countries like Switzerland, Sweden, and Japan are looking to purchase "Internationally Transferred Mitigation Outcomes" (ITMOs) from emission reduction programs with sustainable development benefits. If the Corridor program is registered under ART and has government backing, it could potentially negotiate an arrangement where a buyer country pays for a tranche of the Corridor's emission reductions as part of their international obligations. Such deals typically require the same high standards (environmental integrity, corresponding adjustments) that ART-TREES ensures, so aligning with ART keeps this option open as well.

In all cases, **credibility is king**. The Green Corridor should explicitly commit to following best practices on safeguards (e.g. no involuntary resettlement of people, respect for indigenous rights), on transparency (publicly sharing data and documents), and on environmental integrity (using conservative baselines and independent verification). By doing so, it will not only meet the criteria of ART-TREES and LEAF, but also gain broader confidence from climate finance stakeholders. This positioning will make the difference between a theoretical carbon project and a bankable, impactful program.

The next sections provide concrete recommendations on designing and executing the carbon program for the Corridor, and a step-by-step roadmap for getting from the current concept to a fully operational, revenue-generating jurisdictional carbon initiative.

Operational recommendations for program design and execution

Designing a jurisdictional carbon program for the Green Corridor is a complex endeavor, but it can be distilled into a set of clear operational recommendations. These recommendations focus on governance, technical design, stakeholder engagement, and financing – the critical components to get right from the outset:

1. Establish a Multi-Stakeholder Steering Committee and a robust and flexible governance structure

Form a governing body for the carbon program that includes representatives from national government (ICCN-AMRCA), provincial authorities within the Corridor, local community leaders, and civil society (e.g. environmental NGOs, indigenous peoples' representatives). This committee should be empowered to make decisions on program design (such as approving the benefit-sharing plan) and oversee implementation. Inclusivity in this committee will ensure that the program remains aligned with both national priorities and local needs, preventing top-down decisions that might alienate communities. A technical sub-committee can also be formed under it to handle MRV and other specialized tasks.

The Presidential Decree establishes a public-private partnership (PPP) governance structure for the Green Corridor, tasked with managing and coordinating projects transparently, ensuring FPIC adherence, and promoting social acceptability. Institutionally, the governance model will involve multiple levels, including ARMCA as the regulatory authority, ICCN (with a delegated private partner) as the operational coordinator, and provincial/local entities alongside community representatives ensuring inclusive ground-level implementation and benefit-sharing. Given the complexity of managing carbon initiatives across the vast, multi-provincial Kivu–Kinshasa landscape, a two-tiered governance system could be investigated: a central Corridor Authority or Steering Committee (likely within ICCN), handling strategic direction and external coordination, combined with decentralized local committees for context-specific activities and monitoring. Effective horizontal and vertical coordination, possibly through an inter-ministerial task force, is critical for integrating diverse sectoral efforts (e.g., agriculture, energy, security). Additionally, robust transparency, accountability mechanisms, independent audits, and civil society participation will be essential to safeguard against corruption, build external credibility, and ensure local trust.

2. Develop a Benefit-Sharing plan early

A transparent benefit-sharing mechanism is crucial to maintain local support and meet donor expectations. We recommend developing this plan in a participatory manner **from the start**, rather than waiting until credits are about to be issued. The plan should define how revenues from carbon credits will be allocated – what percentage to local communities, to provincial governments, to reinvestment in conservation, and to cover administration costs. For example, Guyana's program directs 15% of carbon revenue to indigenous communities; DRC could consider a significant share (e.g. 30-50%) for community projects in the Corridor, given the high population. The plan should also set up transparent channels (perhaps using existing local development committees or a trust fund)

A governing body for the carbon program that includes representatives from national government (ICCN-AMRCA), provincial authorities within the Corridor, local community leaders, and civil society (e.g. environmental NGOs, indigenous peoples' representatives), should be empowered to make decisions on the program design. Inclusivity in this committee will ensure that the program remains aligned with both national priorities and local needs, preventing top-down decisions that might alienate communities.

Local community leaders meeting.
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to deliver funds and report on their use. Having an agreed benefit-sharing arrangement in place will improve trust and also fulfill requirements of standards like ART (which asks for evidence of benefit-sharing arrangements).

3. Implement capacity building and hire key expertise

Launch a capacity-building program targeted at the teams who will run the Corridor's carbon initiative. This includes training government staff in Kinshasa and the provinces on carbon accounting, GIS and remote sensing technicians for MRV, and community facilitators for engagement. It may be wise to bring on board a specialized consulting group or NGO with experience in REDD+ to act as a **technical advisor** during the design phase – for instance, to assist with drafting the TREES concept, designing the MRV system, and training local counterparts. Over time, capacity should be transferred to national institutions. Additionally, designate (and if needed hire) a **Program Coordinator** who manages day-to-day development of the jurisdictional program and serves as the liaison among government, communities, and international partners. This "carbon champion" role is vital to maintain momentum and communication.

4. Conduct comprehensive stakeholder consultations

Use a structured process to inform and consult stakeholders across the Corridor about the carbon program. This would involve local workshops in different sub-regions of the Corridor (from the Kivu side to the Kinshasa side) to explain what the jurisdictional program means, how it could generate income, and what obligations or changes it entails (for example, any new land-use rules under the Corridor's protected status). Soliciting feedback and gaining broad support is not only a safeguard requirement, but will also surface potential conflicts or implementation issues early. Special attention should be given to engaging indigenous peoples and marginalized groups – possibly by working with or through local NGOs that have their trust. The output of these consultations can be used to refine the program design (e.g. adjusting which activities to prioritize, such as more focus on community forestry if communities show interest) and to document the free, prior, and informed consent process.

5. Design an integrated package of Emission Reduction Activities

The program should not rely on a single strategy to reduce deforestation, but rather deploy a **package of interventions** that address multiple drivers. Based on studies of deforestation drivers in DRC, likely interventions include: supporting **sustainable agriculture** and agroforestry to reduce slash-and-burn farming; improving **energy access** (e.g. efficient cookstoves, small-scale renewable energy) to curb charcoal-driven forest loss; strengthening **protected areas and community forests** (through patrols, community rangers, and legal recognition of land rights); and **road/infra planning** to minimize new deforestation from transport projects. Each of these activities should be incorporated into the Corridor's overall implementation plan, with responsible parties and budgets. For example, a partnership with an agroforestry NGO could be established to work in the eastern Corridor on cacao agroforestry as an alternative to clearing forest for crops. By bundling such efforts, the program increases its chance of achieving real emission reductions and also provides resilience – if one strategy underperforms, others can compensate.

6. Develop a nesting mechanism and avoid double counting

The decree establishing the Corridor provides for an integrated approach to governance including all existing stakeholders (private operators, communities, customary titles). In order to avoid double counting and to guarantee the environmental integrity of the programme, the following mechanisms are planned or in the process of being structured:

1. **Inventory and mapping of existing projects:** A comprehensive census has to be implemented to identify all voluntary carbon projects existing or in preparation within the perimeter (VCS, Plan Vivo, Gold Standard, etc.). These projects will be geo-referenced and integrated into the spatial register of the corridor.
2. **Nesting Agreement / 'Jurisdictional Nesting Programme'**: The programme will have to develop a nesting framework, in accordance with ART-TREES guidelines, including:
   - a clear distribution of emission rights between the programme and the projects,
   - rules for compensating for leakage and for avoiding double counting,
   - an integrated register (centralised by ARMCA), harmonised with VCM standards.
3. **Protocol for authorisation and ex ante harmonisation:** Active or interested operators will have to sign a harmonisation protocol with the jurisdictional programme, defining the perimeters, the methodologies used, the volumes to be allocated, and the methods for sharing the results.
4. Integrated **MRV tool** with spatial disaggregation module: the MRV system currently being designed will enable a fine-grained disaggregation of emission reductions, project by project, to guarantee:
   - the correct allocation of results,
   - the avoidance of double counting with the upper layer (jurisdiction),
   - the transparency of credits transferred or claimed.

7. Ensure Robust Monitoring and Enforcement on the Ground

A carbon program's success will be measured in tons of CO_2 not emitted, which ultimately comes down to **slowing/halting deforestation and degradation**. Thus, on-the-ground monitoring and enforcement are critical operational components. We recommend creating **"Community Monitoring Teams"** trained in basic forest surveillance (possibly equipped with smartphones or GPS devices) to feed information into the MRV system and to act as the eyes and ears in remote areas. In tandem, strengthen enforcement by coordinating with provincial environmental ministries and park rangers to respond to illegal activities. Given the security challenges in parts of the Corridor, innovative community-based security initiatives (as hinted in the Corridor proposal should be explored – for instance, involving local communities in reporting armed group activities that lead to deforestation, coupled with broader security sector reforms. While solving regional conflict is beyond the carbon project's scope, acknowledging and planning for it (perhaps by focusing initial efforts in more secure areas and gradually expanding) is an important operational consideration.

8. Develop a communications and transparency strategy

To support execution, the program should maintain strong communications – both locally and internationally. This involves creating accessible materials in local languages to explain progress to communities and setting up a grievance redress mechanism (a hotline or community focal points where complaints can be logged, aligning with best practice that grievances be addressed early). Internationally, it means documenting milestones and making key documents (like the benefit-sharing plan, MRV results, safeguard reports) publicly available. This transparency will help manage the program's reputation and pre-empt misinformation or opposition. It also signals to carbon buyers that the program is being run professionally.

9. Secure bridging finance and invest in early actions

Prior to receiving any carbon credit payments (which could be years out), the Corridor will need funding to implement the above activities. It is advisable to secure **bridging finance** – possibly grants or advance market commitments – so that emission reduction activities start as soon as possible. Quick-start actions, even modest ones like initiating agroforestry plots or community patrols, can demonstrate early success. Showing a year-on-year decrease in deforestation in parts of the Corridor during the preparation phase would strengthen the case when the program goes for verification. Options for such finance include tapping into the existing CAFI funding to DRC, seeking a dedicated grant from bilateral donors interested in the Corridor, or exploring a development policy loan that supports DRC's climate efforts.

Additionally, **phased implementation** can be an approach: start with a pilot zone within the Corridor (perhaps a particularly high-deforestation area or a province like Tshopo as a test case) to refine the model, then scale up to the full Corridor. This allows learning by doing, without compromising the integrity of the whole program.

By following these recommendations, the Green Corridor initiative will be grounded in solid operational practices. These steps will help ensure that when the program is formally launched, it has a legitimate governing body, an engaged constituency, and a clear plan of action. With the design and preparatory work well in hand, the program can move confidently into the next phase: the step-by-step process of preparing, registering, and ultimately implementing the jurisdictional carbon program. This is outlined in the roadmap below.

Roadmap for Preparing and Implementing a Jurisdictional Carbon Program under ART-TREES

Achieving a fully operational jurisdictional carbon program for the Green Corridor Kivu–Kinshasa will require a sequenced approach. Below is a **comprehensive roadmap** that outlines the major phases and milestones from inception to implementation under the ART-TREES framework:

Phase 0: Activation and institutional setup (Months 0–3)

1. **Formalize Government Backing:** Designate the **lead agency** (e.g. through a Public-Private Partnership between ICCN and Virunga Foundation) responsible for coordinating the carbon program ; Constitute the **multi-stakeholder Steering Committee** (as foreseen in the decree) with clear roles for government, provincial authorities, local communities, and private actors; Define the terms of reference and decision-making rules for carbon-related functions (e.g. MRV oversight, benefit-sharing, and nesting governance).

Milestone: Carbon program Steering Committee formally constituted by ministerial order, with terms of reference, chairperson designated, and first meeting held.

2. **Secure Preliminary Funding:** Mobilize initial funds for program design. This could mean reallocating some FONAREDD resources, or obtaining a preparatory grant from a donor (e.g. a quick-start grant from CAFI or UN-REDD technical support).

Milestone*:* At least $X million secured for the next 12 months of preparation activities.

Phase 1: Preparation and Concept Development (Months 3–12)

3. **Baseline Data Collection & Analysis:** Assemble a technical team to gather historical deforestation data for the Corridor and draft a preliminary Forest Reference Emission Level. Use 5–10 years of satellite data to calculate annual forest loss and associated emissions (CO_2). Also assess drivers of deforestation to inform target setting.

Milestone*:* Draft deforestation baseline report completed, showing historic emissions trend in Corridor. Preliminary results are presented here after in the report.

4. **Stakeholder Consultation Round 1:** Conduct the first round of community and stakeholder consultations in all key regions of the Corridor. The aim is to introduce the project, gather input on drivers and potential interventions, and ensure local concerns are heard.

Milestone*:* Consultation report produced, summarizing input from communities, local authorities, and other stakeholders across the Corridor.

5. **Draft TREES Concept Note:** Using outputs from steps 3 and 4, prepare the TREES Concept document for ART. This high-level document will include: description of the Corridor jurisdiction (area, forest cover, population), the reference period and estimated emissions baseline, initial strategies to reduce emissions, and demonstration of political commitment and stakeholder engagement.

Milestone*:* TREES Concept Note submitted to the ART Secretariat for approval.

6. **Interim engagement with buyers/partners:** While the concept is under review, initiate dialogues with potential partners – e.g. inform the LEAF Coalition of the upcoming program, engage with multilateral initiatives. If possible, sign a memorandum of understanding with a technical partner (such as an NGO or research institute) for MRV support.

Milestone*:* At least one partnership formalized (technical or financial) to support program development.

Phase 2: Program Design and Documentation (Months 12–24)

7. **ART Concept Approval & Feedback Integration:** Ideally, within this timeframe, ART will approve the Corridor's TREES Concept (this has been the first step for other countries like Colombia). Upon approval, review any feedback from ART and plan to address it in the full program design.

OPERATIONAL RECOMMENDATIONS FOR PROGRAM DESIGN AND EXECUTION

1. Establish a Multi-Stakeholder Steering Committee and a robust and flexible governance structure
2. Develop a Benefit-Sharing plan early
3. Implement capacity building and hire key expertise
4. Conduct comprehensive stakeholder consultations
5. Design an integrated package of Emission Reduction Activities
6. Develop a nesting mechanism and avoid double counting
7. Ensure Robust Monitoring and Enforcement on the Ground

Milestone*:* ART approves the TREES Concept, making the Corridor an officially listed ART participant jurisdiction.

8. **Full Program Design (TREES Registration Document):** Develop the comprehensive TREES program document. This involves detailing all aspects: governance arrangements, MRV methodology (including forest stratification, carbon density data, and monitoring plan), safeguard implementation plan (how the program meets social/environmental requirements), benefit-sharing plan (how proceeds will be distributed), and nesting approach for any projects. This document is essentially the business plan and technical plan for the program. It should also include an implementation schedule for the crediting period (e.g. 2025–2030) with expected annual activities and outputs.

Milestone*:* Full TREES program documentation completed in draft form.

9. **Stakeholder Consultation Round 2:** Present the key elements of the program design (from step 8) back to stakeholders for validation. This second round of consultation ensures that communities and local leaders see how their input was used and agree with the final plans for benefit sharing and activities. It also serves to finalize Free, Prior, Informed Consent processes with any indigenous communities.

Milestone*:* Endorsement obtained from local stakeholder representatives (e.g. a signed resolution from community assemblies or provincial councils supporting the program design).

10. **National Approval and NDC Alignment:** Before submission, get formal approval of the program document from the national REDD+ oversight body (e.g. the FONAREDD Steering Committee and the Minister of Environment). Additionally, coordinate with the national climate change focal point to ensure the program's emissions will be accounted appropriately relative to DRC's NDC. The government should issue a statement that it will authorize corresponding adjustments for any internationally sold credits, to align with Article 6 requirements.

Milestone*:* Government endorsement letter signed, confirming the program is part of DRC's climate strategy and detailing the conditions for international credit sales (avoiding double counting).

11. **Submit Program for Validation:** Submit the finalized TREES registration documents to the ART Registry for official review and subsequent validation by an independent accredited body. This triggers the formal **validation/verification process**, where an auditor will assess the program design against the TREES standard.

Milestone*:* TREES Registration documents accepted by ART and validation process initiated (auditor assigned).

Phase 3: Early Implementation (Months 24–36)

12. **Launch Pilot Activities:** While validation is underway (a process that can take a number of months), begin implementing on-the-ground activities that are ready. This could include things like launching a community forestry project in one territory, distributing improved cookstoves in a high-deforestation community, or stepping up forest patrols in critical zones. Early implementation not only starts generating emissions reductions (which will count once the crediting period begins, if within the baseline/monitoring timeline) but also demonstrates progress to both validators and potential investors.

Milestone*:* Pilot interventions operational in at least 2-3 areas, with monitoring in place to track their impact (e.g. quarterly deforestation rates).

13. **Capacity Ramp-up:** By this time, the MRV system should be finalized and tested. Set up the data management systems, perhaps an online platform where satellite imagery analyses are updated periodically and results can be viewed. Train provincial teams to use these tools. Also, operationalize the benefit-sharing mechanism institutionally (even if no funds are distributed yet, have bank accounts or local committees in place to manage funds).

Milestone*:* MRV system running for the Corridor (even if in test mode), and institutional mechanisms (funds, committees) established at local levels, ready to receive performance-based finance.

Phase 4: Verification and Credit Issuance (Approximately Month 36 and beyond)

14. **Complete Validation and Initial Verification:** Work closely with the appointed validation/verification body (VVB) to provide all necessary evidence and clarifications. Once the program is validated (design is approved), the first monitoring period's data will be verified. Suppose the crediting period is set to start from January 2025; by the end of 2025 or 2026, the first monitoring report can be compiled showing deforestation rates versus the baseline. The VVB will verify the emission reductions achieved.

Milestone*:* Successful validation of program design, and first verification report completed confirming XX million tonnes CO_2 emissions reduced in the first monitoring period.

15. **Issuance of Credits:** Upon a successful verification, the ART Board can approve issuance of TREES credits to the jurisdiction. These credits would then appear on the ART Registry, serialized and ready for transaction. For example, DRC could see issuance of credits after year 2 or 3 of the program, covering the initial reduction achieved.

Milestone: ART issues the first batch of TREES credits to DRC's Green Corridor program (each credit representing one tonne of CO_2 emission reduction).

16. **Monetization (Sale of Credits):** With issued credits in hand (or even in anticipation, via forward contracts), execute the agreements with buyers. If a deal with LEAF Coalition or a private buyer (like an energy company or tech firm under a climate pledge) has been arranged, the credits can now be transferred and payments received. For instance, if LEAF or another buyer agreed to purchase 10 million tonnes at $10/ton, that would mean $100 million incoming to the program, disbursed according to the terms (possibly in tranches). At this stage, make sure all corresponding adjustments and attestations are done so that the buyer can claim the credits internationally.

Milestone: First payment for carbon credits received in DRC's designated account – marking the transition of the program from setup to revenue-generating.

17. **Benefit Distribution and Reinvestment:** Once revenue is received, implement the benefit-sharing plan. Disburse the agreed shares to community projects, local governments, and

other stakeholders. It's crucial to do this promptly and transparently to demonstrate tangible benefits. Simultaneously, recycle a portion of the funds into scaling up successful interventions (e.g. expanding agroforestry to new villages or hiring more community rangers) – this creates a positive feedback loop increasing emissions reductions in subsequent years.

Milestone*:* Documented distribution of carbon revenue to beneficiaries (communities, etc.) with public transparency, and a funded workplan for expanded activities in the next phase.

18. **Ongoing Monitoring and Adaptive Management:** The program enters a cycle of continuous implementation, monitoring, and periodic verification (likely every 2-5 years per ART requirements). Use data and lessons from initial years to adapt the strategy. For example, if certain areas still experience forest loss, investigate causes and intensify efforts there. Maintain stakeholder engagement through regular reporting sessions or forums in the Corridor.

Milestone: Mid-term evaluation of the program (around year 5) completed, showing deforestation trends, evaluating social impacts, and recommending any course corrections for the next crediting period.

Phase 5: Long-Term Sustainability (Year 5 and beyond)

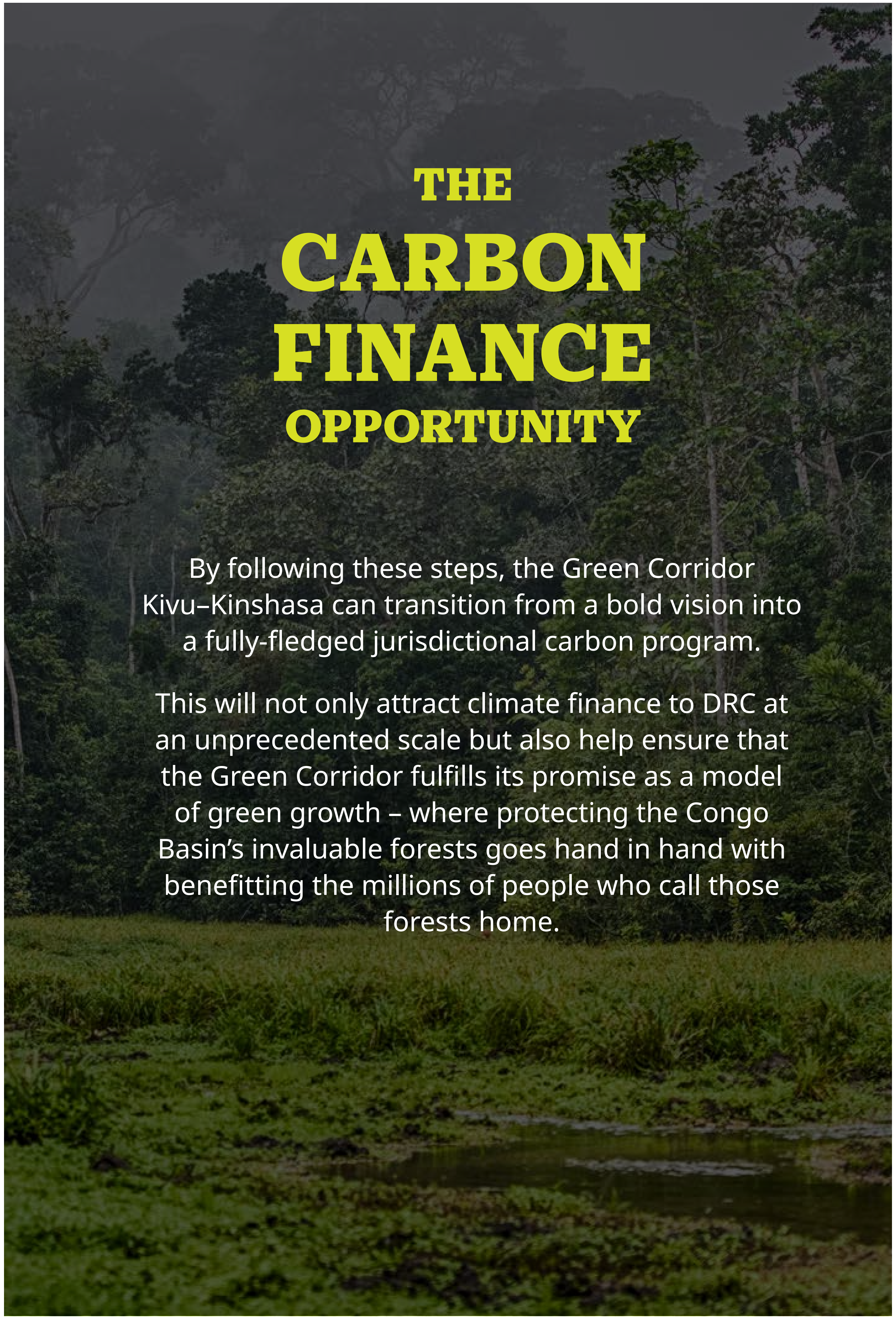
19. **Planning for Next Crediting Period:** As the first crediting period winds down (ART-TREES crediting periods are typically 5 years), begin updating the baseline for the next period as per standard rules (which might require using a later reference period, etc.). Also, integrate the Corridor program into DRC's next NDC submission, highlighting its contribution to climate goals (or the portion sold as ITMOs).

Milestone*:* Approval to continue or scale up the program into subsequent periods, with any revised targets or methods, ensuring continuity of finance.

20. **Scale and Replication:** If the Green Corridor program proves successful, consider scaling or replicating the model to other parts of DRC. The Corridor itself might be expanded or new corridors designated. The institutional and technical capacity built can be a foundation for a national approach covering all major forest regions in DRC, creating a true national REDD+ carbon finance framework integrated with development – making DRC a leader among tropical forest nations in jurisdictional REDD+.

Milestone: Knowledge transfer and possibly proposals for new jurisdictional programs (e.g. a program for the Cuvelai region or an expansion northwards), capitalizing on the Green Corridor experience.

This roadmap is ambitious but achievable. It lays out a timeline where, within roughly three years, the Green Corridor could progress from concept to the issuance of verified carbon credits – a timeline consistent with experiences in countries that have moved quickly on REDD+. Throughout, it will be essential to maintain flexibility: timelines may shift due to unforeseen challenges (political changes, technical delays, etc.), so the plan should be revisited regularly by the Steering Committee. Nonetheless, having this roadmap provides direction and accountability.



THE CARBON FINANCE OPPORTUNITY

By following these steps, the Green Corridor Kivu–Kinshasa can transition from a bold vision into a fully-fledged jurisdictional carbon program.

This will not only attract climate finance to DRC at an unprecedented scale but also help ensure that the Green Corridor fulfills its promise as a model of green growth – where protecting the Congo Basin's invaluable forests goes hand in hand with benefitting the millions of people who call those forests home.

Coffee farmer, Beni, Eastern DRC.

ACKNOWLEDGEMENTS

This study was made possible through the financial support of the **European Union**. We gratefully acknowledge the contributions of **VisioTerra**, who produced the maps and provided expert cartographic analysis under the guidance of **Zhour Najoui**. We also thank **Quentin Jungers** (Key Expert for the B4Life 2.0 facility) for their vital input in shaping the analytical framework, writing key sections and gathering critical datasets. The work was led by the Virunga Foundation, with **Jérôme Gabriel** serving as the coordinator of the study. Special thanks go to **Gaia De Battista**, whose insights and editorial support were instrumental in refining the final document.

APPENDIX

Lubero, DRC.

Rural households are benefitting from access to electricity.

Appendix

Appendix 1 – Deep dive reports

In this section, we have reproduced the sector-specific reports which were written and developed using only artificial intelligence search. Data actually used from those reports was always verified before usage.

Energy

Average Household Energy Consumption in Rural Areas

Rural households in sub-Saharan Africa typically consume only modest amounts of electricity, on the order of a few hundred kilowatt-hours per year. In fact, most rural African households use roughly **50–500 kWh per household per year** (), far below consumption levels in developed countries. This low usage reflects the limited number of appliances in off-grid homes – often just a few LED lights, mobile phone charging, a radio or small TV, and occasionally a small refrigerator. Initial data from private mini-grid operators show **very low monthly usage** – an average of only about **6.1 kWh per customer per month** (≈73 kWh/year) in practice (Benchmarking Africa's Minigrids | Africa Energy Portal). This corresponds to basic needs like lighting and phone charging.

Households that acquire more appliances (such as a television or an efficient mini-fridge) can increase their consumption toward the upper end of the range. For example, adding a small refrigerator running several hours a day, alongside a TV and lights, might raise household demand to **200–500 kWh over a year** (). One case study estimated about **465 kWh per household annually** when service tiers included a fridge and TV (). In summary, typical rural homes without grid power use only a few kilowatt-hours per month, while those with a full suite of basic appliances might use on the order of **20–40 kWh per month** (approximately 240–480 kWh/year). These low consumption levels have important implications for mini-grid design and revenue, as each customer yields relatively little energy sales.

Breakeven Energy Price for a Viable Mini-Grid (Unsubsidized)

Because of high upfront costs and limited scale, the **cost of electricity from solar mini-grids** in rural Africa is much higher than national utility tariffs. **Breakeven prices** (i.e. cost-reflective tariffs) without subsidies are often in the range of **$0.50–$0.80 per kWh**, or even higher. Studies by the Rocky Mountain Institute find that the **levelized cost of energy (LCOE)** for a well-run solar hybrid mini-grid is typically **at least about $0.55–$0.60 per kWh** in current conditions (FS: Mini-grids costs can be reduced by 60% by 2030). Other analyses indicate that fully cost-reflective tariffs for remote mini-grids often **exceed $0.60/kWh and can approach $1.00/kWh** (What is the Cost of Reliable Electricity? | by REES Africa - Medium). For instance, Sierra Leone's rural mini-grid regulatory framework has approved tariffs on the order of **$0.80–$0.90 per kWh** for private mini-grids, reflecting the real cost of service in the absence of subsidies (). By comparison, typical grid electricity tariffs in African cities are only around $0.10–$0.20/kWh, highlighting the gap.

Such high breakeven prices are driven by the capital-intensive nature of mini-grids and the small customer bases. A financial modeling perspective shows that to cover operating costs, asset depreciation, and financing costs (often a mix of development loans and private equity aiming for returns in the mid-teens), **tariffs must be several times higher than main-grid tariffs** (FS: Mini-grids costs can be reduced by 60% by 2030) (). For example, one country caps mini-grid investor returns at ~18% IRR () – requiring a high unit price to achieve that. In practice, most mini-grid projects are not financially viable at purely commercial tariffs in the ~$0.60+ range because rural customers struggle to afford such rates. This is why **viability often depends on grants or subsidies** to buy down costs or on cross-subsidization schemes. In the absence of subsidies, the steep cost-reflective price of mini-grid electricity remains a major barrier to commercial sustainability, and developers often seek concessional finance to lower the required breakeven tariff.

Typical Size of a Solar Mini-Grid (PV and Battery Capacity)

Off-grid solar mini-grids in rural communities are generally **small power systems**, usually on the order of a few tens of kilowatts in generation capacity. A **"typical" solar mini-grid in Africa is about 10–100 kW_peak (solar PV)** (), which is sufficient to electrify a small village or cluster of villages. Many deployments fall in this range – for example, a mini-grid project in Burkina Faso uses a **50 kWp solar PV array** (with a diesel backup) to supply its community (PowerPoint Presentation). Smaller villages or pilot projects might install systems around **10–20 kWp**, while larger villages and trading centers demand systems at the higher end (50+ kW). These systems are usually accompanied by battery storage to provide power at night and stabilize solar variability. The battery banks are typically sized for a few hours of supply – for instance, a **15 kWp PV mini-grid might have ~60 kWh of battery storage** to cover evening and early morning loads (PowerPoint Presentation). A 50 kW solar farm might use a battery on the order of 150–300 kWh, depending on the desired hours of autonomy and peak load profile.

Real-world deployments illustrate the range of mini-grid sizes. In East Africa, private developers have built systems of **20–50 kW PV with battery storage** to connect hundreds of households (). In remote parts of West and Central Africa, many mini-grids are below 100 kW to stay within easier licensing regimes (systems under 100 kW often face simpler regulatory requirements) (). That said, some projects serving larger populations or anchor loads do scale higher: for example, Zimbabwe recently commissioned a **200 kW solar mini-grid** powering households, businesses, schools, and a clinic in a district center (Solar mini-grid transforms lives of Zimbabweans in rural areas). In Nigeria and Zambia, mini-grids in the 100–200 kW range have been built to serve bigger villages and productive uses like mills and water pumps (Africa Solar Industry Association - Facebook). Generally, however, most community solar mini-grids in rural SSA remain well under 100 kW. They typically serve on the order of a **few hundred connections** (households and small enterprises), and the component sizing (PV and battery) is tailored to the expected demand, evening peak, and desired reliability (with some including a standby generator for backup if loads grow).

CAPEX Costs and Major Components Breakdown

The **capital expenditure (CAPEX)** for a solar mini-grid includes the generation equipment (solar panels, mounting structures, inverters), the battery storage system, the distribution network (wires, poles, transformers, meters, etc.), and all installation and project development costs. Total CAPEX can vary widely by project size and local context, but recent benchmarks show costs **declining** as the industry matures. According to a 2024 market report, average investment costs have fallen to roughly **$2,200 per kW of installed capacity** (down from around $3,000/kW a few years prior) (). Another metric is cost per customer connection: this has dropped from over $1,200 per connection

around 2020 to about **$700 per connection in 2024** for larger-scale mini-grid programs (). (Smaller pilot mini-grids with fewer customers still see higher per-connection costs, often $1,000–$2,000 or more (Microsoft PowerPoint - 4.A.Chris Greacen.World Bank consultant.pptx).) For example, a 50 kW mini-grid serving 200 households might entail a total CAPEX on the order of **$150,000–$250,000** (roughly consistent with ~$3k–$5k per kW, or ~$750–$1250 per household). The exact cost depends on how far customers are spread out (affecting distribution line lengths), whether lithium-ion or lead-acid batteries are used, import duties, and other project-specific factors.

Major cost components of a solar mini-grid typically break down as follows:

- **Solar PV array (panels and mounting):** Roughly **10–15% of total CAPEX** ([PDF] MINI GRID COSTING AND INNOVATION). PV module prices have fallen significantly, making the panels themselves a smaller share of costs. For instance, if total system cost is $250k, the solar panels might be on the order of $25–30k of that.
- **Battery storage:** Approximately **15% of CAPEX** on average ([PDF] MINI GRID COSTING AND INNOVATION), though this varies with the hours of storage and battery type. Lithium-ion batteries cost more upfront but can provide longer life; lead-acid batteries are cheaper but may need earlier replacement. Developers often balance these factors.
- **Power electronics (inverters, charge controllers):** This typically accounts for around 5–15% of costs (varies by design). Inverters and controllers are essential for converting and managing power, and their costs have been dropping (inverter prices fell from ~$320/kW in 2010 to ~$90/kW in 2017) (Microsoft PowerPoint - 4.A.Chris Greacen.World Bank consultant.pptx) (Microsoft PowerPoint - 4.A.Chris Greacen.World Bank consultant.pptx). These components ensure the system delivers stable AC power and safely charges the batteries.
- **Distribution network and customer connections:** Around **14–15% of CAPEX** on average ([PDF] MINI GRID COSTING AND INNOVATION) (Network Cost Estimation for Mini-Grids in Large-Scale Rural Electrification Planning). This includes low-voltage cabling, poles, and meters to connect each home. In many projects, the **mini-grid distribution** is a major expense, especially if houses are far apart – requiring lots of wiring for relatively few kilowatts. (One study of dozens of mini-grids found distribution networks made up about 14% of total project cost on average (Network Cost Estimation for Mini-Grids in Large-Scale Rural Electrification Planning).) Efforts like optimizing grid layout and clustering customers closer together can reduce these costs.
- **Balance of system and soft costs:** The remainder (often 40% or more) goes to other hardware and project costs. This includes **civil works and site infrastructure** (equipment housings, mounting structures, land preparation), **installation labor**, shipping and logistics, and **project development** expenses (engineering design, permitting, community engagement, etc.). In some cases, the land or site preparation alone is significant – for example, in one country's mini-grids, site and land costs were on the same order as the solar panels themselves (PowerPoint Presentation). Developer overheads, contingencies, and financing fees also fall into this category. These soft costs can be substantial, so reducing

them (through standardized system designs, bulk procurement, and streamlined permitting) is key to bringing down overall CAPEX.

From a financial modeling standpoint, high CAPEX is the fundamental driver of the high energy cost discussed earlier. Depreciating a mini-grid's capital cost over, say, 15–20 years, with typical financing, leads to a high cost per kWh unless usage grows significantly. For example, with a total CAPEX of a few thousand dollars per kW, the annualized capital cost alone might be on the order of $0.30–$0.50 per kWh (depending on financing terms and energy output) (FS: Mini-grids costs can be reduced by 60% by 2030). This is why every cost component matters: **bringing down CAPEX through innovation and scale is crucial to make tariffs affordable**. Indeed, analysts project that with continued declines in solar PV and battery prices, plus economies of scale and better operating efficiency, the mini-grid LCOE could potentially fall to around **$0.22–$0.25/kWh by 2030** (FS: Mini-grids costs can be reduced by 60% by 2030) (FS: Mini-grids costs can be reduced by 60% by 2030). Achieving such reductions would likely make many mini-grids commercially viable without heavy subsidies, by narrowing the gap between cost-reflective tariffs and what rural customers can pay. In the meantime, however, the economics of off-grid solar mini-grids in Africa remain challenging – requiring careful financial structuring (grants, concessional loans, or results-based financing) to bridge the viability gap. Each project must balance system size to community needs, set tariffs that recover costs, and secure financing to cover the upfront investment, all while aiming to improve livelihoods with reliable energy access.

OPEX Breakdown for Small-Scale Solar Mini-Grids in Sub-Saharan Africa

Operating costs for community solar mini-grids can be substantial – roughly **40% of a mini-grid's levelized cost of electricity** comes from ongoing OPEX (with ~60% from upfront CAPEX) (FS: Mini-grids costs can be reduced by 60% by 2030). Key OPEX components include maintenance, staff salaries, customer service, security, and various administrative costs. Below is a breakdown of typical OPEX categories, with percentage allocations and example cost estimates, followed by notes on how costs scale for ~20 kWp, 50 kWp, and 100 kWp systems.

Maintenance & Repairs

What it Covers: Routine servicing of solar panels, inverters, battery bank upkeep, replacement of worn components (e.g. batteries every few years, electronics), and managing wear & tear. This is an ongoing cost to keep the system running reliably.

Typical Share of OPEX: Maintenance and repairs generally account for about **20–30% of total OPEX** for solar mini-grids. One industry analysis found that **"component replacements" make up roughly 26% of operating costs** (as a fraction of O&M costs) (FS: Mini-grids costs can be reduced by 60% by 2030). In purely solar systems (with no fuel cost), maintenance can be one of the largest expense categories after labor. Developers often budget on the order of **2–5% of the initial capital cost per year** for maintenance activities (for example, setting aside funds for battery replacements and equipment servicing).

Real-World Benchmarks: For a small community mini-grid, maintenance costs are significant but not overwhelming. *For instance, a 30 kW solar mini-grid in Zambia budgets about **€4,215 per year** on maintenance (this was 1.5% of the generation equipment cost and 4% of the grid cost annually) ().* *That amounted to roughly **37% of the site's total OPEX** ().* In absolute terms, **a 20 kWp solar mini-grid might spend on the order of $500–$1,000 per year on maintenance**, while a larger 100 kWp system could spend several thousand dollars annually on upkeep (due to more extensive equipment and batteries). However, as system size grows, maintenance economies of scale can improve – e.g. replacing one inverter in a 100 kW system affects more kW and customers than in a 20 kW system.

Labor Costs (Staffing)

What it Covers: Salaries or wages for the mini-grid's personnel – typically including a local operator/technician for daily operations, technicians for periodic maintenance, customer service agents, and any administrative or management staff. In some cases, a single staffer wears multiple hats (operator, customer liaison, basic maintenance), especially on very small grids. Larger installations might have a technician plus support staff or part-time roles.

Typical Share of OPEX: Labor is usually **the single largest OPEX component**, often **30–50% of total operating costs**. Surveys consistently show personnel costs at or near the top of the OPEX share. For example, in a West African mini-grid dataset, **staff/personnel expenses were about 37% of OPEX on average** (PowerPoint Presentation). Another analysis found that **labor made up ~44% of overall O&M expenses** for solar-hybrid mini-grids (FS: Mini-grids costs can be reduced by 60% by 2030). In very small systems, the labor share can be even higher (since even one salary is a large fixed cost relative to other expenses) – in one 30 kW Zambian mini-grid, staffing (a manager, technician, and a security guard) was about **€6,850/year**, roughly **60% of that site's OPEX** (). As mini-grids scale up, the percentage spent on labor tends to drop slightly (one operator can manage more customers/kW), but it remains a major cost driver for all sizes.

Real-World Benchmarks: In practice, operator salaries in rural Africa might range from modest stipends to a few hundred $ per month. *For a ~20 kW mini-grid serving a small village, one might allocate on the order of **$1,500–$3,000 per year** for local labor (e.g. a part-time operator or technician). A 50 kW site might employ a full-time technician and maybe a part-time administrator, totaling perhaps **$3,000–$5,000/year**. A 100 kW mini-grid serving a larger community could incur **$5,000–$8,000+ per year** in labor costs* (potentially including an on-site manager, maintenance crew visits, and central support staff). These values will vary by country (local salary levels) and operational model, but in all cases **labor is a significant chunk of OPEX** (PowerPoint Presentation) (FS: Mini-grids costs can be reduced by 60% by 2030).

Customer Management & Billing

What it Covers: This category includes the costs of managing customers and revenue collection. It involves meter reading (or data management for smart meters), preparing bills or usage reports, handling mobile payment fees, maintaining billing software or pay-as-you-go platforms, and customer service activities (answering inquiries, community engagement on energy use, etc.). In modern mini-grids, many use mobile money and remote monitoring, which can streamline billing but still incur transaction fees and software subscriptions.

Typical Share of OPEX: Customer management and billing generally make up a smaller portion of OPEX (relative to maintenance or labor), but are still important. Often this is on the order of **~5–15%**

of OPEX. In some analyses these costs are bundled under administrative or "other" expenses. For example, a study in Sierra Leone found that **"other operating costs" – including customer billing expenses, metering, and technical operation materials – were about 20% of OPEX** (PowerPoint Presentation). Not all of that 20% was billing, but it gives a sense that the customer service/admin bucket is significant. Where mobile prepaid systems are used, the **fees for mobile money transactions and IT platforms are relatively low** – one West African developer reported mobile payment service fees as under **1% of OPEX** (almost negligible) (PowerPoint Presentation). Thus, the bulk of this category is often staff time for managing customers (which may already be counted in labor costs) and any software/license fees.

Real-World Benchmarks: In a small solar mini-grid with perhaps 100 customers (~20–30 kW), the **total customer management cost might be a few hundred dollars per year** – e.g. paying ~1–2% fees on mobile payments collected, plus maybe $20–50/month for a cloud metering software, etc. This could equate to, say, **$300–$500/year (around 5–10% of a small project's OPEX)**. For larger mini-grids with more customers, the absolute cost of billing software and transaction fees will rise, but often **economies of scale** improve the percentage: a 100 kW mini-grid with 500+ customers might spend on the order of **$1,000/year on billing & software**, which could be well under 5% of that larger system's OPEX. In summary, efficient prepayment technology has kept these costs relatively low (often one of the **smallest OPEX categories** in well-run projects) (PowerPoint Presentation) (PowerPoint Presentation).

Security & Theft Prevention

What it Covers: Measures to protect the mini-grid assets from theft or vandalism. This may include hiring security guards to watch the solar farm and battery house, installing fencing, anti-theft fixtures on solar panels, alarm systems or cameras, and community engagement to prevent tampering. In high-risk areas, a night guard is a common solution. In lower-risk settings, developers might rely on the community's stake in the project or one of the staff doubling as a watchman.

Typical Share of OPEX: Expenditures on security can vary widely. Some mini-grids allocate **~5–10% of OPEX** to security, especially if a full-time guard is hired. For a single small site, a guard's salary might be similar to the operator's, effectively doubling the labor in a worst-case scenario. However, many developers try to minimize this cost – using one staff for both operations and site security at night, or investing in robust fencing (a one-time CAPEX). Thus, security might be **minimal (0–5%) for well-secured or community-supported sites**, or up to the higher single digits if dedicated personnel are employed for guarding.

Real-World Benchmarks: As an example, the 30 kW Zambia mini-grid mentioned earlier includes **a security guard as part of the staff**, contributing to the €6,850 annual staff cost (). If the guard's share is ~€1,200 of that (just as an illustration), that's about **10% of total OPEX on security** for that small site. In a 20 kW village mini-grid, a guard paid, say, $100/month would cost $1,200/year – which could be ~15–25% of the tiny OPEX budget (hence many such projects avoid hiring a separate guard). For a larger 100 kW mini-grid serving hundreds of customers, one guard ($1.2k/year) would be a smaller fraction – maybe **3–5% of the OPEX** – so larger systems can absorb security costs more easily. In summary, **security costs in African mini-grids are typically kept low**, either by design or by necessity; where used, a guard's salary is often on the order of **$1–2k per year**, and many systems manage with periodic community policing and secure enclosures to avoid ongoing security expenses.

Insurance & Regulatory Costs

What it Covers: This includes **insurance premiums** to cover the mini-grid assets (and possibly liability insurance), as well as any **license fees or regulatory compliance costs**. Insurance can protect against damage from events like fire, lightning, or theft. Regulatory costs might involve obtaining/renewing mini-grid permits, environmental compliance, and reporting overhead. In some countries these fees are minimal or waived to encourage rural electrification, but developers may still incur costs for maintaining compliance and certifications.

Typical Share of OPEX: These costs are generally **small – often only a few percent of OPEX**. Insurance is usually on the order of **1–3% of the asset value per year**, which translates to a similar fraction of yearly expenses. Reported data shows insurance frequently at **~2% of OPEX** in African mini-grids (PowerPoint Presentation). Regulatory fees (if any) also tend to be minor (some countries charge a token annual license or a small percentage of revenue). Overall, this category is usually **<5% of total OPEX**.

Real-World Benchmarks: In Sierra Leone mini-grid data, insurance was only about **2% of operating costs (roughly $0.04 out of $2.53 per connection per month) (PowerPoint Presentation).** The 30 kW Zambian solar mini-grid carried **€250/year in insurance**, which was ~2.2% of its €11.3k OPEX (). Many smaller projects simply insure major equipment; at, say, $100k replacement value and ~1% premium, that's **$1,000/year for insurance**. Regulatory costs vary: some developers pay on the order of **$100–$500 per year** for licenses and inspections, while others operating under pilot programs pay nothing formal. For instance, the Zambia case had no mini-grid license fee at the time (the project hadn't undergone the full licensing process) (). In summary, **insurance and regulatory fees combined might only be on the order of a few hundred to a couple thousand dollars per year** even for systems up to 100 kW – a small slice of the budget.

Other OPEX Categories (Logistics, Communications, etc.)

In addition to the main categories above, mini-grid operators face other running costs: **logistics and transportation** (travel to remote sites for maintenance, fuel for vehicles, delivery of spare parts), **communications and IT** (internet or telecom for remote monitoring systems, staff communications, advertising or community engagement activities), and miscellaneous office/admin expenses. These tend to be medium-sized contributors to OPEX, often grouped under "general overhead."

- **Logistics/Travel:** Remote mini-grids often require technicians to travel for periodic maintenance or troubleshooting. This includes transport fuel, vehicle maintenance, or hiring contractors for site visits. Such costs can be on the order of **10–20% of OPEX**. For example, **"logistics" accounted for ~17% of OPEX in Sierra Leone mini-grids on average (PowerPoint Presentation)**, and an industry breakdown showed **about 30% of O&M costs attributed to logistics (site visits, transport, etc.) (FS: Mini-grids costs can be reduced by 60% by 2030)**. A smaller 20–50 kW site might spend a few hundred dollars a year on generator fuel for a maintenance truck or boat transport in difficult terrains, whereas a company operating many sites will have higher absolute logistics costs but may optimize routing to reduce per-site expense.

- **Communications & IT:** This includes costs for remote monitoring systems, data connectivity (SIM cards/modems in smart meters), and any customer communication or marketing ("promotions"). These are usually single-digit percentages of OPEX. The Sierra Leone data showed **"communication and promotions" about 17% of OPEX** (PowerPoint Presentation) (possibly higher than normal, as it may include community engagement programs). In many cases, satellite or GSM connectivity for a mini-grid might cost ~$20–$50 per month. So a 50 kW site might spend ~$600/year on communications (around 5% of OPEX), and a 100 kW site perhaps $1,000+ (still <5%).

- **Office/Admin Miscellaneous:** Any office supplies, small tools, uniforms, training, or an overhead allocation for head-office support. These are typically minor. In one breakdown, "office equipment" was <1% of OPEX (PowerPoint Presentation) (PowerPoint Presentation). Miscellaneous buffers and contingencies might add a few percent as well.

Impact of System Size (20 kW vs 50 kW vs 100 kW) on OPEX

Economies of Scale: Larger community mini-grids generally achieve **lower OPEX per kWh and per customer** than smaller ones. Many fixed costs (a technician's salary, basic maintenance gear, software subscriptions) are spread over more kilowatts and customers as system size grows. In practice, this means a 20 kWp solar mini-grid will have higher relative operating costs (and likely a higher required tariff) than a 100 kWp mini-grid, even if absolute costs are lower. Industry benchmarking data illustrates this trend: in 2019, African mini-grid OPEX ranged from **$2.5–6.0 per customer per month**, whereas by 2020 (with more sites and improved scale) it ranged **$1–4 per customer per month** ([PDF] BENCHMARKING AFRICA'S MINIGRIDS REPORT ©2022). Smaller systems tend toward the upper end of that range (around a few dollars per user monthly), while larger 50–100 kW projects trend to the lower end (~$1–$2 per user).

- **20 kWp Mini-Grid:** A system this size might serve on the order of 50–150 households. **Annual OPEX might roughly be in the ~$5,000 range** (e.g. $4k–$8k depending on context). For example, if 100 customers are connected, an OPEX of ~$4/customer/month would total $4,800/year. In a breakdown, you might see **labor ~40–50%** (at least one operator's salary), **maintenance ~20–25%**, **customer service/billing ~10%**, **security ~0–15%** (depending on whether a guard is hired), **insurance/admin ~5%**, and **other logistics ~10%**. Real-world data support this order of magnitude: a developer survey showed some smaller mini-grids spending about **$3–$4 per connection per month on OPEX** ([PDF] BENCHMARKING AFRICA'S MINIGRIDS REPORT ©2022) – which indeed for ~100 connections is ~$4,000–$4,800 per year.

- **50 kWp Mini-Grid:** This medium-size mini-grid might serve perhaps 200–300 households (or fewer if some small businesses are included). **Expected OPEX could be on the order of $8,000–$12,000 per year**. The cost structure starts to improve: one technician might handle operations, possibly with an assistant or weekly visits from a roving team. Maintenance costs rise in absolute terms (more panels and batteries to look after) but not drastically. Labor might now be, say, **30–40% of OPEX** (still one or two salaries), maintenance maybe **25–30%**, customer/billing ~**10%**, security ~**5%**, insurance/regulatory a few percent, and the remainder in logistics and admin. In practice, developers report that moving from tens of kW to ~50 kW sites yields **meaningful per-customer cost reduction** – for instance, if a 50 kW mini-grid has 250 customers, even a $10k annual OPEX is about $3.33 per customer-month, lower than the ~$4+ of the 20 kW example. (Indeed, the industry average OPEX per customer has been dropping into the $1–3 range as portfolios include more 50+ kW sites ([PDF] BENCHMARKING AFRICA'S MINIGRIDS REPORT ©2022).)

- **100 kWp Mini-Grid:** A system of this size can electrify a sizable village or town segment – often **500+ connections** including households, businesses, and institutions. **Annual OPEX might fall in the ~$15,000+ range**, depending on staffing and battery replacements. Economies of scale are most evident here: many 100 kW mini-grids still only have 1–2 on-site operators (with occasional support), keeping labor perhaps **25–35% of OPEX**. Maintenance and repairs will be a larger absolute budget (more hardware to maintain, and potentially larger battery reserve funds), but as a percentage might remain **around 20–30%**. Customer management overhead doesn't necessarily grow proportionally – efficient PAYG systems can handle hundreds of customers at relatively low incremental cost – so this might stay near **5–10%** of OPEX. Security often remains one guard or the same fencing as smaller sites (so maybe **<5%** of OPEX). Insurance costs will scale with asset value but still only a few percent. **In total, OPEX per connection for a 100 kW mini-grid can be quite low** – potentially on the order of **$1–2 per customer per month** ([PDF] BENCHMARKING AFRICA'S MINIGRIDS REPORT ©2022). For example, 500 customers at $2 each is $1,000/month (~$12k/yr). Many efficient 100 kW projects target an OPEX well under $0.20 per kWh delivered (FS: Mini-grids costs can be reduced by 60% by 2030), which helps make tariffs more affordable.

Summary of Benchmarks: Across the African mini-grid industry, operational costs are gradually declining as systems get larger and more efficient. A recent sector report noted that by 2020, typical OPEX in Africa had **fallen to about $1–4 per customer per month**, down 30–60% from the previous year ([PDF] BENCHMARKING AFRICA'S MINIGRIDS REPORT ©2022). This improvement is attributed to scaling up system sizes, better technology (like remote monitoring to cut travel and outage costs), and refined business models. Still, the breakdown of OPEX remains consistent in order of magnitude: **labor and routine O&M are the top costs**, with everything else (billing, security, insurance, etc.) making up the other roughly half of the expenses in total (PowerPoint Presentation) (FS: Mini-grids costs can be reduced by 60% by 2030). By planning for these costs – roughly **30–50% labor, 20–30% maintenance, ~10% customer/billing, ~5% security, ~2% insurance, and the balance in transport and admin** – developers in sub-Saharan Africa have been able to structure tariffs and subsidies to keep mini-grids running sustainably. Each additional kW and customer tends to improve the ratios slightly, which is why achieving scale (moving from 20 kW pilots to 100 kW village grids) is seen as key to making community solar mini-grids financially viable in the long run ([PDF] BENCHMARKING AFRICA'S MINIGRIDS REPORT ©2022) (FS: Mini-grids costs can be reduced by 60% by 2030).

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9. World Bank ESMAP – *Mini Grids for Half a Billion People* (2019) and Greacen et al. – cost per customer and component cost shares (Microsoft PowerPoint - 4.A.Chris Greacen.World Bank consultant.pptx) ([PDF] MINI GRID COSTING AND INNOVATION).
10. PowerForAll Fact Sheet (2019) – potential cost reduction to $0.22/kWh by 2030 with scale and innovation (FS: Mini-grids costs can be reduced by 60% by 2030) (FS: Mini-grids costs can be reduced by 60% by 2030).
11. OPEX : Real-world mini-grid operational cost data and industry reports were used to compile these figures. For example, Sustainable Energy for All's West Africa OPEX benchmark study provided breakdowns of OPEX by category (showing personnel, maintenance, etc. shares) (PowerPoint Presentation). A Rocky Mountain Institute analysis of mini-grid economics likewise quantified the makeup of O&M costs (finding ~44% labor, 30% logistics, 26% parts replacement) (FS: Mini-grids costs can be reduced by 60% by 2030). Specific case studies, such as a 30 kWp Zambian solar mini-grid, illustrate absolute cost levels for a smaller system (). These benchmarks align with the Africa Mini-Grid Developers Association (AMDA) findings that operating costs per customer have been trending downward as systems scale ([PDF] BENCHMARKING AFRICA'S MINIGRIDS REPORT ©2022). All data points are drawn from African mini-grid deployments or studies focused on sub-Saharan Africa. The percentages and values above provide a representative guide to OPEX allocation and expected costs for 20 kW, 50 kW, and 100 kW community solar mini-grids in the region.

Agriculture

Agricultural Potential in DRC's Green Corridor and Sub-Saharan Africa

Overview: The "Green Corridor" initiative in the Democratic Republic of Congo (DRC) aims to boost smallholder agriculture and connect producers to markets from eastern DRC (Kivu) to Kinshasa (Global Gateway: A Green Corridor preserving the last lungs of the earth through green economic growth - European Commission) (Global Gateway: A Green Corridor preserving the last lungs of the earth through green economic growth - European Commission). Smallholder farming dominates both the Green Corridor region and much of Sub-Saharan Africa, but staple crop yields are often low due to traditional practices and constraints. Below we examine key crops – maize, rice, sweet potatoes, beans, potatoes, peanuts, bananas, cassava (manioc), and plantain – focusing on typical yields, harvest cycles, profitability, and challenges for small farmers.

Yields and Harvest Cycles of Key Crops

- **Maize:** Smallholder maize yields in DRC are very low – around *0.8 tonnes per hectare* on average in eastern provinces (Typology of smallholder maize farmers in South-Kivu, Eastern D.R. Congo: implications in improving farming practices and markets | Discover Agriculture), versus a potential of 3–5 t/ha with improved seeds and practices (). (By comparison, some neighboring countries attain 4–5 t/ha on better-managed farms.) Maize is usually rain-fed with *1 main harvest per year* in most areas; however, in regions with bimodal rainfall, farmers can plant a second season crop, yielding *2 harvests per year* if conditions allow (FAO GIEWS Country Brief on Democratic Republic of the Congo -).
- **Rice:** Upland rice grown by smallholders in SSA typically yields about *1–2 t/ha* under rain-fed conditions (Status quo and challenges of rice production in sub-Saharan Africa). In irrigated lowlands, yields are higher (often *~4 t/ha*), but irrigation is limited in DRC (only a few thousand hectares are irrigated nationwide) (Democratic Republic of the Congo). Most small farmers grow rice once per year with the rainy season, though in well-watered areas a short-cycle variety might allow *a second annual crop*. Overall, rice yields in DRC are well below the global average (~4.8 t/ha) (Status quo and challenges of rice production in sub-Saharan Africa), reflecting low-input methods.
- **Sweet Potatoes:** African smallholders achieve roughly *5–6 t/ha* on average in sweet potato production (Total and Per Capita production of sweetpotato, estimated total... | Download Scientific Diagram). This is low compared to the crop's potential – improved varieties on research stations yield 20–30 t/ha (Exploring the yield gap of orange-fleshed sweet potato varieties on ...). Sweet potato is a quick-growing tuber; farmers can often plant and harvest *two cycles per year* (each cycle ~4–5 months) in tropical climates if moisture is adequate. It is usually propagated from vine cuttings, and harvest can be somewhat staggered to dig roots as needed once mature.
- **Beans:** Common bean yields are generally *below 1 t/ha* for smallholder farmers. In South Kivu (DRC), for example, beans were yielding under 1 t/ha with traditional methods (DR Congo: Boosting agricultural productivity and livelihoods in South Kivu through AID-I GLR's

innovative approaches and practices – IITA Blogs). With better management, yields around 1.5–2 t/ha are attainable (and experimental plots can reach 3 t/ha) (Intensification of common bean and maize production through ...). Beans have a short growing season (~3 months) and are often grown twice a year (main and secondary season) if rainfall patterns permit. Many farmers intercrop beans with maize or cassava. Typically *1–2 harvests per year* are possible depending on the region's rainy seasons.

- **Potatoes:** Smallholder "Irish" potato yields in Sub-Saharan Africa average about *6–10 t/ha*, far below attainable yields of 25–35 t/ha with good seed and inputs (Potato production (in tonnes) in sub-Saharan Africa (mean 2014 ...). In the highland areas of Central/East Africa (including Eastern DRC), farmers can often plant potatoes *two seasons per year* (e.g. during both rainy seasons). However, yield per crop is limited by factors like degenerated seed tubers and disease. With proper management (clean seed, fertilizer, pest control), progressive farmers in the region have achieved 20+ t/ha in one season ([PDF] Tackling Low Potato Yields in Eastern Africa - CGSpace), showing the yield gap.

- **Peanuts (Groundnuts):** Groundnut yields in African smallholder systems are typically around *0.7–1.0 t/ha*. The regional average is only about **0.96 t/ha** (Groundnut (Arachis hypogaea L.) improvement in sub-Saharan Africa), which is much lower than the crop's potential of 3–4 t/ha under ideal conditions. Peanuts are usually grown once per year in the main rainy season (they require about 3–4 months to mature). In some bimodal areas a short-duration variety might be planted again, but generally *1 harvest per year* is the norm. Yield is often constrained by poor soils and intermittent drought during the growing period.

- **Bananas:** In Eastern DRC, banana yields have **decreased to ~4.6 t/ha** on average for smallholders (Banana (Musa spp), largely due to disease and old orchards. Across East Africa, small farm banana yields range widely (5–30 t/ha) depending on variety and management (Microsoft Word - IITA_MT EDIT A_G_MT.docx), but even the higher end is well below the *50 t/ha* that commercial plantations can produce with intensive management (Banana facts and figures). Bananas (including plantains) are perennial: once established, they produce fruit continuously rather than in seasonal harvests. Each banana plant takes roughly 9–12 months to fruit, so farmers maintain staggered mats of plants to yield bunches throughout the year. In practice there are *no fixed "harvest periods"* – families harvest banana bunches year-round as they ripen.

- **Plantains:** Plantain (cooking banana) is a major staple in West and Central Africa (and parts of DRC). Yields on smallholdings average around *5–7 t/ha* (Microsoft Word - IITA_MT EDIT A_G_MT.docx), similarly depressed by pests and low inputs. Improved hybrid plantains can yield up to 20 t/ha (Microsoft Word - IITA_MT EDIT A_G_MT.docx), but such varieties are not yet widespread. Like dessert bananas, plantains are a perennial crop with continuous production once the grove is established. A given mat of plantain may produce one or two bunches per year (depending on how sucker growth is managed), but overall farmers can harvest bunches intermittently *throughout the year* rather than a single annual crop.

- **Cassava (Manioc):** Cassava is a hardy root crop and DRC's number-one staple. Average fresh root yields in DRC are about *8–10 t/ha* (World Bank Document) (Cassava Source-Sink Project: Home) under smallholder conditions, which aligns with the African average of ~8–12 t/ha (Cassava Source-Sink Project: Home). (For context, research stations can produce 20–30 t/ha with improved clones and fertilization.) Cassava is typically grown on a **12-month cycle** – farmers plant stem cuttings and harvest the tuberous roots roughly a year later (sometimes a bit earlier or much later, as cassava is flexible in harvest timing). In practice this means *1 harvest per planting*, though farmers may stagger plantings across plots for a steady supply. In the Green Corridor region, cassava grows well in the climate, but disease outbreaks have slashed yields in some areas (see Challenges below).

Profitability and Potential Revenues

Market Prices: The profitability of each crop depends on market prices and the cost of production. Staple commodity prices in DRC and Sub-Saharan Africa fluctuate with local supply and demand, but several trends hold:

- **Maize:** Maize is widely consumed and prices vary by season. Farm-gate prices often range from about **$200 to $400 per ton** (i.e. $0.20–$0.40 per kg) in many African regions. In DRC, deficits have driven prices higher – for example, in 2023 a price of about $450/ton was used to evaluate a maize project in South Kivu (). At such a price, a smallholder's typical yield (~1 t/ha) would generate roughly **$200–$450 per hectare** in revenue. This is modest, but with improved yields the picture improves: farmers who adopted hybrid seed and fertilizer in South Kivu boosted maize yields to ~2.7 t/ha and earned an estimated $1,210/ha (with around $900/ha net profit after input costs) (). Key cost drivers for maize are **seeds** (especially if purchasing hybrid seed), **fertilizer** (maize is nutrient-demanding), and **labor** for land preparation, weeding, and harvesting. Post-harvest drying and storage are also important – without proper storage, pests (like weevils) can cause losses, which effectively cuts into profits.

- **Rice:** Rice generally commands a higher price per weight than coarse grains. In many African markets, milled rice can sell for **$400–$600 per ton** or more (roughly $0.40–$0.60 per kg), especially in urban centers, because much rice is imported at high cost (FAO GIEWS Country Brief on Democratic Republic of the Congo -). If a smallholder achieves 2 t/ha of paddy rice, and assuming a farm-gate price around $300/t for paddy (unmilled) or higher, the **gross revenue might be on the order of $600/ha** (and considerably more if sold as milled rice in retail markets). However, rice production costs can also be high: labor for transplanting and weeding is intensive, and if irrigation is used, farmers may have irrigation service fees or pumping costs. **Labor** is the primary input in traditional systems (for tasks like land leveling, bird-scaring, harvest, and threshing). Where fertilizers or improved seed are used, those add to costs but can raise yields. Profitability for rice is very sensitive to yields – with low yields (1 t/ha), many farmers barely produce enough to eat or trade, whereas achieving 3–4 t/ha can substantially increase income.

- **Sweet Potatoes:** Sweet potato is often grown as a food security crop and local market vegetable. Prices per ton are relatively low because the product is bulky and perishable – farm prices might be roughly **$100–$300 per ton** in many areas (equivalent to only $0.10–$0.30 per kg at farm gate). At an average yield of ~6 t/ha, that gives *perhaps $600–$1,800/ha* gross revenue. In practice, many smallholders cultivate sweet potato on a small scale for subsistence and sell surplus in local markets by the bag or pile. **Labor** is a key cost (for mounding ridges, planting cuttings, weeding, and digging up the roots). Input costs are minimal – farmers usually use saved vines for planting and seldom apply fertilizer or chemicals. This means cash expenses are low, so even though revenue per hectare is not very high, sweet potato can be profitable in the sense of return to labor. The main challenge to profitability is post-harvest handling: without proper storage or processing, sweet potatoes must be sold quickly after harvest, which can flood markets and depress prices at peak harvest times.

- **Beans:** Common beans are a high-value staple – they fetch higher prices per ton than cereals. In East Africa, retail bean prices have recently been **$0.8–$1.5 per kg** (for example, 174–197 KSh/kg in Kenya, about $1.30+ per kg) (Beans Price in Kenya - March 2025 Market Prices (Updated Daily)). Farm-gate prices are lower than urban retail, but farmers might still get on the order of $500–$800 per ton for dry beans in many cases. However, because yields are low, total revenue per hectare is modest. At 0.5–0.8 t/ha yield, a small farmer might earn only **$300–$600 per hectare**. If they can reach 1.2 t/ha (as some improved practices in DRC achieved (DR Congo: Boosting agricultural productivity and livelihoods in South Kivu through AID-I GLR's innovative approaches and practices – IITA Blogs)), and sell at ~$600/t, that would be ~$720/ha. The **costs** for beans are relatively low in cash terms – seed is often farm-saved or obtained through local exchange (improved varieties exist, but many farmers replant a portion of their harvest). Beans benefit from fertilizer (especially phosphorus), but many smallholders do not apply any, relying on soil residual fertility. The biggest cost is **labor**, particularly if beans require staking (certain climbing varieties) or multiple weedings. Harvesting and shelling beans are laborious as well. Despite these challenges, beans can be profitable due to their strong market demand and high unit price, as long as farmers can protect the crop from diseases and avoid significant losses.
- **Potatoes:** Potatoes can be a cash crop for highland farmers. Farm prices typically range around **$200–$400 per ton** for ware potatoes (e.g. in Rwanda, farm-gate prices have been about 300–600 RWF/kg which is ~$0.30–$0.60/kg (Potatoes Price in Rwanda - Selina Wamucii), roughly $300–$600/t). Assuming ~8 t/ha yield, gross revenue might be on the order of **$2,000–$3,000 per hectare**, making potatoes quite lucrative compared to grains. In practice, however, **production costs for potatoes are high**. The biggest expense is usually **seed tubers** – farmers often need to set aside or buy a large quantity of seed potatoes (up to 2 tons of seed tuber per hectare). Improved (disease-free) seed is expensive, so many use saved seed which can carry diseases and reduce yield. Other major costs include **fertilizer** (potatoes respond well to manure or chemical fertilizer), and possibly fungicides if late blight is a problem. Labor for hilling, weeding, and harvest is significant as well. Transport costs can also cut into profit because potatoes are heavy to haul to market on poor roads. Despite these costs, well-managed potato farming can provide good income – but if disease strikes (for example, a blight epidemic), farmers can also suffer losses. Profitability is thus closely tied to access to inputs and ability to manage pests/diseases.
- **Peanuts:** Peanuts (groundnuts) have decent market value, especially shelled nuts for consumption or seed. Depending on the variety and processing, prices might be around **$500–$800 per ton** unshelled at farm gate, and higher for shelled or processed peanuts (oil processors or snack buyers may pay a premium for quality). A yield of 1 t/ha could therefore bring in roughly **$500–$800/ha**. In some regions, demand is strong and can drive prices up – for example, peanut traders in parts of Africa will pay high prices for nuts to export or crush for oil, but in other areas, markets are very local. **Costs:** Groundnut production is quite labor-intensive; land preparation and planting (often done by hand) and harvesting (pulling up plants and picking off pods) require a lot of work. Labor for shelling the nuts after drying is also a factor if farmers sell shelled nuts. Input costs are usually low – some farmers apply gypsum or lime to improve pod yield and quality (calcium is important for peanuts), and improved seed can boost yields but is not always available. Disease control (e.g. fungicides for leaf spots) and pest control (for aphids that spread rosette virus) are rarely used by smallholders due to cost. Post-harvest, farmers must dry the pods properly to avoid aflatoxin contamination which can reduce market value. Overall, peanut farming can be profitable where yields are at least moderate and labor costs (often family labor) are not counted in cash terms, but low yields or a bad rain year can make the returns per hectare quite low.
- **Bananas:** Bananas and plantains are mostly sold in local markets and are often consumed on-farm, but surplus bunches provide a regular source of income for many households. Bananas are sold per bunch or by weight; prices per ton are relatively low compared to other crops because of their bulk and perishability. In rural DRC, a large bunch of cooking banana might sell for the equivalent of only a couple of US dollars (one analysis of African plantain prices found averages around $280–$300 per ton in regional trade) (Africa's Plantain Market to Reach Over 30M Tonnes by 2025). If we estimate around 5 t/ha yield, the *gross revenue would be roughly a few hundred dollars per hectare per year*. However, banana and plantain fields produce continuously, and farmers can harvest and sell some fruit every week, which provides **steady cash flow** rather than one large payout. Costs for bananas/plantains are generally low – farmers propagate new plants from suckers (at no cost), and typically do not use fertilizers or pesticides in traditional systems. The main inputs are **labor for plantation upkeep**: pruning dead leaves, removing excess suckers, weeding, and harvesting/transporting bunches. In areas near cities, farmgate prices are higher and farmers who manage pest and disease issues can do well. For example, in East African highlands, banana beer brewing provides a market – farmers allocate up to half their banana area to beer cultivars because there is reliable demand (Banana (Musa spp) (Banana (Musa spp). Still, major disease outbreaks have hit profitability; when Banana Xanthomonas Wilt or Banana Bunchy Top virus strikes, farmers lose many mats and thus lose income until fields recover.
- **Cassava:** Cassava is often considered more of a subsistence crop, but it has significant commercial value in the form of processed products (dry chips, flour, etc.). Fresh cassava roots are bulky and perishable, so they usually sell cheaply right after harvest. In normal times, farm-gate prices for fresh cassava can be as low as **$50–$100 per ton** (just a few cents per kg) in high-production zones. This means at 8–10 t/ha yield, a farmer might only get around $500–$800 per hectare for fresh roots. Many farmers therefore process cassava into more shelf-stable forms like fermented cassava flour (fufu flour) or dried cassava chips, which fetch higher prices per weight. Cassava flour in DRC retail markets has been priced around **1,100–1,350 CDF/kg** (Congolese francs) in recent years (Cassava Flour Price in DRC Congo - Selina Wamucii), which is roughly $0.55–$0.68 per kg or $550–$680 per ton. Even accounting for the weight loss in processing (it takes several kg of fresh roots for 1 kg of flour), this can roughly double the value compared to selling fresh roots. Thus, a hectare of cassava, if processed and sold as flour, might generate on the order of **$1,000+ per hectare**. Costs for cassava production are minimal in terms of cash – farmers usually obtain **stem cuttings** from neighbors or their own fields, and rarely use fertilizer or chemicals on cassava. The biggest cost is **labor**, especially for harvesting and processing. Harvesting cassava is laborious since the roots must be dug up; processing (peeling, soaking, drying, milling) is also labor-intensive. Additionally, transporting cassava or its products to market can be costly due to the volume involved. Profit margins can shrink if farmers have to pay for hauling heavy

cassava tubers over long distances on poor roads. Nonetheless, cassava can be an important income source in the Green Corridor: it is a staple that never lacks demand, and in times of scarcity, prices can spike. (For instance, during a recent disease-induced shortage in Kisangani, a basket of cassava that sold for 6,000–7,000 CDF in 2018 jumped to 20,000 CDF in 2021 (DRC's Key Food Source Is Under Threat — From a Virus) – a more than threefold increase, illustrating how market prices can rise sharply when supply falters.)

Challenges and Constraints for Smallholder Farming

Despite the opportunities, smallholder farmers in DRC's Green Corridor and across Sub-Saharan Africa face numerous **challenges and constraints** that limit crop yields and profitability:

- **Climate and Water:** Agriculture is predominantly rain-fed, making it highly vulnerable to weather variability. DRC has ample rainfall in many areas, but its distribution can be erratic. In recent years, climate change has contributed to more unpredictable rains – including droughts in some seasons and floods in others (). For example, in South Kivu heavy rains led to floods between November 2023 and January 2024, damaging fields and delaying planting/harvest of staple crops (FAO GIEWS Country Brief on Democratic Republic of the Congo -). Such events can wipe out harvests or reduce yields dramatically. Most smallholders lack irrigation facilities (only a tiny fraction of DRC's cropland is irrigated (Democratic Republic of the Congo)), so they depend entirely on rainfall. In savanna regions, a late start or early end to the rains can mean crop failure (maize and beans are especially sensitive to drought at flowering). Conversely, excessive rain can waterlog fields or cause soil erosion and nutrient leaching. The **water availability** constraint means farmers have only 1–2 cropping seasons, and in a bad year they may not get a crop at all. Climate-related risks also discourage investment – a farmer may hesitate to invest in expensive inputs if a flood or drought could negate those efforts. As part of the Green Corridor strategy, climate-resilient practices (like drought-tolerant varieties and better drainage) are being promoted to mitigate these risks (), but implementation is still in early stages.

- **Soil Fertility and Inputs:** Low inherent soil fertility and minimal use of inputs is a widespread problem. Many smallholders farm the same plots continuously with little or no fertilizer, leading to depleted nutrients and declining yields. In Eastern DRC, studies identify **poor soil fertility management** as a key constraint on crops like maize (Typology of smallholder maize farmers in South-Kivu, Eastern D.R. Congo: implications in improving farming practices and markets | Discover Agriculture). Fertilizer usage in DRC is among the lowest in the world (historically just a few kilograms per hectare on average) (Democratic Republic of the Congo). Farmers often cannot afford chemical fertilizers, or it is simply not available in remote areas. Similarly, improved seeds (high-yield or disease-resistant varieties) are not widely adopted – access to quality seed is limited (Typology of smallholder maize farmers in South-Kivu, Eastern D.R. Congo: implications in improving farming practices and markets | Discover Agriculture). For example, the adoption rate of improved maize and cassava varieties in parts of South Kivu has been very low, despite government and NGO extension efforts (Typology of smallholder maize farmers in South-Kivu, Eastern D.R. Congo: implications in improving farming practices and markets | Discover Agriculture). This means farmers continue to recycle seeds and planting material that may be of poor quality. The result is a big **yield gap** – e.g. local maize yielding <1 t/ha when it could yield 3–4 t with the right inputs, or cassava stuck around 8 t/ha when improved varieties could give double that () (World Bank Document). Even when inputs are available, their cost can be prohibitive. Fertilizer and fuel price inflation has driven up input costs in recent years (World Bank Document), and many smallholders lack credit or capital to purchase them at planting time. Programs under the Green Corridor are looking to improve input access (for instance, via subsidy packages and agrodealer networks), but reaching remote villages is challenging. Until soil fertility is restored and farmers can use inputs effectively, low yields will persist.

- **Pests and Diseases:** Crop pests and diseases pose major risks across all these staples, often causing significant yield losses for smallholders. In DRC and much of Africa, farmers typically do not have the resources to apply pesticides or other controls, so outbreaks can be devastating. Some notable examples:
  - *Maize:* The arrival of the Fall Armyworm in Africa in recent years has been a serious threat. This caterpillar can infest maize fields and has caused losses in DRC; tens of thousands of hectares have been affected in the southeast, leading to local maize price spikes. Smallholders also struggle with stem borers and storage pests in maize.
  - *Cassava:* Cassava suffers from two viral diseases – **Cassava Mosaic Disease** (CMD) and **Cassava Brown Streak Disease** (CBSD). These diseases are rampant in parts of DRC. In the Kisangani area, the newer brown streak virus slashed cassava yields by over 80% (from a potential 45 t/ha to only 7 t/ha in one researcher's estimate) (DRC's Key Food Source Is Under Threat — From a Virus). Because cassava is propagated by cuttings, diseases spread quickly through shared planting material. If not addressed, cassava disease can lead to total crop failure (brown streak rots the roots, making them inedible (DRC's Key Food Source Is Under Threat — From a Virus)). Efforts are underway to distribute virus-resistant cassava varieties, but coverage is still limited.
  - *Bananas/Plantains:* Banana bunches in the Green Corridor are under assault from a suite of pests and pathogens. **Black Sigatoka** (a fungal leaf spot) reduces photosynthesis and yields, **Fusarium wilt** (Panama disease) can wipe out entire banana mats, **Xanthomonas wilt** (BXW) is an especially lethal bacterial disease in East/Central Africa, and **Banana Bunchy Top Virus** stunts plants severely (Banana (Musa spp). Additionally, banana weevils bore into corms and microscopic nematodes attack the roots (Banana (Musa spp). These issues have already caused the decline in yields noted (down to ~4.6 t/ha in parts of DRC) (Banana (Musa spp). Farmers often have little knowledge or tools to manage these problems – for instance, controlling BXW requires strict sanitation (cutting and burying infected mats) which is laborious and not always followed.
  - *Beans and Peanuts:* These legumes face their own challenges. Common beans are prone to fungal diseases like root rot and anthracnose, and insect pests (aphids, bean beetles). Groundnuts in Africa frequently suffer from **groundnut rosette virus** (spread by aphids) that can wipe out yields, as well as early/late leaf spot fungi. Without fungicides or resistant varieties, yield losses can be severe. Post-harvest, both beans and groundnuts are vulnerable to storage pests and fungal contamination if not dried properly.
  - *Potatoes:* Potato diseases, especially **late blight** (Phytophthora infestans), are a major constraint in wetter highland climates. Unless farmers have access to fungicides or resistant potato varieties, blight can destroy the foliage and tubers, cutting yields drastically. Bacterial wilt and potato virus diseases also accumulate

when farmers recycle seed tubers, contributing to the low yields (7–8 t/ha vs. 20+ potential) (Potato production (in tonnes) in sub-Saharan Africa (mean 2014 ...). Many smallholders are caught in a cycle of planting disease-infected seed and getting poor harvests.

Overall, inadequate pest and disease control is a critical issue. Research confirms *"widespread crop diseases and pests"* are a leading cause of low smallholder yields in DRC (Typology of smallholder maize farmers in South-Kivu, Eastern D.R. Congo: implications in improving farming practices and markets | Discover Agriculture). Unlike commercial farms, most smallholders cannot easily access crop protection chemicals or resistant varieties, making them largely defenseless against outbreaks. This highlights the need for agricultural extension services in the Green Corridor to teach integrated pest management and to multiply resistant crop varieties (e.g. disease-free cassava cuttings, banana tissue culture plantlets, etc.).

- **Infrastructure and Market Access:** Physical and market infrastructure limitations heavily constrain small farmers' profitability. **Poor rural roads** and transport links mean that many farmers in the Green Corridor have difficulty getting their produce to major markets. For instance, moving goods from eastern DRC to Kinshasa is extremely challenging – one of the very aims of the Green Corridor project is to improve transport infrastructure (Global Gateway: A Green Corridor preserving the last lungs of the earth through green economic growth - European Commission). Currently, high transport costs and insecurity on some routes mean farmers often accept low farm-gate prices from local traders. According to reports, fuel costs and bad roads drive up food prices in urban centers, but the benefit doesn't reach the farmers – it's absorbed by the cost of transport and handling (Democratic Republic of Congo Price Bulletin, October 2024). Thus, remote farmers face **market access barriers**: they are far from buyers, lack timely market information, and often must sell at the farm gate for whatever price is offered. A study in South Kivu noted "low market access" as a key constraint for smallholders, alongside production issues (Typology of smallholder maize farmers in South-Kivu, Eastern D.R. Congo: implications in improving farming practices and markets | Discover Agriculture). Moreover, the absence of organized farmer groups or cooperatives means individual smallholders have little bargaining power in the value chain.

Another infrastructure challenge is the lack of **storage and processing facilities**. Because farmers cannot store their harvest long, they tend to sell right after harvest when prices are lowest. In DRC, there is a shortage of warehouses and crop drying/storage tech, leading to "large post-harvest losses" for crops (World Bank Document). For example, without proper cribs or silos, a maize farmer might lose a good portion of the crop to rot or pests within weeks of harvesting. Similarly, lack of local mills or processing means crops like cassava and groundnuts are sold raw rather than as higher-value processed goods. This limits the revenue farmers can earn.

Additionally, **financial infrastructure** is weak – rural credit is scarce, so farmers cannot easily borrow to invest in inputs or equipment. And extension services have historically been under-resourced in DRC, meaning farmers often don't get information on better farming practices or market opportunities (Typology of smallholder maize farmers in South-Kivu, Eastern D.R. Congo: implications in improving farming practices and markets | Discover Agriculture). However, with the Green Corridor initiative, there is an effort to improve these support systems (e.g. developing agribusiness hubs, farm-to-market roads, and market information systems) to better integrate

smallholders into value chains (Global Gateway: A Green Corridor preserving the last lungs of the earth through green economic growth - European Commission).

- **Labor and Other Constraints:** Most smallholder agriculture relies on family labor. Labor availability can be a bottleneck, especially during peak planting and weeding periods. In some areas, **labor scarcity** (due to rural out-migration or conflicts) has affected farming operations (Typology of smallholder maize farmers in South-Kivu, Eastern D.R. Congo: implications in improving farming practices and markets | Discover Agriculture). For instance, households with many dependents and few working adults may struggle to cultivate all their land or harvest crops in a timely way. In DRC, decades of conflict, especially in the East, have displaced farming communities and often left fields fallow. Even in stable areas, farming is hard manual work – without mechanization (very few smallholders have tractors or even animal draft power), the amount of land that can be prepared and weeded is limited. This is one reason farm sizes remain small and yields per labor-hour are low.

Other challenges include land tenure insecurity (some farmers, especially women, may not have clear rights to the land they cultivate, disincentivizing long-term improvements), and issues like crop theft or wildlife damage in certain locales. **Infrastructure for education and extension** plays a role too – farmers with less access to education or training may be slower to adopt new techniques that could improve productivity.

In summary, the agricultural potential in the DRC's Green Corridor is significant – the region has good rainfall, expansive arable land, and high regional demand for food. Crops like maize, cassava, and plantain are deeply important for food security and have untapped yield potential. If smallholder farmers can get past the current constraints (through better seeds, inputs, training, and infrastructure investments), yields per hectare could increase substantially, raising incomes. For example, demonstration projects have shown maize yields tripling and cassava yields doubling with improved methods () (World Bank Document). Likewise, closing the yield gap in potatoes, bananas, and other crops could transform them into surplus-producing, income-generating activities for farm families. Realizing this potential will require addressing the challenges – improving rural roads and market access, ensuring farmers can obtain inputs and know-how, combating pests and diseases with science-based interventions, and helping farmers adapt to climate variability. The Green Corridor initiative explicitly targets many of these needs (Global Gateway: A Green Corridor preserving the last lungs of the earth through green economic growth - European Commission), aiming to strengthen agricultural value chains while conserving the environment. Over time, such efforts could enable smallholders in DRC and across Sub-Saharan Africa to achieve higher yields, more harvests per year where feasible, and better profitability for these vital crops, thereby improving livelihoods and food security in the region.

Sources

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- Number of cropping seasons per year in DRC/SSA (FAO GIEWS Country Brief on Democratic Republic of the Congo -) (Status quo and challenges of rice production in sub-Saharan Africa)
- Crop prices and revenues (maize, beans, cassava flour, etc.) () (Beans Price in Kenya - March 2025 Market Prices (Updated Daily)) (Cassava Flour Price in DRC Congo - Selina Wamucii)
- Key cost factors and value chain issues () (World Bank Document)
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Transport

Rehabilitation Costs per km by Road Type

- **Paved Roads:** Rehabilitating paved highways (asphalt or concrete) in DRC is expensive due to severe deterioration and logistical challenges. Typical costs range in the hundreds of thousands of $ per km. For Sub-Saharan Africa, **rehabilitation of paved roads** has been estimated around **$230,000 per km** on average (Microsoft Word - SSATPWP10 - Commercializing Africa's Roads Transforming th–), though complex projects or remote areas can cost more (sometimes $500k+ per km). This involves strengthening the pavement, fixing drainage, and often reconstructing sections to restore all-weather durability (Cost of Roads in Africa) (Cost of Roads in Africa).
- **Gravel Roads: Rehabilitating gravel roads** (unpaved but with an aggregate surface) usually costs an order of magnitude less than paved roads. Estimates in Central Africa are on the order of **tens of thousands of $ per km**. A World Bank analysis noted an average of about **$36,000 per km** to rehabilitate gravel roads in poor condition (Microsoft Word - SSATPWP10 - Commercializing Africa's Roads Transforming th–). This typically includes re-grading the road, re-applying gravel, and repairing culverts/bridges. Simpler spot improvements on rural gravel roads can sometimes be done for as low as ~$10,000–15,000 per km (excluding major structures) in easier terrain (Cost of Roads in Africa).
- **Earth (Dirt) Roads: Earth roads** are tracks with no engineered surface, and rehabilitation mainly involves grading, compacting, and improving drainage. These are the cheapest to restore per km. Rough guidelines put basic earth road improvement at around **$8,000–10,000 per km** (Cost of Roads in Africa) under normal conditions – essentially restoring shape and minor structures so the road is passable. However, if heavy works are needed (e.g. adding culverts, small bridges) costs can rise toward the level of gravel roads. Still, rehabilitating earth roads is generally the most cost-effective way to reconnect isolated communities in DRC's interior.

Maintenance Costs per km (Routine & Periodic)

Keeping roads in good condition requires regular **maintenance**, which varies by road type:

- **Paved Roads:** Paved roads need both routine maintenance (pothole patching, clearing drains, etc. done yearly) and periodic maintenance (resurfacing every 5–10 years). Annual (covering routine works and saving for periodic overlays) (Microsoft Word - SSATPWP10 - Commercializing Africa's Roads Transforming th–). For instance, thin asphalt overlays or sealings every few years might cost tens of thousands per km (e.g. $20k+ per km for a new surface every 5–7 years), but if routine care is consistent (at a few hundred dollars per km quarterly), overall life-cycle costs stay near this range (World Bank Document). Without timely maintenance, paved roads can deteriorate rapidly, leading to far higher rehabilitation costs down the line (Cost of Roads in Africa).
- **Gravel Roads:** Gravel/unpaved roads require continual upkeep, especially with DRC's heavy rains. **Routine maintenance** (grading the surface, cleaning ditches) can cost on the order of **$1,000 per km per year** (Microsoft Word - SSATPWP10 - Commercializing Africa's Roads Transforming th–). In addition, **periodic re-graveling** is needed every few years as the top layer erodes – this periodic renewal might cost **$2,000–4,000 per km** each cycle (Cost of Roads in Africa). If maintenance is neglected, gravel roads quickly become impassable; thus, donors stress funding regular grading and spot repairs to keep them all-season passable.
- **Earth Roads:** Earthen roads (dirt tracks) are often maintained at a very basic level. Routine measures like filling ruts and smoothing the surface might only cost a few hundred dollars per km each year if done with labor-based methods. However, maintaining drainage is critical to prevent washouts. **Periodic regrading** (perhaps annually after rainy season) could run a few thousand dollars per km. One estimate suggests combining routine and periodic maintenance for unpaved rural roads in Africa at roughly **$1,000 per km yearly** on average (Cost of Roads in Africa). In practice, many earth roads in DRC receive little to no maintenance, which is why rehabilitation needs (though cheap per km) are so frequent after seasonal damage.

Studies and Recommended Strategies for Road Rehabilitation in DRC

Reputable international institutions have studied DRC's transport needs and developed strategies to improve road connectivity. Key findings and recommendations include:

- **Prioritize Maintenance Funding:** A consistent theme in World Bank and African Development Bank (AfDB) reports is that **sustainable maintenance financing** is as important as upfront rehabilitation. DRC established a dedicated Road Maintenance Fund (FONER) funded by fuel levies to bankroll repairs. While annual funding rose from about **$60 million in 2009 to $164 million by 2021** (World Bank Document), it remains **insufficient for the vast network**. Both the World Bank and AfDB recommend strengthening FONER's governance and revenue base so that rehabilitated roads don't fall back into disrepair (World Bank Document) (World Bank Document). This includes improving transparency (past mismanagement led to prosecutions for misuse of funds) and ensuring monies are allocated to the most critical road links on a rational basis (World Bank Document).
- **"Pave the Priority Corridors":** Given DRC's size and climate, studies suggest **moving away from reliance on gravel roads** for major corridors. Gravel roads often fail under heavy rain and traffic, requiring constant repair. The World Bank stresses that climate adaptation for DRC's road sector means **upgrading key routes to paved standards and installing robust**

drainage in flood-prone and hilly areas (World Bank Document). Paved roads, while costlier upfront, are more durable and economical over the long term for high-traffic corridors (if maintained). For example, the **Green Corridor** concept itself envisions a reliable all-weather highway from the Kivus to Kinshasa. This aligns with African Development Bank recommendations to invest in paving National Routes like RN1 and RN2 that link major cities, rather than continually rehabilitating them as gravel (World Bank Document).

- **Focus on Connectivity Impact:** Studies by the World Bank note that **only 4 of 25 provincial capitals** in DRC are currently accessible from Kinshasa by reliable road (World Bank Document). The AfDB and UN agencies (e.g. UNECA) have called for a **"connectivity first" approach**, targeting road segments that reconnect isolated population centers and markets. Projects like the **ProRoutes** program (World Bank) and **Transport Rehabilitation Projects** (AfDB) reopened thousands of kilometers of roads, linking cities like Kisangani, Bukavu, Goma, and Lubumbashi back into the network. These projects demonstrate that even basic road rehabilitation (often to earth or gravel standard initially) yields huge socio-economic benefits by shortening travel times from days to hours, lowering transport costs, and enabling trade (World Bank Document) (World Bank Document). The lesson is to concentrate resources on strategic corridors (often called **"high-priority corridors"**) that maximize impact on trade and poverty reduction.
- **Institutional Reforms and Local Capacity:** Donor reports emphasize that physical works must be paired with institutional strengthening. The **AfDB** highlights the need to clarify roles of agencies (national vs. rural road authorities) and build provincial capacity for road upkeep (DRC - Nsele-Lufimi and Kwango-Kenge Roads Rehabilitation Project - Appraisal Report) (DRC - Nsele-Lufimi and Kwango-Kenge Roads Rehabilitation Project - Appraisal Report). The **World Bank** has similarly advocated for reforming the road sector's governance – for example, empowering the **Road Agency (Office des Routes)** and provincial public works offices with funding and accountability for maintaining the rehabilitated roads (). Training local contractors and community-based maintenance crews is a recommended strategy to ensure routine maintenance is done. In one AfDB-funded project on RN1, the plan included **training local road maintenance committees (CLER)** and integrating those roads into the national maintenance program (). This community involvement approach, also tried in other African countries, creates local jobs and helps instill a maintenance culture so the investment in rehabilitation is preserved.
- **Cost Estimates and Best Practices:** International financial institutions have published benchmark cost data to guide DRC's road investments. The Africa Infrastructure Country Diagnostic (AICD) noted DRC's unit costs tend to be higher than the African average due to its challenging environment (thick forests, weak contractor base, insecurity). Best practices to control costs include **competitive bidding**, packaging works in larger contracts to get economies of scale, and rigorous supervision to prevent cost overruns (Study on Road Infrastructure Costs- Analysis of Unit Costs and Cost Overruns of Road Infrastructure Projects in Africa) (Study on Road Infrastructure Costs- Analysis of Unit Costs and Cost Overruns of Road Infrastructure Projects in Africa). The AfDB's analysis of road projects across Africa found that smaller projects in remote regions often have higher per-km unit costs, so they advise aggregating works where possible (Study on Road Infrastructure Costs- Analysis of Unit Costs and Cost Overruns of Road Infrastructure Projects in Africa) (Study on Road Infrastructure Costs- Analysis of Unit Costs and Cost Overruns of Road Infrastructure Projects in Africa). Additionally, adopting appropriate technology (e.g. labor-based methods for light works, which can be ~25% cheaper) and using local materials can lower costs (Cost of Roads in Africa). Organizations like the **UNOPS** and **African Development Bank** often provide technical assistance on these best practices in DRC, ensuring that funds (whether from the government, World Bank, AfDB, or donors like the EU) are used efficiently in the Green Corridor initiative.

Development Costs:

Rehabilitating the Congo's river ports would require substantial but relatively modest investments compared to other infrastructure. As noted, Kisangani's upgrade was budgeted around $5 million for critical fixes (Inland Waterways | The Northern Corridor Transit and Transport Co-ordination Authority (NCTTCA)). Extending similar improvements to Mbandaka and additional equipment for Kinshasa might be on the order of $10–20 million more. Donors like the World Bank have included port components in larger transport projects (e.g. purchasing cranes, building river training works), and regional bodies have called for improving **navigation aids and port facilities** as part of corridor development (Inland Waterways | The Northern Corridor Transit and Transport Co-ordination Authority (NCTTCA)). Upgraded ports would reduce turnaround times for barges, lower cargo losses (through better storage), and ultimately improve the **break-even economics** for river transport.

Environmental Mitigation Measures for Forest Preservation

(When a Road Leads to Deforestation) *Figure: Road expansion (2003–2018) in the Congo Basin (green = existing roads pre-2003, purple = new roads by 2018). The rapid growth of road networks in previously intact forests has accelerated deforestation rates (When a Road Leads to Deforestation). Studies show that **95% of deforestation** in tropical rainforest regions occurs within a few kilometers of a road (Infrastructure projects in Congo Basin need greater oversight, report says), underscoring the need for strong environmental safeguards when improving connectivity.*

Expanding and rehabilitating roads in DRC's **"Green Corridor" –** a region rich in tropical rainforest (the "lungs of the Earth") **–** must be done with strict measures to **avoid forest degradation**. Reputable sources and case studies from similar African contexts recommend several forest-friendly infrastructure practices:

- **Rigorous Environmental Assessment & Planning:** Before any road works, conduct thorough Environmental Impact Assessments (EIAs) and apply the **mitigation hierarchy (avoid, minimize, mitigate, offset)** (Forest-friendly Infrastructure | | WWF Forest Solutions). This means **rerouting roads to avoid core forest habitats and protected areas** wherever possible, and choosing alignments that follow existing disturbed corridors (old roads or logging tracks) instead of carving new paths through pristine forest. Strategic planning at the landscape level (often called **Strategic Environmental Assessments**) is advised by the UN and WWF to evaluate cumulative impacts of multiple road segments and to design networks that minimize ecological disruption (Forest-friendly Infrastructure | | WWF Forest Solutions).
- **Minimizing Forest Clearance & Restoring Vegetation:** During construction or rehabilitation, limit the road's footprint. Contractors should be required to **avoid unnecessary clearing** of vegetation beyond the roadway. For example, the AfDB's environmental plan for DRC road projects mandates *"taking necessary measures to avoid destroying the vegetation along the roads"* and specially protecting unique flora (such as

stands of bamboo) near the alignment ([DRC - Nsele-Lufimi and Kwango-Kenge Roads Rehabilitation Project - Appraisal Report]). Any areas disturbed (work camps, borrow pits for material) should be **replanted and restored** after construction ([DRC - Nsele-Lufimi and Kwango-Kenge Roads Rehabilitation Project - Appraisal Report]). Using native tree species to reforest bare soils, and quickly rehabilitating quarries and embankments, helps the forest recover and prevents erosion. Essentially, the road should not become a strip of deforestation – vegetation should remain right up to the roadside, and canopy cover over the road can often be preserved on earth and gravel tracks.

- **Anti-Poaching and Anti-Logging Measures:** A major concern is that improved roads enable illegal resource extraction (wildlife poaching, bushmeat trade, and logging). Successful mitigation in other forested regions has involved a combination of **enforcement and community engagement**. For instance, a DRC transport study noted that opening roads increases hunting profitability and recommended countering this *"by strengthening the capacities of control services, [park] personnel… and the application of regulations in force,"* coupled with educating local officials and communities (). In practice, this can mean establishing **checkpoints** along the road to inspect for illegal timber or wildlife, deploying more **park rangers** in nearby reserves, and working with police to patrol the corridor. Public awareness campaigns are also important – informing villagers and road workers about wildlife laws and the long-term value of conserving species. Such measures were planned under the World Bank's ProRoutes project (e.g. funding ICCN – the national park authority – to increase patrols in the Okapi Wildlife Reserve when a road through it was rehabilitated) (). Ensuring these safeguards are actually implemented and funded is key; independent monitoring by NGOs or panels can help track compliance () ().
- **Community Forest Management and Offsets:** An innovative strategy in the **Green Corridor** initiative is to involve local communities in forest preservation. The DRC government, with support from partners like the EU, plans to establish a **community-managed reserve** along the corridor – essentially empowering local people to steward the forest and benefit from its protection ([Global Gateway: A Green Corridor preserving the last lungs of the earth through green economic growth - European Commission]). Free, prior, and informed consent (FPIC) of indigenous communities is obtained so that new economic opportunities from the road go hand-in-hand with setting aside land as conservation areas. This approach has parallels in other countries – for example, community forestry zones or extractive reserves in Amazonia have successfully curbed deforestation by giving locals a stake in sustainable use rather than wholesale clearing. Along the Green Corridor, mapping of key ecosystems is underway to identify critical biodiversity areas ([Global Gateway: A Green Corridor preserving the last lungs of the earth through green economic growth - European Commission]). Those areas can then be targeted for **offsets or extra protections** – for instance, if forest must be cleared in one stretch, another area might be formally protected or reforested to compensate for the loss. Such balancing mechanisms are recommended by UN environmental agencies to ensure no net loss of forest cover.
- **Physical Design Measures:** Road engineers can also incorporate features that mitigate environmental harm. In dense forest zones, **wildlife crossing points** (e.g. enlarged culverts or overpasses for animal movement) can be installed if large mammal migration routes are known. Proper **drainage systems** are critical not only for climate resilience but to protect the forest's hydrology – culverts and bridges should allow natural water flow so that the road doesn't create swampy die-off areas upstream or dry zones downstream ([World Bank Document]). Additionally, setting and enforcing a **right-of-way buffer** can prevent settlers from immediately encroaching beyond the road. Some projects mark a corridor where farming is prohibited (for example, a 50 m buffer inside a World Heritage forest), buying time to organize land use planning ([Okapi Wildlife Reserve - UNESCO World Heritage Centre]). Where roads traverse parks or reserves, speed bumps and signage can reduce wildlife roadkill.
- **Post-Project Road Management:** A lesson from Central Africa is that **temporary roads** (like logging roads) need to be closed or repurposed after use to avoid permanent forest loss. In Congo Basin logging concessions, companies have had success by **physically blocking off retired roads** to allow regrowth ([When a Road Leads to Deforestation]). For the Green Corridor's rehabilitated routes, which will be permanent, this concept translates into controlling side-effects: for instance, side spur routes created for construction should be closed if they lead into intact forest zones. Ongoing monitoring via satellite of the corridor can detect illegal new branch roads or forest clearing, prompting authorities to take action. The use of remote sensing and community forest watchers (patrolling and reporting any illegal clearing) is a modern best practice to ensure the road doesn't become a conduit for unchecked deforestation.

In summary, the **Green Corridor road improvements must balance development with conservation**. International experience in Africa's rainforests shows that with proper planning, robust enforcement, and community inclusion, it is possible to improve connectivity between cities **without sacrificing the forests**. DRC's government and partners like the World Bank, AfDB, EU, and UN are all aware that this corridor will set a precedent – often cited as a model of "green infrastructure". By following best practices on cost-effective rehabilitation, committing funds for upkeep, and implementing strong environmental safeguards, the Green Corridor can indeed boost economic connectivity while preserving the invaluable Congo Basin forests for future generations ([Global Gateway: A Green Corridor preserving the last lungs of the earth through green economic growth - European Commission]) ([The Democratic Republic of Congo to create the Earth's largest protected tropical forest reserve | World Economic Forum]).

Profitability of Container Shipping (Kisangani–Kinshasa Corridor)

Operating Costs: Running a barge or riverboat between Kisangani and Kinshasa involves significant operating expenses. Key cost components include:

- **Fuel:** Diesel fuel is a major expense given the long distance (~1,724 km by river) () and slow speeds. A full Kinshasa–Kisangani round trip can take around 80 days (one month each way) (), consuming large volumes of fuel.
- **Crew & Maintenance:** Vessels require skilled crew (pilots, engineers, deckhands) and regular maintenance. Much of the river fleet is aged and in *"outdated and insufficient infrastructure"* condition (), which raises maintenance costs and lowers fuel efficiency.
- **Port Fees & Informal Levies:** Barges incur port handling charges in Kinshasa, Kisangani, and intermediate stops. In addition, operators face a *"plethora of taxes and controls by regions in ports between origin and destination"*, i.e. provincial authorities often impose unofficial fees (). These add to overall costs and delays.

Freight Rates and Revenue: Due to limited capacity and high demand, freight tariffs on the river are relatively expensive. Estimates suggest barge operators charge on the order of **$50–$80 per ton** for the full Kisangani–Kinshasa trip (transportation Grand Kivu and Kinshasa). This translates to roughly **$1,500–$2,000 per 20-foot container**, comparable to the cost of shipping the same container by ocean from Asia to West Africa. In fact, moving a container from Kinshasa to Kisangani costs about as much as shipping it from **Shanghai to Pointe-Noire** (Republic of Congo) (). These high freight rates reflect the difficult logistics and are only viable because road alternatives are virtually non-existent in much of the DRC's interior.

Breakeven and Profitability: Despite high tariffs, profitability is not guaranteed. The relative cost advantage of river transport – roughly **$0.05 per ton-km by barge vs $0.15 per ton-km by road** in Central Africa () – is often eroded by inefficiencies. Long transit times (several weeks or more) mean low asset turnover, and boats must carry full loads in both directions to breakeven. Any downtime for repairs or waiting for cargo can quickly eat into margins. Formal operators like the state-run SCTP (formerly ONATRA) have struggled; many have **"exited the market"** due to high costs and competition from informal operators (). In practice, the few companies running container barges must carefully manage costs and keep vessels full to achieve profitability. Economies of scale are important – large convoys of barges (sometimes 5–10 barges lashed together) help dilute fuel and crew costs per ton, but require functioning tugboats and river channel maintenance.

Socio-Economic and Environmental Impacts of Improved River Transport

Benefits to Communities and Trade: Revitalizing river transport on the Congo can have profound socio-economic benefits for riverine communities and the country at large. The river is effectively "DRC's Highway 1" – many towns can only be reached by boat (On The Congo, A Floating Marketplace For A Nation : NPR). Improved connectivity would:

- **Create Employment:** Port rehabilitations and increased barge traffic generate jobs for crew, dockworkers, mechanics, and traders. A Congolese transport official noted that *"thousands of jobs could be generated if river traffic were operating at full capacity"*, underscoring the untapped employment potential (On The Congo, A Floating Marketplace For A Nation : NPR). These jobs would range from formal positions with shipping companies to informal work (stevedores, vendors serving boat passengers, etc.) along the route.
- **Lower Consumer Prices and Boost Trade:** Cheaper, more reliable river freight means essential goods (food, fuel, medicine, building materials) can reach inland cities and villages at lower cost. This improves living standards and food security for remote populations. Likewise, farmers and producers in the interior gain **access to markets**. For example, an initiative by the African Wildlife Foundation in 2005 launched a 700-ton cargo barge to collect corn, rice, cassava and other crops from isolated ports and deliver them to Kinshasa (Congo River Cargo Boat Brings Promise to Endangered Great Apes | African Wildlife Foundation) (Congo River Cargo Boat Brings Promise to Endangered Great Apes | African Wildlife Foundation). By reopening this supply line, hundreds of farming families were able to sell their produce, reactivating the regional economy and providing alternatives to poverty-driven activities like bushmeat hunting (Congo River Cargo Boat Brings Promise to Endangered Great Apes | African Wildlife Foundation) (Congo River Cargo Boat Brings Promise to Endangered Great Apes | African Wildlife Foundation). This case illustrates how river commerce can spur **regional trade development** – connecting the rural agricultural sector with urban demand. Overall, a vibrant river transport system knits the country together, encouraging inter-provincial commerce and even cross-border trade (e.g. barges to Bangui in CAR or to Brazzaville) in a way that road transport currently cannot. One World Bank diagnostic concluded that *"the prosperity of Congo will come from the Congo River"* if properly managed (On The Congo, A Floating Marketplace For A Nation : NPR).
- **Regional Integration:** Historically, the Congo River and its tributaries also facilitate trade with neighboring countries. Strengthening river ports could boost **regional trade corridors** – for instance, barge routes from Kisangani link into the Ubangi River toward the Central African Republic, and via Kisangani's rail connection, goods can come from East Africa. Improved river navigation can thus complement regional integration efforts by ECCAS/CEEAC and others, helping landlocked areas access seaports through multimodal links.

Environmental Benefits: Shifting more freight to the Congo River has positive environmental implications:

- **Reduced Emissions and Road Pressure:** Inland water transport is fuel-efficient on a per-ton basis. With functioning navigation, the river can carry bulk cargo at a fraction of the fuel consumption (and CO_2 emissions) of trucks. As noted, costs per ton-km are about one-third by barge vs by road (), which correlates with lower fuel use. Every barge convoy (often carrying 800+ tons) can replace dozens of heavy trucks, thereby reducing road traffic, accident risk, and diesel exhaust. In DRC's context, where road networks are sparse, an environmental benefit of river transport is also avoiding the need to carve new roads through pristine rainforest. A study on the Congo Basin found that while new roads tend to catalyze deforestation, **waterway transport has minimal impact on forests** () (). Thus, investing in river infrastructure can support economic growth **without the extensive land clearing** that roads entail.
- **Conservation Co-Benefits:** By improving livelihoods and market access for remote communities, river transport can indirectly aid conservation. The AWF's bonobo conservation project demonstrated this – when farmers can ship crops easily, they are less likely to turn to hunting wildlife for income or food (Congo River Cargo Boat Brings Promise to Endangered Great Apes | African Wildlife Foundation) (Congo River Cargo Boat Brings Promise to Endangered Great Apes | African Wildlife Foundation). In essence, the **river acts as a sustainable "green corridor"**: it enables human development (through trade and mobility) in an energy-efficient way, and can reduce pressure on ecosystems compared to alternative transport modes. Additionally, boats produce far less noise and disturbance than constructing highways, preserving the tranquility of wildlife habitats along the riverbanks.

In summary, a better inland waterway system on the Congo would not only connect communities and lower transport costs, but also yield environmental dividends by cutting carbon emissions and safeguarding the Congo Basin's forests. These socio-economic and environmental upsides reinforce the case for revitalizing the river corridor as a key component of DRC's development strategy.

Market Size and Formal vs. Informal Trade Flows

Volume of Goods Moved: The Congo River is already a major freight artery, though official statistics are fragmented. According to World Bank estimates, the busiest routes carry on the order of **200,000–340,000 tonnes per year**. For example, the Kinshasa–Brazzaville crossing (across Malebo

Pool) sees about **340,000 tons** of freight annually, while the long Kinshasa–Kisangani river corridor moves roughly **203,000 tons** per year (). Additional significant volumes flow on the Kasai River (linking Kinshasa to Ilebo) and on upstream tributaries for local trade. These figures give a sense of the **formal market size** of inland water transport. By comparison, the DRC's railways carry far less (SCTP's western railway was down to ~50,000 tons/year by mid-2010s) (), making river barges the primary mode for heavy cargo in the interior.

Formal vs Informal Flows: A large proportion of river commerce in DRC is **informal and under-reported**. The state-owned operator (SCTP/ONATRA) handles only a fraction of traffic – most services are provided by **"small, informal private operators"** with their own barges or pirogues (). These operators often do not manifest cargo in official records, especially for domestic trade of agricultural goods or local market produce. As a result, the true volume of goods moving on the river network is likely much higher than official stats. In many cases, individual traders will rent space on a barge (or a whole barge) and move goods outside of any formal company structure.

Informal trade flows are notoriously large in the DRC. In cross-border commerce, studies have found informal trade can **exceed formal trade**; for instance, on the eastern border, *"informal trade between Uganda and the DRC was nearly twice the amount of formal trade"* by value () (). A similar pattern holds on internal routes – staples like cassava, fish, palm oil, or charcoal are frequently shipped by "private arrangement" without documentation. Therefore, the **total tonnage on the Congo River** (formal + informal) might be significantly above the 200,000 tons cited formally – possibly several hundred thousand tons more when including all the unrecorded timber, produce, and merchandise carried on countless small boats.

To illustrate, one river convoy (called a **baleinière** in local terms) can be a floating market carrying everything from produce to livestock. Such convoys operate on a cash basis, outside of corporate oversight. While this informal system is vital for livelihoods, it also means infrastructure planning is based on incomplete data. Nonetheless, even the documented volumes confirm that the Congo River is a **major transport corridor** for DRC's economy. If navigability and ports improve, both formal sector logistics companies and informal traders would scale up their activities – potentially transforming some of the currently informal trade into formal, higher-value supply chains.

In summary, the market for fluvial transport on the Congo comprises a **formal segment** (hundreds of thousands of tonnes per year handled by recognized shippers or state entities) and an **informal segment** that is at least equally large. Strengthening the river transport infrastructure and governance could help formalize more of this trade, boosting government revenues and improving safety, while still preserving the vital role the river plays in supporting livelihoods across the region () ().

Similar Inland Waterway Corridors – A Comparative Note: The importance of the Congo River finds parallels in other African river transport corridors. For example, Nigeria has been dredging the Niger River to enable barges to move goods to inland cities, aiming to cut road congestion. In West Africa, the Senegal River (managed by the OMVS) has been developed for navigation to connect Mali to the Atlantic, illustrating how regional cooperation on rivers can stimulate trade. Likewise, East Africa's Lake Victoria ferry routes (between Tanzania, Uganda, and Kenya) carry hundreds of thousands of tonnes annually (Inland Waterways | The Northern Corridor Transit and Transport Co-ordination Authority (NCTTCA)), providing landlocked areas access to international ports. These cases show that where infrastructure and management are put in place, **inland waterways can be viable, cost-effective transport channels**. The Congo River – being Africa's largest by discharge and spanning the heart of the continent – has perhaps the greatest potential of all, if its economic use can be optimized. As one Congolese official declared, *"Let's take care of the Congo River, because our future is tied to that network"* (On The Congo, A Floating Marketplace For A Nation : NPR).

Sources

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- NPR reportage on Congo River transport (On The Congo, A Floating Marketplace For A Nation : NPR) (On The Congo, A Floating Marketplace For A Nation : NPR) (On The Congo, A Floating Marketplace For A Nation : NPR)
- African Development initiatives and humanitarian logistics data () () (transportation Grand Kivu and Kinshasa)
- Academic and NGO studies (AWF, UN/ECA) on trade and environmental impacts () (Congo River Cargo Boat Brings Promise to Endangered Great Apes | African Wildlife Foundation) (Congo River Cargo Boat Brings Promise to Endangered Great Apes | African Wildlife Foundation).
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Appendix 2 – List of cities and inhabit

#	Ville	Population, #	Population
1	Kinshasa	15,500,000	61.88%
2	Kisangani	1,300,000	5.19%
3	Goma	1,050,000	4.19%
4	Butembo	950,000	3.79%
5	Beni	750,000	2.99%
6	Mbandaka	550,000	2.20%
7	Rutshuru	457,684	1.83%
8	Lisala	246,527	0.98%
9	Bandundu	237,048	0.95%
10	Buta	183,332	0.73%
11	Oicha	163,137	0.65%
12	Kyondo	135,907	0.54%
13	Mushie	126,124	0.50%
14	Mweso	112,266	0.45%
15	Bolobo	103,133	0.41%
16	Kasindi	99,760	0.40%
17	Mangina	97,264	0.39%
18	Kitchanga	97,191	0.39%
19	Yata	96,837	0.39%
20	Nyanzale	86,506	0.35%
21	Binga	66,331	0.26%
22	Kanyabayonga	62,633	0.25%
23	Yumbi	59,821	0.24%
24	Malambo	58,730	0.23%
25	Basankusu	58,193	0.23%
26	Maluku	57,146	0.23%
27	Nobili	56,357	0.22%
28	Kibirizi	55,029	0.22%
29	Mutwanga	54,849	0.22%
30	Aketi	54,385	0.22%
31	Lukanga	53,857	0.22%
32	Inongo	49,499	0.20%
33	Bulambo	49,404	0.20%
34	Nyamilima	47,993	0.19%
35	Mabuku	47,472	0.19%
36	Likati	47,400	0.19%
37	Lukolela	45,764	0.18%
38	Bambu	45,414	0.18%
39	Bikoro	44,199	0.18%
40	Basoko	42,790	0.17%
41	Vuyinga	42,766	0.17%
42	Budjala	42,401	0.17%
43	Eringeti	42,357	0.17%
44	Ngeleza	41,243	0.16%
45	Kirumba	41,133	0.16%
46	Musienene	40,626	0.16%
47	Aloya	39,619	0.16%
48	Makanza	38,354	0.15%
49	Lubero	37,827	0.15%
50	Bafwasende	36,205	0.14%

Appendix 2 – List of cities and inhabit

#	Ville	Population, #	Population,
51	Bunagana	34,166	0.14%
52	Kasseghe	33,533	0.13%
53	Manguredjipa	32,368	0.13%
54	Kisaro	32,035	0.13%
55	Kwamouth	31,253	0.12%
56	Mambasa	30,524	0.12%
57	Komanda	29,383	0.12%
58	Mbau	29,347	0.12%
59	Bwasinge	29,248	0.12%
60	Banalia	29,129	0.12%
61	Kinyatsi	28,927	0.12%
62	Kinyandoni	28,132	0.11%
63	Zacharia	27,661	0.11%
64	Menkao	27,355	0.11%
65	NSele	26,214	0.10%
66	Dongo-Moke	26,128	0.10%
67	Bingi	25,505	0.10%
68	Manduli	23,730	0.09%
69	Mavivi	23,414	0.09%
70	Saha	22,614	0.09%
71	Mayimoya	22,460	0.09%
72	Biakato	21,680	0.09%
73	Kipese	21,194	0.08%
74	Kitsambiro	20,970	0.08%
75	Isangi	20,634	0.08%
76	Ngongo-Basengele	19,648	0.08%
77	Kimpoko	19,580	0.08%
78	Djolu	19,362	0.08%
79	Ishasha	19,018	0.08%
80	Shinda	18,769	0.07%
81	Rumangabo	16,975	0.07%
82	Kayna	16,818	0.07%
83	Yandongi	16,037	0.06%
84	Kamango	15,836	0.06%
85	Bafwabango	15,729	0.06%
86	Mohangi	14,725	0.06%
87	Mongama	14,458	0.06%
88	Mbunia	14,160	0.06%
89	Nia-Nia	14,113	0.06%
90	Rubingo	14,074	0.06%
91	Lgalika	14,022	0.06%
92	Hibumba	13,926	0.06%
93	Panga	13,896	0.06%
94	Kabasha	13,876	0.06%
95	Kiseguro	13,209	0.05%
96	Kabaya	12,836	0.05%
97	Kotili	12,408	0.05%
98	Titulé	12,049	0.05%
99	Buyinga	12,042	0.05%
100	Lebia	11,929	0.05%

Appendix 2 – List of cities and inhabita

#	Ville	Population, #	Population,
101	Lobango	11,803	0.05%
102	Kimbulu	11,449	0.05%
103	Dulia	11,164	0.04%
104	Miriki	10,355	0.04%
105	Kabizo	10,163	0.04%
106	Mandumbi	10,062	0.04%
107	Musingiri	10,050	0.04%
108	Biambe	9,775	0.04%
109	Ubundu	9,652	0.04%
110	Kikuvo	9,068	0.04%
111	Mokandayeka	8,439	0.03%
112	Kyavinyonge	6,931	0.03%
113	Aliafu	6,923	0.03%
114	Ntandembelo	6,468	0.03%
115	Kamande	6,445	0.03%
116	Vitshumbi	6,339	0.03%
117	Luofu	6,080	0.02%
118	Opienge	5,709	0.02%
119	Mambelenga	5,498	0.02%
120	Masina	5,191	0.02%
121	Mbwavinwa	4,709	0.02%
122	Ikengo	4,681	0.02%
123	Yindi	2,452	0.01%
124	Bingo	2,243	0.01%
125	Mbankana	2,042	0.01%
126	Bafwambaya	1,635	0.01%
127	Buhoyo	1,398	0.01%
128	Badengayido	1,391	0.01%
129	Bomongo	853	0.00%

Appendix 3 – Results per city for their respective electrification based on solar technology

#	Ville	Connexions possibles	Revenus potentiels – total (TVAc), $	Capacité installée, kWp	Batteries installées, kWh	CAPEX, $	OPEX (hors taxes), $	Taxes (TVAc), $	Profit, $
1	Kinshasa	1,550,000	1,293,072,000	4,637,260	18,549,041	1,162,500,000	193,750,000	323,268,000	717,929,000
2	Kisangani	130,000	36,862,800	105,567	422,268	130,000,000	12,350,000	9,215,700	8,797,100
3	Goma	105,000	29,773,800	85,266	341,063	105,000,000	9,975,000	7,443,450	7,105,350
4	Butembo	95,000	26,938,200	77,145	308,581	95,000,000	9,025,000	6,734,550	6,428,650
5	Beni	75,000	21,267,000	60,904	243,616	75,000,000	7,125,000	5,316,750	5,075,250
6	Mbandaka	55,000	15,595,800	44,663	178,652	55,000,000	5,225,000	3,898,950	3,721,850
7	Rutshuru	45,768	10,520,599	14,968	59,873	68,652,600	4,119,156	2,630,150	338,663
8	Lisala	24,653	5,666,818	8,062	32,250	36,979,050	2,218,743	1,416,704	182,418
9	Bandundu	23,705	5,448,928	7,752	31,010	35,557,200	2,133,432	1,362,232	175,404
10	Buta	18,333	4,214,179	5,996	23,983	27,499,800	1,649,988	1,053,545	135,657
11	Oicha	16,314	3,749,965	5,335	21,341	24,470,550	1,468,233	937,491	120,713
12	Kyondo	13,591	3,124,040	4,445	17,779	20,386,050	1,223,163	781,010	100,564
13	Mushie	12,612	2,899,162	4,125	16,499	18,918,600	1,135,116	724,790	93,325
14	Mweso	11,227	2,580,614	3,672	14,686	16,839,900	1,010,394	645,153	83,071
15	Bolobo	10,313	2,370,677	3,373	13,491	15,469,950	928,197	592,669	76,313
16	Kasindi	9,976	2,293,143	3,263	13,050	14,964,000	897,840	573,286	73,817
17	Mangina	9,726	2,235,769	3,181	12,724	14,589,600	875,376	558,942	71,970
18	Kitchanga	9,719	2,234,091	3,179	12,714	14,578,650	874,719	558,523	71,916
19	Yata	9,684	2,225,953	3,167	12,668	14,525,550	871,533	556,488	71,655
20	Nyanzale	8,651	1,988,479	2,829	11,316	12,975,900	778,554	497,120	64,010
21	Binga	6,633	1,524,724	2,169	8,677	9,949,650	596,979	381,181	49,082
22	Kanyabayonga	6,263	1,439,720	2,048	8,193	9,394,950	563,697	359,930	46,345
23	Yumbi	5,982	1,375,081	1,956	7,826	8,973,150	538,389	343,770	44,265
24	Malambo	5,873	1,350,003	1,921	7,683	8,809,500	528,570	337,501	43,457
25	Basankusu	5,819	1,337,659	1,903	7,613	8,728,950	523,737	334,415	43,060
26	Maluku	5,715	1,313,592	1,869	7,476	8,571,900	514,314	328,398	42,285
27	Nobili	5,636	1,295,456	1,843	7,372	8,453,550	507,213	323,864	41,701
28	Kibirizi	5,503	1,264,930	1,800	7,199	8,254,350	495,261	316,232	40,719
29	Mutwanga	5,485	1,260,792	1,794	7,175	8,227,350	493,641	315,198	40,586
30	Aketi	5,439	1,250,126	1,779	7,114	8,157,750	489,465	312,532	40,242
31	Lukanga	5,386	1,237,989	1,761	7,045	8,078,550	484,713	309,497	39,851
32	Inongo	4,950	748,425	895	3,580	4,949,900	371,243	187,106	- 57,419
33	Bulambo	4,940	746,988	893	3,573	4,940,400	370,530	186,747	- 57,309
34	Nyamilima	4,799	725,654	868	3,471	4,799,300	359,948	181,414	- 55,672
35	Mabuku	4,747	717,777	858	3,434	4,747,200	356,040	179,444	- 55,068
36	Likati	4,740	716,688	857	3,428	4,740,000	355,500	179,172	- 54,984
37	Lukolela	4,576	691,952	828	3,310	4,576,400	343,230	172,988	- 53,086
38	Bambu	4,541	686,660	821	3,285	4,541,400	340,605	171,665	- 52,680
39	Bikoro	4,420	668,289	799	3,197	4,419,900	331,493	167,072	- 51,271
40	Basoko	4,279	646,985	774	3,095	4,279,000	320,925	161,746	- 49,636
41	Vuyinga	4,277	646,622	773	3,093	4,276,600	320,745	161,655	- 49,609

Appendix 3 – Results per city for their respective electrification based on solar technology

#	Ville	Connexions possibles	Revenus potentiels – total (TVAc), $	Capacité installée, kWp	Batteries installées, kWh	CAPEX, $	OPEX (hors taxes), $	Taxes (TVAc), $	Profit, $
42	Budjala	4,240	641,103	767	3,067	4,240,100	318,008	160,276	- 49,185
43	Eringeti	4,236	640,438	766	3,064	4,235,700	317,678	160,109	- 49,134
44	Ngeleza	4,124	623,594	746	2,983	4,124,300	309,323	155,899	- 47,842
45	Kirumba	4,113	621,931	744	2,975	4,113,300	308,498	155,483	- 47,714
46	Musienene	4,063	614,265	735	2,938	4,062,600	304,695	153,566	- 47,126
47	Aloya	3,962	599,039	716	2,866	3,961,900	297,143	149,760	- 45,958
48	Makanza	3,835	579,912	694	2,774	3,835,400	287,655	144,978	- 44,491
49	Lubero	3,783	571,944	684	2,736	3,782,700	283,703	142,986	- 43,879
50	Bafwasende	3,621	547,420	655	2,619	3,620,500	271,538	136,855	- 41,998
51	Bunagana	3,417	516,590	618	2,471	3,416,600	256,245	129,147	- 39,633
52	Kasseghe	3,353	507,019	606	2,425	3,353,300	251,498	126,755	- 38,898
53	Manguredjipa	3,237	489,404	585	2,341	3,236,800	242,760	122,351	- 37,547
54	Kisaro	3,204	484,369	579	2,317	3,203,500	240,263	121,092	- 37,161
55	Kwamouth	3,125	472,545	565	2,260	3,125,300	234,398	118,136	- 36,253
56	Mambasa	3,052	461,523	552	2,208	3,052,400	228,930	115,381	- 35,408
57	Komanda	2,938	444,271	531	2,125	2,938,300	220,373	111,068	- 34,084
58	Mbau	2,935	443,727	531	2,123	2,934,700	220,103	110,932	- 34,043
59	Bwasinge	2,925	442,230	529	2,115	2,924,800	219,360	110,557	- 33,928
60	Banalia	2,913	440,430	527	2,107	2,912,900	218,468	110,108	- 33,790
61	Kinyatsi	2,893	437,376	523	2,092	2,892,700	216,953	109,344	- 33,555
62	Kinyandoni	2,813	425,356	509	2,035	2,813,200	210,990	106,339	- 32,633
63	Zacharia	2,766	418,234	500	2,001	2,766,100	207,458	104,559	- 32,087
64	Menkao	2,736	413,608	495	1,979	2,735,500	205,163	103,402	- 31,732
65	NSele	2,621	396,356	474	1,896	2,621,400	196,605	99,089	- 30,408
66	Dongo-Moke	2,613	395,055	472	1,890	2,612,800	195,960	98,764	- 30,308
67	Bingi	2,551	385,636	461	1,845	2,550,500	191,288	96,409	- 29,586
68	Manduli	2,373	358,798	429	1,716	2,373,000	177,975	89,699	- 27,527
69	Mavivi	2,341	354,020	423	1,694	2,341,400	175,605	88,505	- 27,160
70	Saha	2,261	341,924	409	1,636	2,261,400	169,605	85,481	- 26,232
71	Mayimoya	2,246	339,595	406	1,625	2,246,000	168,450	84,899	- 26,054
72	Biakato	2,168	327,802	392	1,568	2,168,000	162,600	81,950	- 25,149
73	Kipese	2,119	320,453	383	1,533	2,119,400	158,955	80,113	- 24,585
74	Kitsambiro	2,097	317,066	379	1,517	2,097,000	157,275	79,267	- 24,325
75	Isangi	2,063	311,986	373	1,492	2,063,400	154,755	77,997	- 23,935
76	Ngongo-Basengele	1,965	297,078	355	1,421	1,964,800	147,360	74,269	- 22,792
77	Kimpoko	1,958	296,050	354	1,416	1,958,000	146,850	74,012	- 22,713
78	Djolu	1,936	292,753	350	1,400	1,936,200	145,215	73,188	- 22,460
79	Ishasha	1,902	287,552	344	1,376	1,901,800	142,635	71,888	- 22,061
80	Shinda	1,877	283,787	339	1,358	1,876,900	140,768	70,947	- 21,772
81	Rumangabo	1,698	256,662	307	1,228	1,697,500	127,313	64,166	- 19,691
82	Kayna	1,682	254,288	304	1,216	1,681,800	126,135	63,572	- 19,509

Appendix 3 – Results per city for their respective electrification based on solar technology

#	Ville	Connexions possibles	Revenus potentiels – total (TVAc), $	Capacité installée, kWp	Batteries installées, kWh	CAPEX, $	OPEX (hors taxes), $	Taxes (TVAc), $	Profit, $
83	Yandongi	1,604	242,479	290	1,160	1,603,700	120,278	60,620	- 18,603
84	Kamango	1,584	239,440	286	1,145	1,583,600	118,770	59,860	- 18,370
85	Bafwabango	1,573	237,822	284	1,138	1,572,900	117,968	59,456	- 18,246
86	Mohangi	1,473	222,642	266	1,065	1,472,500	110,438	55,661	- 17,081
87	Mongama	1,446	218,605	261	1,046	1,445,800	108,435	54,651	- 16,771
88	Mbunia	1,416	214,099	256	1,024	1,416,000	106,200	53,525	- 16,426
89	Nia-Nia	1,411	213,389	255	1,021	1,411,300	105,848	53,347	- 16,371
90	Rubingo	1,407	212,799	254	1,018	1,407,400	105,555	53,200	- 16,326
91	Lgalika	1,402	212,013	254	1,014	1,402,200	105,165	53,003	- 16,266
92	Hibumba	1,393	210,561	252	1,007	1,392,600	104,445	52,640	- 16,154
93	Panga	1,390	210,108	251	1,005	1,389,600	104,220	52,527	- 16,119
94	Kabasha	1,388	209,805	251	1,004	1,387,600	104,070	52,451	- 16,096
95	Kiseguro	1,321	199,720	239	955	1,320,900	99,068	49,930	- 15,322
96	Kabaya	1,284	194,080	232	928	1,283,600	96,270	48,520	- 14,890
97	Kotili	1,241	187,609	224	897	1,240,800	93,060	46,902	- 14,393
98	Titulé	1,205	182,181	218	871	1,204,900	90,368	45,545	- 13,977
99	Buyinga	1,204	182,075	218	871	1,204,200	90,315	45,519	- 13,969
100	Lebia	1,193	180,366	216	863	1,192,900	89,468	45,092	- 13,838
101	Lobango	1,180	178,461	213	854	1,180,300	88,523	44,615	- 13,691
102	Kimbulu	1,145	173,109	207	828	1,144,900	85,868	43,277	- 13,281
103	Dulia	1,116	168,800	202	807	1,116,400	83,730	42,200	- 12,950
104	Miriki	1,036	156,568	187	749	1,035,500	77,663	39,142	- 12,012
105	Kabizo	1,016	153,665	184	735	1,016,300	76,223	38,416	- 11,789
106	Mandumbi	1,006	152,137	182	728	1,006,200	75,465	38,034	- 11,672
107	Musingiri	1,005	151,956	182	727	1,005,000	75,375	37,989	- 11,658
108	Biambe	978	147,798	177	707	977,500	73,313	36,950	- 11,339
109	Ubundu	965	145,938	175	698	965,200	72,390	36,485	- 11,196
110	Kikuvo	907	137,108	164	656	906,800	68,010	34,277	- 10,519
111	Mokandayeka	844	127,598	153	610	843,900	63,293	31,899	- 9,789
112	Kyavinyonge	693	104,797	125	501	693,100	51,983	26,199	- 8,040
113	Aliafu	692	104,676	125	501	692,300	51,923	26,169	- 8,031
114	Ntandembelo	647	97,796	117	468	646,800	48,510	24,449	- 7,503
115	Kamande	645	97,448	117	466	644,500	48,338	24,362	- 7,476
116	Vitshumbi	634	95,846	115	458	633,900	47,543	23,961	- 7,353
117	Luofu	608	91,930	110	440	608,000	45,600	22,982	- 7,053
118	Opienge	571	86,320	103	413	570,900	42,818	21,580	- 6,622
119	Mambelenga	550	83,130	99	398	549,800	41,235	20,782	- 6,378
120	Masina	519	78,488	94	375	519,100	38,933	19,622	- 6,022
121	Mbwavinwa	471	71,200	85	341	470,900	35,318	17,800	- 5,462
122	Ikengo	468	70,777	85	339	468,100	35,108	17,694	- 5,430
123	Yindi	245	37,074	44	177	245,200	18,390	9,269	- 2,844
124	Bingo	224	33,914	41	162	224,300	16,823	8,479	- 2,602

Appendix 3 – Results per city for their respective electrification based on solar technology

#	Ville	Connexions possibles	Revenus potentiels – total (TVAc), $	Capacité installée, kWp	Batteries installées, kWh	CAPEX, $	OPEX (hors taxes), $	Taxes (TVAc), $	Profit, $
124	Bingo	224	33,914	41	162	224,300	16,823	8,479	- 2,602
125	Mbankana	204	30,875	37	148	204,200	15,315	7,719	- 2,369
126	Bafwambaya	164	24,721	30	118	163,500	12,263	6,180	- 1,897
127	Buhoyo	140	21,138	25	101	139,800	10,485	5,284	- 1,622
128	Badengayido	139	21,032	25	101	139,100	10,433	5,258	- 1,614
129	Bomongo	85	12,897	15	62	85,300	6,398	3,224	- 989

Appendix 4 - Methodology & key assumptions for electricity section

Urban centers

To identify and characterize urban centers within the Kivu-Kinshasa green corridor, this study draws on the **GRID3 COD - Settlement Extents v3.1** dataset, developed by CIESIN at Columbia University. This geospatial dataset offers a high-resolution, harmonized mapping of settlements across the Democratic Republic of the Congo (DRC), based on a combination of eleven data sources including satellite imagery, building footprints, and field-collected points of interest. Settlement extents are represented both as polygons and as centroids of 100-meter grid cells, each enriched with attributes such as building count, building area, and a modeled probability of settlement presence. Crucially for this study, settlements are categorized into built-up areas, small settlements, and hamlets, enabling the extraction of all urban areas with over 5,000 inhabitants. The data's alignment with WorldPop's population grid also facilitates integration with demographic and service delivery analyses. The version used (v3.1, released in July 2024) reflects enhanced accuracy through improved building area estimates and machine learning classification to distinguish true settlements from false positives, particularly in rural zones.

For each urban centre, several indicators have been developed to support the evaluation of their economic dynamism, population density and socio-economic attractiveness.

Built and population density score (score_pop_built_density)

This indicator measures the relationship between building density and population density, taking into account the surface area of the urban centre. The computation is built as following :

$$score\_pop\_built\_density = \frac{\frac{Total\ area\ of\ buildings}{number\ of\ buildings}}{\frac{population}{number\ of\ buildings} + population\ density} / urban\ center\ area$$

$$= \frac{\frac{buildingg_a}{buildin_c}}{\frac{population\ (2025)}{bulding_c} + population\ density} / area\_km^2$$

Where

$Building_a$ is the total surface area of the buildings (this field is automatically present in the urban centres file).

$Building_c$ is the number of buildings (this field is automatically present in the town centre file).

$\frac{Building_a}{Building_c}$ is the average surface area of buildings, an indicator of dwelling size. Average number of inhabitants per building, representing density.

Population gives the population per urban centre according to the GHS-POP R2023A - GHS population grid multitemporal (1975-2030) database for 2025[13].

[13] https://data.jrc.ec.europa.eu/dataset/2ff68a52-5b5b-4a22-8f40-c41da8332cfe

POP_GHS_density represents the GHS population density in inhab/km^2. area_km2 gives the area in km^2 per urban centre.

The interpretation of the indicator indicates :

- A high score means more spacious buildings and lower population density, generally associated with greater purchasing power.
- A low score indicates a high concentration of the population in smaller buildings, reflecting greater economic pressure.

Commercial density score (score_commerce)

This indicator reflects the density of shops in each urban centre. The data comes from the Open Street Map (OSM) database using the "shop" entities.

$$score\_commerce = \frac{Total\ number\ of\ shops}{area\ of\ the\ urban\ centre}$$

The interpretation of the indicator indicates :

- A high value indicates strong commercial activity and economic dynamism.
- A low value indicates a more limited commercial presence.

Public services density score (score_services)

This indicator accessibility to public services such as schools, hospitals and banks. The data comes from the OSM database using the "amenity" entities.

$$score\_services = \frac{total\ number\ of\ public\ services}{area\ of\ the\ urban\ centre}$$

The interpretation of the indicator indicates :

- A high score means good access to public services.
- A low value indicates a lack of essential infrastructure.

Tourism attractiveness (score_tourism)

This indicator measures the density of tourist infrastructures in each urban centre. The data comes from the OSM database using the "tourism" entities.

$$scores\_tourism = \frac{total\ number\ of\ touristic\ infrastructures}{area\ of\ the\ urban\ centre}$$

The interpretation of the indicator indicates :

- This high score reflects the region's strong tourism potential, with a well-developed range of tourist facilities.
- A low score indicates a more limited appeal to tourists.

Purchasing power (score_achat)

This score aggregates several factors though weighted ponderation to estimate the purchasing power in each urban centre.

$$score\_achat = (0{,}3 * score\_commmerce) + (0{,}4 * score\_services) + (0{,}4 * score\_tourism)$$

The interpretation of the indicator indicates :

- A higher value means greater purchasing and a quality of life.
- A low value reflects greater economic pressure and reduced access to commercial and service infrastructures.

Normalised purchasing power score (score_achat_norm)

This indicator is a standardised version of the score_achat, allowing urban centres to be compared on a scale of 0 to 1.

$$score\_achat\_norm = \frac{socre\_achat - min(score\_achat)}{area\ of\ the\ urban\ centre}$$

The interpretation of the indicator indicates :

- A value close to 1 indicates an urban centre with the best economic and service conditions.
- A value close to 0 indicates areas where conditions are least favourable.

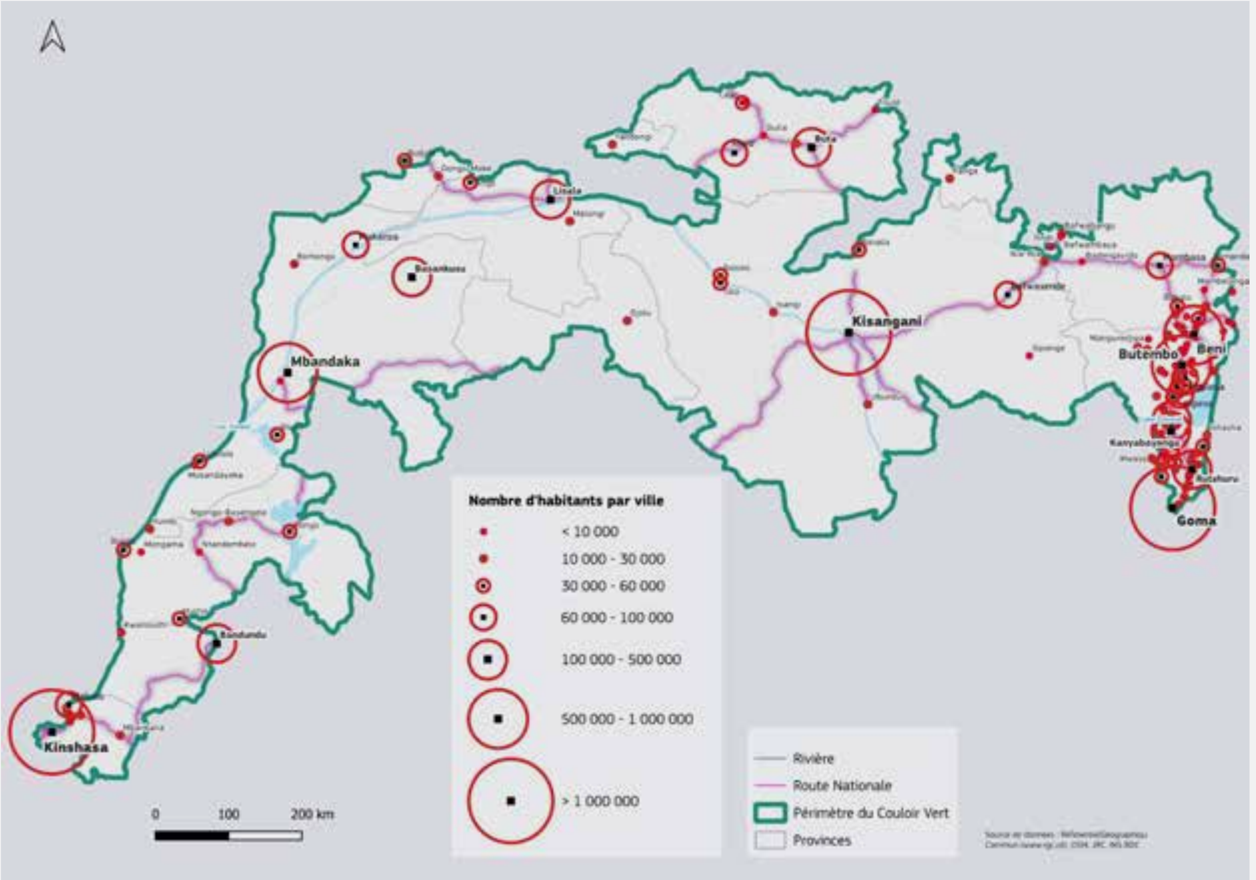


Figure xx: urban centres in the Green Corridor Kivu-Kinshasa

Categories of towns, cities and villages

Four categories of towns have been defined. Those four categories have different unit economics for key parameters such as demand for energy per capita, tariff per kWh, CAPEX & OPEX per connection.

- Capital (Kinshasa)
- Large city (Kisangani, Goma, Butembo, Beni, Mbandaka): with a population above 500 000 inhabitants
- City: with a population of over 50 000 inhabitants
- Villages: with a population below 50 000 inhabitants

Demand for energy

Demand for energy was estimated by modelling demand for three categories of customers:

1. Households
2. SMEs
3. Industrials & other facilities (e.g., healthcare)

The following assumptions were used using historical data from Virunga Energies, based on its experience in different types of cities (Goma, rural villages, peri-urban towns) and interpolations when required.

Households

For each entity, it was assumed that 70% of the urban center would connect to the grid, and each household, equating one connection, represents 7 inhabitants. A full list of entities (towns) is available in Appendix 2, along with the respective number of inhabitants.

Demand for energy is expressed in kWh / year per connection (a household). Tariffs were set to reflect the higher (or lower) cost of serving customers and maintaining the grid.

Demand - households	kWh / year	$ / kWh	$ / year
Capital	2400	0.20	480
Large city	672	0.25	168
City	300	0.50	150
Village	144	0.60	86

SMEs

The number of SMEs, and demand in kWh per year per SME, was estimated based on a percentage of connections and is reflective of historical data from Virunga Energies.

Tariffs set for SMEs are lower to ensure their competitiveness with other sources of energy.

Demand - SMEs	% SMEs	kWh / year	$ / kWh	$ / year
Capital	5%	19200	0.18	3456
Large city	5%	4800	0.23	1080
City	8%	1440	0.45	648
Village	10%	960	0.54	518

Industrials and other uses

A general, catch-all factor was defined to estimate demand from industrials and other facilities (typically healthcare centers, and public administration) as it is the most difficult category of customers to estimate, given their relatively limited number.

The factor is increasing along with the categories of towns to reflect the probable presence of large industrials contributing to a larger share of electricity demand in highly urbanized and dense city centers.

Demand - industrials	Factor	kWh / year	$ / kWh	$ / year
Capital	30%	6480	0.18	1166
Large city	30%	1642	0.225	369
City	15%	261	0.45	117
Village	10%	110.4	0.54	60

Installed capacity

Large cities and the capital aside, which were modelled individually, installed capacity was estimated by comparing demand for energy with the solar energy potential across the Green Corridor. It was assumed the following key parameters:

1. kWh generated per day per kWp of solar panel : 4 kWh / kWp (historical data, including from the Joint Research Center of the EU[14] , indicate ~4.2 – 4.5 kWh / kWp)
2. kWh of batteries for each kWp of solar panel : 4 kWh of batteries / kWp of installed capacity. This ratio was estimated based on historical irradiance data from the Joint Research Center and assumed the following.
    a. Batteries were sized to provide energy during the worst month in terms of generation of solar energy (around June / July) but did not account for periods with no sun during multiple days within a month.
    b. Demand for energy followed a similar curve throughout the day as observed by Virunga Energies

[14] https://joint-research-centre.ec.europa.eu/photovoltaic-geographical-information-system-pvgis_en

Hour of day	Demand, in % of peak
1	51%
2	50%
3	50%
4	50%
5	54%
6	54%
7	59%
8	70%
9	78%
10	81%
11	84%
12	82%
13	78%
14	80%
15	83%
16	81%
17	77%
18	88%
19	99%
20	91%
21	84%
22	75%
23	69%
24	61%

CAPEX, OPEX, depreciation and taxes

CAPEX for large cities and the capital were individually estimated either by external reputable sources (e.g., World Bank), or based on internal modelling.

For cities and villages relying on solar farms, a CAPEX and OPEX per connection factor was used based on data from the World Bank.

Taxes, including VAT, were estimated at 25% of revenues. An amortization factor of 20 year was assumed (most likely slightly pessimistic for hydropower station and slightly optimistic for solar farms).

Cost per connection	CAPEX	Yearly OPEX	Taxes, % revenue	Amortization, in years
Capital			25%	20
Large city			25%	20
City	1500	90	25%	20
Village	1000	75	25%	20

The lower CAPEX per connection for villages reflects the lower demand for energy in such villages compared to cities. A similar reasoning applied to OPEX (reduced OPEX for maintenance, given the lower installed capacity per capita).

Appendix 5 - Estimation of cultivated areas in the Kivu-Kinshasa Green Corridor

In this note, we present the **detailed methodology** used to estimate the cultivated areas per crop in the Kivu-Kinshasa Green Corridor, then the **results per crop** accompanied by historical and geographical analyses, before concluding with a numerical summary, the limitations of the exercise and the prospects for future improvement.

The aim of this section is to provide a *rough but reasoned* estimate of the total cultivated area for each crop type along the corridor. Two methodologies for estimating production and cultivated area have been subdivided and distinguished for food and cash crops due to the availability of data, the extent of cultivation, practices (intensive vs. extensive) and other classification criteria.

Data sources used

Several types of data were used:

- Official agricultural **statistics (INS and Ministry of Agriculture)**: We used the provincial data on production and acreage by crop published by the National Institute of Statistics (INS) and the agricultural services (annual reports, agricultural surveys). These data provide an official basis covering the entire territory.

Advantages: they provide an overall order of magnitude and a breakdown by province for many food and cash crops.

Limitations: they may be dated (some series go back to the 2010s), incomplete or underestimated due to conflicts (collection interrupted in some areas) and the predominance of unregistered

informal agriculture. For example, official figures report ~29,000 tonnes of coffee and ~3,600 tonnes of cocoa in 2018 for the whole country, while field sources suggest a much higher actual production once informal channels are taken into account. It was therefore often necessary to adjust these raw data.

- **Export data (OCC)**: The reports of the Office Congolais de Contrôle et des Douanes (Congolese Office of Control and Customs) were consulted to determine the quantities of cash crops exported (notably coffee, cocoa, rubber and palm oil).

Advantages: this data is generally reliable for identifying production intended for external markets, and therefore for locating surplus production basins (for example, the tonnages of coffee exported via Uganda or Rwanda to the east, of cocoa via Ituri, etc.).

Limitations: they only reflect the formal and exported share, omitting local consumption or smuggled exports. In the Green Corridor, many products circulate unofficially (coffee and cocoa crossing regional borders without control, artisanal palm oil consumed locally, etc.), which means that the information from the OCC must be supplemented by other sources.

- **Inventories of plantations by GPS**: Geolocated data has been collected for large plantations and structured agricultural perimeters. This includes, among others, the *historical agro-industrial concessions* (e.g. PHC oil palm plantations in Yaligimba, Lokutu, Boteka) and some recent projects (e.g. cocoa plantations in the **Watalinga sector** in North Kivu, thousands (2000+) village palm groves around Virunga Park, rubber trees of the former Socfin). These GPS locations have enabled the creation of precise *GIS layers* of plantation polygons.

Advantages: a direct measurement of the areas for the farms concerned and their exact location in relation to the perimeter of the Green Corridor is obtained.

Limitations: these surveys cover only part of the landscape – mainly organised cash crops – and ignore dispersed smallholder agriculture. In addition, some of these data are several years old and may not reflect the recent expansion (or possible abandonment) of plantations.

- **Land cover maps and satellite data**: We used high-resolution land cover maps (Sentinel-2 images at 10 m, Landsat at 30 m, etc.) and existing classifications produced by specialised institutions (such as the **ESA Climate Change Initiative Land Cover**, the maps of the **CAFI/EU Project** for the DRC, or the data of the **GLAD (Global Land Analysis & Discovery** of the University of Maryland**,** and the **Copernicus Hot-spot land cover maps** on theYangambi and Virunga landscapes). These maps provide information on agricultural areas by distinguishing, for example, cultivated or fallow land from forest areas, savannahs, water, etc.

Advantages: the satellite data covers the entire Green Corridor, including areas that are difficult to access on the ground, and provides an *up-to-date* view (images from 2020-2023 have been analysed) of the extent of agricultural land. This makes it possible to estimate the total agricultural area in the corridor.

Limitations: satellite images do not easily identify specific crops - most classifications distinguish *agriculture in general* without differentiating between cassava vs. maize, or palm trees vs. regeneration forest. In addition, frequent cloud cover in the Congo Basin complicates optical observation, sometimes requiring the use of radar data (Sentinel-1) to detect plantation structures (alignments of palm trees, etc.). Finally, agroforestry mosaics (e.g. cocoa under forest cover) can be confused with natural forest on the images, which requires cross-checking with field data.

- **Reports and specialised studies**: We have incorporated information from various technical studies (FAO, World Bank, USAID, local NGOs, etc.) dealing with specific crops in the DRC. For example, a study by **UNIDO (2019)** on the cocoa sector in South Ubangi, reports by the **ICCO** and **ONAPAC** on coffee, or notes by the **FAO** on cassava and rice.

Advantages: these documents often provide valuable specific data (observed yields, plantation density, adoption rate of improved crops) as well as the *historical context* and dynamics (growth or decline of a particular crop in a particular province).

Limitations: they may only cover a limited area or a sample, and their updating may vary. Nevertheless, they have helped to define certain **key parameters** (e.g. the average cocoa yield per hectare in smallholder systems, the share of arabica coffee production actually commercialised, etc.) used in our calculations.

By combining these sources, we have built up a consolidated database by *province* and by *crop*, serving as a starting point for the estimation in the Green Corridor.

Estimated cultivated area in the Kivu-Kinshasa Green Corridor

The approach adopted is based on the cross-referencing of several cartographic sources of land use, in order to identify cultivated land within the Kivu-Kinshasa Green Corridor (a community protected area of approximately 544,000 km^2 linking the east to the west of the DRC).

The data used includes the global ESA-CCI (Climate Change Initiative) map at ~300 m resolution, which classifies the world's land surface into 22 land use categories (including agricultural areas), the DRC land cover map produced by Verhegghen et al. (early 2010s) offering a detailed typology of vegetation in ~20 classes at ~300 m resolution, as well as the high-resolution maps of the Copernicus Hotspot programme for two key landscapes of the Green Corridor: the Greater Virunga (approximately 39,000 km^2 mapped in 2015 with a level of detail ranging from 8 to 32 classes according to the nomenclature, based on independently validated high-resolution satellite images) and the Yangambi landscape (≈7,300 km^2 mapped in 2016 on the same methodological basis).

These different layers of information have been integrated into a geographic information system (GIS) to be combined spatially. In concrete terms, each dataset has been re-projected into the same coordinate system, then clipped according to the official perimeter of the Green Corridor in order to keep only the data within this right-of-way. The land use classes were harmonised by grouping all those relating to agriculture (e.g. arable land, mosaic crops, fallow land, plantations, etc.) into a binary category 'agricultural zone'. A common analysis resolution of approximately 100 m was adopted in order to aggregate the fine-scale data with the lower-resolution data. All the pixels/polygons thus identified as agricultural, from either of these sources, were then merged to estimate the total agricultural area within the Green Corridor (by summing the individual areas), which is **approximately 3 million hectares**.

Finally, it should be emphasised that this estimate is based on data that is heterogeneous in terms of date and accuracy: the maps used correspond to different years (between ~2019 and 2023 depending on the source) and have varying resolutions (from 10–20 m for local data to 300 m for global data), which can introduce uncertainties in the detection of small agricultural plots and the comparability of classifications. Nevertheless, the cross-referencing of multiple complementary sources makes it possible to reinforce the reliability of the result by partially compensating for the limitations of each of them.

Estimated cash crops area in the Kivu-Kinshasa Green Corridor

The objective of the method implemented here, harvesting the data available from the Virunga Foundation and the province of North Kivu, is to provide a *rough but reasoned* estimate of the total cultivated area for each product (cocoa, oil palm, rubber, coffee) along the corridor, beyond the area immediately surrounding Virunga National Park. The aim is to indicate orders of magnitude supported by available data and literature, while emphasising the uncertainties.

Estimation method in the Nord-Kivu

The province of North Kivu concentrates a significant part of the economic activities of the green corridor around the cash crops value chains selected. Relevant and up-to-date data were collected to develop a robust methodology to be scaled-up on the whole corridor Kivu-Kinshasa. The successive steps involve :

1. Local **analysis (Virunga National Park and the 50 km buffer zone)** – *reference sample*:

Using the land use map around Virunga, identify the **total agricultural area** in this buffer zone and the proportion corresponding to woody perennial crops (cocoa, coffee, palm, rubber) vs. annual herbaceous crops. The GPS points of **cocoa and palm plantations** will be cross-referenced with this map to verify which cover classes they correspond to (they are expected to fall within the 'woody' or agroforestry crop zones) and to perform quality control and validation of the data. This will also allow to **calibrate the density** of certain cash crops in a given region.

2. **Identification of the crops represented**: Still in the Virunga area - *use the shapefiles:*

Cacao_Watalinga: a census of cocoa producers in the Watalinga sector (North Kivu). For example, this file includes more than **1,100 georeferenced cocoa plantations**, often small (in the order of 0.5 to 2 hectares per individual plantation according to the attributes) - reflecting a fragmented village-based cocoa cultivation.

PalmierHuile_Virunga: a set of points locating **palm groves** in the same area. These points confirm the presence of oil palms cultivated on the outskirts of the park.

Hevea_Production: a polygon encompassing a historical rubber tree production zone to train the algorithm.

3. **Extrapolation to the entire corridor**:

Based on the Virunga sample area, carry out a reasoned extrapolation. This is not a simple rule of three (as agricultural conditions and densities vary in the corridor), but a combination of field information with **secondary data by province**. This will be based in particular on:

- **Statistics or national/regional studies** on the sectors (e.g. USAID and FAO studies, NGO reports),
- The DRC's **agricultural history** (e.g. former vs. current surface areas, in order to assess what is still cultivated today),
- The known **geographical distribution** of crops: for example, cocoa mainly in North Kivu/Ituri and Ecuador/Ubangui, Arabica coffee concentrated in mountainous Kivu, rubber in certain concessions in the west, oil palm in the equatorial basin, etc.
- The **boundaries of the corridor** provided (shapefile) to circumscribe the estimates to this precise geographical area (and avoid counting areas outside the perimeter).

4. **Summary in table form**:

present for each product a **range of estimated surface area** over the entire corridor, detailing the assumptions (e.g. based on concrete examples: *'plantation X of palm trees covers Y hectares'*, *'in 2023 it is estimated Z hectares of cocoa to the east…'*).

5. **Uncertainties**:

identify the error factors - for example the existence of **intercropping** (cocoa often associated with banana trees or coffee under shade, etc., which complicates the calculation of *exclusively* dedicated area), shifting cultivation (temporary plots), or the fact that some **registered plantations are not fully exploited** (case of rubber trees where large concessions are partly fallow).

Cash crops in the Virunga buffer zone (50 km)

In the 50 km buffer zone around Virunga National Park, the land use map shows a mosaic of forests, savannahs and agricultural land. Class **A11 - 'Cultivated and Managed Terrestrial Area(s)'** (according to the FAO LCCS nomenclature) represents cultivated land. In this zone, there are more than **6,000 A11 agricultural polygons**, which is evidence of a strong human presence. Although it is not possible for us to calculate precisely here the total agricultural area of the buffer (due to the lack of exhaustive tools in this report), it can be estimated that **several tens of thousands of hectares** around the Virungas are cultivated (food crops and plantations combined). This agricultural land is divided into:

- **Annual herbaceous crops** (fields of corn, cassava, etc.), often small, scattered in villages and clearings.
- **Shrub crops** (medium-sized perennial plants).
- **Woody crops** (trees grown in stands or agroforests).

According to legend, **cocoa and palm groves** fall into the category of ligneous (tree) crops. Indeed, the planting points provided mainly overlap with polygons of type **A11 - cultivated areas** on the map:

- The **palm oil geolocation** points are located in areas identified as agricultural land, often near rivers or peripheral swamps where oil palms thrive (warmer climate at lower altitudes). We can therefore confirm that there are **village palm groves** around the Virungas, albeit modest ones (a few hectares each).
- The locations of **cocoa trees** around Watalinga are also in agricultural areas. The Watalinga sector (Beni Territory, North Kivu) is a region of plains where cocoa revival programmes have been carried out in recent years. The shapefile lists more than **1,150 cocoa plots** affiliated with cooperatives (e.g. COPAREPAWA) - often small family farms (often <1 ha of *pure cocoa* per farm). The attribute data indicate, for example, cocoa areas of *0.5 ha* on a total farm of *2 ha*, the rest being devoted to other uses (banana plantations, food crops, etc.). This illustrates an **agroforestry system**: the cocoa trees are cultivated under the partial shade of other trees (banana trees, secondary forest trees), which corresponds well to the *woody* class on the satellite images.
- Regarding **coffee**: no explicit GPS data were immediately available in the Virunga area, but historically North Kivu was a land of (arabica) coffee before the appearance of tracheomycosis (coffee tree disease) in the 1990s. Many coffee trees were decimated at that time, pushing some farmers towards cocoa as a replacement. It is therefore likely that the **shrub/woody category** also includes some plots of **residual coffee trees** or those in the process of conversion (e.g. young cocoa trees planted under old coffee trees).
- For the **rubber tree**: this is not a traditional crop in Kivu, and no rubber plantations have been reported around the Virungas. Rubber trees are grown in tropical lowlands (mainly in the western part of the greater Congo Basin). The *Hevea_Production* shapefile provided does not cover the immediate Virunga area (see next section).

In summary – Virunga area: the densely populated buffer zone shows **intense agricultural fragmentation**. The share of perennial cash crops (mainly cocoa, some coffee and palm) is significant but remains lower than that of food crops (maize, cassava, plantain, etc.). According to Watalinga data, it can be estimated that in the entire Virunga buffer zone, there are around **a few thousand hectares of cocoa** in production. Palm groves are more scattered (a few hundred hectares at most, mainly in small individual plots). Coffee, once dominant, now occupies only a relatively small fraction of the area in this zone (many former coffee plantations have been abandoned or replaced).

This **local snapshot** serves as a basis for understanding the typical agricultural land use in the eastern part of the corridor. In particular, it can be seen that: **(a)** cocoa is well established in the small-scale farming system (small agroforestry), **(b)** oil palms are present in an artisanal way but not yet in intensive plantations in this zone, **(c)** coffee has declined, **(d)** rubber trees are absent. These observations will inform the estimate for the entire corridor.

Extension of the analysis to the entire Green Corridor

The corridor extends over a **vast geographical area** from the east (North Kivu) to the west (Kinshasa), encompassing multiple ecological zones and provinces. The agricultural density varies greatly: some portions are almost untouched (primary forests), others are old agricultural land (e.g. a string of villages along the Congo River in the provinces of Équateur, Mongala, Tshuapa, etc.). To estimate the cultivated area by sector, it is therefore necessary to aggregate the available regional information:

1. Cocoa:

Cocoa is a crop that has recently emerged as an export sector in the DRC, particularly in the east and north of the country. **Introduced during the colonial period** (1930s) at a few sites along the Congo and to the east, the cocoa tree had never reached the scale it has in West Africa. In recent decades, in the face of growing global demand and as a profitable alternative to coffee, cocoa has been booming in the corridor. The provinces of **Kivu, Ituri and Tshopo** are now the main producers of Congolese cocoa. It is estimated that there are around **65,000 cocoa farmers** in North and South Kivu alone, often smallholders with plots of 0.5 to 2 ha integrated into the forest (agroforestry system). The quality of Congolese cocoa is recognised as exceptional – fine, organic and from ancient varieties – which gives it significant economic interest in niche markets.

In the Green Corridor, the **key cocoa production areas** include: the territories of **Beni** and **Lubero** (North Kivu) where local cooperatives were formed after the partial pacification of these areas, the territory of **Mambasa** (Ituri) on the outskirts of the Okapi Reserve, and increasingly the **Yangambi sector** in Tshopo (around Yanonge, Isangi). The latter has seen an influx of planters from Kivu, fleeing the conflicts, who are clearing the forest to establish new cocoa plantations. This migration of Nande farmers to Tshopo contributed to the increase in deforestation locally in 2020-2021, revealing the importance of better planning this expansion (for example, through agroforestry rather than monoculture).

Supporting factors: cocoa is now the main agricultural export product of the DRC and its production quadrupled from 2015 to 2020 to reach 48,000 tonnes. The figures of 65,000 ha are in line with these volumes (low average yields of ~500-800 kg/ha in agroforestry). The majority of these cocoa plantations are organic and of the Forastero variety, cultivated by smallholders. This also means that they are rarely pure monocultures: these **65,000 ha often include agroforestry**

systems, but for the evaluation of the processing potential (cocoa paste, chocolate), the total area occupied by cocoa trees is considered.

*Figure A – Agroforestry plot based on **cacao trees** combined with banana trees and teak trees in Yanonge (Tshopo Province, near Kisangani) – an example of sustainable agroforestry in the Green Corridor. (Photo Axel Fassio/CIFOR-ICRAF, 2023)*

Harvesting the 2023 statistics from the **Office Congolais de Contrôle (OCC)**, we can affinate the preliminary results as following:

- **Cocoa exported (2023):** 68 433 tons
- **Estimated mean yield:** 600 kg/ha
- **➜ Estimated cultivated area (in production) :**

$$\frac{\mathbf{68\ 433}}{\mathbf{0.6}} = \mathbf{114\ 055}\ \boldsymbol{hectares}$$

This gives us a credible minimum area of actual production. Considering that:

- This figure does not take into account post-harvest losses or local consumption,
- And that cocoa is often grown in agroforests on mixed plots (not all of the land is dedicated solely to cocoa),

It would therefore be reasonable to set an adjusted reference area of around **115,000 hectares for all the cocoa produced in the country** - and to allocate the vast majority of it to the Green Corridor, since it concentrates the main basins (North Kivu, Ituri, Équateur, Sud-Ubangi, etc.).

We therefore go from 65,000 ha to an estimated **110,000 ha in the corridor**, considering that more than 95% of production comes from the provinces covered by the corridor (there is very little cocoa in Kwilu, Kongo Central or elsewhere).

2. Oil palm:

The oil palm (Elaeis guineensis) is of historical and strategic importance in the DRC. It was one of the flagship crops of the colonial era: as early as 1911, the industrialist William Lever established vast plantations in the Belgian Congo to supply European soap factories. At its peak, the DRC (Zaire) was the world's second largest producer of palm oil. Current oil palm cultivation in the DRC presents a very different profile, with on the one hand former industrial plantations inherited from colonisation, and on the other a myriad of scattered village palm groves. Historically, the country had **147,000 ha of palm trees planted in 1958**. However, since the 1960s, national production has collapsed, falling from ~220,000 t in 1960 to around **150,000 t in recent years**, far below domestic demand (estimated at 500,000 t), resulting in a deficit of ~350,000 t that is being filled by massive imports. This decline is due to a lack of maintenance of the palm groves, the Zairianisation that led to the abandonment of many plantations, and a lack of investment.

The **Green Corridor** includes most of the DRC's main palm areas, as these are located along the Congo River and in the northeast: the **PHC (Plantations et Huileries du Congo)** plantations of **Lokutu** (Tshopo), **Yaligimba** (Mongala) and **Boteka** (Équateur) are located there, totalling more than 100,000 ha of concessions (of which about 20,000 ha are currently cultivated). These sites, formerly managed by Unilever and then the Canadian company Feronia, have suffered from financial difficulties and recent labour disputes, but have enormous potential for recovery. In addition to these industrial complexes, there are many scattered **village palm groves**: around Yangambi (Tshopo), in **Mai-Ndombe** (Mbandaka-Kinshasa axes), in **Tshuapa** (Ikela territory, etc.), as well as on the outskirts of old industrial sites (local populations continue to harvest palm bunches on the abandoned or fallow land of former plantations). In the east, palm cultivation is more limited by the mountain climate, but there are some palm groves in the lowlands of **North Kivu** (Lubero, Beni) and **Maniema** (Pangi), generally to produce artisanal red oil for local use.

As demand is high (both for cooking oil and for recent **biodiesel** projects), the authorities are encouraging the revival of this sector. In 2024, the President called for the development of **145,000 ha of new palm groves** across the country (1,000 ha in each of the 145 territories) to supply an emerging biodiesel industry. This effort, if it materialises, will directly affect the Green Corridor, particularly the northern territories (Tshopo, Equateur) where palm trees grow naturally. EU investment in the Green Corridor is explicitly aimed at developing *sustainable agriculture* in the palm oil sector, avoiding the destructive model seen in Asia. The aim is to **restore old plantations** rather than clearing new primary forests: for example, replanting young palm trees on the thousands of hectares of old, unproductive stems in **Lokutu and Yaligimba**, or developing agro-industrial plots on the savannahs and fallow land around the villages (some local cooperatives, with the support of NGOs, have started to distribute selected improved palm seedlings in the province of Équateur).

To resume, most of these areas are located within the Green Corridor:

- The three large PHC (formerly Feronia) concessions at **Lokutu** (Tshopo), **Yaligimba** (Mongala) and **Boteka** (Equateur). Between them, **around 21,400 ha** of palm trees are currently planted (9,700 ha at Lokutu, ~8,000 ha at Yaligimba, ~3,700 ha at Boteka). These are the **industrial centres** of oil production, with integrated oil mills.
- The **Miluna concession** in Sud-Ubangi, founded in 1911, which revived production: today, nearly **1,000 ha of oil palms** are cultivated there (in addition to rubber trees, cocoa, coffee - see below).
- Numerous **family palm groves** along rivers and in humid savannah areas. For example, in the Kasai and Sankuru region (southern edge of the corridor), *35% of households* owned 50 to 100 palm trees in 2014 (i.e. ~0.5 to 0.8 ha of palm grove per household). Similar situations can be found in Eqateur and in the Tshopo, where each village cultivates a few hectares of natural or planted palm trees for the artisanal production of red oil.

Indirect data (PHC, USAID, FAO reports) indicate approximately:

- 40,000 to 50,000 tonnes of palm oil produced/year officially (local and export)
- Estimated average yield: 1 tonne/ha gross (often much less in smallholdings)

In view of these elements, we can estimate a range of the total area of oil palms *in production* in the green corridor: approximately 40,000 to 50,000 hectares, but taking into account the poorly recorded village palm groves, we adjust to **60,000 to 70,000 ha for the green corridor**. The lower end of the range (~60,000 ha) corresponds to identified active plantations (PHC + others) and a few village palm groves. The upper end of the range (~70,000 ha) takes into account the immense multitude of small, scattered stands that have not been individually mapped.

This confirms that our estimate is of the right order of magnitude. Finally, it should be noted that the Congo Basin offers enormous potential (more than 280 million ha would be favourable in Central Africa), but **the green corridor aims precisely to reconcile agricultural development and forest protection** - it is not a question of converting all this potential, only of sustainably developing the areas already affected by human activity.

3. Hevea (natural rubber):

The rubber tree (Hevea brasiliensis) also has a long history in the Congo, albeit a more modest one. At the beginning of the 20th century, before the introduction of plantations, rubber was harvested by exploiting wild lianas (the *'rubber boom'* having left a dark legacy). Subsequently, **rubber plantations** were established during the colonial period - first on an experimental basis in Yangambi and Ecuador, then on a larger scale in the 1940s and 50s. In 1925, there were already around 4,000 hectares of rubber trees planted in the Belgian Congo, an area that increased after the war. The main rubber-growing areas were the same as for oil palms: the **Yangambi** region (INÉRA developed rubber plantations there), the **Mongala and Équateur** basin (around Bokungu, Befale, etc.), and certain areas of **Eastern Kasai** (Lodja, Lomela) at the southern end of the corridor. Under the Mobutu regime, several of these plantations were abandoned (due to lack of maintenance after Zairianisation).

Today, rubber production in the DRC is almost non-existent - around **14,000 tonnes in 2018** - and comes mainly from a few *village rubber trees* or abandoned plantations where latex is still harvested by hand. For example, in the territory of **Opala** (Tshopo), there are reportedly *'around twenty thousand hectares of rubber plantations invaded by the bush'* inherited from colonisation, some of which are occasionally exploited by the villagers (for the production of artisanal rubber).

The **Green Corridor** includes precisely these areas: Yangambi–Isangi, Opala–Yahuma, as well as the former plantations of **Sankuru** (Lodja) on the southern edge. The emblematic example is still the **Miluna** concession in Sud-Ubangi: it is *'the only plantation from the colonial era to have regained its full capacity'* in the province, with **5,000 hectares of rubber trees** in production. There is therefore potential for rehabilitation here. The Congolese government has launched calls for investors to **rehabilitate the former rubber plantations** of Équateur, Orientale and Sankuru. New initiatives are underway: for example, in Tshopo province (central corridor), Asian companies obtained rights to plant rubber near Yangambi and Kisangani in the 2010s (several thousand hectares planned). The idea is to take advantage of the demand for rubber (tyres, etc.) while occupying already cleared land (therefore without putting pressure on the forest). However, no major project has yet been completed, due to restoration costs and competition from Asia.

Thus, for the **rubber tree in the green corridor**, we estimate:

- **Area currently exploited (productive plantations)**: only around **15,000 hectares** of natural rubber. These are mainly Miluna (5,000 ha) and possibly a few hundred scattered hectares (for example, young experimental plantations near Kisangani or in northern Ecuador, or the RBL nursery in Yangambi). Rubber production is modest (~14,000 tonnes for the whole country in 2018, largely from Miluna and tapping of residual village rubber trees).

- **Area of** land ***potentially available* or planned**: several tens of thousands of hectares. For example, the Sud-Ubangi concession has a total area of 25,000 ha, part of which is conserved primary forest.infonile.org Similarly, the Tshopo area (shapefile) of ~200,000 ha could eventually see tens of thousands of ha planted with rubber trees if the projects are successful. However, **as things currently stand**, these areas are not yet producing or contributing to a local processing industry. They are mentioned to emphasise that the **corridor has significant latent potential** for rubber (suitable climate in the equatorial basin), but this potential has yet to be realised.

- Estimate yield (conservative): **1,5 à 2 t/ha**

➜ This corresponds to **around 7,000 to 10,000 ha** actually farmed, although the area planted with trees may be larger.

In conclusion, for rubber, we will retain approximately **8,000 ha effective in 2025** in the corridor, while noting that an optimistic development scenario could increase this figure to 20,000–30,000 ha in the future (if investors replant the old abandoned plantations). For the immediate assessment of the transformation potential, the current figure should be favoured.

4. Coffee (arabica and robusta):

Coffee was for a long time the DRC's main cash crop. There is **Arabica coffee** (mountain coffee, top of the range) grown mainly in the east, and **Robusta coffee** (lowland coffee, more productive) dominant in the west and north. Historically, the Congolese coffee industry was flourishing: during the 1980s, the country produced between 80,000 and 120,000 tonnes of coffee per year, making it one of the main African exporters. **Robusta coffee** from eastern Congo expanded dramatically during colonisation, going from almost nothing to **51,000 tonnes in 1959** following the establishment of vast smallholder coffee plantations in the former Orientale Province. However, successive shocks (falling prices, looting during the wars, plant diseases such as tracheomycosis of the robusta coffee tree) led to a collapse. In 2018, production was only about **29,000 tonnes** of all coffees combined.

In the Green Corridor, there are two types of coffee cultivation:

- In the east, the highlands of **Kivu** (North and South Kivu) produce high-quality **arabica** coffee. Around Lake Kivu and the volcanoes, tens of thousands of small farms grow high-altitude arabica (often <1 ha each). Although affected by disease, cultivation persists thanks to cooperatives and replanting projects (e.g. ICO/NCO project targeting 46,000 ha rehabilitated in post-conflict zones).

- In the north and centre of the country, the plains of the **Cuvette Centrale** (former Equateur and Orientale provinces) were the domain of **robusta** coffee. Industrial plantations and vast peasant estates existed: in the 1930s, there were already 56,000 ha of coffee trees in the Belgian Congo, and in the 1980s the Haut-Uele region alone had a total of 27,000 ha of coffee trees in production. With the unrest, these figures have fallen, but many coffee trees remain in a semi-abandoned state in villages along the river and its tributaries. For example, the province of **Tshuapa** or **Mongala** still has robusta coffee trees among elderly farmers, even if marketing is sporadic.

Currently, the major difficulty for coffee is **marketing it**: as the roads are unreliable, many coffee farmers in the east sell their production via neighbouring countries (Rwanda, Uganda), where Congolese coffee is mixed with local batches. This causes a loss of traceability and added value for the DRC. The European Union now imposes strict requirements for traceability and the absence of deforestation for imported coffee, which threatens to exclude non-certified producers. Fortunately, the DRC has begun the certification of certain coffee-growing areas (North Kivu certified 'zero deforestation' in 2024) to maintain access to the EU market. In the Green Corridor, the **preservation of the forest** will be a selling point: coffee grown under shade in an ecological corridor will have a positive image, provided that it can be proven that no primary forest is converted after 2020.

Harvesting the 2023 statistics from the **Office Congolais de Contrôle (OCC)**, we can affinate the preliminary results as following:

- In 2023, around **30,000 tonnes of coffee** produced in the DRC (source: FAO/OCC)
- Average yield: **0.5–0.7 t/ha** (varies greatly depending on maintenance)

➜ This gives an estimate of **45,000 to 60,000 ha in production**

In the entire corridor, combining arabica and robusta, the total area of coffee trees *still in place* can be estimated at around **60,000 hectares**. This figure includes a large proportion of ageing and underproductive plantations. Kivu (North and South) is the main basin for quality arabica. In terms of coffee that is actually tended and harvested, the area is probably closer to **40,000 ha**.

For example, **North Kivu has around 11,000 registered coffee** producers – if each cultivates ~1 ha, that makes ~11,000 ha active for this province; add South Kivu and Ituri, and we may reach ~20,000 ha of arabica in production in the East. For the robusta of Equateur/Tshopo, the estimates are unclear but probably in the order of 10,000 ha harvested (mainly in areas such as Lisala, Bikoro, Isangi, etc.). In total, **we will retain ~40,000 ha of coffee currently exploitable in the corridor**.

That said, the potential for rehabilitation is very high: a national plan could upgrade up to **46,000 additional hectares** just by rehabilitating old robusta plantations, bringing the total to over 80,000 hectares. However, this potential has not yet been realised – it is mentioned to show the sector's margin for growth if the green corridor project includes support for coffee growing.

Supporting evidence: Recent agricultural statistics indicate ~29,000 tonnes of coffee produced annually. At a very low average national yield (≈0.5 t/ha due to the abandonment of many plantations), this suggests **~58,000 ha *in use*.** Our estimate of ~40,000 ha in use is therefore conservative, but it should be remembered that a lot of coffee is not exported (local self-consumption) and that ONC estimates vary. In any case, coffee is still present over a significant area of the corridor, although its contribution to the local economy is declining compared to the past.

Summary table of estimated cash crop areas

In summary, here are the **orders of magnitude** used for the cultivated areas by sector in the Kivu-Kinshasa Green Corridor:

Estimated selected crop cultivated area (Green Corridor)

Cocoa ≈ 110,000 ha (mostly smallholders) Mainly North Kivu/Ituri and Équateur/Ubangi. Strong recent expansion following the decline of coffee.

Oil palm ≈ 65,000 ha (60,000–70,000 ha depending on the area considered). Includes ~21,000 ha of industrial plantations (PHC) and ~15–20,000 ha of village plantations. Large concessions available for expansion.

Hevea (rubber) ≈ 10,000 ha currently exploited (potential > 20,000 ha) Essentially Miluna plantation (5,000 ha). Other projects in the pipeline (Tshopo, etc.) not yet productive.

Coffee (arabica+robusta) ≈ 60,000 ha in production (70,000+ ha of existing coffee trees) Historically in sharp decline. Eastern arabica (Kivu) ~20k ha; north/western robusta ~20k ha. Significant rehabilitation potential.

(NB: All these values are rounded and are intended to give an order of magnitude, not absolute precision.)

An illustrative example is the *Miluna* concession (South Ubangi province) which combines **5,000 ha of rubber trees, 1,000 ha of oil palms, 500 ha of cocoa and 100 ha of coffee** on the same farm. This shows that, at the local level, these crops coexist and that multi-purpose processing units (oil mills, cocoa dryers, rubber factories, etc.) could benefit from diversified supplies.

Discussion of uncertainties and points of attention

The above estimates, although supported by data, include several uncertainties that should be emphasised:

- **Cartographic uncertainties**: In the absence of a recent detailed land use map for the entire corridor (such as the Virunga map), we have combined different sources. It is possible that some agricultural areas have not been taken into account (e.g. remote clearing crops not reported) or, on the contrary, that some estimated areas include fallow land. **Shifting cultivation** (slash-and-burn-rotation) means that part of the land is fallow at any given time; our figures do not distinguish between *'cultivated this year'* and *'potentially cultivable'*.

- **Associated crops**: The same plot of land can be used for **several crops** in combination. For example, one hectare of cacao trees in agroforestry often contains banana trees and sometimes coffee trees - how do you count this area? In our estimates, we attributed it entirely to cacao (the main crop that generates income). This could lead to **slight double counting** if someone naively added up all the sectors (because the shade banana plantation is not listed, etc.). To remain consistent with the objective (local processing), we consider each sector separately.

- **Rapid evolution of the sectors**: cocoa is growing exponentially (new plantations every year), while coffee continues to stagnate or decrease in some places. Our figures are valid for the current period (2024-2025) but could change. For example, several thousand additional hectares of cocoa are planted every year in North Kivu. Conversely, if a coffee revival programme were implemented, the harvested area could increase significantly. The **green corridor**, if accompanied by technical support, could influence these dynamics (e.g. replanting of rubber trees or intensification of village palm groves).

- **Delimitation of the corridor**: We have taken into account the official perimeter provided. Nevertheless, some crops on the edge could partially be just outside it. For example, **Mayombe (Central Kongo)** is home to large palm groves and rubber trees (SCAM company near the Luki reserve), but it is probably outside the corridor as defined. We have therefore not included it, focusing the estimate on the strict interior. If the perimeter were ever to be enlarged, it would then be necessary to adjust (the Mayombe would possibly add an additional 5,000 ha of palm trees and 1,000 ha of rubber trees, for example).

- **Variable human density**: The Virunga area is relatively densely populated (North Kivu), while the average for the corridor may be less dense (there are still many intact forests in Tshuapa, Mai-Ndombe, etc.). **Linearly extrapolating the agricultural density of Virunga to the entire corridor would overestimate** the surface areas. This is why we have injected empirical data by province instead of a simple rule of three. For example, **only ~3% of the country's total area is cultivated**; the corridor is ~10 million ha, one could expect ~300,000 ha of agricultural land in total if one took this average. Our estimates focused on 4 cash crops reach ~150,000 ha, which is consistent (food crops occupy the rest up to ~300k ha). This is a rough cross-validation: it is plausible in terms of magnitude.

- **Potential for transformation vs. actual** production: It should be noted that not all cultivated areas are synonymous with raw materials available in quantity. **The yield per hectare** and the **collection rate** matter. For example, of the 40,000 ha of coffee, perhaps less than half is actually harvested annually due to lack of maintenance. Similarly, the 40,000 ha of oil palms in the corridor include old, unproductive stands (some farmers only harvest a fraction of the bunches due to lack of transport, etc.). To assess the potential for local processing, it will therefore be necessary to **adjust with productivity coefficients**. Here, we have limited ourselves to surface areas as an index of gross territorial potential.

Conclusion and recommendations

In conclusion, the Kivu-Kinshasa Green Corridor is home to **significant areas of cash crops**: it can be estimated that by 2025 approximately **240,000 hectares** of the corridor will be planted with cocoa, coffee, oil palm or rubber (about half of which will be cocoa). Although modest in national terms, these areas represent significant **opportunity for local development**. Their distribution along the corridor means that it is feasible to develop **centres for local processing** at different stages: for example, **an artisanal chocolate factory** in Beni to add value to the cocoa from the east, **community oil mills** towards Mbandaka for palm oil, a **rubber factory** in Gemena for rubber, or **coffee washing stations** in Kivu. This would create local added value instead of only exporting raw materials.

Nevertheless, a few recommendations are in order:

- **Refining the map** would be useful – ideally an up-to-date map of land use along the entire corridor, with remote sensing (Sentinel-2 or Planet satellite imagery) to detect perennial crops. This would make it easier to locate **islands of cocoa or rubber hidden**, for example.
- Integrating the **dynamics of time**: the green corridor project must follow the evolution of the sectors. For example, the **cocoa sector is booming** in Ituri/North Kivu, which is positive for the economy but can cause deforestation problems if unchecked (or conversely, be a tool for reforestation through cocoa agroforestry). Similarly, if thousands of hectares of palm trees are replanted on degraded land, this can revitalise rural areas (jobs), but the environmental impact will need to be monitored.
- Ensuring an **integrated approach**: the green corridor aims for **conservation AND development**. The figures show that cash crops currently occupy a small fraction of the total space of the corridor (a few percent at most). It is therefore possible to increase their surface area (to improve the income of the population) without drastically encroaching on the forests if this is done on land that is already open. For example, we could encourage the **reconversion of fallow land into agroforestry plantations** (coffee under acacia trees, cocoa under safoutiers, etc.) to combine reforestation and production.

In short, **the potential for local transformation is real but will depend on the structuring of the sectors**. With ~110,000 ha of cocoa, we can aim to set up small centralised fermentation/drying units and even a local chocolate factory. With ~65,000 ha of palm trees, there is scope for rehabilitating oil mills (many are at a standstill in the old plantations) to produce palm oil and derivatives (soaps) locally. The current ~10,000 ha of rubber trees hardly justify a large factory (Miluna ships its raw production), but if we reach 20,000 ha in the long term, a unit for processing latex into semi-finished products could be set up. As for coffee (60,000 ha active), the promotion of **Arabica speciality coffee** from the DRC could encourage more local processing (roasting) instead of only exporting green coffee.

The Green Corridor project, by coordinating conservation and development, has the opportunity to **support these sectors in a sustainable way** - for example through agroforestry programmes (cocoa-coffee under forest cover, palm trees in agroecological systems), cooperatives improving yields, and of course the establishment of processing units **appropriate at the local level** (minimising the long-distance transport of heavy products). This would strengthen the economic viability of the corridor while involving local communities in its management, thus ensuring that the protection of forest cover does not conflict with livelihoods, but rather makes them complementary.

Estimated food crops in the Kivu-Kinshasa Green Corridor

To estimate the areas dedicated to the main food crops in the Kivu-Kinshasa Green Corridor, an integrated approach was adopted, combining recent spatial data (ESA-CCI, Verhegghen, Copernicus) with available agricultural statistics (INS, 2023). Of a total agricultural area estimated at around 3 million hectares in the Green Corridor, around 85% (2.58 million hectares) is actually cultivated each year, with the remainder reserved for fallow land and secondary crops. From this basis, the INS data (2023), although generally considered to be underestimated, served as an initial reference point, making it possible to establish realistic empirical ratios between the main food crops. These ratios were then adjusted to more accurately reflect the realities on the ground and the trends observed locally in the corridor, particularly by increasing the share allocated to rice (≈245,000 ha) to better correspond to its real potential area, estimated at between 200,000 and 300,000 hectares. The other dominant crops in the corridor, including cassava (~1.16 million hectares), maize (~465,000 ha), plantain (~349,000 ha) and other food crops (~233,000 ha), have had their areas proportionally adjusted. This method of estimation, although it involves some uncertainties related to the available data (in particular the frequent under-reporting in the official statistics), provides a solid basis for guiding strategic decisions on agricultural development in the Green Corridor.

Cassava:

Cassava is the **primary food crop** of the DRC, the staple diet for millions of Congolese. Hardy and tolerant of poor soil and variable climate, it is grown in virtually every village in the Green Corridor. The DRC is one of the world's leading producers of cassava, with nearly **30 million tonnes** per year in recent years. Taking into account losses and the method of calculation, this corresponds to approximately 15–20 million tonnes of fresh roots consumed, making the country the world's largest consumer of cassava per capita. The Green Corridor, which crosses areas of high consumption (East) and production (Cuvette), contributes greatly to this supply.

History and dynamics: Cassava (of Amazonian origin) was introduced to the Congo in pre-colonial times, then spread everywhere, partly supplanting indigenous tubers (yams) thanks to its ease of cultivation and conservation. In the provinces of the former Équateur, Bas-Congo and Bandundu, it has always been the main crop – these three former provinces provided 30% of the country's production in the 2000s.

In the Green Corridor, the main areas of overproduction were traditionally: **Mai-Ndombe** and **Tshuapa** (savannahs and secondary forests where manioc fields occupy vast areas around the villages), and **North Equateur**. The Kivus also produce cassava but consume almost all of it locally. In the 1990s, the African cassava mosaic disease ravaged the fields, particularly in the east, causing a dramatic drop in yields (a 20–30% national drop in production over the decade). Fortunately, thanks to the introduction of improved resistant varieties (supported by IITA and INERA), production recovered in the 2000s and 2010s. In 2023, a projection by Akademiya 2063 estimated cassava production at **33.5 million tonnes**, with a slight annual increase, reflecting a continuous expansion of cultivated areas.

In the Green Corridor, cassava is grown by almost every rural household on small, scattered plots. It is often *cultivated in association* – for example, *cassava + maize* or *cassava + groundnut/cowpea*. After 1 to 2 years of growth, it is harvested and the plot is either left fallow or replanted. The cycles are therefore staggered, making precise monitoring difficult. The corridor does not include large single-species cassava plantations (with the exception of recent projects such as an initiative to plant 1,400 ha of industrial cassava in Kongo Central for bread flour, outside the corridor zone). It is a very fragmented mosaic.

Estimated area in the Green Corridor: Based on production data and a modest average productivity (~8 to 10 t/ha of fresh roots, given extensive cultivation practices), we estimate that approximately **1.3 to 1.4 million hectares** are devoted to cassava in the Green Corridor.

This considerable figure reflects the spatial extent of this crop: in the savannah areas of Mai-Ndombe and Tshuapa, cassava fields of 1–2 ha per household are strung together around rural settlements. In North Kivu, where demographic pressure is high, cassava also occupies every available plot of land in the plains. It should be noted that this estimate corresponds to the area actually *under cassava cultivation at the moment*, but due to rapid rotation, the area *harvested over a year* is higher (each planted hectare is harvested and then possibly replanted elsewhere the following year). In terms of contribution, the cassava of the Green Corridor would represent about 20–25% of the national cassava. The rest comes mainly from Kongo Central, Kwilu, Kasai and Katanga (not included in the corridor). The corridor areas such as **Mai-Ndombe** are strategic for supplying Kinshasa with dried cassava chips (chikwangue, etc.), while in the east cassava provides the caloric base for Goma, Bukavu and Kisangani. Improving cassava productivity in the Green Corridor - through new varieties, the use of organic fertilisers, disease control (especially cassava brown streak disease, which is rife in some areas) - is a **crucial lever for food security**. Our surface area estimates underline the scale of the effort: more than half a million hectares scattered across the country, over which crop innovations will need to be disseminated.

Maize:

Maize is the second most important food crop in the DRC in terms of volume, with around **2 million tonnes** produced in 2018. In the Green Corridor, maize is often planted in association with cassava or as a secondary flood recession crop (for example, maize is sown on the banks of the river after the water recedes). It is used as a staple food (corn flour, porridge) but also as livestock feed in peri-urban areas.

History and situation: Corn has been cultivated in the DRC for centuries (introduced by the Portuguese in the 17th century). It is particularly important in the south-east (Katanga) and south-west (Bandundu). The Green Corridor is not the country's main 'maize belt', but it does include enclaves of high production, notably: the alluvial plains of the **Tshopo** and **Tshuapa** (where the light soils are well suited to maize), certain areas to the east of the **Mai-Ndombe**, and the terroirs around **Kisangani**. During the 1970s and 80s, large cornfields were established near Kisangani to supply the former state office UNELE, but they fell into disuse. Currently, production is mainly family-based, with some incipient mechanisation initiatives around the cities (e.g., tractors provided to young farmers' associations in Tshopo in 2020-21).

Maize is strategic because Kinshasa and urban centres consume large quantities of it. In 2017-2018, faced with a local shortage, the DRC had to import maize from Zambia and South Africa to feed Kinshasa and Lubumbashi. Developing maize in the Green Corridor could reduce this dependence. Nevertheless, this crop requires more inputs than cassava (seeds selected each season, soil fertility) and suffers from the poor condition of the roads when it comes to exporting the harvest - surplus maize from Nord-Ubangi or Tshopo has difficulty reaching consumers due to the lack of inexpensive transport.

Estimated area in the Green Corridor: Based on an annual production of around 600,000 tonnes of grain maize in the provinces crossed by the corridor (out of ~2 million nationally) and an average yield of around 1.5 t/ha, we estimate that at least **400,000 hectares** of maize are in the Green Corridor. However, these are largely associated or temporary crops: rarely large continuous monocultures. If we consider the area *mainly dedicated* to corn (pure crop), it would be more like around 200,000 ha, the rest being shared with other food crops. The highest densities of maize in the corridor are found around the major populated axes (Kisangani-Banalia axis, Befale basin, etc.). This figure is consistent with the total cultivated area (maize occupies about 10-15% of the agricultural area of the corridor, which corresponds to the practices observed).

The **challenge of maize** in the Green Corridor is to improve yields (introducing more productive hybrid varieties, which can yield 4–5 t/ha with fertiliser, instead of the current 1–2 t/ha) and to organise the supply chain. For example, setting up **small drying and storage units** along the river would make it possible to buy corn from farmers, store it and transport it by barge to Kinshasa at a lower cost, thus transforming these vast under-exploited plains into a granary for the capital. Our estimates show that there is already a significant production base in place (several hundred thousand hectares), which could be intensified rather than expanded geographically (to save the forest).

Rice:

Rice in the DRC is a growing crop, driven by strong urban demand. The country imports a large proportion of the rice it consumes, due to insufficient local production. Nevertheless, certain regions of the Green Corridor offer favourable conditions for **rainfed rice** (plateau cultivation) or **irrigated rice** in the marshes. Traditionally, rice was cultivated in the marshy savannah areas of the former Équateur and in the valleys of the former Kivu.

Areas in the Green Corridor: The **Ruzizi** plain (South Kivu) can be cited – although geographically to the east of the main corridor, it is part of the East-West dynamic – where irrigation schemes have existed since the 1950s. More directly in the corridor: the rice paddies of the **Tshuapa** basins (Boende territory in particular), the **Lomami** valley and some tributaries of the Congo. For example, the province of Tshopo has encouraged rice around Yangambi (INERA was conducting varietal trials there). In **Bas-Uele**/Ituri too, upland rice is cultivated by people from South Sudan. National paddy rice production was around **990,000 tonnes in 2018**, most of which was consumed directly or husked locally. In the corridor, it can be estimated that perhaps 30% of this volume is produced there (i.e. 300,000 tonnes of paddy rice), mainly in Orientale and Équateur provinces.

In recent years, several programmes (JICA, ADB) have attempted to revive rice cultivation by training farmers in intensive techniques (SRI - System of Rice Intensification) and introducing short-cycle varieties. One challenge is to **develop the lowlands and marshes** available: the Green Corridor has vast areas of peat bogs and swamps that could be used for rice cultivation **without further deforestation** (provided that water is properly managed). For example, the **Lusambila** marsh in Tshuapa could be developed into rice paddies.

Estimated surface area in the Green Corridor: Based on a low average yield (1.0–1.5 t/ha), the surface area cultivated with rice in the Green Corridor is estimated at between **200,000 and 300,000 hectares**. This estimate includes both upland rice (often in mixed cultivation) and lowland rice. The range is wide because peasant rice cultivation is very variable: some years, the farmer plants rice according to rainfall, others not. The areas are not permanent. Nevertheless, in the corridor zone, some communities (particularly in Équateur/Tshuapa) are traditionally rice-growing, so that rice is cultivated there every season on the same sites. It is likely that less than 100,000 ha are *developed and* monitored (e.g. nurseries, transplanting), the rest being rice sown by broadcast seeding in multi-purpose fields.

The **modernisation of** this sector in the Green Corridor requires hydro-agricultural development. For example, the **rehabilitation of 1,000 ha of rice paddies** could give a big boost to local production and reduce imports. The corridor effect can play a role if river transport of paddy rice to husking

centres is facilitated (Kinshasa consumes a lot of husked rice). The problem of **artisanal husking**, which results in lower quality rice on the domestic market, will also have to be overcome. Motorised mini-rice mills, set up in the corridor hubs (e.g. in Mbandaka, Kisangani), could improve processing yields and encourage producers.

Other food crops (plantain, groundnut, etc.):

Finally, the Green Corridor is home to a multitude of other food crops that are considered secondary but are crucial to local diets and incomes: **plantain bananas** (and sweet bananas), **legumes** (common beans, cowpeas/peas, peanuts), **tubers** (sweet potatoes, taro), as well as various vegetables and fruits (pineapples, citrus fruits, mangoes, etc.). Taken individually, each of these crops occupies smaller areas than cassava or corn, but collectively they mobilise a significant portion of the land cultivated in a polyculture system.

The **plantain banana** deserves a special mention: the DRC is the world's leading producer with 4.7 million tonnes, mainly in the humid forest regions. The Green Corridor, which crosses the forest belt, includes large areas of plantain, for example: along the RN4 (the Nande and Mbuti peoples have been growing plantain in Ituri and North Kivu for generations), and the entire central basin where bananas are often grown in cottage gardens. We estimate that there are around **200,000 hectares** of plantain banana trees in the corridor, often in association with other crops (cocoa, coffee, tubers). Productivity is generally low (the banana plantations are not intensively maintained), but it is a perennial crop that is valuable for food security (the fruit is harvested all year round).

Leguminous plants (peanuts, beans, soya) are commonly intercropped with cassava or maize. For example, the **peanut** is widespread in the province of Équateur – it is sown at the same time as maize or cassava, and it covers the soil by fixing nitrogen. Its surface area in the Green Corridor can be estimated at ~100,000 ha (often mixed with other crops). The (common) **bean** is more common in the East (Kivu, Maniema) on perhaps 50,000 ha in the corridor, particularly in rotation after maize or between young cassava plants.

Tubers other than cassava, in particular **sweet potatoes** (approx. 384,000 tonnes produced in the country in 2018 and **taro/malanga**, occupy modest but locally significant areas (wetlands). In Tshopo and Mongala, sweet potatoes are grown on light alluvial soils; it is included in ‘other food crops’ for a few tens of thousands of hectares.

In short, these diverse food crops form a **complex agricultural mosaic** in the Green Corridor. Our aggregate estimate for ‘Other food crops’ (excluding cassava, maize, rice) is approximately **150,000 to 200,000 hectares** in the corridor, dominated by plantain. This figure is deliberately approximate because these crops are often interspersed on the same plots as the main field crops.

The challenge for these productions is to improve technical itineraries (for example, introducing plantain varieties resistant to Panama disease, promoting high-yield peanut varieties, etc.) and to better integrate them into economic circuits. Some, such as **pineapple** (213,000 t in 2018), many of them in Ecuador), could become local cash crops (transformed into dried juice, etc.). By promoting sustainable agribusiness, the Green Corridor can help develop *value chains* for these products, which are currently confined to self-consumption or small local markets.

Adjustments and distribution of estimated areas by crop and by province

In order to complete the overall estimate of the areas cultivated in the Kivu-Kinshasa Green Corridor, a breakdown by province has been carried out by combining available field data, agro-ecological characteristics, sector dynamics and historical or recent production trends.

Each portion of province intersecting the Green Corridor has been identified. This allows the results to be broken down by province of the corridor. For example, the province of Mongala is only included for its south-eastern fringe around Bumba (corridor zone), while the province of North Kivu is only represented by the territory of Beni (eastern end of the corridor). A table of correspondence between provinces/territories and inclusion in the corridor has been drawn up.

For each province crossed by the **Green Corridor** (approximately 3.04 million hectares cultivated in total according to the data provided), we have distributed the main crops according to several stages and assumptions:

- **Reserve for fallow land and secondary crops (15%):** Approximately **15%** of the total provincial agricultural area is kept unallocated, corresponding to fallow land and secondary crops not considered in detail. Thus, we allocate only about **85%** of the agricultural area of each province to the crops listed below. This unallocated 15% share reflects fallow crop rotation (common practice in these regions) and other minor crops not taken into account in this analysis.
- **Cash crops (cocoa, coffee, oil palm, rubber)**: We have incorporated specific figures adjusted in previous analyses for these commercial crops, **setting them by province** according to available estimates:
  - *Cocoa* – a total of around **15,000 ha** across the entire Green Corridor, mainly distributed in **North Kivu**, **Ituri** and **Tshopo** (main cocoa-growing areas, for example in the Beni and Kisangani region). These 15,000 ha have been divided between these provinces (e.g. a majority in North Kivu, the rest shared between Ituri and Tshopo) on the basis of available information.
  - *Coffee* – total area estimated at around **25,000 ha** in the Green Corridor, spread over several traditionally coffee-producing provinces. In particular, **North Kivu** (Arabica coffee in the highlands) and certain provinces in the equatorial basin such as **Equateur**, **Mongala**, **Tshuapa**, **Bas-Uele** and **Tshopo** (Robusta coffee) where plantations or village coffee crops still exist are considered. Each province concerned is allocated a share of these 25,000 ha according to its historical importance in coffee production (for example, North Kivu ≈ 8,000 ha, Ituri ≈ 3,000 ha, Équateur ≈ 3,000 ha, Mongala ≈ 3,000 ha, etc.).
  - *Oil palm* – total area of around **85,000 ha** allocated to palm oil. This crop is mainly present in provinces with an equatorial climate. We have therefore distributed these 85,000 ha mainly in **Tshopo**, **Mongala** and **Équateur**, which are home to former industrial plantations (e.g. Lokutu in Tshopo, Yaligimba in Mongala, Boteka in Équateur) as well as numerous village palm farms. Other provinces in the corridor have more modest palm groves (e.g. **Tshuapa**, **Sud-Ubangi**, **Bas-Uele**, **Maï-Ndombe**), to which we have allocated a smaller area. Provinces not traditionally associated with palm groves (e.g. urban Kinshasa, mountainous North Kivu) receive only a negligible share or none at all.
  - *Hevea (*rubber) – less widespread in the Green Corridor (a few old historical plantations). We have estimated a total of around **5,000 ha** of hevea plantations, distributed on a small scale in certain provinces of the equatorial region (notably**, Equateur, Mongala, Tshuapa, Bas-Uele, Tshopo**). This contribution remains marginal compared to other crops.
- **Food crops (cassava, maize, rice, plantain, other food crops)**: Once the areas of cash crops have been deducted, the rest of the agricultural area **(~245 000 ha)** is allocated to basic food crops. The distribution between these food crops is based on **empirical weightings** drawn from previous analyses of the relative importance of each food crop in the region:
  - *Cassava* – around **47%** of cultivated areas (excluding fallow land) are devoted to cassava, the predominant staple food in all provinces of the corridor.
  - *Maize* – approximately **19%** of cultivated land, the second most important food crop, particularly in suburban and savannah areas.
  - *Plantain bananas* – approximately **14%** of cultivated land. Plantains are mainly grown in humid forest areas (a significant proportion in Équateur, Tshopo, etc.), but this average is applied here to the entire corridor.
  - *Rice* – approximately **10%** of cultivated land. Rice is grown in more localised areas (e.g. in valleys or floodplain rice paddies), and its average share remains modest.
  - *Other food crops* - approximately **10%** of the area. This category includes other secondary food crops (sweet potatoes, yams, taro, vegetables, peanuts, beans, etc.) which, cumulatively, occupy the rest of the agricultural land.

These percentages were applied on a **provincial basis**: for each province, we subtracted the hectares already taken up by cocoa, coffee, palm and rubber (according to the estimates set out above), then distributed the remaining food crop area according to the ratios 55/20/10/5/10 (ensuring that all crops occupy ~85% of the provincial agricultural area). The figures obtained per province were then rounded to the nearest hectare.

Updated distribution by province

The updated distribution of agricultural areas by province in the Green Corridor was carried out by integrating the most recent spatial data (ESA-CCI, Verhegghen, Copernicus) and adjusting the estimates to reflect the realities on the ground as well as the data available from the NSI (2023). The total provincial agricultural area was estimated at around **3.04 million hectares**, of which **around 85%** is actually cultivated each year, i.e. around **2.58 million hectares**.

Cash crops (cocoa, coffee, oil palm, rubber) had already been estimated separately on the basis of specific data and validated by sector experts. These areas therefore remained fixed for each province, totalling approximately **130,000 ha** in the Green Corridor. The food crop areas (cassava, maize, rice, plantain, other food crops) were then recalculated by distributing the remaining area on the basis of adjusted ratios, in particular to better reflect the actual estimated area for rice (≈245,000 hectares instead of ≈123,000 hectares initially proposed).

Appendix 6 - Results of analyses for FOBs

#	Ville	Population, #	Population, % of total	Industrial hub type	Transformation capacity, tons / year	CAPEX, $ / year	Revenues, $ / year	Profits, $ / year	Cashflow hub + FOB, $ / year
2	Kisangani	1,300,000	5.19%	10T - Medium insecurity - Expected	11,488	2,800,000	7,218,649	955,791	748,924
4	Butembo	950,000	3.79%	1T - High insecurity - Actual	976	1,471,167	566,169	41,035	-311,432
5	Beni	750,000	2.99%	10T - High insecurity - Actual	8,297	2,800,000	4,812,433	558,796	206,329
8	Lisala	246,527	0.98%	1T - Low insecurity - Expected	1,352	1,321,167	905,870	127,245	-3,821
11	Oicha	163,137	0.65%	10T - High insecurity - Actual	8,297	2,800,000	4,812,433	558,796	206,329
17	Mangina	97,264	0.39%	1T - High insecurity - Expected	1,352	1,471,167	905,870	127,245	-225,221
29	Mutwang	54,849	0.22%	1T - High insecurity - Actual	976	1,471,167	566,169	41,035	-311,432
40	Basoko	42,790	0.17%	1T - Low insecurity - Actual	976	1,321,167	566,169	41,035	-90,032
43	Eringeti	42,357	0.17%	1T - High insecurity - Expected	1,352	1,471,167	905,870	127,245	-225,221
50	Bafwasen	38,205	0.14%	10T - Medium insecurity - Expected	11,488	2,800,000	7,218,649	955,791	748,924
56	Mambasa	30,524	0.12%	10T - Medium insecurity - Expected	11,488	2,800,000	7,218,649	955,791	748,924
57	Komanda	29,383	0.12%	10T - High insecurity - Expected	11,488	2,800,000	7,218,649	955,791	603,324
58	Mbau	29,347	0.12%	1T - High insecurity - Expected	1,352	1,471,167	905,870	127,245	-225,221
72	Biakato	21,680	0.09%	1T - High insecurity - Expected	1,352	1,471,167	905,870	127,245	-225,221
75	Isangi	20,634	0.08%	1T - Low insecurity - Actual	976	1,321,167	566,169	41,035	-90,032
85	Bafwaban	15,729	0.06%	1T - Medium insecurity - Expected	1,352	1,371,167	905,870	127,245	-79,621
89	Nia-Nia	14,113	0.06%	1T - Medium insecurity - Expected	1,352	1,371,167	905,870	127,245	-79,621
109	Ubundu	9,652	0.04%	1T - Low insecurity - Expected	1,352	1,321,167	905,870	127,245	-3,821
126	Bafwamb	1,635	0.01%	1T - Low insecurity - Expected	1,352	1,321,167	905,870	127,245	-3,821
Total					78,615	34,975,167	48,916,965	6,250,099	1,388,232

Appendix 7 - Results of analyses for key processing facilities

#	Ville	Population, #	Transfo capacity total, t / y	CAPEX total	Revenues total, $ / y	Profits total, $
			Total (excluding ZES)			
2	Kisangani	1,300,000	80,560	9,500,000	28,800,000	2,822,400
3	Goma	1,050,000	158,560	30,000,000	119,280,000	9,811,200
6	Mbandak	550,000	33,760	5,000,000	3,840,000	576,000
26	Maluku	57,146	49,360	6,500,000	8,520,000	997,200
29	Mutwanga	54,849	176,120	84,000,000	358,384,000	49,014,000
49	Lubero	37,827	135,784	24,600,000	77,803,840	7,314,576
Total			634,144	159,600,000	596,707,840	70,535,376

Appendix 8 - Matrix of distances between cities in DRC

Distances from Capital City to Major Towns (km)	KINSHASA	MATADI	BANDUNDU	KANANGA	MBUJI MAYI	LUBUMBASHI	KINDU	BUKAVU	GOMA	KISANGANI	MBANDAKA
KINSHASA		355	490	1,105	1,283	2,317	2,033	2,660	2,709	2,624	3,192
MATADI	355		1,051	1,460	1,638	2,672	2,388	3,015	3,064	2,979	3,547
BANDUNDU	490	1,051		973	1,151	2,184	1,901	2,528	2,577	2,492	3,059
KANANGA	1,105	1,460	973		179	1,212	928	1,556	1,604	1,520	2,087
MBUJI MAYI	1,283	1,638	1,151	179		1,036	752	1,379	1,428	1,344	1,911
LUBUMBASHI	2,317	2,672	2,184	1,212	1,036		1,421	1,432	1,655	2,013	2,831
KINDU	2,033	2,388	1,901	928	752	1,421		627	841	591	1,878
BUKAVU	2,660	3,015	2,528	1,556	1,379	1,432	627		220	647	2,028
GOMA	2,709	3,064	2,577	1,604	1,428	1,655	841	220		856	2,237
KISANGANI	2,624	2,979	2,492	1,520	1,344	2,013	591	647	856		1,577
MBANDAKA	3,192	3,547	3,059	2,087	1,911	2,831	1,878	2,028	2,237	1,577	

The table was exported from the following website : https://lca.logcluster.org/democratic-republic-congo-23-democratic-republic-congo-road-network?utm_source=chatgpt.com

Appendix 9 - Carbon Finance detailed calculations

1. Carbon stocks in the Green Corridor

Estimates from global biomass datasets (Baccini et al., 2012; Saatchi et al., 2011) and regional refinements suggest aboveground carbon stock (AGC) values of:

- **150–250 tC/ha** in dense moist forests (e.g., Tshopo, Ituri, Équateur).
- **90–130 tC/ha** in degraded and semi-deciduous forests (e.g., Mongala, Maï-Ndombe).
- **Up to 1,400 tC/ha** in peatlands when considering belowground carbon (Dargie et al., 2017).

To estimate the total amount of carbon stored across the Corridor, we use spatially weighted averages of aboveground carbon density (AGCD) drawn from regional and global studies:

The objective of the corridor is to protect at least **an additional 100,000 km^2, of undisturbed forest** (out of the total 285,000 intact forest it covers of which more than 50,000 km^2 are already under conservation status), an area which and this estimate excludes wetlands and peatlands, savannahs, urban and agricultural zones, and focuses solely on forested areas eligible for carbon crediting under REDD+ or jurisdictional approaches.

Based on data from Baccini et al. (2012), Saatchi et al. (2011), and Dargie et al. (2017), we apply a **conservative average of 180–200 tC/ha** for the Corridor's mix of intact and degraded primary forest.

Considering 1 tonne of carbon = **3.667 tonnes of CO_2**, therefore:

- 180 tC/ha × 3.667 = **660 tCO_2/ha**
- 200 tC/ha × 3.667 = **733 tCO_2/ha**

Low estimate: 10 million ha × 660 tCO_2/ha = **6.6 billion tCO_2**
High estimate: 10 million ha × 733 tCO_2/ha = **7.33 billion tCO_2**

However, **not all of this stock is creditable**. In carbon finance, only the portion of emissions that would be ***avoided*** relative to a projected baseline can be claimed as carbon credits. Also, to reflect *realistic accessible potential*, we discount heavily for non-creditable areas, inaccessibility, and policy constraints.

Applying a **70% ineligibility discount** (common in jurisdictional REDD+ calculations due to land-use limitations, non-forest patches, and MRV buffers):

- 6.6 to 7.3 billion tCO_2 × 30% = **~2.0 to 2.2 billion tCO_2** of potential **creditable and measurable carbon stock**.

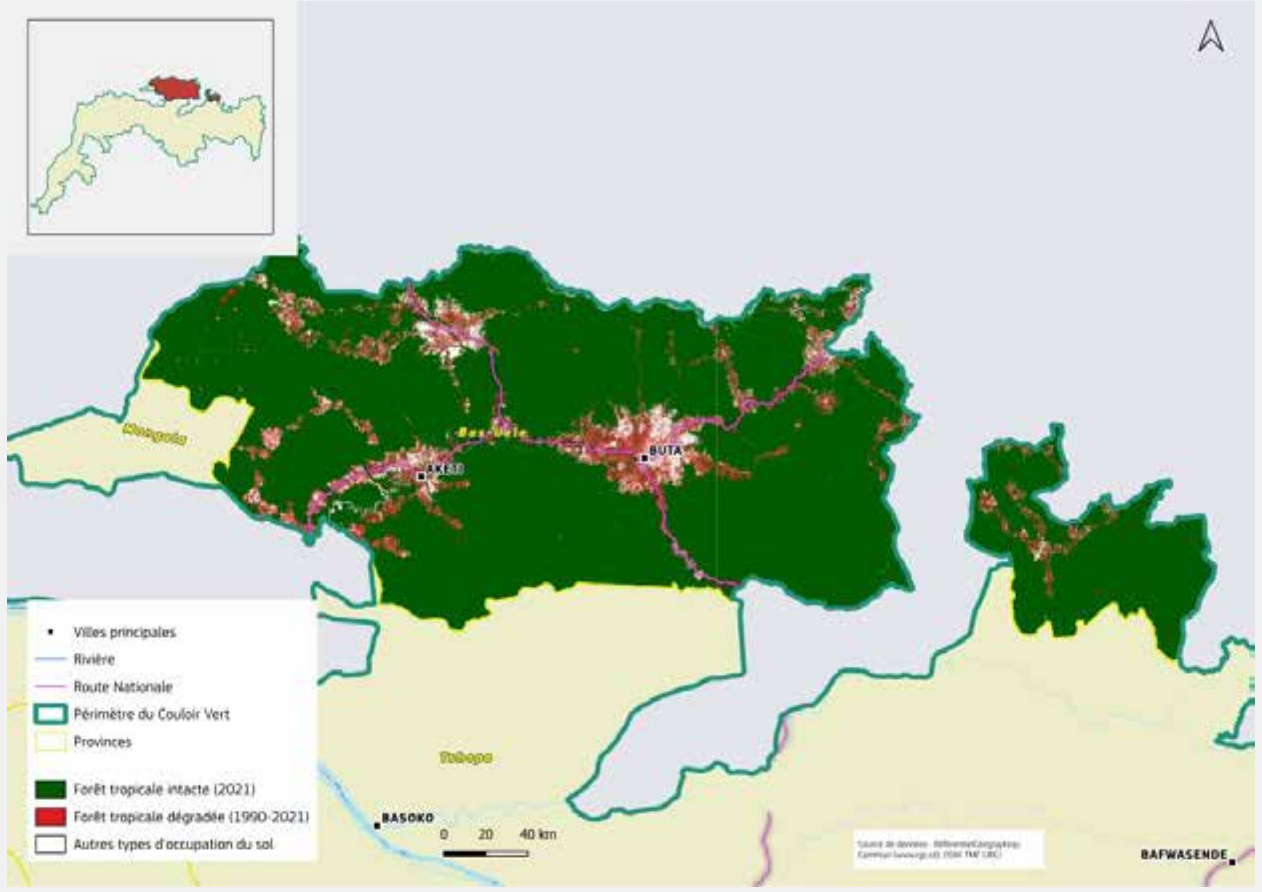
This aligns with conservative jurisdictional estimates used in countries like Colombia, Peru, and Guyana when calculating realistic mitigation supply under ART-TREES or LEAF frameworks.

Note: These estimates include **aboveground biomass only**, and exclude:

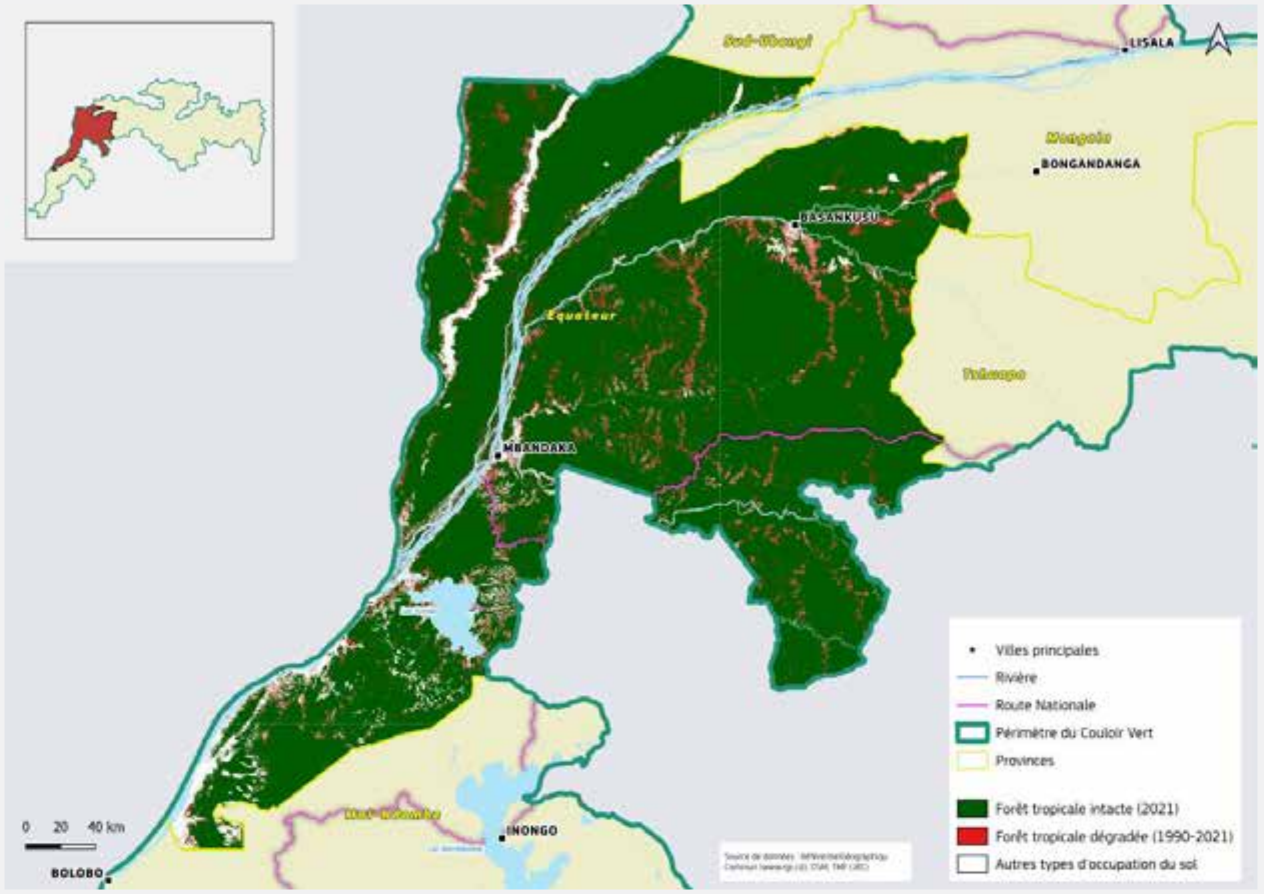
- Belowground root biomass (~15–25% of AGB)
- **Peatland carbon**, which in the Cuvette Centrale can exceed **1,000 tC/ha** in soil organic matter. Including peatlands could raise the total carbon stock by several hundred million tonnes, but these pools are often excluded from current methodologies due to higher uncertainty and permanence risks.

Appendix 10 - Maps of deforestation by province

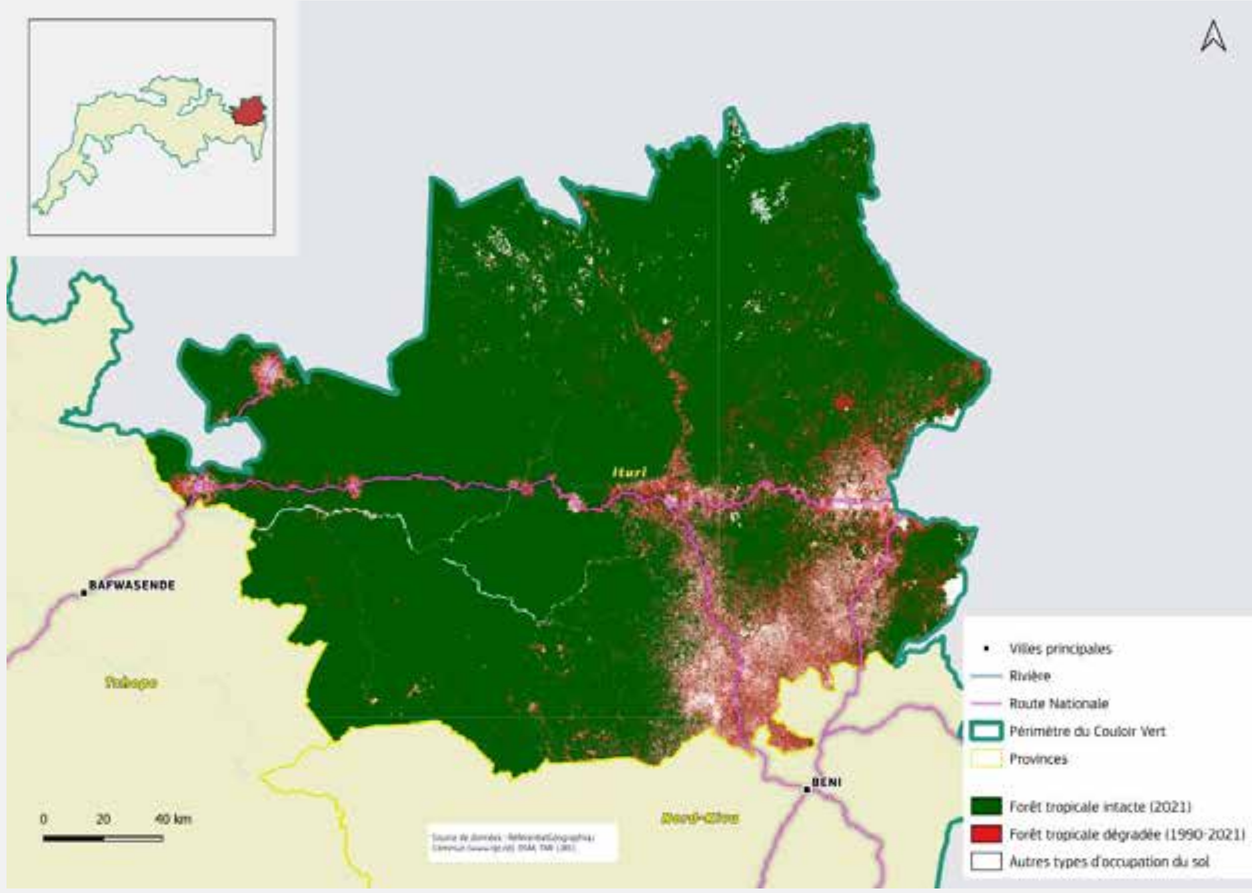
Bas-Uele



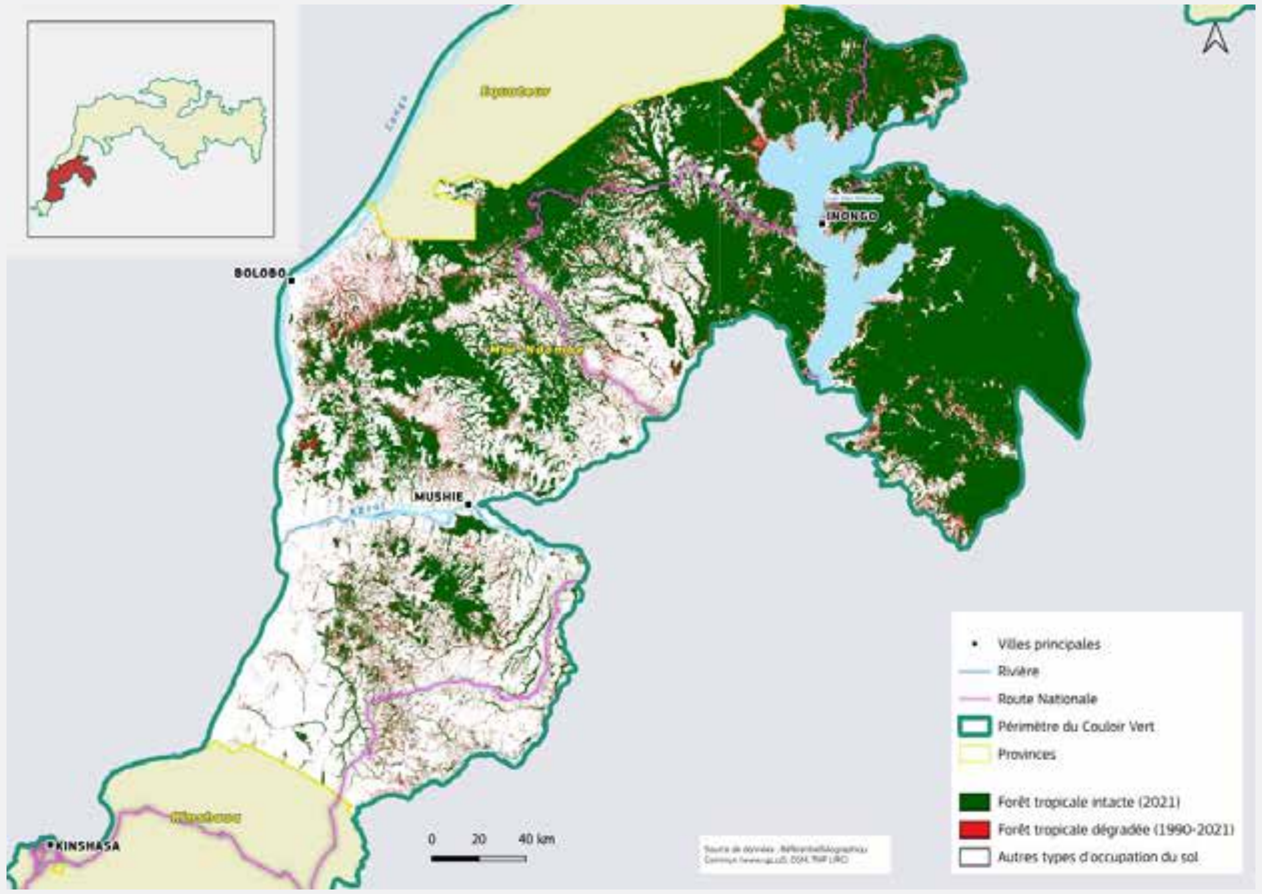
Equateur



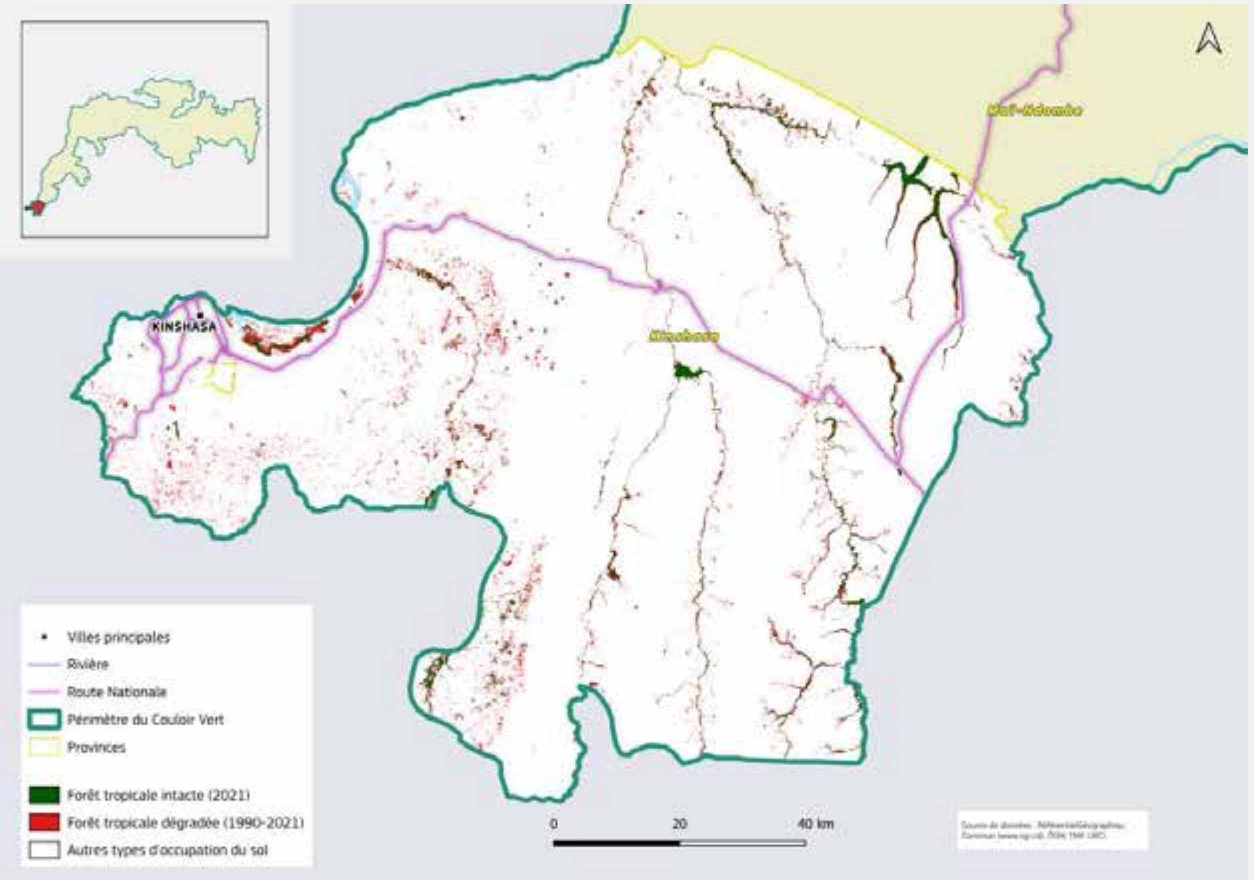
Ituri



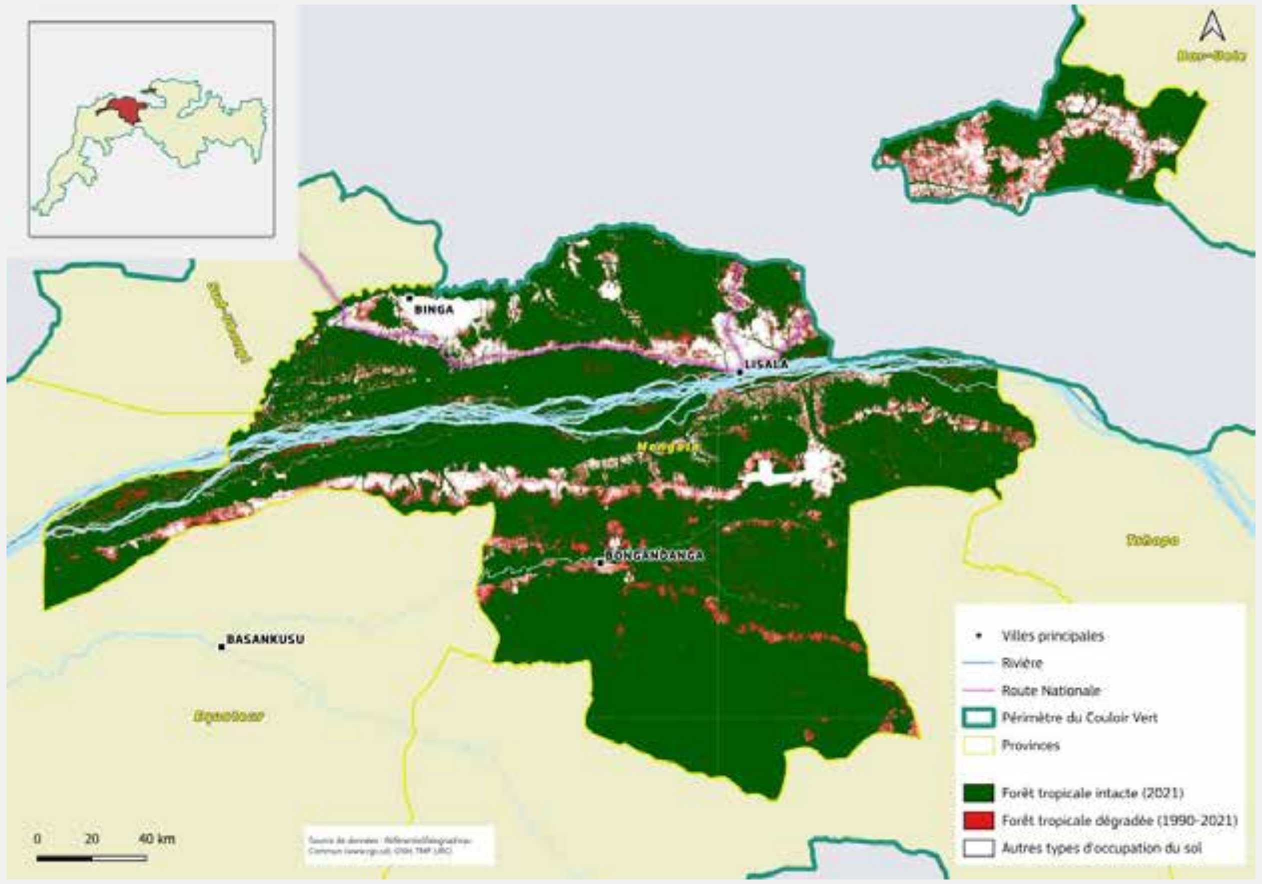
Mai-Ndombe



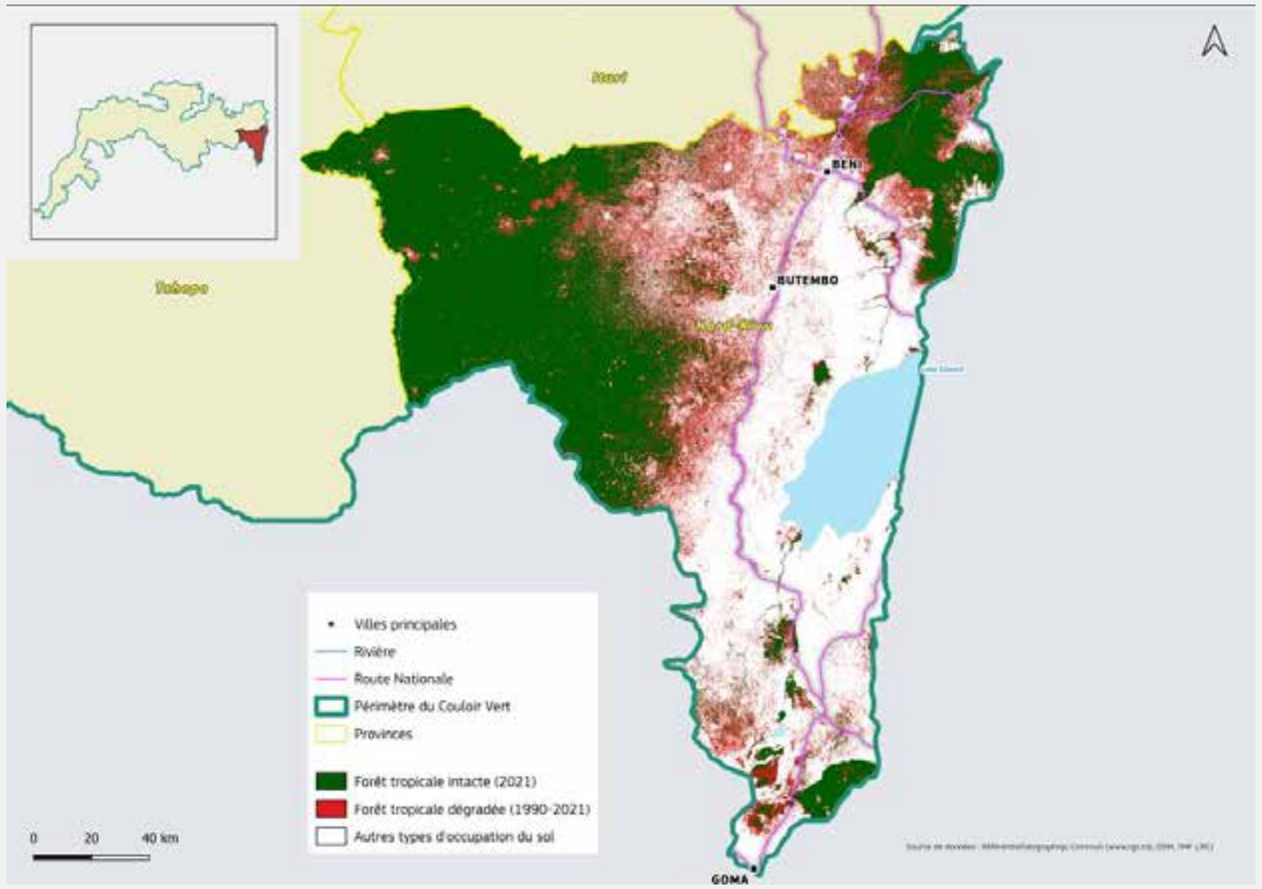
Kinshasa



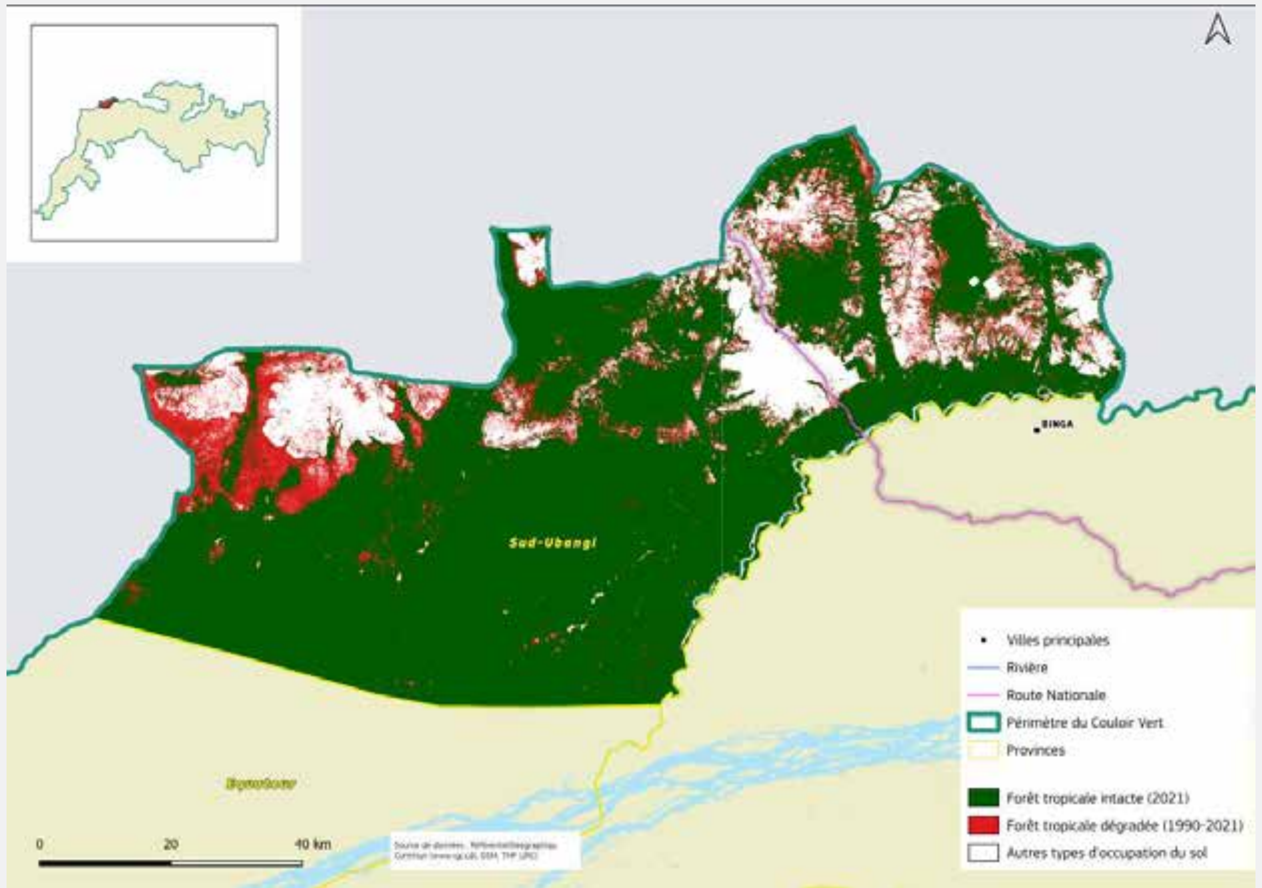
Mongala



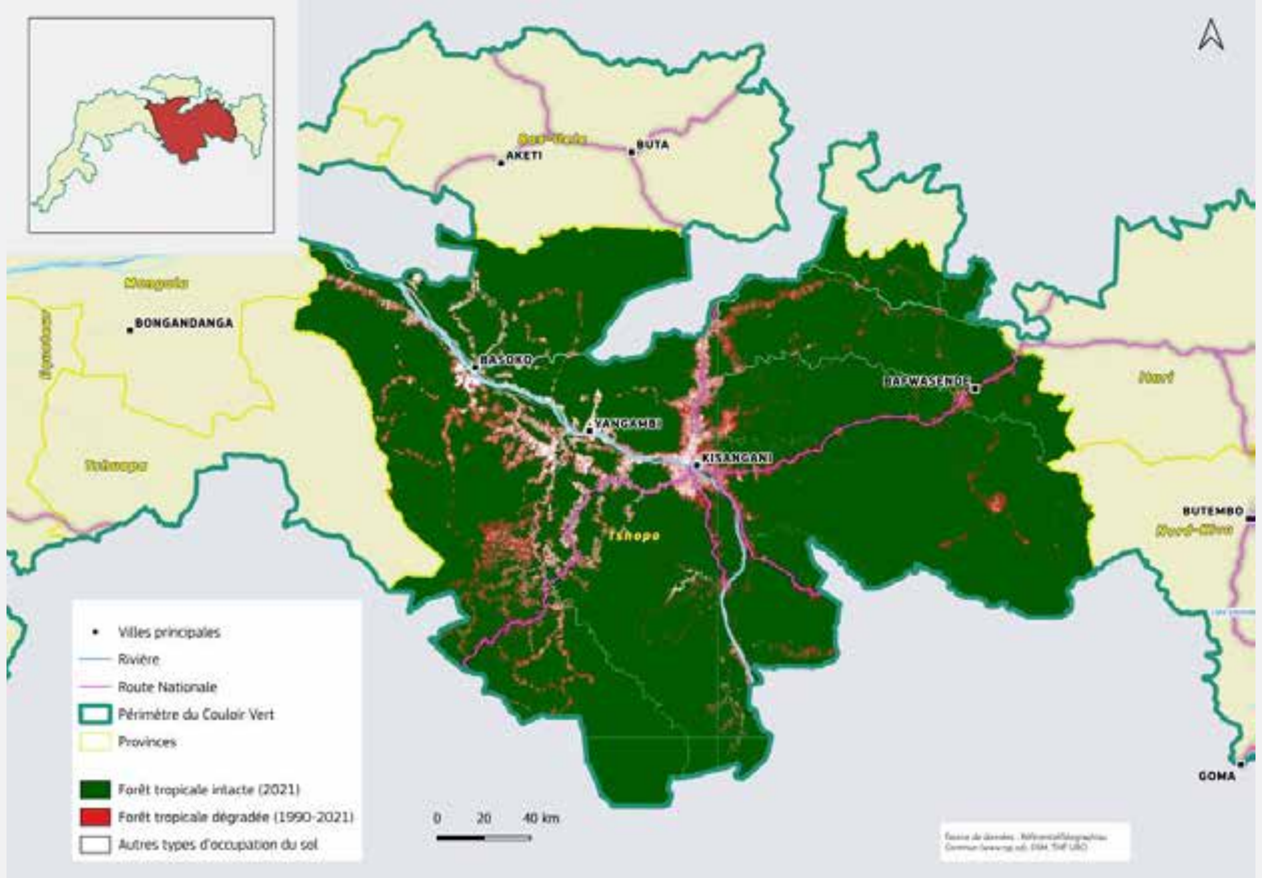
Nord-Kivu



Sud-Ubangi



Tshopo



Tshuapa