

ESTIMATING THE GREENHOUSE GAS EMISSION POTENTIAL DUE TO CONSTRUCTION WORK ON THE 225 kV SEGOU - BAMAKO HIGH VOLTAGE BI-TERNAL ELECTRIC LINE IN MALI IN A CONTEXT OF CLIMATE CHANGE

ABSTRACT

The aim of this study is to assess the carbon emissions resulting from the construction of the power line linking Bamako to Ségou. It focuses on direct emissions, more specifically those linked to the degradation and destruction of the vegetation cover in the project right-of-way. To collect the data, surveys were set up on the project right-of-way, through which 3302 trees were inventoried in situ at the three sites. Circumference was measured at 1.30 m from the ground surface. Allometric equations for direct biomass estimation were used as a predictor of tree diameter. Emission factors were then used to estimate the potential greenhouse gas emissions resulting from tree felling during power line construction. The standard error associated with the carbon fraction in dry biomass was calculated. In the Ségou, Koulikoro and Dioïla project areas, there are a number of plant species that provide local populations with various ecosystem services, including micro-climate regulation through carbon sequestration or absorption of atmospheric CO₂. The implementation of the project will undoubtedly result in the felling of these trees. This felling will generate emissions of 22.11 t.eqCO₂/ha in Ségou, 16.56 t.eqCO₂/ha in Koulikoro and 15.43 t.eqCO₂/ha in Dioïla. Across Ségou, Koulikoro and Dioïla, the trees in the project right-of-way represent a reservoir of 34.04 t/ha of above-ground woody biomass. This biomass represents a carbon stock of around 16.58 t.C/ha. This carbon stock will be transformed into a carbon source with emissions of 60.78 t.eqCO₂/ha if the trees in the power line right-of-way are systematically felled. Mitigation measures are therefore urgently needed, with compensatory reforestation areas planted with species with high carbon sequestration potential.

Keywords: Mali, Greenhouse gas emission potential, power lines, emissions accounting, carbon, carbon dioxide

1. INTRODUCTION

In Mali, as in all developing countries, the energy sector plays a crucial role in the provision of basic social services. However, it has to be said that the country's energy system is still in a state of disrepair, which is slowing down its development. In fact, electrical energy is the lifeblood of income-generating opportunities in all development sectors, notably agriculture, agri-food processing, light and heavy industry, etc.

To develop its energy sector, the Malian government adopted a policy in 2006 aimed at improving the operational efficiency of the existing power system and increasing access to modern energy services. This policy has benefited from the financial support of several donors, one of the most recent of which is a \$150 million financing agreement for the electrification of the city of Bamako and its outskirts. The 2016-2025 action plan, based on the Optimal Investment Master Plan (PDIO) for the electricity sub-sector drawn up in 2008 and updated for the 2015-2035 period, calls for the construction of a 225 kV line linking Bamako to Ségou. The implementation of such a project must take into account

environmental and social aspects in order to best preserve the biophysical and socio-economic environment for sustainable and harmonious development (World Bank, 2019).

Indeed, the corridors of the power lines to be rehabilitated and reinforced are often occupied by human installations, with all the risks of electrocution and impacts from the electromagnetic waves emitted by the lines. For the new lines to be created, including the Ségou-Bamako line, the corridor to be identified is certainly occupied by fields and dwellings of all kinds. It is therefore essential to apply the environmental and social provisions in force for the project, in order to identify and assess the impact of the line's construction work on the environmental components and socio-economic framework of the localities crossed. Accounting for carbon emissions provides an essential basis for assessing efforts to achieve "peak carbon dioxide emissions" and "carbon neutrality" objectives, which can contribute to the implementation of the new power system [Shu, Y.B. et al., 2021].

The construction of the Ségou-Bamako line requires the accounting of carbon emissions during the construction phase. Most carbon emissions from conventional power systems come from the combustion of fossil fuels during electricity generation [Kang, C. et al., 2015]. As a result, current research into carbon accounting in the electricity sector focuses mainly on the electricity generation phase [Ge, Z. et al., 2023]. In the future, the proportion of clean power generation will continue to increase [Wei, W., et al., 2020], leading to a significant reduction in carbon emissions during the power generation phase. However, the proportion of carbon emissions from the construction phase of electricity transmission and transformation projects will continue to increase in overall power system emissions [Wei, W., et al., 2020]. Therefore, research into accounting systems for carbon emissions during the construction phase of power transmission and transformation projects is of great importance in establishing a useful database for carbon emissions in the power system.

In existing research, carbon emissions have mainly been calculated at building level only. To date, very few detailed calculations of carbon emissions during the construction process of electrical equipment have been carried out.

The accounting pool is divided into three stages based on the characteristics of the power line and substation construction process, namely generation, transmission and construction. The aim of this study is to assess the carbon emissions resulting from the construction of the Bamako-Ségou power line. It focuses on direct emissions, more specifically those linked to the degradation and destruction of vegetation cover on the project right-of-way.

2. MATERIAL AND METHODS

2.1 Presentation of the project's receiving environment

Mali is a Sahelian country, with variations from north to south, from arid desert zones to humid Sudanian zones, passing through semi-arid sectors. Geomorphological, geological and biological forms have adapted to the varying aridity of the climate in different parts of the country.

The corridor of the chosen power line crosses a receiving environment whose characteristics are just as varied according to the regions crossed. The line crosses the regions of Koulikoro, Ségou and Dioïla (Figure 1).

The study area is located in the Sahelian zone, and therefore has a climate characterized by two (2) seasons: a dry season and a rainy season. The Ségou region is drained by the waters of the Niger River, which crosses the region in a roughly south-north direction, and the Bani River to the south of Ségou. The Bani and Niger rivers are very important water

currents, covering a watershed network of around 300 km. These rivers also offer enormous hydro-agricultural potential (Markala dam and Talo weir in operation).

Natural factors affecting air quality are largely due to the production and transport of particles by vehicles on the RN6, as well as natural phenomena such as the harmattan. Air quality degradation factors in the area are also anthropogenic (bush fires are very frequent in the area). Potential receptors in the area are the villages crossed by the high-voltage line and the immediate vicinity of the project.

The study area is characterized by a gently sloping relief made up of sandy, alluvial, silty and clayey plains and lowlands suitable for rice growing and livestock farming. The geology is represented by loose sandy-clay formations of the intercalary and terminal Continental (Quaternary). The Upper Cambrian Koutiala sandstone borders the southern part of the Segou region. The lithology is also marked by Quaternary surface formations consisting mainly of old and recent alluvial deposits, dunes and sandy areas frequently encountered in the Macina and Niono circles. In the Ségou region, there are 9 types of soil: dead and flattened dunes, flattened dunes, plain soils (2 types), lateritic cuirass soils, hydromorphic soils (lightly or not flooded), regularly flooded hydromorphic soils, rocky soils and special soils.

UNDER PEER REVIEW

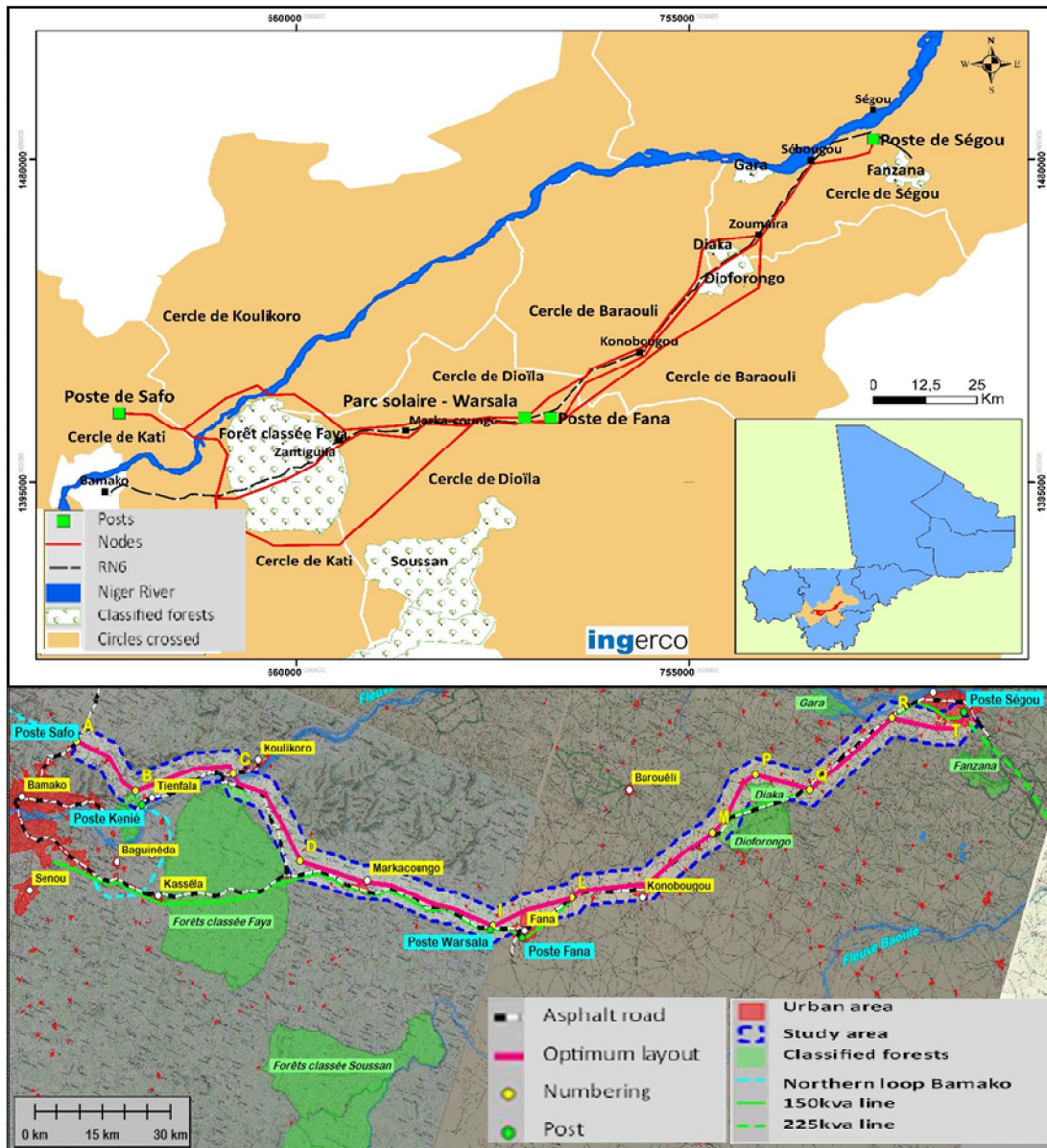


Fig.1. Geographical location of the project's receiving environment

The project is located in six (6) communes in the Ségo region, which, like other communes in Mali, have experienced rapid demographic growth over the past two decades, with an estimated population of 433,725 in 2023. Ségo is the most populous commune in the zone, with around 204,850 inhabitants. It should be noted, however, that the rural exodus is having a considerable impact on these localities.

The economic activities of the study area's populations are essentially based on petty trade, fishing, agriculture (market gardening), livestock breeding, industry and handicrafts. Data collected in the field indicate the following statistics for land use units: 2,335,956.38 m² of fields, 1,676.29 m² of physical structures (wells, henhouses, septic tanks, toilets, basements), 5,195 m² of empty plots and 5,484.42 m² of cement buildings, 1,478.94 m² of

banco buildings, 4,639.60 ml of banco fences, 1,780 ml of cement fences, 150 m² of mosques and 1,672.34 m² of mango plantations.

2.2 Equipment used

Data collection and processing equipment includes:

- a GPS for geographic coordinates;
- a decameter for measuring tree circumference;
- a camera to capture images in the field;
- Excel 2016 software for data processing.

2.3 In situ surveys

The observation unit is the project right-of-way. Tree circumference is the main dendrometric data collected. An exhaustive and systematic tree inventory was carried out in the Ségou, Koulikoro and Dioïla localities. Data and analyses at right-of-way level are extrapolated to the surface area of one hectare to estimate biomass.

A total of 3,302 trees were inventoried **in situ** at the three sites. Circumference was measured at 1.30 m from the ground surface.

2.4 Method for estimating above-ground woody biomass (Ba)

In forestry, several models can be used to estimate tree biomass. *Firstly*, allometric equations for direct biomass estimation, using predictors such as diameter, height, crown dimensions, volume and tree biomass.

Secondly, we note indirect methods that use a cubage rate to convert diameter, and possibly trunk height, into trunk volume and then take into account wood density to convert trunk volume into trunk biomass. The latter is then extended to total above-ground biomass *via* a biomass expansion factor [Panzou *et al.*, 2016; Maliro *et al.*, 2010].

This research has opted for the use of allometric equations for direct biomass estimation, using tree diameter as a predictor.

As the research area is located in the Sudanian domain, where the climate is tropical with an average rainfall of less than 1,500 mm/year, the allometric equation of Mbow *et al.* [2014] is best suited to such climatic conditions, and was therefore used to estimate woody above-

ground biomass. The formula of this model is: $B_a = 1,929 \times D + 0,116 \times D^2 + 0,013 \times D^3$

With Ba: Above-ground biomass in kg, D: Diameter measured at breast height (cm).

2.5 Estimated CO₂ emission potential

There are two main approaches to accounting for greenhouse gas emissions: the calculation approach and the measurement approach. The former can be divided into two categories: the method based on carbon emission factors and the method based on ecological balance analysis. Of these two methods, the measurement approach requires on-site measurement data of emission sources, which enables precise calculation results to be obtained. Given the complex nature and long duration of power line and substation construction work, as well as project volume analysis, the use of the carbon emission factor method for estimating emissions is more appropriate [Gao, H., *et al.*, 2023]. The carbon emission factor method is widely used and simple to implement. Therefore, this method is adopted in the present research to estimate the potential carbon emissions due to tree felling in the right-of-way of the transmission line construction project.

To calculate the above-ground biomass losses that will result from the felling of trees in the project right-of-way, emission factors in CO₂ equivalent are calculated using the following equation:

$$EF = B_a \times FCFC_{(Ba)} \times FCC_{(eqCO_2)}$$

EF: emission factors t.eq CO₂ /ha; *B_a* : above-ground biomass in t.MS; *FCFC_(Ba)* : conversion factor for the carbon fraction of biomass equal to 0.487 proposed by Gendehou *et al.* (2012).

FCC_(eq CO₂): Conversion factor from Carbon to CO₂ equivalent equal to 44/12.

2.6 Uncertainty in estimating above-ground woody biomass and CO₂

The standard error associated with the carbon fraction in dry biomass (FC) is 0.206 (Réjou-Méchain *et al.*, 2017). The 95% confidence interval around FC is therefore ± 1.96. Since carbon stock is the product of biomass (*B_a*) and FC, the error on carbon stock is estimated by following the classic rule of error propagation in the case of a product of uncertain quantities:

$$Ec = Ba \times \sqrt{\left(\left(\frac{EBa}{Ba}\right)^2 + \left(\frac{EFC}{FC}\right)^2\right)}$$

With *EC*: error on carbon stock (tC/ha), *EBa*: error on above-ground biomass *B_a* (in tMS/ha) and *E*: error on carbon fraction in dry biomass (in tMS/ha).

3. RESULTS AND DISCUSSION

Within the project area in Ségou, Koulikoro and Dioïla, there are a number of plant species that provide local populations with various ecosystem services, including microclimate regulation through carbon sequestration or absorption of atmospheric CO₂ (Table 1).

Table 1: Floristic species in the Ségou project right-of-way

Scientific name	Bambara name	Status	Number	Di_moy (m)	Ba (tMS/ha)	C (t/ha)	EF (t.eqCO ₂ /ha)
<i>Vitellaria paradoxa</i>	Shi	EIP	1053	2,47	7,872	3,834	14,057
<i>Adansonia digitata</i>	Zira	EIP	235	2,84	2,820	1,373	5,036
<i>Acacia albida</i>	Balanzan	EIP	232	1,58	0,480	0,234	0,857
<i>Tamarindus indica</i>	Ntomi	EIP	23	2,58	0,337	0,164	0,602
<i>Manguifera indica</i>	Mangoro	EVE	10	2,6	0,233	0,114	0,417
<i>Ficus platyphylla</i>	N'kaba	FR	1	2,95	0,216	0,105	0,385
<i>Parkia biglobosa</i>	Nèrè	EIP	11	2,48	0,210	0,102	0,375
<i>Ficus gnafalocarpa</i>	Toroba	FR	1	1,93	0,064	0,031	0,114
<i>Borassus aethiopum</i>	Sébé	EPP	42	1,17	0,046	0,023	0,083
<i>Bombax costatum</i>	Bumbu	EPP	3	1,31	0,022	0,011	0,040
<i>Azadirachta indica</i>	Neem	BO	11	1,12	0,019	0,009	0,035
<i>Jatropha curcas</i>	Bagani	FR	434	0,4	0,014	0,007	0,025
<i>Anacardium occidentale</i>	Sômô	EVE	23	0,88	0,013	0,007	0,024
<i>Lannea microcarpa</i>	Mpékuba	FR	4	1,02	0,011	0,005	0,020
<i>Annona squamosa</i>	Sunsun	EVE	2	0,97	0,009	0,004	0,015

<i>Balanites aegyptiaca</i>	Zèguènè	BF	3	0,93	0,008	0,004	0,014
<i>Ziziphus mauritiana</i>	N'tômônô	FR	25	0,5	0,003	0,001	0,005
<i>Eucalyptus camaldulensis</i>	Mantilatun yiri	BO	75	0,42	0,003	0,002	0,006
<i>Tectona grandis</i>	Tèki	BO	1	0,55	0,001	0,001	0,003
			2188	Sum	12,38	6,03	22,11
				Average	0,65	0,32	1,16
				Deviation	1,86	0,91	3,32
				± 95% CI	1,04	0,72	1,39
Di _i mean: Mean diameter; Ba: Above-ground biomass; C: Carbon; EF: Emission factor; t.eqCO ₂ /ha: Tonne of carbon dioxide equivalent per hectare, ± 95% CI: Uncertainty EIP: Espèce Intégralement Protégée; EPP: Espèce Partiellement Protégée; BO: Bois d'œuvre; FR: Fruitier; EVE: Espèces à valeur économique, BF: Bois de feu.							

Source: 2023 field survey

A total of 19 species have been identified in the Ségou region, including 5 fully protected species (EIP), 2 partially protected species (EPP), 3 species with economic value (EVE), 3 species used as timber (BO), 5 fruit species (FR) and one firewood species (BF).

Analysis of Table 1 shows that the trees in the project right-of-way in Ségou represent a reservoir of 12.38 tonnes of biomass per hectare, i.e. a carbon stock of around 6.03 t/ha. Implementation of the project will undoubtedly result in the felling of these trees. This felling will generate emissions of 22.11 t.eqCO₂ /ha. These values contain disparities between the different species. The felling of *Vitellaria paradoxa* trees will generate 14.06 t.eqCO₂ /ha, while the felling of *Tectona grandis* trees will result in almost 0.003 t.eqCO₂/ha.

Table 2 shows the plant species in the project right-of-way in Koulikoro.

Table 1 Floristic species in the project area in Koulikoro

Scientific name	Bambara name	Status	Number	Di _i moy (m)	Ba (tMS/ha)	C (t/ha)	EF (t.eqCO ₂ /ha)
<i>Manguifera indica</i>	Mangoro	EVE	209	2,6	4,69	2,285	8,38
<i>Vitellaria paradoxa</i>	Shi	EIP	235	2,12	2,84	1,381	5,06
<i>Adansonia digitata</i>	Zira	EIP	25	2,90	1,21	0,592	2,17
<i>Parkia biglobosa</i>	Nèrè	EIP	2	2,45	0,33	0,162	0,60
<i>Bombax costatum</i>	Bumbu	EPP	6	1,22	0,05	0,024	0,09
<i>Citrus sinensis</i>	Lemourouba	EVE	549	0,40	0,04	0,021	0,08
<i>Borassus aethiopicum</i>	Sébé	EPP	6	1,17	0,04	0,021	0,08
<i>Anacardium occidentale</i>	Sômô	EVE	9	0,97	0,03	0,014	0,05
<i>Ziziphus mauritiana</i>	N'tômônô	FR	85	0,5	0,02	0,007	0,03
<i>Eucalyptus camaldulensis</i>	Mantilatun yiri	BO	56	0,42	0,01	0,003	0,01
<i>Jatropha curcas</i>	Bagani	FR	160	0,40	0,01	0,007	0,02
<i>Carica papaya</i>	-	EVE	205	-	-	-	-
<i>Psidium guajava</i>	-	EVE	5	-	-	-	-
<i>Musa sp</i>	Namassa	EVE	20	-	-	-	-
			1572	Sum	9,27	4,52	16,56

	Average	0,84	0,41	1,51
	Deviation	1,54	0,75	2,76
	± 95% CI	0,99	0,69	1,33

Di_moy: Average diameter; Ba: Above-ground biomass; C: Carbon; EF: Emission factor; t.eqCO₂ /ha: Tonne of carbon dioxide equivalent per hectare,
EIP: Espèce Intégralement Protégée; EPP: Espèce Partiellement Protégée; BO: Bois d'œuvre; FR: Fruitier; EVE: Espèces à valeur économique.

Source: 2023 field survey

A total of 14 species have been identified in the Koulikoro region, including 3 fully protected species (EIP), 2 partially protected species (EPP), 6 species of economic value (EVE), 1 species used as timber (BO), 2 fruit species (FR).

Analysis of Table 2 shows that in Koulikoro, the trees in the project right-of-way represent 9.27 tonnes of biomass per hectare, or a carbon stock of around 4.52 t/ha. The greenhouse gas emission potential of the trees in the Koulikoro right-of-way is estimated at 16.56 t.eqCO₂ /ha. The felling of these trees will transform this carbon sink into a carbon source. These values contain disparities between the different species. Indeed, felling *Mangifera indica* trees will generate 8.38 t.eqCO₂ /ha, while felling *Jatropha curcas* trees will result in almost 0.02 t.eqCO₂ /ha. Table 3 shows the plant species within the project's right-of-way in Dioïla.

Table 3: Plant species within the project's right-of-way in Dioïla

Scientific name	Bambara name	Status	Number	Di_moy (m)	Ba (tMS/ha)	C(t/ha)	EF (t.eqCO ₂ /ha)
<i>Vitellaria paradoxa</i>	Shi	EIP	1142	2,12	6,35	3,090	11,33
<i>Adansonia digitata</i>	Zira	EIP	54	2,90	1,00	0,486	1,78
<i>Mangifera indica</i>	Mangoro	EVE	52	2,6	0,70	0,340	1,25
<i>Parkia biglobosa</i>	Nèrè	EIP	21	2,45	0,32	0,157	0,58
<i>Ficus gnafalocarpa</i>	Toroba	FR	6	1,93	0,10	0,047	0,17
<i>Tamarindus indica</i>	Ntomi	EIP	4	1,58	0,05	0,023	0,09
<i>Borassus aethiopicum</i>	Sébé	EPP	23	1,17	0,04	0,018	0,07
<i>Bombax costatum</i>	Bumbu	EPP	9	1,22	0,03	0,013	0,05
<i>Azadirachta indica</i>	Neem	BO	13	1,12	0,02	0,012	0,04
<i>Elaeis guineensis</i>	N'ten	EVE	3	1,12	0,02	0,008	0,03
<i>Eucalyptus camaldulensis</i>	Mantilatun yiri	BO	181	0,42	0,01	0,004	0,02
<i>Lannea microcarpa</i>	Mpékuba	FR	1	1,02	0,01	0,005	0,02
<i>Ziziphus mauritiana</i>	N'tômônô	FR	75	0,5	0,01	0,003	0,01
<i>Carica papaya</i>	-	EVE	146	-	-	-	-
			1730	Sum	8,64	4,21	15,43
				Average	0,66	0,32	1,19
				Deviation	1,74	0,84	3,10
				± 95% CI	1,16	0,81	1,55

Di_moy: Average diameter; Ba: Above-ground biomass; C: Carbon; EF: Emission factor; t.eqCO₂ /ha: Tonne of carbon dioxide equivalent per hectare,

EIP: Espèce Intégralement Protégée; EPP: Espèce Partiellement Protégée; BO: Bois d'œuvre; FR: Fruitier

Source: Field survey, 2023

A total of 14 species were identified in the Dioïla region, including 4 fully protected species (EIP), 2 partially protected species (EPP), 3 species of economic value (EVE), 2 species used as timber (BO), 3 fruit species (FR).

Analysis of Table 3 shows that in Dioïla, the trees in the project right-of-way represent 8.64 tonnes of biomass per hectare, i.e. a carbon stock of around 4.21 t/ha. The greenhouse gas emission potential of the trees in the Dioïla right-of-way is estimated at 15.43 t.eqCO₂/ha. Felling these trees will transform this carbon sink into a carbon source. These values contain disparities between the different species. Indeed, felling *Vitellaria paradoxa* trees will generate 11.33 t.eqCO₂/ha, while felling *Ziziphus mauritiana* trees will induce almost 0.01 t.eqCO₂/ha.

A total of 5,490 trees have been identified in the project area, including 3,037 fully protected species (EIP), 89 partially protected species (EPP), 1,233 species of economic value (EVE), 340 species used as timber (BO) and 791 fruit trees (FR).

Overall, in the Ségou, Koulikoro and Dioïla localities, the trees in the project right-of-way constitute a reservoir of 34.04 t/ha of above-ground woody biomass. This biomass represents a carbon sink of around 16.58 t.C/ha. Felling the trees in the right-of-way will transform this carbon sink into a carbon source, with emissions estimated at 60.78 t.eqCO₂/ha. Compensatory measures must therefore be taken, with compensatory reforestation areas of 1.5 ha per locality, i.e. 4.5 ha planted with indigenous species with high sequestration potential or fast-growing species such as: *Gmelina arborea*, *Eucalyptus camaldulensis*, *Khaya senegalensis*, *Tectona grandis*. Longer transmission lines mean higher carbon emissions. Clearly, as the distance of lines increases, so does the need for construction materials and electrical equipment, such as overhead lines and pylons, leading to higher carbon emissions. By 2022, electricity generation will be responsible for around 40% of global CO₂ emissions. Of these electricity-related emissions, 73% come from coal-fired power plants, and 22% from gas-fired power plants (<https://www.planete-energies.com/fr/media/article/production-deelectricite-ses-emissions-co2>).

Major new solar and wind power projects are intended to demonstrate the low-carbon trajectory that the African continent could “directly” take to develop its electricity production. Analysts forecast 315 GW to 620 GW of new electricity capacity in Africa by 2030, with, in some scenarios, “a 7 to 12-fold increase” in the share of renewable energies excluding hydropower during this period. According to Ti Liu et al (2024), terrain has a significant impact on the carbon emissions intensity of line projects (carbon emissions per unit length of line, i.e. total carbon emissions divided by line length). When the proportion of swampy land is high in the line construction area, carbon emissions from construction projects are higher.

Wang et al. developed a life-cycle accounting model to analyze carbon emissions from the coal-electricity chain in China (N. Wang et al., 2018). They found that life-cycle carbon emissions are higher than direct emissions from coal-fired power generation by 10-13%. Yu et al. used life-cycle analysis to calculate the carbon emission coefficient for China's coal-to-electricity chain (Yu et al., 2014).

4. CONCLUSION

The aim of this study is to assess the carbon emissions resulting from the construction of the power line linking Bamako to Ségou. It focuses on direct emissions, more specifically those linked to the degradation and destruction of plant cover in the project area. In the project

right-of-way in Ségou, Koulikoro and Dioïla, there are several plant species that provide local populations with various ecosystem services, including micro-climate regulation through carbon sequestration or absorption of atmospheric CO₂. Implementation of the project will undoubtedly result in the felling of these trees. In all the localities of Ségou, Koulikoro and Dioïla, the trees in the project right-of-way constitute a carbon reservoir. Felling them will generate significant CO₂ emissions.

Estimating the GHG emission potential of the 225 kV Ségou - Bamako high-voltage power line is essential for informed decision-making. By integrating a rigorous analysis of environmental effects and adopting appropriate mitigation strategies, this project can not only meet local energy needs but also contribute to the fight against climate change. The implications of this research underline the need for a sustainable approach to energy infrastructure planning, combining economic growth with environmental responsibility.

The results show the need to integrate sustainable construction practices to minimize emissions. Furthermore, the use of local materials and the adoption of efficient construction technologies could significantly reduce carbon footprints. It is therefore important to:

- Use low-carbon materials.
- Integrate green technologies throughout the project life cycle.
- Establish a robust environmental management plan to monitor and mitigate emissions during construction and operation.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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