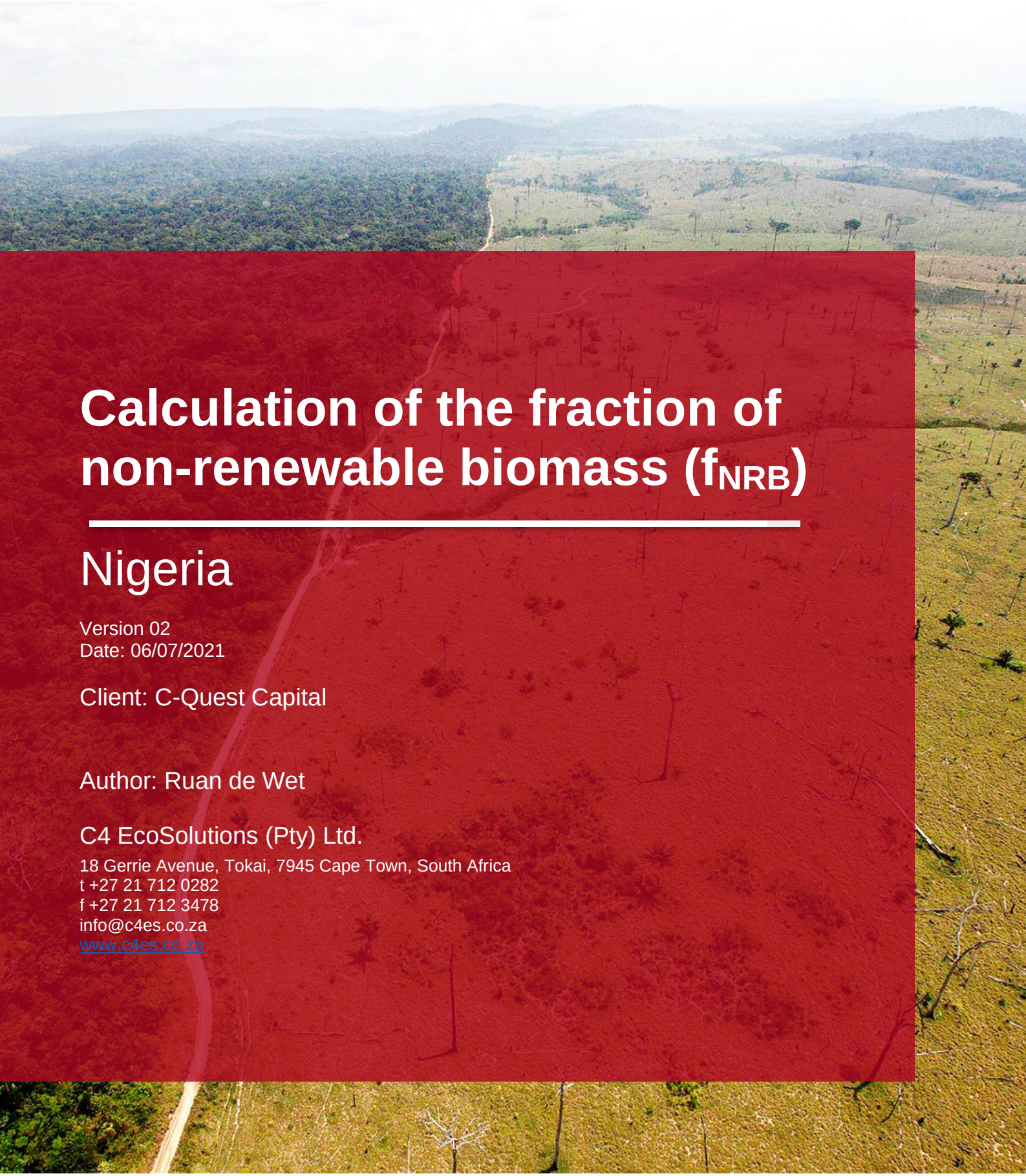

Calculation of the fraction of non-renewable biomass (f_{NRB})

Nigeria

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CARBON I CONSERVATION I CLIMATE I COMMUNITY

Operating at the forefront of the world's climate change and biodiversity challenges

1 Introduction

Carbon offset projects are being developed in Nigeria by C-Quest Capital under both the Clean Development Mechanism (CDM) and Climate Action Reserve (CAR) carbon credit certification schemes. These projects will distribute Improved Cooking Stoves (ICS) to households in project areas where it is anticipated that revenue will be generated through carbon credits gained from reduced fuel demand. The fraction of non-renewable biomass (f_{NRB}) is a critical variable in the calculation of emission reductions. To facilitate the implementation of the ICS projects, C4 EcoSolutions has been contracted to determine the f_{NRB} for Nigeria using the latest CDM methodologies and tools[1].

Nigeria is a country located in West Africa which is experiencing slow social and economic growth, despite rich reserves of oil and natural gas[2,3]. The lack of access to, and the poor quality of, alternative energy sources have led to an over-dependence on fuelwood and the increased pressure placed on forested land in the country. This over-dependence is exacerbated by the amount of poverty in the country, where more than 65% of the population live below the poverty line [2–4], and the country's limited capacity to produce sufficient electricity for the national energy demand. Electricity supply in Nigeria is erratic, with approximately 40% of the population connected to the national grid, leading to a high degree of reliance on fuelwood for activities such as cooking[3,5]. Fuelwood is used for cooking in more than 70% of households in Nigeria, which has led to consumption of fuelwood exceeding sustainable production. The demand for wood products to export has led to further increases in both legal and illegal wood harvesting[3]. This report seeks to determine the fraction of non-renewable biomass that is being harvested across Nigeria.

2 Estimating Nigeria's woody biomass consumption

Per capita domestic fuelwood consumption statistics are not publicly available for Nigeria or are not included in the national census. The estimation of domestic fuelwood consumption was, therefore, derived from the UN Statistics Division[6] and converted from cubic meters to metric tonnes using the FAO default conversion factor (Table 1).

The full extent of non-domestic wood consumption data for Nigeria is not clearly defined. The non-domestic fuelwood consumption estimates derived from the UN Statistics Division[6] have, therefore, been conservatively applied, disregarding the additional consumption likely occurring in the commercial sector (Table 1) by considering the final energy consumption value of the domestic as well as non-domestic fuel wood use for energy purpose. The fuelwood uses for commercial non energy purpose has also been disregarded on account of non-availability of clearly defined data on same. The total woody biomass consumption estimate for Nigeria is 149,568,225 t/yr.

Table 1. Total woody biomass consumption estimate (t/yr) for Nigeria.

Variable	Value	Source
Domestic & Non-Domestic fuelwood consumption (t/yr)		
Fuelwood consumption (m^3/yr)	206,301,000	UN Statistics Division[6]
Conversion factors		
Wood density (t/m^3)	0.725	FAO[7]
Total woody biomass consumption (t/yr)	**149,568,225**	**Calculated**

3 Estimating renewable biomass (RB), non-renewable biomass (NRB) and the fraction of non-renewable biomass (f_{NRB})

Geospatial data products for Nigeria were analysed in R[9–13] to estimate the renewable biomass. The forest and other wooded land cover for 2000 and 2018 was estimated using Hansen/UMD/Google/USGS/NASA[14] spatial data, which is derived from Hansen et al.[15], and disaggregated according to the FAO global ecological zones[16] (Figure 2). The total woody cover extent, including forests and other wooded areas, was calculated for each ecological zone (Figure 3), within the protected areas and within areas that are either accessible or geographically remote (Table 2).

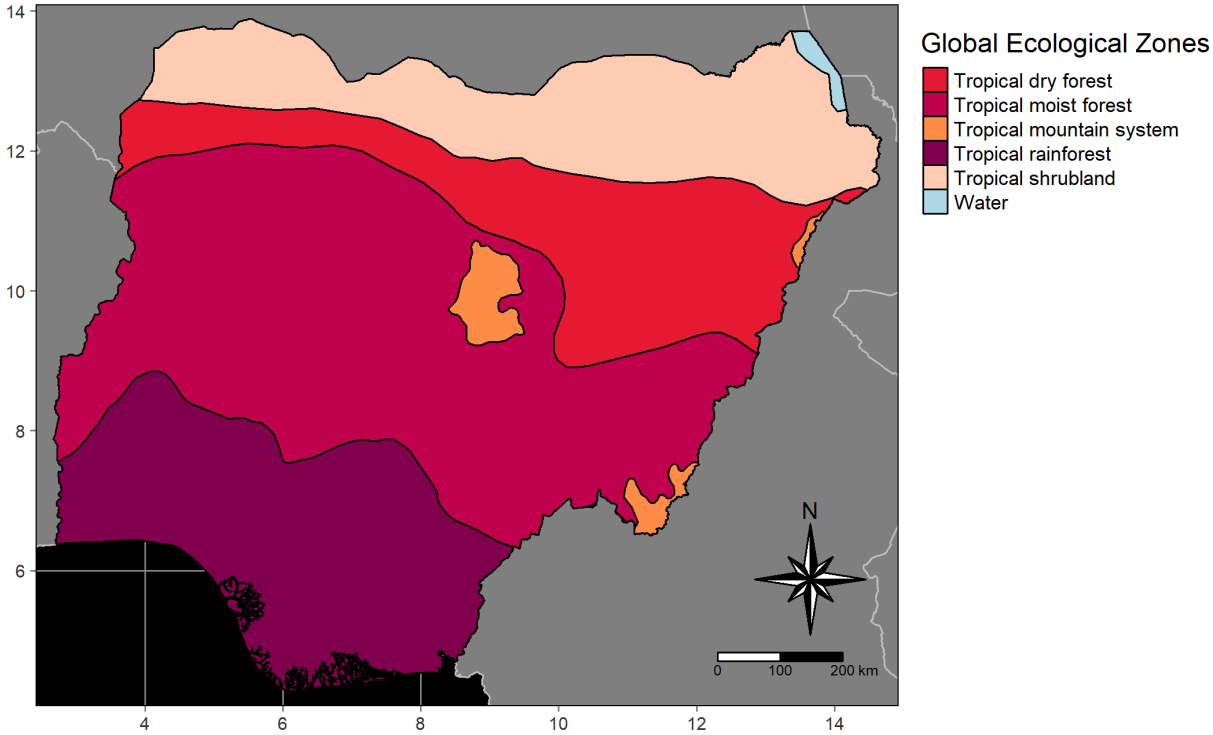

Figure 2. Distribution of the FAO Global Ecological Zones[16] within Nigeria.

Geographically remote areas were determined to be those beyond a harvestable distance from roads and settlements. Conservatively, it was assumed that forests and wooded areas adjacent to all roads within 2.5 km are harvestable, despite how geographically remote or inaccessible these roads may be. This threshold was determined based on the peer-reviewed literature on wood harvesting practices, both regionally and internationally, as described below.

Woody biomass density increases significantly as a function of distance from the edge of a settled area[17,18]. One of the most significant determinants of fuelwood harvesting is the walking distance to the source, with a mean harvesting distance estimated by one study to be 0.95 km[19]. Another study assessed households within 3.5 km of a forest boundary and found that distance alone is a sufficient predictor of resource use[20]. Nigerian households spend an average of 1.6 hours per day collecting fuelwood[21]. Assuming that the harvesting of fuelwood takes at least half of the time spent, and an average walking speed of 4 km/hr over uneven terrain, the average one-way walk distance to fuelwood source can be conservatively estimated to be less than 2.5 km. This estimate has been corroborated by studies in other African countries[22]. Forested areas beyond the harvestable distance of 2.5 km were therefore determined to be geographically remote. The total harvestable woody cover was estimated by subtracting the woody cover of the protected areas[7] and the woody cover of geographically remote areas from the total woody cover.

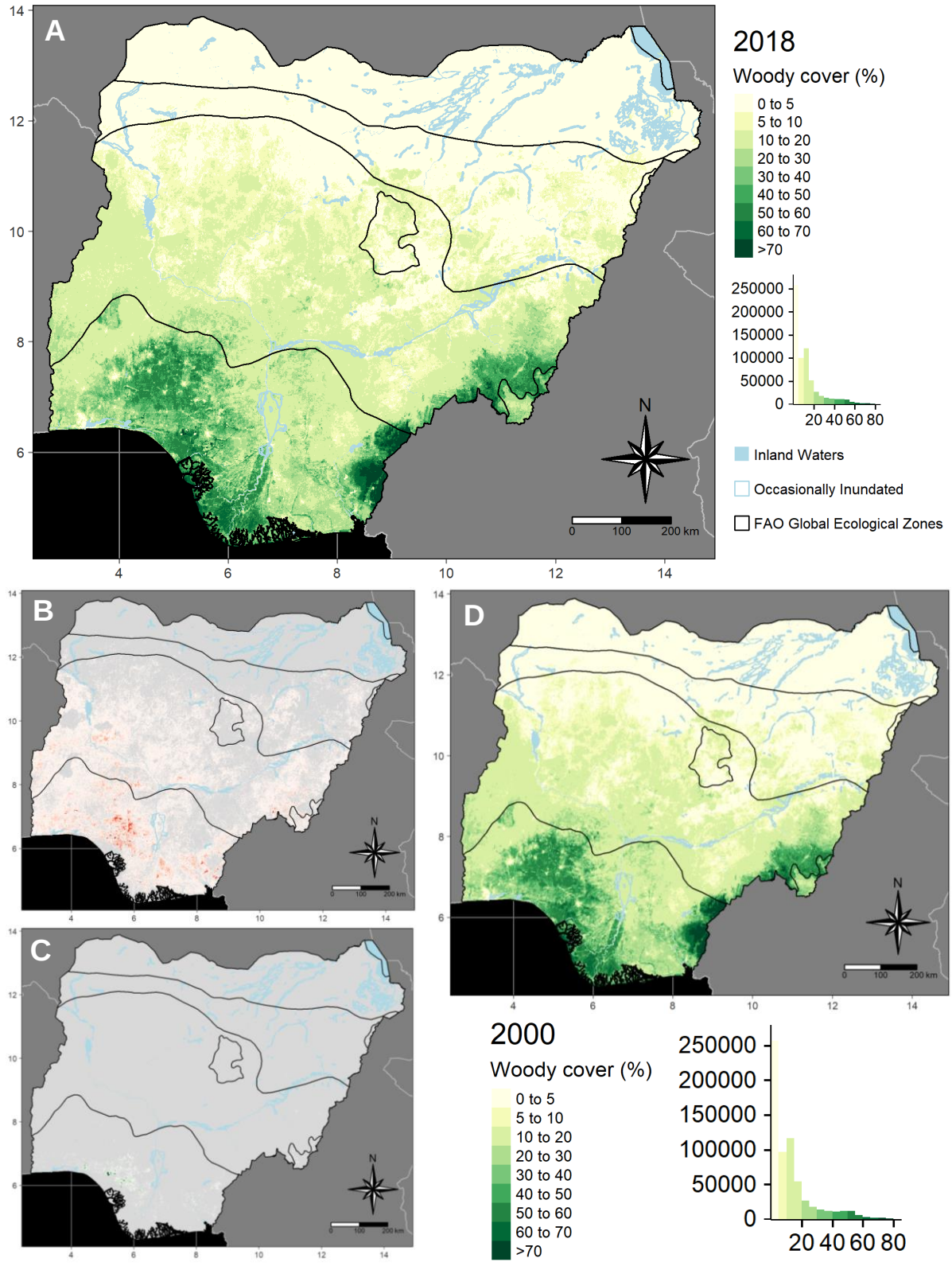

Figure 3. Distribution of woody cover in 2018 (A), woody cover loss since 2000 (B), woody cover gain since 2000 (C) and total woody cover in 2000 (D), based on Hansen/UMD/Google/USGS/NASA data[14].

Box 1

The fraction of harvested biomass that can be established as non-renewable biomass is the f_{NRB}. This fraction ranges between 0 and 1, where 0 indicates that 100% of harvested biomass is renewable (0% is non-renewable) and 1 indicates that 100% is non-renewable. The following equation is used to calculate f_{NRB}:

$$f_{NRB} = \frac{NRB}{NRB + RB} \quad (1)$$

Where:
f_{NRB} = Fraction of non-renewable biomass
NRB = Non-renewable biomass (t/yr)
RB = Renewable biomass (t/yr)

The quantity of non-renewable biomass (NRB) is the difference between the annual biomass consumption (H) and the quantity of renewable biomass (RB), calculated by the following equation:

$$NRB = H - RB \quad (2)$$

Where:
H = Total woody biomass consumption in the absence of project activity (t/yr)

Renewable biomass is the product of the mean annual increment of woody biomass growth and the total extent of the forest and other wooded areas of the country where wood extraction is not prohibited or geographically remote, calculated by the following equation:

$$RB = MAI \times (F - P) \quad (4)$$

Where:
MAI = Mean annual increment of woody biomass (t/ha/year)
F = Total extent of the forest and other wooded areas (ha)
P = Extent of the forest and other wooded areas where wood extraction is not permitted or is geographically remote (ha)

Limited data have been published on the growth rates of Nigerian forests, so the default age-weighted mean annual increment (MAI) estimates of each ecological zone, as reported by the IPCC[8], was used for this study. The average MAI estimates for Nigeria are 2.75, 1.90, 3.65, 5.55 and 0.68 t/ha/year for tropical dry forests, tropical moist forests, tropical mountain systems, tropical rainforests and tropical shrublands, respectively (Table 2). An area equivalent to 0.38% of Nigeria is categorized by the FAO global ecological zones as covered by water, but this doesn't perfectly align with the water bodies in the country. An average of the MAI estimates for the adjacent ecological zones were, therefore, applied to the woody cover included in this category.

Table 2. Forest and other wooded area total, protected and remote cover extent, mean annual increment and renewable biomass by ecological zone for Nigeria.

Ecological Zone	Total forest cover (ha)	Protected cover (ha)	Remote cover (ha)	MAI (t/ha/yr)	Renewable biomass (t/yr)
Tropical dry forest	490,508	34,493	298,078	2.75	434,327
Tropical moist forest	4,122,237	477,792	2,534,584	1.90	2,108,735
Tropical mountain system	249,240	63,350	134,293	3.65	188,328
Tropical rainforest	5,691,593	462,784	3,324,124	5.55	10,571,003
Tropical shrubland	140,637	8,652	67,847	0.68	43,292
"Water"	29,606	29,571	35	0.90	0
Total	**10,723,821**	**1,076,643**	**6,358,962**	**-**	**13,345,685**

The difference between woody biomass consumption and renewable biomass is considered to be non-renewable (Equation 2). Non-renewable biomass utilisation in Nigeria is, therefore, estimated to be 136,222,540 t/yr (Table 3).

The fraction of non-renewable biomass is the quotient of the non-renewable and the total biomass (Equation 1). The fraction of non-renewable biomass for Nigeria is, therefore, estimated to be 0.91 (Table 3).

Table 3. Summary of the fraction of non-renewable biomass (f_{NRB}) calculation for Nigeria.

Variable	Value	Source
Total woody biomass consumption (t/yr)	149,568,225	Table 1
Renewable biomass (t/yr)	13,345,685	Table 2
Non-renewable biomass (t/yr)	136,222,540	Calculated
Fraction of non-renewable biomass	**0.91**	**Calculated**

4 Conclusion

The calculated f_{NRB} of 0.91 indicates that the consumption of woody biomass within Nigeria is greater than the country's capacity to renewably, or sustainably, supply. This finding is supported by the negative annual rate of change of woody cover reported by the FAO[7] and the literature[2–5]. It can be concluded that a successfully implemented improved cooking stove (ICS) project has the potential to reduce the rate of degradation and deforestation in Nigeria by reducing the demand for woody biomass consumption.

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