Journal of Applied Life Sciences and Environment
https://jurnalalse.iuls.ro

USV 1842

Article
https://doi.org/10.46909/alse-583187
Vol. 58, Issue 3 (203) / 2025: 481-496

WOODY PLANT DIVERSITY AND CARBON STOCKS OF LIVE HEDGES IN HIGHLY DEGRADED AREAS IN THE WESTERN HIGHLANDS OF CAMEROON

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Received: Jul. 26, 2025. Revised: Oct. 21, 2025. Accepted: Oct. 24, 2025. Published online: Nov. 03, 2025

ABSTRACT. In the highlands agroecological zone of Cameroon, natural landscapes have disappeared in favour of other land use types, including live hedges (LHs), which are among the relics used to preserve biodiversity and enhance resilience to global change. However, the contribution of LHs to resilience remains unknown. Hence, the objective of this study was to characterise plant diversity and carbon stocks in LHs, emphasising their typology. Trees with diameters ≥ 5 cm were collected from 132 LHs of 50 m each along a linear system, i.e. a total sampled area of 6.6 km (16.5 ha). LH carbon stocks were estimated using allometric equations. Five LH types were identified, namely *Eucalyptus* hedge, *Markhamia* hedge, *Podocarpus* hedge, fir/pine hedge and mixed hedge. A total of 79 species belonging to 58 genera and 31

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Cite: Voumo, L.E.; Chimi Djomo, C.; Kitio Zangue, A.S.; Tabue Mbobda, R.B.; Kabelong Banoho, L.P.R.; Ngueguim, J.R.; Awazi, N.P.; Zapfack, L. Woody plant diversity and carbon stocks of live hedges in highly degraded areas in the western highlands of Cameroon. *Journal of Applied Life Sciences and Environment* **2025**, *58* (3), 481-496. https://doi.org/10.46909/alse-583187

families were identified in the LHs, with 8 (10%) being threatened according to the IUCN Red List. The species richness was significantly different between LHs (Kruskal–Wallis, $p < 0.001$), with the mixed LH having the most diversity (65 species). The Shannon–Wiener index showed low plant diversity in the LHs. Carbon stocks were estimated at 134.25 $tC.km^{-1}$ ($54.10tC.ha^{-1}$), which was significantly different among LHs (ANOVA, $p < 0.0001$). Given the potential of LHs in terms of diversity and carbon storage, emphasis should be placed on monitoring this agroforestry practice to ensure its sustainability and, thus, enhance its contribution to global change mitigation and payments for environmental services.

Keywords: biodiversity; carbon stockage; degraded landscapes; live hedge; typology.

INTRODUCTION

The overexploitation of natural resources has created a big problem for flora and fauna regarding survivability (Bisht *et al.*, 2022). Population pressure, poverty, agricultural expansion/ intensification, infrastructure development and the introduction of invasives have been suggested as major threats to biodiversity and natural resources (Negi *et al.*, 2025). Once established to demarcate plots and boundaries around homes and to cope with land pressures and agricultural intensification (Gautier, 1992; Laflèche, 2017), live hedges (LHs) are now an issue, with implications beyond the farm gate. LHs have been established in rural landscapes throughout many regions of the world (Montgomery *et al.*, 2020). It is an agroforestry technique integrated into agricultural landscapes, made up of perennial trees and shrubs that are deliberately grown in association with annual crops and/or livestock to optimise the ecological and economic interactions of the various components managed by man (Baudry and Jouin, 2003).

LH remains an ancestral agroforestry practice in Cameroon, especially in the highlands of western Cameroon (Dongmo, 1968). LHs are a good surrogate for former forest landscapes that were found in this region many years ago (Njoukam *et al.*, 2008; Temgoua *et al.*, 2020). In addition to sacred forests, they constitute areas where indigenous forest species still exist (Sonké *et al.*, 2001). In this part of the country, the landscape is marked by the presence of LHs, which are the outcome of the fragmentation of the natural environment (Piliot *et al.*, 2002; Temgoua *et al.*, 2020). This fragmentation is attributable to three interdependent factors, namely the limited size of the Bamiléké territory, the high population density and agricultural intensification. These conditions have favoured the development of this agroforestry practice, which has been adapted to local constraints and plays several roles. Local studies have shown that LHs constitute an ecological corridor and a refuge for biodiversity (Sonké *et al.*, 2001) and contribute to local resilience in the face of global change (Dongmo, 1968; Garrity and Stapleton, 2011; Njoukam *et al.*, 2008).

Today, traditional knowledge has become important, leading to debates on biodiversity preservation using traditional knowledge systems, such as LHs, especially in areas where natural ecosystems have disappeared (Djiongo *et al.*, 2002; Piliot *et al.*, 2002). The current trend is to conserve LHs, regulate their use and enhance their value to promote

their socioeconomic and ecological roles (Njoukam *et al.*, 2008). This is particularly true in the western highlands, where natural landscapes have practically disappeared in favour of other land use types, with the degradation of their ecological and socioeconomic functions in the context of global change. LHs are among the relics that provide a diversity of ecosystem goods and services to local populations, making them adapted systems that are essential for environmental maintenance. However, this potential remains largely unknown, especially in the western highlands of Cameroon. It is against this backdrop that this study seeks to answer the following research question: What potential do LHs have in biodiversity conservation and carbon storage? Using the landscape of the Menoua division as a case study, this study set out to assess the floristic and carbon storage potential of LHs to provide information on their contribution to climate change resilience and biodiversity conservation.

MATERIALS AND METHODS

Study site

This study was carried out in Penka-Michel and Nkong-Ni sub-divisions, found in the Menoua division of the western region of Cameroon. The relief of this area is mountainous with many plateaus and plains and an altitude ranging between 1500 and 2000 m. These sub-divisions have a tropical mountain climate made up of two seasons – a dry season from November to April and a rainy season from April to November. The average temperature varies from 11 to 30°C, and the average precipitation is between 1800 and 2400 mm per year. According to Jiotsa *et al.* (2015), this area is generally underlain by brown earth derived from basaltic rocks. These soils are made up of syntectonic granites and anatexites that were later covered by ancient or young basalts. Thus, soils are essentially ferralitic and hydromorphs. The hydrographic network is limited in this area; nevertheless, there are some small rivers and streams crisscrossing the area. The vegetation is essentially Guinea savannah grassland and montane forests (Letouzey, 1985), which have undergone significant degradation due to anthropogenic activities, such as agricultural expansion, which is the main occupation of local people.

Data collection

In addition to obtaining verbal permission from the LH landowners, the chosen hedges to be sampled were selected based on their length (at least 80 m). Given that the LHs in the study area were almost exclusively linear, the sampling design used for the tree species inventories was adapted from Axe *et al.* (2017). This sampling design consisted of delimiting the LHs 50 m from each other. A tree species inventory was carried out to determine the local and/or scientific names of the tree species and the abundance of individuals with a diameter $\geq$ 5 cm. The diameter at breast height (DBH) was measured at 1.3 m above ground level using a dbh-meter. Species were identified based on the discriminating characteristics of each species. However, herbarium samples of species not identified in the field were collected to help identify them later in the herbarium. The IUCN Red List website (2024) was used to determine the threat status of each of the identified trees

species. In the context of this study, the typology of LHs was based on abundance, with one species representing at least 60% of individuals present in the sampling unit compared to the other species. A total of 132 samples of 50 m each belonging to 5 LH categories, i.e. a total length of 6.6 km, corresponding to 16.5 ha were sampled. Here, 1 ha corresponded to 400 linear metres of LH required to delimit 10,000 m² of land, an approach recommended by Axe *et al.* (2017).

Data analysis

The collected data were coded and imputed into an Excel spreadsheet and analysed using the 'Biodiversity R' package in R software (version 4.1.1.) (Kindt and Coe, 2005). The tree species inventory data were used to characterise the biodiversity of the LHs based on the species richness, Shannon–Wiener (Shannon and Weaver, 1964), Piélou (Piélou, 1966) and Simpson (Simpson, 1949) indices. Parameters including basal area and distribution of individuals according to diameter classes were used to characterise the structure of different LH types. The Sorensen similarity index was used to assess the floristic affinities between LH types. The inventory data were used to estimate the aboveground biomass (AGB) using the pantropical equation given by Chave *et al.* (2014). This equation considers the tree diameter, wood density and environmental index for each sampling point.

$$AGB = e^{(-1.803-0.976\times E+0.976\ln(\rho)+2.673\times\ln(D)-0.0299\times(\ln(D))^2)} \quad (1)$$

where AGB is the aboveground biomass (kg); E is the environmental index; ρ is the wood density of the species; and D is the diameter of the tree (cm).

The belowground biomass (BGB) was estimated using the following formula: BGB = 0.24 × AGB (Mokany *et al.*, 2005). The total biomass (TB) considered in this study was the sum of AGB and BGB. The biomass obtained was converted into carbon stocks using the coefficient 0.47. Given the linear nature of LHs, structural parameters (abundance and basal area) and carbon stocks were extrapolated into linear kilometres of LHs and hectares of the delimited area, as recommended by Axe *et al.* (2017). The Shapiro–Wilks normality test was used to determine whether the data followed a normal distribution and to select either a parametric comparison test (analysis of variance (ANOVA) and Tukey honestly significant difference (HSD)) when the data followed a normal distribution or a non-parametric test (Kruskal–Wallis and Wilcoxon) when the data did not follow a normal distribution for comparisons among LH types according to the considered parameters.

RESULTS

Typology of live hedges

The inventory data collected in 132 LHs made it possible to define the following typology of hedgerows in the study area (*Figure 1*). Eucalyptus hedges had an abundance of over 60% of *Eucalyptus saligna*. Markhamia hedges were dominated by *Markhamia lutea* and *Markhamia tomentosa*. Podocarpus hedges were dominated by *Podocarpus manni*, and fir/pine hedges were dominated by *Pinus sylvestris* and *Abies alba*. Mixed hedges were diverse, with no single species showing a dominant abundance.

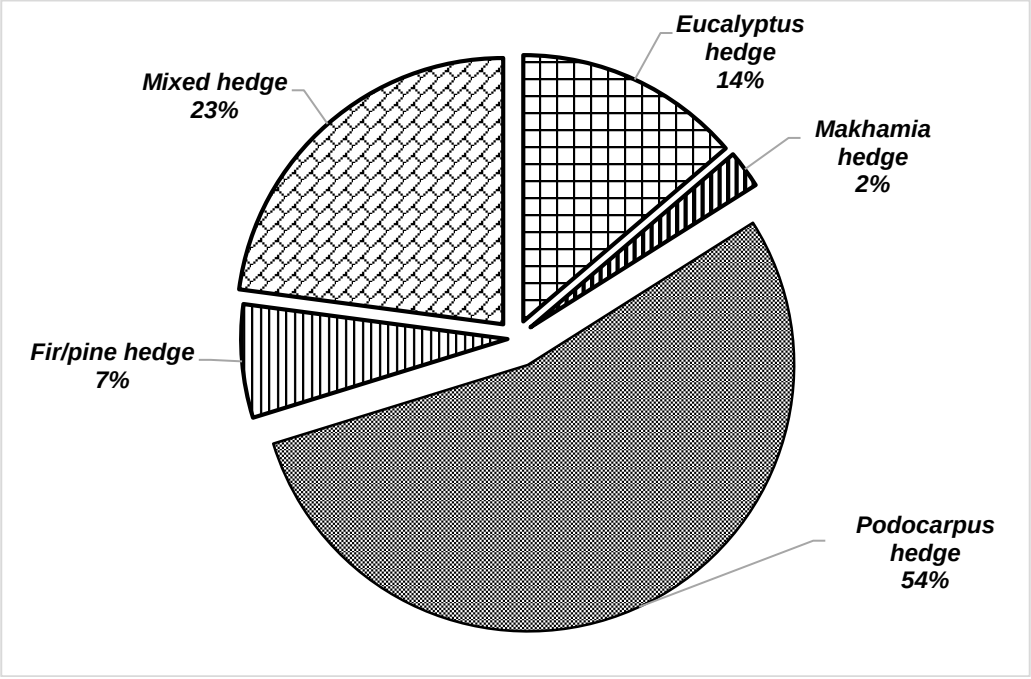

Figure 1 – Proportion (%) of LH samples in the study area

Floristic diversity in the different hedge types

A total of 79 trees species with a diameter ≥ 5 cm belonging to 58 genera and 31 families were identified in the LHs in the study area. The total species richness of LHs significantly differed between LH types (Kruskal–Wallis, p = 0.00000000000912). It was relatively higher in mixed (65) and *Podocarpus* hedges (61), followed by *Eucalyptus* hedges (22), *Markhamia* hedges (12), and fir/pine hedges (7). Species richness at the experimental scale (50 m) varied based on the LH type. The average species richness was highest in *Markhamia* hedges (12 species), followed by mixed hedges and *Podocarpus* hedges with 11 and 6 species, respectively. The least species-rich hedges at the experimental scale were fir/pine hedges and *Eucalyptus* hedges, with an average of 2 and 3 species, respectively (I).

The Shannon–Wiener index showed that the different LHs in study area were floristically poor, except for mixed hedges, which were rich and diversified (3.171). Nevertheless, the Shannon–Wiener index showed that hedges have low diversity (2.120).

However, other biodiversity index parameters varied from 0.209 to 0.760 and from 0.215 to 0.684 especially for the Equitability of Piélou and Simpson indices. The low value of the Equitability of Piélou confirmed the dominance of some species for particular LH types. Based on the Simpson index, the probability that two species taken at random belong to a same species was low.

Based on the IUCN Red List status of the trees species identified in LHs in

the study area, we identified 8 threatened species (10% of the total species inventoried), namely *Podocarpus mannii*, which is Endangered, and *Albizia ferruginea*, *Allophylus bullatus*, *Cordia platythyrsa*, *Ficus chlamydocarpa*, *Khaya senegalensis*, *Leplaea thompsonii* and *Polyscias fulva*, which are Vulnerable.

These species were found in *Podocarpus*, *Eucalyptus* and mixed LHs. The presence of these threatened species confirms the potential of LHs in the highlands of the western region of Cameroon for conserving threatened tree species.

Floristic similarity between hedges (Sorensen index)

Sorensen's similarity index showed that there were floristic similarities between *Podocarpus* and mixed hedges (76%), between *Podocarpus* and *Eucalyptus* hedges (51%), and between mixed and *Eucalyptus* hedges (51%). However, no floristic similarity was found between the other hedgerow types (*Table 2*).

Tree abundance and basal area of live hedges

The average abundance of trees present in LHs was estimated at 758 $N.km^{-1}$ (303 $N.ha^{-1}$). This abundance remained high in *Markhamia* (900 $N.km^{-1}$; 360 $N.ha^{-1}$), *Podocarpus* (895 $N.km^{-1}$; 358 $N.ha^{-1}$), and mixed hedges (679 $N.km^{-1}$; 272 $N.ha^{-1}$), followed by *Eucalyptus* (541 $N.km^{-1}$; 216 $N.ha^{-1}$) and fir/pine hedges (382 $N.km^{-1}$; 153 $N.ha^{-1}$). ANOVA showed that the tree abundance varied significantly between hedge types (ANOVA, $p < 0.00000138$; F-value = 9.251). The Tukey test, which allowed 2-by-2 comparisons, showed that there was a significant difference between *Podocarpus* and *Eucalyptus* hedges but not between the others (*Table 3*).

The basal area was also significantly different between LH types (ANOVA, $p = 0.00157$; F-value = 4.645). The Tukey test showed that only the basal areas of *Podocarpus* and mixed hedges were significantly different.

However, from a descriptive point of view, the basal area was higher in *Markhamia* hedges (42.90 $m^2.km^{-1}$; 17.16 $m^2.ha^{-1}$) and lower in *Podocarpus* hedges (21.93 $m^2.km^{-1}$; 8.77 16 $m^2.ha^{-1}$) (*Table 3*).

Carbon stocks of live hedges

The aboveground carbon stocks varied significantly based on the LH type (ANOVA, $p = 0.0000268$; F-value = 7.266). These stocks were highest in *Markhamia* hedges (233.84 $tC.km^{-1}$; 93.54 $tC.ha^{-1}$), followed by *Eucalyptus* hedges (160.44 $tC.km^{-1}$; 64.18 $tC.ha^{-1}$). However, they were lower in *Podocarpus* (78.30 $tC.km^{-1}$; 31.31 $tC.ha^{-1}$) and fir/pine hedges (99 $tC.km^{-1}$; 39.62 $tC.ha^{-1}$).

The same trends were observed for below and total carbon stocks (Table 4). In this study, *Podocarpus manni* (16.48 $tC.ha^{-1}$), *Eucalyptus saligna* (13.45 $tC.ha^{-1}$) and *Margaritaria disscoidea* (2.76 $tC.ha^{-1}$) were identified as the three species storing the most carbon in the live hedge landscape of the study area (*Table 4*).

The total woody carbon in all LHs in the study area was estimated at 135.3 t $C.km^{-1}$, i.e. 54.1 $tC.ha^{-1}$. Boxplots presented in *Figure 2* show that the total carbon stocks varied considerably within each LH type.

Table 1 – Diversity indices for different hedge types

Type of hedges	Species richness	Shannon–Wiener	Equitability of Piélou	Simpson
Eucalyptus hedge	22	0.648	0.209	0.215
Markhamia hedge	12	1.620	0.652	0.658
Podocarpus hedge	61	1.308	0.318	0.401
Fir/pine hedge	7	0.775	0.398	0.441
Mixed hedge	65	3.171	0.760	0.918
All hedges	79	2.120	0.486	0.684

Table 2 – Floristic similarity (%) between hedges (Sorensen index)

Type of hedges	*Eucalyptus* hedge	*Markhamia* hedge	*Podocarpus* hedge	Fir/pine hedge	Mixed hedge
Eucalyptus hedge	100				
Markhamia hedge	40	100			
Podocarpus hedge	51	32	100		
Fir/pine hedge	14	0	15	100	
Mixed hedge	51	31	76	14	100

Table 3 – Abundance and basal area as a function of the hedge type in the study area

Type of hedges	Abundance		Basal area	
	N.km^{-1}	N.ha^{-1}	m².km^{-1}	m².ha^{-1}
Eucalyptus hedge	541 ± 80	216 ± 19	29.33 ± 18.54	11.73 ± 7.42
Markhamia hedge	900 ± 5	360 ± 3	42.90 ± 0.07	17.16 ± 0.03
Podocarpus hedge	895 ± 386	358 ± 154	21.93 ± 11.07	8.77 ± 4.43
Fir/pine hedge	382 ± 173	153 ± 69	33.85 ± 20.00	13.54 ± 8.00
Mixed hedge	679 ± 188	272 ± 75	33.65 ± 17.30	13.46 ± 6.92
All hedge	760 ± 53	303 ± 141	26.78 ± 15.31	10.71 ± 6.13

Table 4 – Carbon stocks (above and below) as a function of the hedge type

Type of hedges	Aboveground carbon		Belowground carbon	
	tC.km^{-1}	tC.ha^{-1}	tC.km^{-1}	tC.ha^{-1}
Eucalyptus hedge	160.4 ± 129.3	64.2 ± 51.7	38.5 ± 31.0	15.4 ± 12.4
Markhamia hedge	233.8 ± 54.0	93.5 ± 21.6	48.6 ± 12.9	19.5 ± 5.2
Podocarpus hedge	78.3 ± 48.7	31.3 ± 19.5	18.8 ± 11.7	7.5 ± 4.7
Fir/pine hedge	99.0 ± 67.6	39.6 ± 27.1	23.7 ± 16.3	9.5 ± 6.5
Mixed hedge	145.0 ± 99.9	58.0 ± 39.9	34.8 ± 23.9	13.9 ± 9.6
All hedge	109.14 ± 82.40	43.65 ± 33.20	26.2 ± 20.6	10.5 ± 8.3

DISCUSSION

Contribution of live hedges to biodiversity conservation

Sampling carried out in the LHs in the Menoua division of the western region of Cameroon enabled the identification of five LH types according to the dominance of the species that make up these LHs. These LHs, which for decades have remained an essential element in the demarcation of plots or land concessions, abound in flora diversity. In fact, a total of 79 trees species were identified in these LHs, 8 of which have a threatened status according to the IUCN; these LHs have potential for biodiversity conservation. The total

species richness identified in these LH is comparable to the 11 and 12 woody species identified by Lounang *et al.* (2018) and Sonké *et al.* (2001), respectively, in the LHs of Batoufam and Bafou, located in the highlands of the western region of Cameroon.

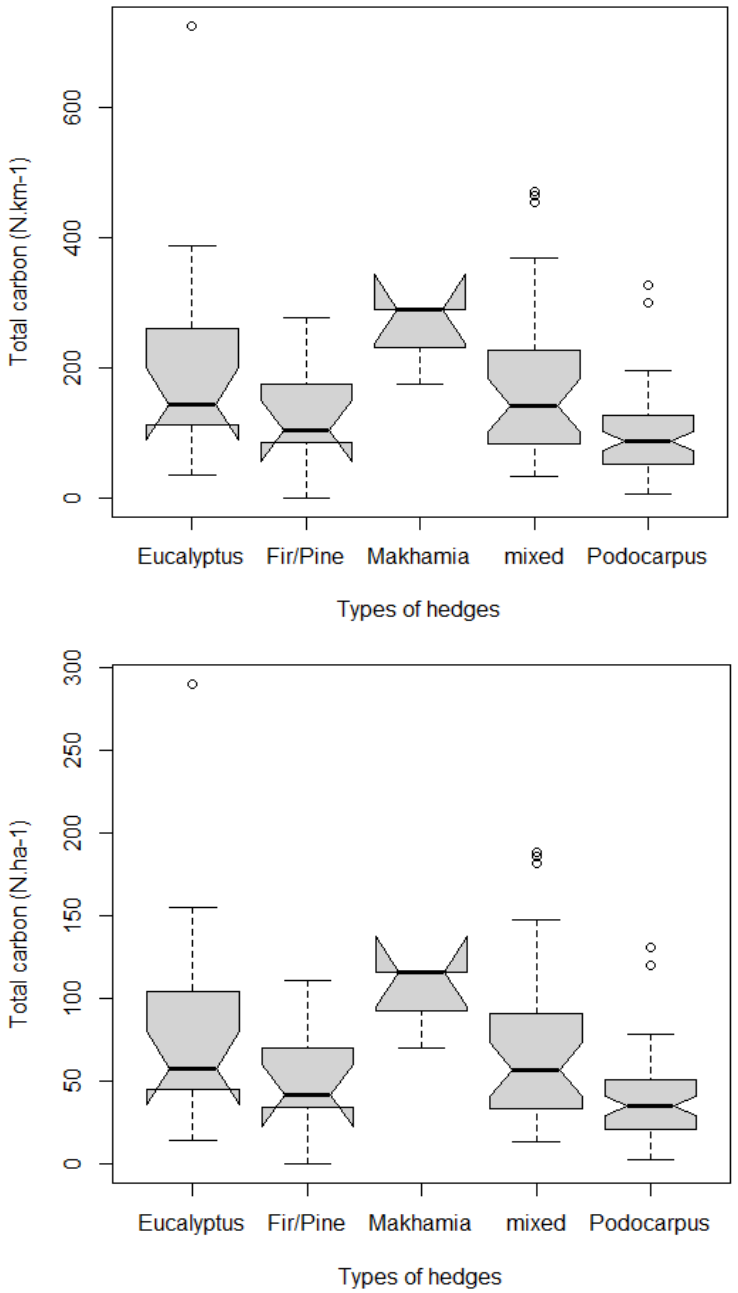

Figure 2 – Variation in total carbon stocks as a function of the live hedge type

The difference with Lounang *et al.* (2018) is due partly to the very small sample size (0.75 ha) and the sampling design used by these authors, which does not comply with the recommendations suggested by Axe *et al.* (2017). Despite the linear nature of the LHs, these authors sampled 5 LHs of 300 m × 5 m each. In contrast, Sonké *et al.* (2001) focused solely on the tree inventory in the LHs (phrorophytes of epiphytes), resulting in a selective inventory. This species richness also remains higher than that in other types of agroforestry systems in the western highlands of Cameroon, in particular the 33 species identified by Ngomeni *et al.* (2021) in coffee-based agroforestry systems.

A greater number of LHs with exotic species (*Podocarpus*, *Eucalyptus*, and fir/pine) was observed compared with LHs with indigenous species (mixed and *Markhamia*). This trend could be explained by the desire of local populations to perpetuate the choice of species that their parents planted in the past, motivated by their socio-cultural and economic value (Lecq, 2013), even if the objectives are no longer entirely the same.

Furthermore, the choice of species planted in the LHs also reflects people's desire to incorporate trees that meet their current economic and agricultural needs. The preference for fast-growing species with a primarily productive vocation (such as fruit trees and species intended for timber) is a determining criterion in the diversity among LH types. This is reflected in the high abundance of fruit trees (*Persea americana*, *Dacryodes edulis*, and *Mangifera indica*) in mixed hedges. The presence of indigenous species in the hedges *(Albizia ferruginea*, *Cordia platythyrsa*, and *Spathodea campanulata)* can be explained by the fact that, after the destruction of the forest that occupied this area many years ago, the LHs remained between landscapes where the original forest species could still be found, as mentioned by Sonké *et al.* (2001). Historically, the demarcation of plots by ancestors was based on natural boundaries dictated by the arrangement of certain indigenous trees. All they had to do was reinforce the boundary by planting more trees along the plots. It is from this perspective that Lecq (2013) defined LHs as a linear forest. Therefore, we conclude that the floristic composition of LHs depends on the choice of species planted by the farmer and the history of the site.

The diversity index values obtained for the LHs in the Menoua division of the western region of Cameroon showed an average tree species diversity, with the distribution of individuals showing a dominance of a few species in terms of abundance. Unlike a natural forest, this is a sign of disturbance. The Shannon–Wiener index (2.12) showed that the average diversity of LHs is higher than that found by Louanang *et al.* (2018) (1.90), who identified 11 species. This difference can be explained by the fact that, these authors restricted their study to trees species with a diameter of ≥ 10 cm, whereas this study considered woody species with a diameter of ≥ 5 cm. Similarly, the sample size of these authors was 0.7 ha with a different sampling design compared to that used in the present study. The Pielou index showed the dominance of certain species over others, thus defining the typology of

the LHs. Mixed hedges with fairly high Shannon–Wiener, Pielou and Simpson index values (i.e. 3.171, 0.76 and 0.918, respectively) are therefore one of the best LH options in terms of preserving biodiversity and a better distribution and equitability of numbers between species, unlike other types of LHs that are almost mono-specific, such as fir/pine hedges, where one species is highly dominant.

When trees are planted or maintained, they are generally planted very close together, with the aim that they should act as a barrier or permanent boundary separating one's plot from that of one's neighbours in the long term, thus avoiding present and future land conflicts. This justifies the high abundance of trees, depending on the LH type and even within each LH type. The significant difference between the LHs in terms of abundance can be explained by the management technique and the age of the LHs. For young LHs, in addition to planting tightly, local residents generally maximise the number of trees planted. This prevents any mortality that might occur over time. This is the case, for example, with *Podocarpus* and *Eucalyptus* hedges.

Moreover, although *Podocarpus manni* and *Eucalyptus saligna* species are dominant, the latter have a less competitive orthotropic growth habit than the species in mixed hedges; thus, the spread of the canopy is not conducive to the development of other trees. The basal area found in this study is much lower than that reported by Lounang *et al.* (2018) in Batoufam LH in West Cameroon (44.18 $m^2.ha^{-1}$). This difference can be explained by the fact that the sampling device used by these authors differs from that adopted in the present study and by the fact that LH management methods vary widely from one area to another in the western highlands.

Furthermore, the wide variation in abundance and basal area observed is justified by the fact that, although the initial role of LHs was to demarcate areas, they are also an important source of income from the sale of timber and/or firewood. To ensure their long-term survival, new trees are regularly replanted after logging to reinforce the LHs. As trees planted after logging are small in diameter, they may account for the variation in basal area observed within the LHs, explaining the high standard deviation values obtained.

Carbon stock potential of live hedges

The results of this study revealed that carbon stocks varied significantly based on LH type. Aboveground stocks were highest in *Markhamia* hedges, followed by *Eucalyptus* hedges. However, it was lower in *Podocarpus* hedges. This could be explained by the influence of structural parameters, which are closely linked to carbon stocks (Gourlet-Fleury *et al.*, 2011; Bocko *et al.*, 2017). The floristic composition could also be a significant factor influencing the variation in carbon stocks (Kabelong *et al.*, 2020). In the case of mixed hedges, due to the high diversity of indigenous species, none of which had large diameters or high wood densities, as key parameters for estimating biomass, their influence was noticeable in these LHs compared to other LHs.

The total woody carbon in all LHs in the study area, estimated at 135.24 $tC.km^{-1}$, or 54.10 99 $tC.ha^{-1}$, is much

lower than the value of 252.99 tC.ha^{-1} found by Lounang *et al*. (2018) and higher than the 32 tC.ha^{-1} found by Djiongo *et al.* (2023) in LHs in the Sudano–Sahelian zone of Cameroon. These differences could be explained by the variation in the sampling design and the carbon pools considered by these authors.

The results of this study support the assertions of Markum *et al.* (2013) on agroforestry systems, which state that in situ conservation of tree species constitute an important means of mitigating climate change and ensuring sustainable agriculture and the well-being of populations.

Species, such as *Podocarpus manni* (16. 99 tC.ha^{-1}), *Eucalyptus saligna* (13.45 99 tC.ha^{-1}) and *Margaritaria discoidea* (2.76 99 tC.ha^{-1}), were identified as storing the most carbon in LHs. This could be explained by their high abundance and dominance in the LHs of the Menoua division. The first two species are exotic species that were introduced into the western region of Cameroon in the 1970s for a number of environmental, socio-cultural and economic services, as shown by Montgomery *et al.* (2020). Since then, it has become a conservation practice that has been perpetuated from generation to generation. *Podocarpus manni*, the hedge species that stores the most carbon in the study area, has a high carbon content due to the protection and preference of farmers. In addition, this species is favoured because of its low influence on crops in terms of shade and its taproot system, rapid growth, cultivation practices, and commercial value as firewood and timber.

Implications of live hedges for peoples' well-being and climate change mitigation

Like all forest and agroforestry ecosystems, LHs play an important role in preserving the environment, with a direct impact on people's well-being and in maintaining the biogeochemical cycles of local microhabitats (Mbolo *et al.*, 2016). Their adoption by local populations in the Menoua division as a means of demarcating spaces and lands makes them a technique that, in addition to its socio-cultural contribution to preventing neighbourhood conflicts, is an important source of supply services, particularly food, medicinal products, timber and firewood (Raj *et al.*, 2017; Montgomery *et al.*, 2020). Discussion with some local residents have shown that LHs play a positive role for farmers, who are paying increasing attention to the choice of species to include in LHs. For example, depending on their expectations, they may plant *Eucalyptus* in the lowlands, which will later be sold as timber/ fuelwood. Some combine fertilising tree species (legumes) with fruit trees, thus optimising the agroecological and economic benefits of LHs.

From an ecological point of view, and particularly in terms of carbon storage, this type of system stores carbon, making it a landscape that can easily be integrated into national and even international climate change mitigation strategies. Although linear, its carbon storage potential (31–94 tC.ha^{-1}) is comparable to that of other types of ecosystems identified in the western highlands, such as coffee-based agroforestry systems (24–41 tC.ha^{-1}) (Ngomeni *et al.*, 2023; Temgoua *et al.*,

2020) and bamboo plantations (54–93 $tC.ha^{-1}$) (Chimi *et al.*, 2022; Kaam *et al.*, 2024).

Given that Cameroon has ratified several international initiatives relating to the promotion of strategies for preserving ecosystems and increasing carbon storage potential, such as REDD+ (Reducing Emissions from Deforestation and Degradation with "+" representing conservation of forest carbon, sustainable management of forests and enhancement of forest carbons stocks), the results of this study show the opportunities offered by LHs, despite their linear nature, to be integrated into initiatives aimed at strengthening resilience in the face of climate change. Therefore, decision-makers could capitalise on this opportunity in lobbying for payments for ecosystem services (as is already the case in many countries, such as Costa Rica, Madagascar, Uganda and Papua), particularly voluntary carbon markets, which is the main objective of environmental and forestry projects worldwide. With an average carbon stock estimated at 135 $tC.km^{-1}$, or 54 $tC.ha^{-1}$, this corresponds to 495 tCO_{2eq}/km (195 $tCO_{2eq}.ha^{-1}$). Given that the price of CO_{2eq} on the voluntary carbon market is not standard, as it varies from one country to another, depending on the project, the ecosystem, whether it is a REDD+ project or a voluntary market, and using the price per ton given by Peters-Stanley and Yin (2013) in the voluntary carbon market, which is 5.9 USD per ton of CO2eq, LHs have a monetary capacity of 2923 $USD.km^{-1}$ (1151 $USD.ha^{-1}$). The potential of LHs in this case could represent an important source of income through the carbon markets, if regular information on emissions/reduction in greenhouse gases resulting from LH carbon stocks is made available. As shown by Djomo *et al.* (2017), the success of international efforts in storing atmospheric carbon in forests in Africa depends on the long-term maintenance of ecosystems, among which the LHs can be counted.

CONCLUSIONS AND POLICY IMPLICATIONS

The aim of this study was to assess the contribution of LHs to conserving biodiversity and combating climate change in a heavily degraded landscape – the highlands of the western region of Cameroon. The species richness observed in the LHs in this region, many of which are threatened, bears witness to their importance in preserving and conserving species. Similarly, with a carbon storage potential ranging from 97.1 to 251.3 $tC.km^{-1}$ (38.8 to 100.5 $tC.ha^{-1}$), the LHs studied demonstrate a significant contribution to climate change mitigation through carbon stocks. The quantities of carbon they store remain far greater than those of several other landscape types in the highlands of the western region of Cameroon. This highlights the importance of these systems in conservation strategies, especially with regards to the implementation of the REDD+ mechanism with a focus on payments for ecosystem services and the voluntary carbon market in a highly degraded environment.

For policymakers seeking to promote LH agroforestry practices in western Cameroon, the policy implications of this study cannot be overlooked. The LH agroforestry system

is one of the most sustainable and nature-based farming practices across the degraded highlands of western Cameroon. Thus, policies that encourage this ancestral practice should be considered in national sustainable policies for tree preservation. Similarly, broad-ranging policies should enable the capacity building of local people through training workshops and sensitisation about the ecological and socioeconomic importance of LHs in the highlands of western Cameroon and their implication in Cameroon's national development strategy (NDS30) as well as its targets to attain sustainable development goals, especially those related goal N°13 and 15 about climate action and life on land, respectively. This will go a long way to encourage local people to maintain the multi-ecological and socioeconomic function of LHs in the highlands of western Cameroon.

Acknowledgements: We thank Conservation Action Research Network (CARN), which provided financial assistance for data collection. We also ex-press our gratitude to the African Nature Conservation (ANC), who provided different facilities to ease the conduct of this study. We also thank traditional authorities and the people of Baleveng and Bamendou for their hospitality and collaboration during the implementation of this study.

Funding: Conservation Action Research Network (CARN).

Author contributions: Conceptualization and resources: LEV, CCD; Methodology and investigation: LEV, CCD, ASKZ, RBTM; Analysis and data curation: CCD; English improvement: JRN, NPA; Supervision: LZ; Write and review: LEV, CCD, ASKZ, RBTM, LPRKB, JRN, NPA, LZ. All authors declare that they have read and approved the publication of the manuscript in this present form.

Data availability statement: The data presented in this study are available on request from the corresponding author.

Conflicts of interest: The authors declare no conflicts of interest regarding the publication of this paper.

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Academic Editor: Dr. Isabela Maria SIMION

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