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Full Length Research Paper

Chemical soil attributes of Cerrado areas under different recovery managements or conservation levels

Thaís Soto Boni*, Kellian Kenji Gonzaga da Silva Mizobata, Marcela Sant'anna Cordeiro da Silva, Laís Naiara Honorato Monteiro, Rayner Sversut Barbieri, Kátia Luciene Maltoni and Marcelo Carvalho Minhoto Teixeira Filho

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The aquatic macrophytes removed from hydroelectric power plants, as well as boiler ash derived from burning sugarcane bagasse can provide nutrients and recover degraded soils more quickly. Thus, this study aimed to evaluate the chemical attributes of a degraded soil in recovery process with mechanical preparation, with or without addition of organic residue (aquatic macrophytes) or agroindustrial residue (ash from sugarcane bagasse), compared to a degraded area without interference in the time of soil removal and in a conserved Cerrado area. The experimental design was a randomized block with four replications. The treatments were: conserved Cerrado soil (T1), area of degraded soil without human intervention since their degradation (T2), soil with mechanized preparation without addition of residue (T3), soil with mechanized preparation and addition of 32 Mg ha⁻¹ of organic residue (T4), soil with mechanical preparation and addition of 45 Mg ha⁻¹ of agroindustrial residue (T5). The orthogonal contrasts analyzed were C1 [(T2+T3+T4+T5)/4 -T1], C2 [(T2+T3) - (T4+T5)], C3 [(T2) -(T3)] and C4 [(T4) - (T5)]. In general, the chemical attributes of degraded soil increased after the incorporation of organic and agroindustrial residue, which is higher than the soil of the conserved Cerrado area. The boiler ash contributed most, to increase the nutrient content and fertility of the degraded soil.

Key words: Aquatic macrophytes, ash from sugarcane bagasse, degraded soil, fertility, soil tillage.

INTRODUCTION

The Cerrado, Latin America's second largest biome, is known as the world's richest savanna. A great diversity of habitats, high species richness and an elevated level of threats lead to the inclusion of the Cerrado in the list of

the world's critical areas for the conservation of biodiversity, the hotspots (Myers et al., 2000; Sloan et al., 2014).

In 1960s, the hydroelectric power plant of Ilha Solteira

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Table 1. Mean values for P, OM, pH, K, Ca, Mg, H+Al, Al, B, Cu, Fe, Mn and Zn in the soil before application of treatments.

P	OM	pH	K	Ca	Mg	H+Al	Al	B	Cu	Fe	Mn	Zn
(mg dm ⁻³)	(g dm ⁻³)	(CaCl ₂)	----- (mmol _c dm ⁻³) -----				----- (mg dm ⁻³) -----					
3	10	4.5	0.5	1	1	27	5	0.11	0.6	2	12	0.06

(UHE/ISA-CESP) was established in the northeast of São Paulo state, Brazil, creating huge degraded areas, called "borrowing areas". Upper soil layers were removed and used for the construction of dam and foundations, exposing subsoil with high density. In the long run this result is negligible in natural regeneration (Rodrigues et al., 2007).

In these conditions of degradation, the Cerrado presents medium to slow natural regeneration potential (Viani et al., 2010). An exposition of subsoil as described in the borrowing areas resembles the destruction observed in mining areas, as reported by Pedrol et al. (2010), who, besides physical and chemical damage, also highlight landscape esthetics.

The planting of seedlings, the facilitation of natural regeneration processes or a combination of both are methods used for recovering of degraded or perturbed environments (Durigan et al., 2011; Pinto et al., 2011). In revegetation processes, the use of native species is recommended (Marques et al., 2014), especially with conditions of low nutrient availability and high aluminium concentrations and acidity, as common in Cerrado soils (Rodrigues et al., 2007).

The physical and chemical suitability of the soil, as well as the selection of proper species for revegetation are very important and depend on each situation. The adequate level of fertilization also depends on the used species and the specificity of the situation. In emergency situations fertilization enables fast establishment of vegetation, which helps to reduce erosion by consequent stabilization of the surface and the majority of soil properties (Duboc and Guerrini, 2007), often allowing the emergence of another species.

In degraded Cerrado, soils with low natural fertility and definite pluvial regime chemical and organic inputs are crucial to precipitate the process of revegetation (Pedrol et al., 2010). This requires the quest for organic inputs that enhance the chemical, physical and biological conditions of degraded soil.

In this context, the use of organic and agroindustrial residues is a possibility for the reduction of costs for mineral fertilizers, removal of aquatic macrophytes from hydroelectric power plants (Gunnarsson and Petersen, 2007), or of ash from boilers after burning of sugar cane bagasse (Balakrishnan and Batra, 2011; Eggleston and Lima, 2015). These can be added to the soil in order to provide nutrients, enhance biological and physical soil

conditions, and therefore recover degraded soil faster.

The objective of this work was to evaluate the chemical attributes of a degraded soil in the recovery process with mechanical treatment of the soil, with and without addition of organic (aquatic macrophytes) and agroindustrial (ash from burning of sugar cane bagasse) residues, in comparison to a degraded area without any interference since soil removal and a conserved Cerrado area, contribute to the rapid recovery of degraded soils.

MATERIALS AND METHODS

The experimental area was established in 2011 at the UNESP/Ilha Solteira campus Experimental Farm, located in Selvíria/MS. The area was degraded in the 1060s for the construction of the hydroelectric power plant "Ilha Solteira" – SP. Native Cerrado vegetation as well as the upper soil layers were removed, exposing clayey subsoil (clay = 450, silt = 128, sand = 422 g kg⁻¹) which remained uncovered until 2011, presenting low nutrient contents determined according to Raij et al. (2001) (Table 1).

The average altitude of the region is 335 m, the climate classification as Aw, according to Köppen, with an average annual temperature and precipitation of 23.7°C and 1300 mm, respectively (Figure 1). The predominant soil type of the region is a Typic Hapludox. The experimental area design was a randomized block with agroindustrial residue levels (AR) applied in bands, in a factorial 3 x 4, 3 doses (0, 16 and 32 Mg ha⁻¹) of organic residue (OR) - macrophytes and 4 doses (0, 15, 30 and 45 Mg ha⁻¹) of agroindustrial residue (RA) - ash from sugarcane bagasse. Together they complete 12 treatments with 3 repetitions, established in 36 blocks of 600 m² each, separated trough 0.5 m belts (Figure 2).

The experimental area soil was grided (0.40 m deep), to rupture the sealing superficial, and scarified (0.37 m depth). The organic residue (OR) was a compound of aquatic macrophytes, consisting *Egeria densa* Planch., *Egeria najas* Planch., *Ceratophyllum demersum* L., *Eichhornia azura* Kunth, *Eichhornia crassipes* (Martius) Solms-Laubach, *Pistia stratiotes* L. and *Typha latifolia* L., according to Thomaz et al. (2008). They were removed from the reservoir of the hydroelectric power plant of Jupia, dried in the sun for 120 days and nutritionally analyzed according to the methodology of Malavolta et al. (1997) (Table 2). The agroindustrial residue (AR) was ash from burning sugar cane bagasse remaining from the production of sugar and alcohol in the Alcoolvale factory in Aparecida do Taboado/MS. It was fully dried in the sun for 30 days and chemically analyzed according to Raij et al. (2001) (Table 3).

Both residues were distributed with a limestone distributor and incorporated in the degraded soil with the medium grid. The area remained uncultivated for three months. In February 2012 seedlings of 10 Cerrado tree species were introduced in a randomized way, planted in 40 cm deep holes with a distance of 4.0 x 5.0 m, demanding 1080 plants.

In March 2015, three years after the implementation of the

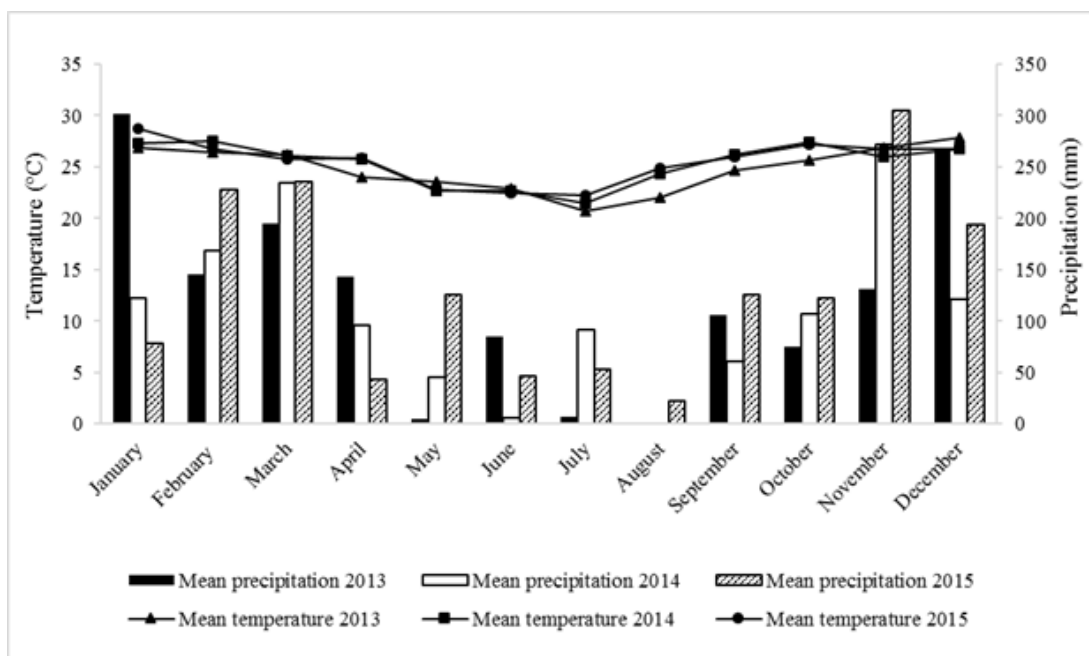


Figure 1. Mean Temperature and Precipitation for 2013, 2014 and 2015. (Source: <http://clima.feis.unesp.br>.)



Figure 2. Localization of the sampling sites in the area of Conserved Cerrado. This experimental area is in a natural recuperation process after being exposed to degradation (without any intervention).

experiment, six soil samples per plot were collected, in a depth of 0.0 to 0.2 m. For comparison purposes, samples were also collected in conserved Cerrado and degraded area without intervention. To collect samples in the conserved Cerrado area (without human intervention after degradation in the 1960s) plots of similar size as in the experiment were located. Georeferences and the sampling were made in the same manner. The experimental setup was in randomized blocks with four repetitions. The treatments were as follows: Soil from conserved Cerrado near the

experimental area (T1), Soil from degraded area without human intervention after degradation (T2), Soil with mechanical treatment without addition of residues (T3), Soil with mechanical treatment and addition of 32 Mg ha⁻¹ dry organic residues (T4), Soil with mechanical treatment and addition of 45 Mg ha⁻¹ dry agroindustrial residues (T5).

The collected soil samples were air dried, sieved and submit to analysis of the following chemical attributes: content of phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) through an

Table 2. Nutrient content of the organic residue of aquatic macrophytes.

N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn
----- (g kg ⁻¹) -----						----- (mg kg ⁻¹) -----				
17.6	1.7	6.5	11.6	2.4	6.7	27	57	2000	194	34

Table 3. Chemical characteristics of the agroindustrial residue (ash from sugar cane bagasse).

P	OM	pH	K	Ca	Mg	H+Al	Al	SB	CEC	V	Ca/CEC	Mg/CEC	m
(mg dm ⁻³)	(g dm ⁻³)	CaCl ₂		----- (mmol _c dm ⁻³) -----								----- (%) -----	
167	28	8.9	36.6	242	23	8	0	301.6	309.6	97	78	7	0

Table 4. Values for P, OM, pH, K, Ca, Mg, H+Al, Al, SB and S for different contrasts according to the treatments.

Contrast	P	OM	pH	K	Ca	Mg	H+Al	Al	SB	S
	(mg dm ⁻³)	(g dm ⁻³)	CaCl ₂		----- (mmol _c dm ⁻³) -----					(mg dm ⁻³)
C1	3.25**	12.5**	-0.21**	0.01ns	2.38**	4.31**	32.63**	24.63*	6.71**	-1.44**
C2	0.00ns	0.00ns	-0.26**	-0.33**	-3.5**	-2.38**	6.75**	3.75**	-5.21**	-1.63**
C3	0.00ns	0.00ns	0.05ns	0.00ns	0.75ns	0.5ns	1.5ns	0.5ns	1.28ns	0.25ns
C4	0.00ns	0.00ns	-0.18**	-0.35*	-2.75ns	-0.75ns	0.00ns	0.00ns	-3.85ns	0.00ns

** significant for 1%, * significant for 5%, ns = not significant for Scheffé test, T1= Soil from conserved Cerrado near the experimental area; T2= Soil from degraded area without human intervention after degradation; T3= Soil with mechanical treatment without addition of residues; T4= Soil with mechanical treatment and addition of 32 Mg ha⁻¹ dry organic residues; T5= Soil with mechanical treatment and addition of 45 Mg ha⁻¹ dry agroindustrial residues. C1 [(T2+T3+T4+T5)/4-T1]; C2 [(T2+T3)-(T4+T5)]; C3 [(T2)-(T3)]; C4 [(T4)-(T5)].

extraction method with ion exchange resins. The content of organic matter (OM) was determined by a colorimetric method and the pH in calcium chloride (CaCl₂), besides the acidic potential (H+Al) pH 7.0 and aluminium content (Al). The sum of bases (SB = Ca+Mg+K), cation exchange capacity (Communications Engineering Company (CEC) = SB + (H+Al)), base saturation (V% = (100 x SB)/CEC) and aluminum saturation (m% = (100 x Al)/CEC = (100 x Al)/(Ca+Mg+K+Na+Al), were calculated according to Raji et al. (2001).

Obtained data was submit to analysis of orthogonal contrasts by Scheffé test (p<0.05), using statistic software SISVAR (Ferreira, 2011). The analyzed orthogonal contrasts were C1 [(T2+T3+T4+T5)/4-T1], C2 [(T2+T3)-(T4+T5)], C3 [(T2)-(T3)] e C4 [(T4)-(T5)].

RESULTS AND DISCUSSION

Contrary to expectations C1 showed the highest content of P, OM, Ca, Mg, Al as well as H+Al, SB, CEC, Mg/CEC, B, Cu, Fe, Mn and Zn in the soils of the degraded area in recuperation. The area of conserved Cerrado soil has higher values for pH and content of S (Tables 4 and 5). These results can lead back to the application of organic (OR) or agroindustrial residues (AR) which contain high amounts of nutrients (Tables 2 and 3).

According to Najjar et al. (2015) the addition of OR can

influence the physical, biological and chemical properties of soils which consequently alter the soil dynamics and finally the fertility of the same. Feitosa et al. (2009) mentioned that, the boiler ash derived from burning sugarcane bagasse is sources for macro and micronutrients. The application of this ash enables a higher retention of water which correlates with the acidity of soils because of the application of one ton of ash which corresponds to 0.5 tons of limestone. For a secure use of this material, studies should be realized to improve the knowledge of its composition and consequently the quantities needed to achieve best results.

Galindo et al. (2015) verifies that, the aquatic macrophyte species *E. densa* has the potential to be used as an organic fertilizer, because the nutrients can be retained in the macrophyte biomass (Câmara et al., 2015). This could also explain the obtained results. In the contrast C2, where no residues were applied, a higher potential acidity could be recorded as well as higher content of Al and m% in the soil samples (Tables 4 and 5). This undesired attributes affect in a negative form the soil quality and consequently the development of vegetation.

Ferreira et al. (2012) pointed that a reduction of acidity after ash application facilitates plant growth. This material

Table 5. Values for CEC, V%, Ca/CEC Mg/CEC, m%, B, Cu, Fe, Mn and Zn for different contrasts according to the treatments.

Contrast	CEC	V%	Ca/CEC	Mg/CEC	m%	B	Cu	Fe	Mn	Zn
	(mmol _c dm ⁻³)		----- % -----				----- (mg dm ⁻³) -----			
C1	39,33 ^{**}	0,75 ^{ns}	-1,63 ^{ns}	2,94 ^{**}	3,75 ^{ns}	0,19 ^{**}	2,89 ^{**}	34,19 ^{**}	24,98 ^{**}	0,38 ^{**}
C2	1,54 ^{ns}	-15,5 ^{**}	-10 ^{**}	-4,13 ^{**}	41,5 ^{**}	0,01 ^{ns}	-0,13 ^{**}	-1,13 ^{**}	-0,58 ^{ns}	0,00 ^{ns}
C3	2,78 ^{ns}	3,0 ^{ns}	1,75 ^{ns}	1,0 ^{ns}	-6,5 ^{ns}	0,02 ^{ns}	0,00 ^{ns}	-0,5 ^{ns}	-0,08 ^{ns}	0,00 ^{ns}
C4	-0,85 ^{ns}	-11,0 [*]	-7,75 [*]	-2,25 [*]	30,0 ^{**}	-0,04 ^{**}	0,15 [*]	0,25 ^{ns}	1,08 ^{ns}	0,00 ^{ns}

** significant for 1%, * significant for 5%, ns = not significant for Scheffé test, T1= Soil from conserved Cerrado near the experimental area; T2= Soil from degraded area without human intervention after degradation; T3= Soil with mechanical treatment without addition of residues; T4= Soil with mechanical treatment and addition of 32 Mg ha⁻¹ dry organic residues; T5= Soil with mechanical treatment and addition of 45 Mg ha⁻¹ dry agroindustrial residues. C1 [(T2+T3+T4+T5)/4-T1]; C2 [(T2+T3)-(T4+T5)]; C3 [(T2)-(T3)]; C4 [(T4)-(T5)].

contains high amounts of alkaline substances which reduces the potential acidity. In the contrast C2, when OR and AR were applied, higher contents of K, Ca, Mg, S, Cu and Fe as well as higher values of Ca/CEC, Mg/CEC, pH, SB and V%, could be observed, which are directly related to the content of nutrients and chemical characteristics (pH) of the residues (Tables 2 and 3).

Application of plant ash has been the subject of many studies showing an increase in the amount of K in tropical soils (Augusto et al., 2008; Ferreira et al., 2012). The high content of K in AR (36, 6 mmol_c dm⁻³ in this study) can be justified by the high content of this macronutrient in sugar cane. The result of the high application rate of K, being this nutrient is the most used for sugarcane cultivations (Oliveira et al., 2010). Lima (2011) also verified that the application of different organic fertilizer reduces the P-fixation in soils and contributes to an increase of its availability to vegetation. Ram and Masto (2014) also observed a rise in soil quality and a significant rise in soil pH after ash application, while Nayak et al. (2014) ascribes to the influence of this material on microbial populations, reducing their diversity in soils.

This study also corroborates the positive effect of application of macrophytes in soils. Masto et al. (2013) observed higher pH values, microbial activity and vigorosity of seedlings, which are the result of an application of biochar from *E. crassipes* in soils, or contains a mixture of aquatic macrophytes with variation in its nutritional composition. Sakadevan and Bavor (1999) as well as Henry-Silva and Camargo (2008) acknowledge that the variation in nutrient absorption of macrophytes is caused by different characteristics of the water body and the time spent in the efflux. The structure of the water body influences the process of nutrient uptake and sedimentation of particles, giving a positive correlation between effectivity of nutrient uptake and residence period in the efflux.

Calgaro et al. (2008) observed an increase in chemical attributes (OM, P, pH, K, SB, CEC, and V %) when *E. crassipes* was applied. The use of this or other residues

have been reported to be beneficial for degraded areas as organic or microbial fertilizers supporting revegetation (Trlica and Brown, 2013). Pavinato and Rosolem (2008) noticed that residues from vegetation improve the Ca, Mg and K content. This causes a complexation of hydrogen and aluminium with bonds of residues before the process of humification gets started, rising SB as could be observed in this study.

Colodro and Espindola (2006), Alves et al. (2007), Kitamura et al. (2008), Modesto et al. (2009), Costa et al. (2014) and Bonini et al. (2015) also studied the soil recuperation of degraded areas after constructions and could verify an improve of chemical properties of soils, which can also be seen in this study, after application of sewage sludge, organic residues or green manure.

Analyzing the contrast C3, the characteristics of the degraded area doesn't show any difference in chemical properties in treatments with or without mechanization and addition of residues (Tables 4 and 5). The systems of use and manage of Cerrado soils correlate directly with the chemical, biological and physical properties, although machining work has the biggest impact on soils (Carneiro et al., 2009). Acceleration in the decomposition process of organic material, cause a reduction in CEC and an increase in leaching of exchangeable bases which consequently reduce water retention, in soils.

Only mechanization doesn't improve chemical properties in soils in an advanced degradation process. Therefore, to the treatment of mechanization up to a depth of 15 cm, material with high nutrient content has to be added. The content of organic matter (OM) was also very low, probably because of a very low initial OM content. Bronick and Lal (2005) describe that, the mechanization techniques used change the structure in soils and accelerate decomposition of organic material, resulting in decrease of productivity and exposure of soil. Pavan and Chaves (1998) explain that to reduce the process of decomposition of organic matter, the superficial machining work also has to be minimized as well as de loss of soil, water or nutrients. The reuse of residues, maintenance of soil nutrients, improvement of

CO₂ fixation and its incorporation into the soil or cultivation rotation with cultivars with high biomass production are other aspects that can decrease the decomposition of organic matter.

In observing contrast C4, it can be noticed that the application of OR and mechanization of the soil, increases m% and the content of Cu in comparison of application of AR and mechanization (Tables 4 and 5). Sampaio and Oliveira (2005) mention that, the application of biomass from *E. densa* which grow in turbines of water bodies, are viable and can be recommended as an organic fertilizer for maize plantations. On one hand the problem of destination of residue from turbines can be solved and on the other hand the application of nutrients and a rise of agricultural production can be achieved.

The application of AR in a mechanized soil, raised the pH and K, Ca, Mg and B contents with amount of SB, CEC V% and Ca/CEC in the soil, in comparison with OR and an addition on mechanized soil. The increase in soil properties can lead back to the application of nutrients through AR (Carrier et al., 2012; Ram and Mastro, 2014). The research of Machado et al. (2014) compared treatments with and without application of organic residues (aquatic macrophytes) and phosphorus (triple superphosphate) as fertilizers for degraded soils. Results showed a positive influence on soil fertility whereby organic residues can be used as fertilizers.

The obtained results of this study show that the application of agroindustrial and aquatic macrophytes residues can be used as a sustainable form to restore fertility of degraded soils. A possible increase of this material can be traced back to anthropogenic eutrophication of water bodies. Using this material as a proposal to minimize the anthropogenic impact on environment originated many decades ago, these can be an alternative to traditional methods that uses large amounts of commercial fertilizers in recovering of degraded soils.

Conclusion

The chemical attributes of the degraded soil increased after the introduction of organic and agroindustrial residues, being even higher in relation to Cerrado soil. The ash from sugar cane bagasse was the residue that contributed most to increasing nutrient content and fertility of the degraded soil.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests regarding the publication of this paper.

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Full Length Research Paper

Communal knowledge and perceptions of African wild dog (*Lycaon pictus*) reintroduction in the western part of Serengeti National Park, Tanzania

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This study assessed communal knowledge and perceptions regarding the reintroduction of the African wild dog (*Lycaon pictus*). Questionnaires were employed to acquire information from 216 randomly selected respondents within six villages. Our results indicate that gender differences exist among respondents; more males than females correctly identified wild dogs from photo cards. Males also wanted the species to be of high conservation priority. Moreover, because of their education, more males suggested that the wild dog population should increase after being released into the Serengeti National Park (SNP). Finally, gender and education level significantly explained the variation of the outcome of answers with respect to wild dog reintroduction to SNP. The study recommends that conservation authorities should incorporate communal knowledge and perceptions during implementation of the wild dogs' reintroduction programmes.

Key words: Gender, education, conservation priority, protected areas, reintroduction.

INTRODUCTION

Worldwide, most communities living close to protected areas are knowledgeable about wildlife behaviour (Gandiwa, 2012; Lagendijk and Gusset, 2008; Thorn et al., 2011; Lescureux and Linnell, 2010) and management (Uddin and Faisal, 2007; Ogada et al., 2003; Mills, 1991; Lagendijk and Gusset, 2008; Kideghesho et al., 2007;

Kaltenborn et al., 2006; Inskip et al., 2016). Previous studies have shown that communal knowledge has been widely applied by scientists and policy makers as source of ideas for ecosystem management and ecological restoration (Folke, 2004; Gadgil et al., 1993; Hayward et al., 2007; Gusset et al., 2006; Gusset et al., 2010;

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Sjölander-Lindqvist et al., 2015). Therefore, indigenous knowledge has been used by researchers to evaluate wildlife interactions with their environment (Scholte, 2011; Gadgil et al., 1993; Mwakatobe et al., 2012; Kideghesho et al., 2007; Holmern et al., 2007; Lembo et al., 2008).

Previous studies have shown that information focused on communal knowledge of protected area management and predators are well recognized by decision makers (Kaltenborn et al., 2006; Tessema et al., 2010; Kideghesho et al., 2007; Lindsey et al., 2005; Sjölander-Lindqvist et al., 2015; Smith et al., 2014). Studies addressing such people's perceptions of large carnivore management are well documented in several ecosystems in Tanzania (Goldman et al., 2010; Koziarski et al., 2016; Dickman et al., 2014). Therefore, it is essential from both a scientific and conservationist perspective to understand communal knowledge on wildlife conservation (Taylor, 2009; Kideghesho, 2008).

Studies have shown that both positive and negative human perceptions are affected by gender and education level (Røskaft et al., 2007; Conforti and de Azevedo, 2003; Andersone and Ozolinš, 2004; Røskaft et al., 2003). Having that in mind, conservation authorities have taken into consideration different suggestions in undertaking species-appropriate conservation measures (Andersone and Ozolinš, 2004; Okello et al., 2011; Abram et al., 2015; Koziarski et al., 2016). Several studies have reported that negative perceptions of carnivores in the local community land are due to conflict with farmers or human attack (Gusset et al., 2008; Lescureux and Linnell, 2010; Inskip et al., 2016). Thus, scientists have been incorporating human perceptions into approaches for managing biodiversity (Gandiwa, 2012; Gusset et al., 2010; Okello et al., 2011; Caruso and Pérez, 2013; Gadgil et al., 1993).

The study by Okello et al. (2011) suggested that sustainable animal species conservation and management requires routine knowledge of species interaction with the community and ecosystem functions. Most educated people living around protected areas have been shown to play a central role in managing carnivore species because of their better understanding on the importance of natural resources protection in protected as well as open areas in community land (Gusset et al., 2006; Legendijk and Gusset, 2008; Lindsey et al., 2005). Management of large carnivores is a difficult task, which requires good governance and thorough understanding of human interactions with wildlife species and habitats (Sjölander-Lindqvist et al., 2015; Jacobsen and Linnell, 2016; Megaze et al., 2017; Redpath et al., 2013). Studies have shown that the African wild dog (*Lycan pictus*) can be successfully managed as a metapopulation through the involvement of ranch owners and bordering communities (Gusset et al., 2008; Lindsey et al., 2005). Despite these findings, studies on communal knowledge and perceptions of wild dog conservation in the western

Serengeti ecosystem are scant. Wild dog packs have not been sighted inside the Serengeti National Park (SNP) since its local extinctions in the early 1990s (Ginsberg et al., 1995; Holmern et al., 2007). Since Tanzania holds large populations of large carnivores (Riggio et al., 2013; Dickman et al., 2014), the African wild dogs have received high protection status due to its recent decline (TAWIRI, 2009). Reintroduction of African wild dogs is necessary in the SNP due to its high tourism potential. Also, such reintroduction will reduce human-wild dog conflicts in Loliondo Game Controlled Area and improve the protection of this species in the area. Because of its wide-ranging behaviour, conserving wild dogs requires integrating community knowledge and perceptions due to the ability of wild dogs to live in human-dominated landscape.

Therefore, this study hypothesized that communal knowledge and perceptions of African wild dog reintroduction and conservation would be influenced by gender and education levels in the study area.

MATERIALS AND METHODS

Study area

The study was conducted in western Serengeti focusing on eastern part of the Simiyu region, which covers an area of 23,808 km² bordering Maswa Game Reserve (MGR) and SNP, between latitudes 2° and 4° S and between 33° and 35° E (Figure 1) (URT, 2013). The area is characterized by high human population, totaling 2 million people, with an annual growth rate of 2.8%, due to increased birth rates and immigration, of which Sukuma tribe is dominant (Nuno et al., 2014; NBS, 2012; Sinclair et al., 2008). Communities' main economic activities include farming crops such as maize, sorghum, cotton and cassava, and livestock keeping (NBS, 2012; Meertens et al., 1995). There are fewer wildlife species remaining adjacent to MGR due to habitat destruction (Songorwa, 2004), while the area inside the SNP has a high diversity of wildlife including herbivores, carnivores and birds (Sinclair et al., 2002, 2008). The topography of the area is characterized by flat, gently undulating hills and low hills, sparse vegetation, with some places covered with miombo woodland (URT, 2013). Rainfall usually starts in October and ends in May, and the rainfall ranges from 600 to 900 mm (URT, 2013) and is influenced by Lake Victoria through tidal rhythms generated by temperature differences between the lake and the land (Campbell and Hofer, 1995; Norton-Griffiths et al., 1975). The temperature ranges from 18 to 31°C annually (URT, 2013). The soils are dominated by heavy black soils with areas of red loamy and sandy soil (Meertens et al., 1995).

Data were collected in August 2012 from six villages, namely Nyamikoma, Matongo, Nyawa, Halawa, Ihusi and Mwasinasi, and were purposively sampled (Figure 1) at gradient distance of 0 to 10 km from the park boundary. Prior to the interview, researchers explained the main purpose of the study to the village authorities. Permission for conducting interviews was then granted. For this study, the household was regarded as a sampling unit. Respondents above 18 years old were assigned numbers obtained from the village register book. Each number was written on a piece of paper, folded and placed inside a box from which 36 respondents were randomly picked for interview. Randomized face-to-face semi-structured interviews, using both open and closed questions, were

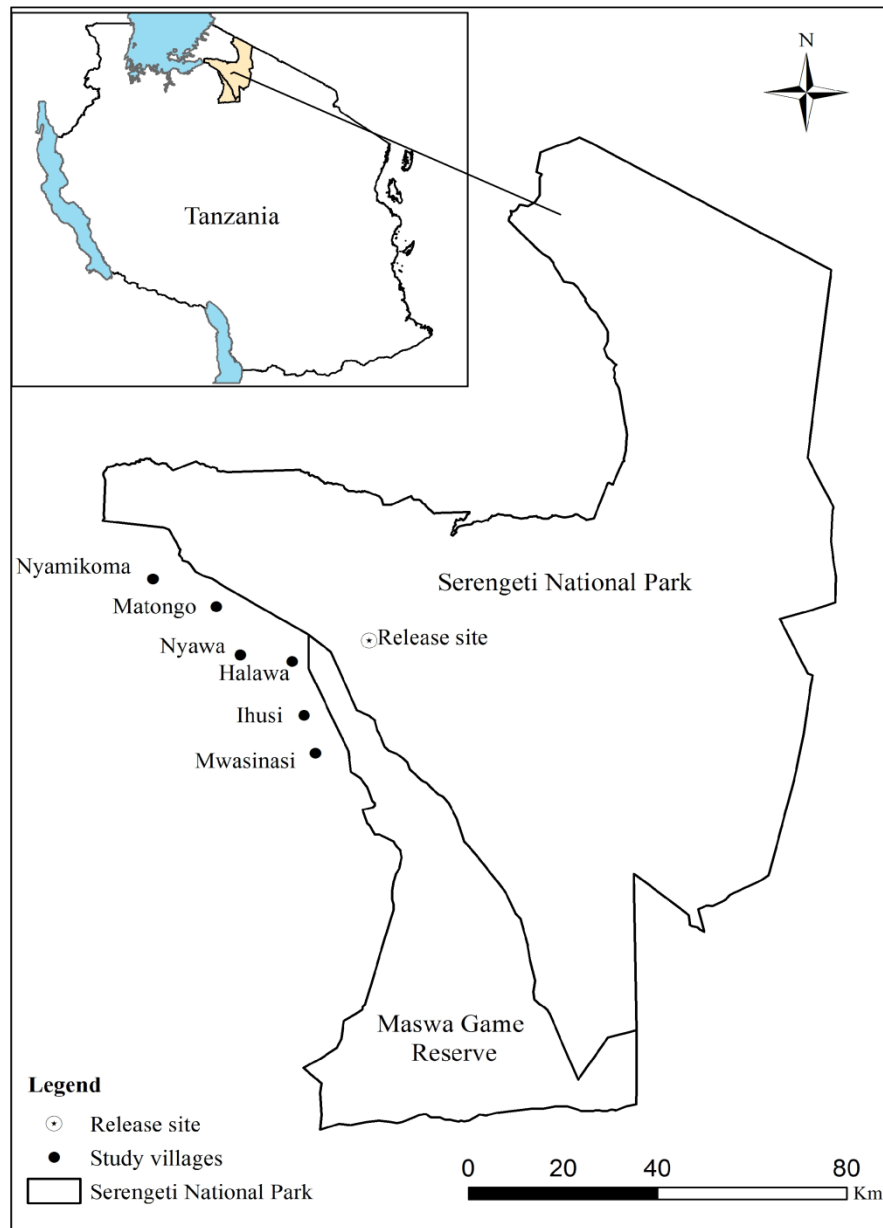


Figure 1. Map of Tanzania showing the study area and surveyed villages in the Western part of the Serengeti National Park (SNP).

then conducted with 216 respondents. The researchers interviewed each respondent by asking open-ended questions that allowed respondent to answer freely. In addition, close ended questions with limited answers (yes or no) were also used. The researchers developed clear judgments on respondents' (his/her) understanding regarding the asked question. The language used to interview people was *Swahili*, and where necessary it was translated to the *Sukuma* language with the help of a local field assistant with a secondary education background. Before the interview, each question was explained to the respondent in order to obtain meaningful answers. The following questions were asked to the respondents to capture the required information about their

knowledge of and perception towards African wild dog reintroduction in the western Serengeti ecosystem: (i) Do you know the animal species shown on the photo (yes, no)?, (ii) What is your level of conservation priority for African wild dogs? (high, medium, do not know and low), (iii) What is your opinion about African wild dogs reintroduction into the SNP from Loliondo Game Controlled Area (LGCA), where are they currently occurring? It will increase (pack sizes will increase in numbers and they will reproduce), no opinion (no suggestion of either increase or decrease in pack numbers) and it will decrease (packs will die or move outside the park after being reintroduced), and (iv) "What are the outcome of conserving wild dog packs in the SNP?" (it will be a stronger

Table 1. Numbers and percentages of respondents who were able to identify African wild dogs from a photo in the Western part of the Serengeti National Park (SNP) in relation to gender.

Identified animal shown on the photo	Gender		Total N (%)
	Men N (%)	Women N (%)	
Yes	105 (70.5%)	20 (29.9%)	125 (57.9%)
No	44 (29.5%)	47 (70.1%)	91 (42.1%)
Total	149 (100%)	67 (100%)	216 (100%)

Table 2. Numbers and percentages of respondents regarding the level of conservation priority status that should be given to wild dogs in relation to gender.

Conservation priority	Gender		Total N (%)
	Men N (%)	Women N (%)	
High	81 (54.4%)	23 (34.3%)	104 (48.1%)
Medium	11 (7.4%)	7 (10.4%)	18 (8.3%)
Don't know	26 (17.4%)	26 (38.8%)	52 (24.1%)
Low	31 (20.8%)	11 (16.4%)	42 (19.4%)
Total	149 (100%)	67 (100%)	216 (100%)

protection of the species, it is a dangerous animal that should be removed from human-dominated areas and I do not know). Socio-demographic variables including gender, age, job status and education level were used to assess respondents' knowledge and perceptions with respect to the above questions.

Data analysis

Statistical analyses were conducted using Statistical Package for Social Sciences (SPSS version 21, Chicago, USA) to analyze the data. Descriptive statistics were used to summarize the questionnaire response data. Since most of our data were categorical, Pearson's Chi-square analyses were performed to determine the differences in the independent variables that explain communal knowledge and perceptions. Furthermore, linear regression analysis was used to determine the factor that contributed most to statistical significance. All statistical tests were two-tailed and significant level was set at $P < 0.05$.

RESULTS

Respondents' general information

Of all interviewed respondents ($n = 216$), 69% were men and 31% were women. Eighty percent were between 18 and 45 years, 14% were between 46 and 60 years, and 6% were older than 60 years. Fewer respondents, approximately 16%, had secondary education and above, 24% had never been to school and the majority, 60% had

primary education. Majority of the respondents were farmers (87%), while the remaining 13% were businessmen, government employees and students.

Knowledge about African wild dogs

Majority of the men correctly identified African wild dogs from the photo card, when compared with the women ($\chi^2 = 31.27$, $df = 1$, $P < 0.001$; Table 1). Conversely, age ($P = 0.360$), education level ($P = 0.547$) and job status ($P = 0.241$) had no effect on respondents' ability to recognize African wild dogs. Furthermore, statistically significantly, more men than women suggested that African wild dogs should be given high conservation priority status ($\chi^2 = 13.59$, $df = 3$, $P = 0.004$) (Table 2).

Respondents' perceptions of African wild dogs reintroduction into the SNP

Respondents had different opinions regarding what will happen to the wild dogs after the reintroduction into SNP. Generally, 72.5% of the men believed that the wild dog population would increase after being reintroduced into SNP, while statistically significantly, fewer women did ($\chi^2 = 7.18$, $df = 2$, $P = 0.020$) (Table 3). Furthermore, women had significantly different opinions from men about the

Table 3. Numbers and percentages of what respondents believed would happen to the African wild dog population after release into the Serengeti National Park (SNP) in relation to gender.

After African wild dog release, the species will	Gender		Total N (%)
	Men N (%)	Women N (%)	
Increase	108 (72.5%)	38 (56.7%)	146 (67.6%)
No opinion	25 (16.8%)	22 (32.8%)	47 (21.8%)
Decrease	16 (10.7%)	7 (10.4%)	23 (10.6%)
Total	149 (100%)	67 (100%)	216 (100%)

Table 4. Numbers and percentages of respondents' opinions on the outcome of African wild dog reintroduction to the Serengeti National Park (SNP) in relation to gender.

Opinion about release of wild dogs into SNP	Gender		Total N (%)
	Men N (%)	Women N (%)	
It will be a tourist attraction	48 (32.2%)	14 (20.9%)	62 (28.7%)
A stronger protection of the species	44 (29.5%)	4 (6.0%)	48 (22.2%)
It is a dangerous animal that should be removed from human-dominated areas	16 (10.7%)	10 (14.9%)	26 (12.0%)
I do not know	41 (27.5%)	39 (58.2%)	80 (37.0%)
Total	149 (100%)	67 (100%)	216 (100%)

outcome of reintroducing wild dogs into the SNP ($\chi^2 = 26.04$, $df = 3$, $P < 0.001$) (Table 4). Additionally, respondents with no education had significantly different opinions on the potential outcome of the reintroduction to SNP than educated people ($\chi^2 = 22.61$, $df = 6$, $P = 0.001$) (Table 5). Conversely, respondents with primary education suggested that tourism would increase ($\chi^2 = 22.61$, $df = 6$, $P = 0.001$) (Table 5). Using a linear regression model with method enter to the questions, "what are your opinions about reintroducing wild dogs back to SNP" as dependent variable and gender and education level as independent variables was statistically significant ($F = 11.096$, $df = 2$ and 213 , $P < 0.001$, $r^2 = 0.092$). Both gender ($t = 3.981$, $P < 0.001$) as well as education level ($t = -2.145$, $P = 0.033$) were statistically significant demographic independent variables in explaining this variation.

DISCUSSION

Respondents' knowledge on African wild dogs

The findings suggest that men are more knowledgeable than women in identifying African wild dogs and also proposed a higher conservation priority status for the species. This is probably because in agro-pastoral communities, more men have formal education than

women (URT, 2010), and the former are also more powerful in the society, while the latter are not allowed to provide information in the presence of men (Assenga et al., 2016). Furthermore, it was noted that in the Sukuma tribe, men are engaged in social activities, such as listening to the radio, dancing and watching television programs which may increase the exchange of ideas from one person to another. The results are consistent with earlier studies that have suggested that gender differences exist in levels of conservation knowledge (Dickman et al., 2014; Lyamuya et al., 2016; Kaltenborn et al., 2006; Nombo et al., 2015; Clamsen and Røskoft, 2013; Allendorf and Allendorf, 2012). Males may have suggested high conservation priority status for the species because of awareness of reporting on local extinction of African wild dog in early 1990s within the Serengeti ecosystem (Ginsberg et al., 1995; Burrows et al., 1994). Therefore, the findings support our hypothesis that gender is an important demographic factor explaining communal knowledge about African wild dog conservation.

Respondents' perceptions of African wild dog reintroduction into the SNP

Furthermore, the results suggested that males believe that the African wild dog population would increase after

Table 5. Numbers and percentages of the respondents' opinions on the outcome of African wild dog reintroduction to the Serengeti National Park (SNP) in relation to education level.

Opinion about release of wild dogs into SNP	Level of education			Total
	No education	Primary education	Secondary and above	
Tourist attraction	9 (17.0%)	43 (33.3%)	10 (29.4%)	62 (28.7%)
Stronger protection of the species	6 (11.3%)	32 (24.8%)	10 (29.4%)	48 (22.2%)
It is a dangerous animal that should be removed from human-dominated areas	7 (13.2%)	19 (14.7%)	0 (0.0%)	26 (12.0%)
I do not know	31 (58.5%)	35 (27.1%)	14 (41.2%)	80 (37.0%)
Total	53 (100%)	129 (100%)	34 (100%)	216 (100%)

reintroduction into the western part of the Serengeti ecosystem, where presently the species is rarely seen. This is probably because of high diversity of prey species in the park, which is influenced by resource distribution (McNaughton and Georgiadis, 1986; Fryxell et al., 2005; Sinclair, 2003; Sinclair et al., 2008) that would reduce the incidence of wild dogs moving outside the park. These authors pointed out that lack of human-wild dog conflict in the area was because wild dogs have not been sighted for several decades (Holmern et al., 2007). The community in western Serengeti would wish to see the African wild dogs in their area probably due to lack of experience of human-wild dog conflict. These findings are also in support of the previous studies (Lindsey et al., 2005; Nilsen et al., 2007; Smith et al., 2014).

Majority of the respondents, independent of gender and education level, acknowledged that they did not know the outcome of the released wild dog packs into SNP. The study findings, suggest that respondents are not fully involved in the management of natural resources. Contrary to this observation, studies elsewhere have reported that local residents living close to protected areas are aware of ongoing conservation activities conducted by authorities in the protected areas (Yen et al., 2015; Mcgovern and Kretser, 2015; Piédallu et al., 2016; Caruso and Pérez, 2013; Inskip et al., 2016; Gandiwa, 2012; Megaze et al., 2017). Concurrently, the data also suggest that educated respondents acknowledged that the presence of more wild dog packs in the SNP, following release, will lead to an increased tourist attraction. Likewise, other studies have suggested that education level plays an important role in people's perceptions about wildlife conservation (Legendijk and Gusset, 2008; Conforti and de Azevedo, 2003; Megaze et al., 2017; Redpath et al., 2013). Given this fact, it is important to sensitize and conduct more research on large carnivores in this part of the Serengeti ecosystem. Hence, the community expressed positive opinions about the conservation of African wild dogs in their area as they anticipate wild dogs are important as a source of economic incentives in the future. The respondent's

opinions will form the baseline information for management authorities of the wild dogs in the area after reintroduction. These findings support the hypothesis that communal perceptions of African wild dogs' conservation are mostly influenced by gender and education levels.

CONCLUSIONS AND RECOMMENDATIONS

The study concludes that both gender and education level are significant in explaining variations between community knowledge of and perceptions towards wild dog reintroduction and conservation in the western Serengeti ecosystem because they supported the release of wild dogs in the area. Moreover, because of their knowledge, males believed the African wild dog should be given a high conservation priority in the area. The study recommends that conservation authorities should incorporate communal knowledge and perceptions of local people during implementation of the wild dogs' reintroduction programmes. Future studies should be directed towards this part of the ecosystem to explore the large carnivores' presence and local peoples' attitudes towards the future existence. Additionally, it is recommended that after the reintroduction exercise has ended, the same community should be interviewed to evaluate the increase of awareness and knowledge of African wild dogs.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interest.

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Full Length Research Paper

Phenotypic characterization of indigenous Maefur goat population in Tigray, Northern Ethiopia

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The study was conducted in Erob district eastern Tigray, Ethiopia to phenotypic characterize Maefur goat based on physical body feature and linear body measurements. Six hundred (297 male and 303 female) goats were randomly selected and grouped into four age groups of 0, 1, 2 and ≥ 3 PPI. General Linear Model (GLM) procedure of SPSS version 16.0 and descriptive statistical analysis were used to summarize the collected data. Short ear size (12.3 cm for male and 11.8 cm for female), long and thick horn, medium body size (42.8 kg for male and 32.7 kg for female), and large heart girth (82.1 cm for male and 73.4 cm for female) are the major body characteristics of Maefur goat breed. There was a significant ($P < 0.05$) effect of sex and age on live body weight and linear measurements. Mean \pm SE of live body weight, heart girth, body length and height at wither in male were 34.7 ± 0.57 kg, 75.3 ± 0.53 cm, 64.3 ± 0.61 cm and 64.7 ± 0.46 cm, respectively while in female 28.9 ± 0.35 kg, 70.0 ± 0.33 cm, 60.0 ± 0.40 cm, and 59.3 ± 0.31 cm, respectively. For heart girth in these age groups were 61.1 ± 0.53 , 69.4 ± 0.33 , 70.6 ± 0.4 and 77.7 ± 0.39 cm, respectively while body length were 50.3 ± 0.43 , 56.8 ± 0.42 , 59.3 ± 0.58 and 68.2 ± 0.42 cm, respectively. For height at wither in these age groups were 54.0 ± 0.45 , 59.1 ± 0.35 , 58.4 ± 0.32 and 66.5 ± 0.40 cm, respectively. Heart girth and height at wither were significantly ($P < 0.05$) different among the age groups except between 13-18 and 19-24 months. The study revealed that large heart girth is a unique characteristic of the Maefur indigenous goat. The study concluded that Maefur goat breed is identified as one of the potential goat breed in Tigray, Ethiopia.

Key words: Indigenous goat, Maefur goat, phenotypic characterization, body measurement.

INTRODUCTION

The day to day livelihood activity of smallholder farmers depends on the agricultural practices in almost all part of Ethiopia. The contribution of agriculture in Ethiopian accounts for more than 40% of the national GDP, 90% of

exports, and serve as source of income and basic needs to more than 90% of the poor farmers (Diao, 2010). Ethiopia is endowed with huge livestock biodiversity adapted to varied agro ecological conditions. Among the

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farm animal genetic resources, indigenous goats have unique adaptive mechanisms which enable them to fit in varied agro ecologies and contribute to the livelihood of small holder farmers through producing valuable milk and meat products. Within the agro ecology there are also sub agro ecologies and developed in to niches as home of specific adapted ecotypes. Kolo et al. (2015) described the domestic goat (*Capra Aegagrus*) as a subspecies of goat domesticated from the wild goat of southwest Asia and Eastern Europe. FARM-Africa (1996) described the origin and historical distribution of the highland indigenous goat population of Ethiopia that emphasized on documentation of the goat breeds. The institute of biodiversity conservation (IBC) documented fifteen (15) indigenous goat breeds inhabited in the low land, midland, and highland agro ecologies of Ethiopia (IBC, 2004). The total population of goat in Ethiopia are reported as 24.06 million of which 99.99% are indigenous goat breeds (CSA, 2013). To ensure sustainable utilization of the indigenous goat, there should be a conservation strategy for the present and future use. Phenotypic characterization is the first step for identification of qualitative and quantitative traits of the indigenous goat. An accurate description of Maefur goat kept under extensive management conditions would enable an accurate comparison of this breed with other goat breeds and improvement programs can then be developed using such information. Body weight and linear body measurements determine body size which is important to classify goat breed into groups. Based on height at wither and body weight, indigenous goat in Ethiopia are classified in to three classes (large, >65 cm and weighing 37-50 kg; small, 51-65 cm and weighing 26-36 kg; dwarf, <50 cm and weighing 18-25 kg) (Kassahun and Solomon, 2008). The improvement on local goat depends on the phenotypic information for mass selection, whereby individuals with better trait values is chosen to be parents of the next generation (Carneiro et al., 2010). Maefur goats population is one of the potential indigenous goat breeds found in the regional government of Tigray but not yet well described with limited attempts to characterization for sustainable utilization and designing management intervention under smallholder farmer. Hence identifying and characterizing Maefur indigenous goat population is very important to integrate animals into various production systems and to make effective use of their potential. The objectives of this study were to phenotypic characterization of the indigenous Maefur goat population using linear body measurement (LBM) and physical body characteristics and to evaluate the effect of sex and age on body weight and LBM under extensive management conditions.

MATERIALS AND METHODS

Description of the study area

The study was conducted in Erob district found 47 km northeast of

Adigrat in the eastern zone Tigray. It is located at 14010' to 14025'N and 390 40' to 390 50'E (Tesfay et al., 2011). The max and min annual temperature ranges from 25 to 30°C and 12 to 16°C, respectively. Mean annual rainfall ranges from 250 to 300 mm during the rainy months of June and August (EAZT, 2005). The study area covers an altitude ranging between 1200 and 3000 m above sea level (Tesfay et al., 2011). It has also notable topographic features including the "Ayga" (Appendix Figure 2) and "Assimba" mountains (Appendix Figure 3).

Sampling procedure

Purposive sampling of the district and potential PA was used because of the existence of the potential indigenous goat population named as Maefur DAGRIS (2004) and the information about their distribution in the regional government of Tigray is already reported by Tigray Agricultural Research Institute but no one tried to reach them for phenotypic characterization. About 600 randomly selected indigenous goats of 49.5% male and 50.5% female goats were used during phenotypic characterization. The variables measured included live weight recorded using Salter scale with capacity of 50 kg (accuracy nearest 200 g) and linear body measurements using meter tape (1.5 meter and accuracy 0.5 cm). Age of the sampled animals was determined using dentition as recommended by Solomon (2009) and Wilson and Durkin (1984). The selected animals were grouped into one of the following age categories: 0 PPI (04 to 12 month with 46 male and 36 female, 1 PPI (13 to 18 months) with 47 male and 40 female, 2 PPI (19 to 24 months) 57 male and 77 female, and ≥ 3 PPI (25 to 36 months and above) with 147 male and 150 female. Linear body measurements recorded for each study animal were heart girth, height at withers, height at rump, shoulder width, chest depth, body length, ear length, ear width, horn length, head width and head length.

Procedures of recording body measurements

The coat color (using color chart) and pattern, shape and orientation of the horns and ears, size of tail, and profile of head, back and rump can be recorded using coded descriptors (FAO, 2012). Descriptive information should be recorded on the common flock sizes and structures as well as uses.

Recording LBM

Linear body measurements (LBM) were recorded in the morning before the animals are fed, with the animals standing on a flat surface with head held up (Appendix Table 1). Hanging spring scale was used to measure body weight (BW) to the nearest 0.1 kg. Heart girth (HG) was measured by taking the circumference of the chest using a tailor's tape calibrated in cm, taken as the circumference of the body immediately behind the shoulder blades in a vertical plane, perpendicular to the long axis of the body. Height at wither (HW) was measured as the distance from the ground to the withers. Height at rump (HR) is measured as the distance from the ground to the rump. Shoulder width (SW) was measured as a distance between the shoulders. Chest depth (CD) was measured as the distance between the top behind the scapular and the flow of the sternum (taken to be the depth of brisket) immediately behind forelegs. Body length was the distance from the head of humerus to the distal end of the pubic bone.

Statistical data analysis

Different analysis methods were applied using SPSS version 16.0

software program. Live body weight and linear body measurements were subjected to List-square analysis of variance using the General Linear Model (GLM) procedure of SPSS version 16.0 with sex and age as fixed effects. The Tukey's simultaneous test was used to separate significance of least-square means. Physical body traits were analyzed using descriptive analysis for mean and standard deviation (quantitative data) and frequency (qualitative) of the variables.

$Y_{ij} = \mu + S_i + A_j + L_{ij} + E_{ij}$ Model 1 (General Linear Model, GLM)

Where: Y_{ij} = the observation of the i^{th} animal within the j^{th} age of i^{th} sex; μ = overall mean; S_i = effect of the i^{th} sex (male and female); A_j = effect of j^{th} age (04-12, 13-18, 19-24, and 25-35 months and above); L_{ij} = interaction effect of the i^{th} sex and j^{th} age groups, and E_{ij} = Random error factor.

The effect of sex, age and their interaction on live body weight and linear body measurements were determined at 5% level of significance. Least-squares means for sex and age groups were separated using Student's t-test and Duncan's Multiple Range Test (DMRT), respectively. The difference between and among the least squares means was determined at 5% level of significance. Indices were calculated in the excel Microsoft to provide ranking of the observed body and head color.

Index = Sum of [4 for tick + 3 for rank 1 + 2 for rank 2 + 1 for rank 3] for each color divided by sum of [4 for tick + 3 for rank 1 + 2 for rank 2 + 1 for rank 3] for each color

RESULTS AND DISCUSSION

Physical body characteristic of the indigenous Maefur goat population

The study observed variety of coat pattern in Maefur goat population. The overall coat color pattern of the sampled goat was described as spotty (32.3%), pied 27%, uniform (25%) and shaded (light brown, black, and gray) (15.3%) (Table 1). Medium (1-2 mm) (64%) and short (29.3%) hair length were the overall description of the indigenous Maefur goat population. Short, narrow, thin, and laterally oriented ear (92% of incidence) was the overall characteristic of Maefur indigenous goat breed. This observation of the current study revealed that Maefur goat has dominant lateral ear orientation distinguished from Begait goat with dropped ear orientation. Solomon (2009) stated that ear orientation and size are important for discrimination of more related indigenous goat breeds. The overall descriptions for horn orientation of the observed indigenous Maefur goat breed were backward (45%) and upright (41%), respectively with frequently observed straight (81%) and spiral (18%) horn shapes. The overall body shape characteristics of the sampled Maefur goat breed was in-between with 76% and lanky with 20% (Figure 1). The dominant body shapes (in-between leggy and compacted) had some implication to distinguish Maefur indigenous goat from 12 indigenous goat breed of Ethiopia documented by DAGRIS (2004) and Kassahun and Solomon (2008). Concave (83%) and flat (straight 16%) facial profiles were the most descriptor for the overall facial profile of Maefur goat breed.

Body color of the indigenous Maefur goat was

assessed using randomly selected 750 goats 5 goats from each 150 household (Appendix Figure 1). The most frequently observed body coat color was beige, black and brown with an index value of 0.30, 0.20 and 0.18 (Table 2). Figure 2 illustrates the variety of morphological characteristics of Maefur goat flock. The smooth hair type with spotty coat color, long horn (straight and spiral) and sometimes polled in male), short ear size, straight facial profile and potential for meat improvement are the most important physical characteristics of the indigenous goat population. It has its own distinguishing feature and local name apart from the afar goat. Afar goats are characterized as small breed in Ethiopia (Solomon, 2009). The afar goats are recognized with local name of Adal in Afar region and widar (dwarf) in the border area of Tigray brought to be sold in Mekelle city for meat purpose. Maefur and Afar goat populations are distinct in phenotypic performance (Maefur has larger body size than afar goat) but they have some similarities in the coat color patterns (Figure 2 and Appendix Figure 10).

Body weight and linear body measurement in Maefur goat

Table 3 summarized the least squares means for live body weight and body measurement in different age groups and sex for the Maefur goat breed. The main source of variation on live body weight and linear body measurement were sex, age and the interaction of both sex and age.

Effect of age, sex and their interaction on body weight and linear body measurements

There was a significant ($P < 0.001$) variation for live body weight, heart girth, height wither, height at rump, shoulder width, body length, chest depth, horn length, tail length, head width and head length among the four age groups (04-12, 13-18, 19-24 and 25-35 months) but no significant ($P > 0.05$) variation for ear length and ear width among these age groups. The variation for live body weight, heart girth, height withers, height at rump, shoulder width, body length, and chest depth was also significant ($P < 0.001$) between male and female but no significant ($P > 0.05$) variation for horn length, tail length, ear length, ear width, head width and head length for interaction of sex and age group. The report of this finding is in line to the findings reported by Khan et al. (2006) and Fajemilehin and Salako (2008) and Alemayehu et al. (2012).

Live body weight and linear body measurements

Live body weight

The average live body weight of Maefur male goat in four age groups (04-12, 13-18, 19-24 and 25-35 months) was

Table 1. Morphological features of Maefur goat population.

Morphology traits	Variable	Male		Female		Overall	
		N	%	N	%	N	%
Coat pattern	Pied	50	33.3	32	21	82	27.3
	Spotty	30	20.0	67	45	97	32.3
	Shaded	16	10.7	30	20	46	15.3
	Uniform	54	36.0	21	14	75	25.0
	Subtotal	150	100.0	150	100.0	300	100.0
Hair length	Medium(1-2mm)	93	62	99	66	192	64.0
	Long(>2mm)	11	7	9	6	20	6.7
	Short(<1mm)	46	31	42	28	88	29.3
	Subtotal	150	100.0	150	100.0	300	100.0
Hair type	Curly	5	3	4	3	9	3.0
	Glossy	51	34	52	35	103	34.3
	Smooth	74	49	78	52	152	50.7
	Dull	7	5	9	6	16	5.3
	Straight	13	9	7	5	20	6.7
	Subtotal	150	100.0	150	100.0	300	100.0
Ear orientation	Lateral	141	94	135	90	276	92.0
	Dropping	1	1	3	2	4	1.3
	Forward	2	1	3	2	5	1.7
	Upright	6	4	9	6	15	5.0
	Subtotal	150	100.0	150	100.0	300	100.0
Horn presence	Present	136	91	138	97	274	93.5
	Absent	14	9	5	3	19	6.5
	Subtotal	150	100.0	143	100.0	293	100.0
Horn shape	Curved	3	2	5	3	8	2.7
	Spiral	27	18	12	8	39	13.0
	Polled	8	5	0	0	8	2.7
	Straight	111	74	133	89	244	81.3
	Subtotal	150	100	150	100.0	300	100.0
Horn orientation	Upright	86	57	37	25	123	41.0
	Forward	3	2	4	3	7	2.3
	Lateral	40	27	94	63	134	44.7
	Dropping	12	8	15	10	27	9.0
	Polled	9	6	0	0	9	3.0
	Subtotal	150	100.0	150	100.0	300	100.0
Body shape	Compact	5	3	5	5	10	4.1
	Lanky/leggy	30	20	23	25	53	22.0
	In between	115	77	63	69	178	73.9
	Subtotal	150	100	91	100	241	100
Face profile	Flat	30	20	19	13	49	16.3
	Concave	118	79	130	87	248	82.7
	Convex	2	1	1	1	3	1.0
	Subtotal	150	100.0	150	100.0	300	100.0
Beard	Absent	25	17	150	50.0	175	58.3
	Present	125	83	0	.0	125	41.7
	Subtotal	150	100.0	150	100.0	300	100.0



Figure 1. Adult male (left) and female (right).

Table 2. Ranked body color of Maefur goat breed in the study site.

Body color	Ranks			Index
	1	2	3	
Aqua	1	-	-	0.00
Beige	224	112	29	0.30
Black	144	90	14	0.20
Blue	2	1	-	0.00
Blue gray	67	21	7	0.08
Brown	155	37	9	0.18
Darker red	3	7	2	0.01
Gray	48	30	11	0.07
Orange	7	2	-	0.01
Red	1	-	-	0.00
Red brown	39	12	3	0.05
Violet	5	20	0	0.02
White	54	65	6	0.10
Total	750	397	81	1.00

Index = sum of [3 for rank 1 + 2 for rank 2 + 1 for rank 3] for particular body color of goats divided by sum of [3 for rank 1 + 2 for rank 2 + 1 for rank 3] for all body color of randomly selected goats.

20.5±3.3, 28.6±3.1, 31.2±4.1 and 42.8± 6.6 kg, respectively while that of female in the same age groups were noted as 18.5±4.4, 26.4±2.9, 27.9±4.59, and 32.7±4.1 kg, respectively (Table 4). Significant ($P<0.05$) difference was found in live body weight between male

and female goat in all age groups. This finding of the current study is agreed with the report of Khan et al. (2006) and Alemayehu et al. (2012). The average live body weight of Maefur goat was 42.8 and 32.7 kg for adult male and female goat, respectively. For pooled sex



Figure 2. Maefur goat flock.

of the adult Maefur goat, the average live body weight was 37.7 kg. For the indigenous goat breed of Ethiopia, the average live body weight for Gumuz, Agew goats, Begia-Medir goats, Bati goat, Abergelle goats, and Central Abergelle goats was 34.6, 31.5, 32.5, 29.9 and 28.1, 27.9 kg, respectively (Hassen et al., 2012). According the east Africa goat size classification method, body size of the goat breed is categorized in to three groups: Small (20-30 kg), medium (30-45 kg) and large (45-60 kg) (Kiwuwa, 1992).

Accordingly, Maefur goat is classified as medium sized indigenous goat. Saanen goat is a large goat breed with average live body weight of 65 kg for male and 50 kg for female (Pesmen and Yardimci, 2008). Therefore, live body weight is among the production trait used to classify goat population in to breed standard and are important in giving information about the morphological structure and development ability of the animal (Kiwuwa, 1992, Hassen et al., 2012; Riva et al., 2002). Ethiopian goats are classified according to the body weight and height at wither. Based on the average adult age (25-35 months), both male and female Maefur goats have medium body size.

Heart girth

The average heart girth of Maefur male goat in four age groups (04-12,13-18,19-24 and 25-35 months) were found to be 61.9±3.8, 69.9±3.2, 72.8±4.7 and 82.1±6.3

cm while that of female in these age groups were investigated to be 59.9±5.8, 68.7±2.7, 69.0±4.1 and 73.4± 3.2 cm, respectively. Significant ($P<0.05$) difference was reported in heart girth between male and female goat within age group 3 and 4. There was no significant ($P>0.05$) difference in heart girth between male and female in the age group of 1 and 2. The average heart girth 82.1 cm for male and 73.4 cm for female adult Maefur goat breed was higher than that of Abergelle reported as 68.67 and 64.44 cm for adult male and female, respectively (Alemayehu et al., 2012). Body size of the adult goat is the indication of heart girth, body length, height at wither and height at rump. Among these major linear body measurement heart girth is widely used to classify physical characteristic of Ethiopian goat families and breeds (Solomon, 2009). Adult female Maefur goat with an average value of heart girth 73.4 cm had comparable size with Western Highland goats with 75.8 cm classified as large whereas Afar goat with average heart girth 67.4 cm are classified as small indigenous goat in Ethiopia (Solomon, 2009).

Height at wither

The average height at wither of Maefur male goat in four age groups (04-12, 13-18, 19-24 and 25-35 months) were determined as 55.5±3.9, 59.4±2.8, 60.9±3.1, and 70.8±6.1 cm while that of female in these age groups were recorded to be 52.2 ± 3.7, 58.7± 3.8, 56.6±3.1 and

Table 3. MANOVA for live body weight and linear body traits of the indigenous Maefur goat.

Source variation	of	Df	Body measurement (cm)											
			LBW	HG	HW	HR	ShW	BL	ChD	EL	EW	HL	TL	HeW
Age	3	8080.1 ^a	6703 ^a	4572 ^a	1611 ^a	84 ^a	8691.1 ^a	230.4 ^a	13.0 ^b	0.8 ^b	967.9 ^a	33.0 ^a	452.5 ^a	500.0 ^a
Sex	1	5755.4 ^a	4785.0 ^a	4925.2 ^a	2443.0 ^a	202.4 ^a	3736.2 ^a	320.0 ^a	14.5 ^b	2.5 ^b	1159.4 ^a	0.1 ^b	522.5 ^a	291.7 ^a
Age X Sex	3	578.5 ^a	509.5 ^a	442.9 ^a	269.6 ^a	42.9 ^a	641.1 ^a	97.7 ^a	4.1 ^b	1.4 ^b	42.8 ^b	7.4 ^b	38.5 ^b	24.8 ^b
Residual	592	22.5	21.2	20.3	19.3	3.3	31.6	7.1	5.8	1.1	22.6	4.1	18.1	9.6

^a Significant at ($P < 0.001$) and ^b not significant at ($P > 0.05$); HG=Heart girth; WH=Height Withers; RH=Rump height; ShW=Shoulder Width; BL=Body length; ChD=Chest depth; EL=Ear Length; EW=Ear width; HL=Horn, Length; TL=Tail Length; HeW=Head Width; HeL=Head length.

Table 4. Mean value \pm (SD) of the linear body measurement and body weight.

Variable	0PPI		1PPI		2 PPI		≥ 3 PPI	
	Male N=46	Female N=36	Male N=47	Female N=40	Male N=57	Female N=77	Male N=147	Female N=150
BW	20.5 \pm 3.3 ^a	18.5 \pm 4.4 ^b	28.6 \pm 3.1 ^a	26.4 \pm 2.9 ^b	31.2 \pm 4.1 ^a	27.9 \pm 4.6 ^b	42.8 \pm 6.6 ^a	32.7 \pm 4.1 ^b
HG	61.9 \pm 3.8 ^a	59.9 \pm 5.8 ^a	69.9 \pm 3.2 ^a	68.7 \pm 2.7 ^a	72.8 \pm 4.7 ^a	69.0 \pm 4.1 ^b	82.1 \pm 6.3 ^a	73.4 \pm 3.2 ^b
HW	55.5 \pm 3.9 ^a	52.2 \pm 3.7 ^a	59.4 \pm 2.8 ^a	58.7 \pm 3.8 ^a	60.9 \pm 3.1 ^a	56.6 \pm 3.1 ^b	70.8 \pm 6.1 ^a	62.3 \pm 4.6 ^b
HR	56.8 \pm 4.7 ^a	56.2 \pm 4.9 ^a	61.8 \pm 4.1 ^a	61.2 \pm 4.3 ^a	62.2 \pm 4.2 ^a	58.5 \pm 5.1 ^b	67.6 \pm 4.5 ^a	61.5 \pm 3.9 ^b
SW	10.1 \pm 1.7 ^a	8.5 \pm 2.3 ^b	9.7 \pm 3.1 ^a	10.8 \pm 2.0 ^a	11.6 \pm 1.5 ^a	10.3 \pm 2.0 ^b	12.1 \pm 1.4 ^a	10.4 \pm 1.5 ^b
BL	51.0 \pm 4.1 ^a	49.4 \pm 3.6 ^a	56.2 \pm 4.0 ^a	57.5 \pm 3.7 ^a	61.8 \pm 6.8 ^a	57.6 \pm 6.4 ^b	72.3 \pm 7.1 ^a	64.3 \pm 5 ^b
CD	7.0 \pm 2.3 ^a	5.4 \pm 2.5 ^b	7.1 \pm 2.4 ^a	7.4 \pm 2.7 ^a	7.0 \pm 2.6 ^a	7.3 \pm 1.7 ^a	10.4 \pm 2 ^a	7.6 \pm 2.7 ^b
EL	11.7 \pm 1.8 ^a	11.5 \pm 2.5 ^a	11.6 \pm 2.5 ^a	11.1 \pm 2.3 ^a	11.9 \pm 2.3 ^a	12.0 \pm 2.4 ^a	12.3 \pm 2.5 ^a	11.8 \pm 2.3 ^a
EW	4.9 \pm 0.8 ^a	4.9 \pm 0.8 ^a	5.2 \pm 1.1 ^a	4.9 \pm 0.7 ^a	5.0 \pm 1.1 ^a	5.1 \pm 1.3 ^a	5.2 \pm 1.0 ^a	5.0 \pm 0.1 ^b
HL	11.4 \pm 3.5 ^a	9.9 \pm 5.0 ^a	16.7 \pm 4.1 ^a	13.4 \pm 3.5 ^b	16.6 \pm 3.6 ^a	15.0 \pm 4.4 ^b	19.3 \pm 5.9 ^a	15.7 \pm 4.2 ^b
TL	12.4 \pm 1.2 ^a	12.4 \pm 1.9 ^a	13.7 \pm 2.2 ^a	12.8 \pm 2.4 ^a	13.3 \pm 4.3 ^a	13.5 \pm 1.7 ^a	13.6 \pm 2.1 ^a	13.8 \pm 2.2 ^a
Hew	9.2 \pm 4.0 ^a	9.4 \pm 3.5 ^a	12.3 \pm 3.5 ^a	9.4 \pm 3.9 ^b	12.9 \pm 2.4 ^a	10.7 \pm 3.3 ^b	14.4 \pm 5.0 ^a	12.5 \pm 4.5 ^b
HeL	17.2 \pm 3.2 ^a	14.0 \pm 4.2 ^b	19.0 \pm 3.3 ^a	18.2 \pm 2.5 ^a	19.3 \pm 2.5 ^a	18.1 \pm 3.8 ^b	21.1 \pm 3.1 ^a	19.9 \pm 2.5 ^b

^{a, b}Mean within age group connected with different superscripts differ significantly ($P < 0.05$); HG=Heart girth; WH= Height Withers; RH=Rump height; ShW=Shoulder Width; BL=Body length; ChD=Chest depth; EL=Ear Length; EW=Ear width; HL=Horn Length; TL=Tail Length; HeW=Head Width; HeL=Head Width.

62.3 \pm 4.6 cm, respectively (Table 4). Significant ($P < 0.05$) difference was reported in height at wither between male and female goat within age group 3 and 4. There was no significant ($P > 0.05$)

difference in height at wither between male and female between age group of 1 and 2. The stage of growth and development might mask the difference between male and female at early age.

The adult female (25-35 months) Maefur goat breed with 62.3 cm height at wither is in between the Afar and Western Highland goat breed as 60.9 and 70.8 cm, respectively (Solomon, 2009). Both

male and female adult Maefur goat with average height at wither 70.8 and 62.3 cm, respectively are larger than the Abergelle goat reported as 61.05 and 59.44 cm, respectively for adult male and female (Alemayehu et al., 2012). According to the classification criteria using height at wither and body weight for body size of Ethiopia indigenous goat suggested by Kassahun and Solomon (2008), there are three classes: large, >65 cm and weighing 37-50 kg; small, 51-65 cm and weighing 26-36 kg; dwarf, <50 cm and weighing 18-25 kg). Therefore, both male and female Maefur indigenous goats are classified as large body size.

Heights at rump

The average heights at rump of the Maefur male goat in four age groups (04-12, 13-18, 19-24, and 25-35 months) were determined as 56.8±4.7, 61.8±4.1, 62.2±4.2 and 67.6±4.5 cm, respectively whereas in female were noted to be 56.2±4.9, 61.2±4.3, 58.5±5.1 and 61.5±3.9 cm, respectively. Significant ($P<0.05$) difference was reported in height at rump between male and female goat within age group 3 and 4. There was no significant ($P>0.05$) difference between male and female in age group of 1 and 2.

Shoulder width

The average shoulder width of the Maefur male goat in four age groups (04-12, 13-18, 19-24 and 25-35 months) were recorded to be 10.1±1.7, 9.7±3.1, 11.6±1.5, 12.1±1.4 cm while in female in these age groups were 8.5±2.3, 10.8±2.0, 10.3±2.0 and 10.4±1.5 cm, respectively. Significant ($P<0.05$) difference was reported in shoulder width between male and female goat within age groups 1, 3, and 4. There was no significant ($P>0.05$) difference between male and female in age group 2.

Body length

The average body length of Maefur male goat in four age groups (04-12, 13-18, 19-24, and 25-35 months) were recorded to be 51.0±4.1, 56.2±4.0, 61.8±6.8, and 72.3±7.1 cm while in female in these age groups were 49.4±3.6, 57.5±3.7, 57.6±6.4, and 64.3±5.0 cm, respectively. Significant ($P<0.05$) difference was reported in body length between male and female goat within age group 3 and 4. There was no significant ($P>0.05$) difference between male and female in the age group of 1 and 2. Both male and female adult Maefur goat with average body length 72.3 and 64.3 cm, respectively are larger than the Abergelle goat reported as 53.00 and 52.03 cm, respectively for adult male and female (Alemayehu et al., 2012). The faster growth of male goats

than females at early stage is suggested because of the hormonal effect that is non-release of androgen (which is known to have growth and weight - stimulating effects) in male animals until the testis are well developed (Frandsen and Elmer, 1981). Therefore, male goats are heavier and larger than female goat.

Chest depth

The average chest depth of Maefur male goat in four age groups (04-12, 13-18, 19-24, and 25-35 months) were recorded to be 7.0±2.3, 7.1±2.4, 11.9±2.6, and 10.4±2 cm, respectively whereas in female in these age group were 5.4±2.5, 7.4±2.7, 7.3±1.7, and 7.6±2.7 cm, respectively. Significant ($P<0.05$) difference was reported in chest depth between male and female goat within age group 1 and 4. There was no significant ($P>0.05$) difference chest depth between male and female in the age group of 2 and 3.

Ear length and ear width

The average ear length of Maefur male goat in four age groups (04-12, 13-18, 19-24 and 25-35 months) were determined to be 11.7±1.8, 11.6±2.5, 5.0±1.1 and 12.3±2.5 cm, respectively while in female in these age groups were 11.5±2.5, 11.1±2.3, 12.0±2.4 and 11.8±2.3 cm, respectively. The average ear width of Maefur male goat in four age groups (04-12, 13-18, 19-24 and 25-35 months) were determined to be 4.9±0.8, 5.2±1.1, 16.6±3.6 and 5.2±1.0 cm while in female in these age groups were 4.9±0.8, 4.9±0.7, 5.1±1.3 and 5.0±0.1 cm, respectively (Table 5). There was no significant ($P>0.05$) difference in ear length between male and female in all age groups whereas ear width significantly ($P<0.05$) differed between male and female in age group 4 whereas it was not significantly ($P>0.05$) differed in age group 1, 2, and 3. The indigenous Maefur goat is described as short and narrow ear.

Horn length

The average horn length of Maefur male goat in four age groups (04-12, 13-18, 19-24 and 25-35 months) were determined to be 11.4±3.5, 16.7±4.1, 13.3±2.1 and 19.3±6.3 cm while in female in these age groups were 9.9±5.0, 13.4±3.5, 15.0±4.3 and 15.6±4.2 cm, respectively. Significant ($P<0.05$) difference was reported in horn length between male and female goat within age group 2, 3 and 4 whereas there was not significantly ($P>0.05$) differed in age group 1. Maefur indigenous goat has medium sized and thick horn with some times spiral shape pointed upward for male whereas for female, short, thick, straight, and backward oriented horn.

Table 5. LSM± (SE) of the live body weight and linear body measurements for pooled age.

Body traits	Sex of goat	
	Male	Female
Body weight	34.7±0.6 ^a	28.9±0.4 ^b
Heart girth	75.3±0.5 ^a	70.0±0.3 ^b
Height at Wither	64.7±0.5 ^a	59.3±0.3 ^b
Height at Rump	64.8±0.3 ^a	59.2±0.3 ^b
Shoulder Width	11.3±0.1 ^a	10.2±0.1 ^b
Body length	64.3±0.6 ^a	60.0±0.4 ^b
Chest depth	8.7±0.2 ^a	7.2±0.1 ^b
Ear Length	12.0±0.1 ^a	11.7±0.1 ^a
Ear width	5.1±0.1 ^a	5.0±0.1 ^a
Tail Length	13.4±0.1 ^a	13.4±0.1 ^a
Horn Length	17.1±0.3 ^a	14.5±0.3 ^b
Head Width	13.0±0.3 ^a	11.3±0.2 ^b
Head length	19.8±0.2 ^a	18.5±0.2 ^b

^{a, b} means across the row connected with different subscription are differed significantly ($P < 0.05$).

Tail length

The average tail length of Maefur male goat in four age groups (04-12, 13-18, 19-24 and 25-35 months) were determined to be 12.4±1.2, 13.7±2.2, 12.9±4.3 and 13.6±2.1 cm while in female in these age groups were 9.2±4.0, 12.3±3.5, 19.2±2.4 and 14.4±5.0 cm, respectively. There was no significant ($P > 0.05$) difference in tail length between male and female in all age group.

Head width and length

The average head width of Maefur male goat in four age groups (04-12, 13-18, 19-24 and 25-35 months) were determined to be 9.2±4.0, 12.3±3.5, 9.4±3.9, 10.7±3.3 and 14.4±5.0 cm while in female in these age groups were 9.4±3.5, 9.4±3.9, 10.7±3.3 and 12.6±4.5 cm, respectively. The average head length of male in these age groups were 17.2±3.2, 19.0±3.3, 19.3±2.5 and 21.1±3.1 cm while for female in these age group were 14.0±4.2, 18.9±1.7, 18.2±2.5 and 19.9±2.5 cm, respectively. Significant ($P < 0.05$) difference was reported in head length between male and female goat within age group 2, 3 and 4 whereas it was not significantly ($P > 0.05$) differed in age group 1. Significant ($P < 0.05$) difference was reported in head width between male and female goat within age group 1, 3 and 4. It was not significantly ($P > 0.05$) differed in age group 2.

Effect of sex on body weight and linear body measurements

The LSM of body weight, heart girth, height wither, height

at rump, shoulder width, body length, chest depth in male were 34.7±0.57 kg, 75.3±0.53 cm, 64.7±0.46 cm, 64.8±0.34 cm, 11.3±0.12 cm, 64.3±0.61 cm, and 8.7±0.18 cm, respectively (Table 5). The LSM for these measurements (same order) in females were 28.9±0.35 kg, 70.0±0.33 cm, 59.3±0.31 cm and 59.2±0.27 cm, 10.2±0.11 cm, 60.0±0.40 cm, and 7.2±0.15 cm, respectively. There was significant ($P < 0.05$) difference between male and female LSM value of these measurements. Considering the LSM value of the live body weight and the major linear body measurement like heart girth, height at wither, body length and height at rump, the study revealed that male goat are heavier and larger than female goat at 95% level of confidence. This result of the current study is in line to the findings of Hassan and Ciroma (1990) in the Red Sokota goat breeds.

Effect of age on body weight and linear measurements

There was a significant ($P < 0.05$) difference both in live body weight and linear body measurements among the four age groups (04-12, 13-18, 19-24 and 25-35 months) of Maefur goat breed (Table 6). Superscripts (a), (b), (c) and (d) are used to indicate the order of the difference from larger (a) to small (d) mean value respectively at 5% level of significance with larger mean (a) and smaller mean (b) otherwise similar superscripts (either of these letters) connected for non-significant pair of difference. The LSM value of live body weight in four age groups (04-12, 13-18, 19-24 and 25-35 months) were 19.6±0.4, 27.6±0.3, and 29.3±0.4 and 37.5±0.4 kg, respectively.

Table 6. LSM (\pm SE) for body weight and body measurements for goats of pooled sex.

Body traits	Age group			
	04-12 months =1	13-18 months =2	19-24 months=3	25-35 months =4
Body weight	19.6 \pm 0.4 ^d	27.6 \pm 0.3 ^c	29.3 \pm 0.4 ^b	37.5 \pm 0.4 ^a
Heart girth	61.1 \pm 0.5 ^d	69.4 \pm 0.3 ^c	70.6 \pm 0.4 ^b	77.7 \pm 0.4 ^a
Height at Wither	54.0 \pm 0.4 ^c	59.1 \pm 0.3 ^b	58.4 \pm 0.3 ^b	66.5 \pm 0.4 ^a
Height at Rump	56.5 \pm 0.5 ^d	61.5 \pm 0.4 ^c	60.2 \pm 0.4 ^b	64.5 \pm 0.3 ^a
Shoulder Width	9.4 \pm 0.2 ^c	10.2 \pm 0.3 ^b	10.9 \pm 0.1 ^a	11.2 \pm 0.1 ^a
Body length	50.3 \pm 0.4 ^d	56.8 \pm 0.4 ^c	59.3 \pm 0.6 ^b	68.2 \pm 0.4 ^a
Chest depth	6.3 \pm 0.3 ^c	7.2 \pm 0.3 ^b	7.2 \pm 0.2 ^b	9.0 \pm 0.2 ^a
Ear Length	11.4 \pm 0.3 ^a	11.6 \pm 0.3 ^a	11.9 \pm 0.2 ^a	12.0 \pm 0.1 ^a
Ear width	4.9 \pm 0.1 ^a	5.1 \pm 0.1 ^a	5.1 \pm 0.1 ^a	5.1 \pm 0.1 ^a
Horn Length	10.8 \pm 0.5 ^c	15.20.4 ^b	15.7 \pm 0.4 ^b	17.4 \pm 0.3 ^a
Tail Length	12.4 \pm 0.2 ^b	13.3 \pm 0.2 ^a	13.4 \pm 0.2 ^a	13.7 \pm 0.1 ^a
Head Width	9.3 \pm 0.4 ^c	10.9 \pm 0.4 ^b	11.6 \pm 0.3 ^b	13.5 \pm 0.3 ^a
Head length	15.8 \pm 0.5 ^c	18.6 \pm 0.3 ^b	18.8 \pm 0.3 ^b	20.5 \pm 0.2 ^a

a, b, c, d Means carrying the same superscript within a row are not significantly different ($P > 0.05$).

Live body weight was significantly ($P < 0.05$) differed among the four age groups, the oldest (25-35 month) age group is heavier than the younger age group 04-12 month. As there were consistent increases in live body weight as the animals aged. The LSM of heart girth in these age groups were 61.1 \pm 0.5, 69.4 \pm 0.3, 70.6 \pm 0.4, and 77.7 \pm 0.4 cm, respectively. The LSM of height at wither in these age groups were 54.0 \pm 0.4, 59.1 \pm 0.3, 58.4 \pm 0.3, and 66.5 \pm 0.4 cm, respectively. There was significant ($P < 0.05$) difference between the age group pairs in heart girth and height at wither but there was no significant ($P > 0.05$) difference between the least squares mean of age group 13-18 and 19-24 month in both measurements. The LSM of high at rump in these age groups were 56.5 \pm 0.5, 61.5 \pm 0.4, 60.2 \pm 0.4, and 64.5 \pm 0.3 cm, respectively whereas for body length in these age groups were 50.3 \pm 0.4, 56.8 \pm 0.4, 59.3 \pm 0.6 and 68.2 \pm 0.4 cm, respectively. There was a significant ($P < 0.05$) difference between the age group pair in both body length and height at rump. The LSM of shoulder width in these age groups were 9.4 \pm 0.23, 10.2 \pm 0.28, 10.9 \pm 0.17 and 11.2 \pm 0.10 cm, respectively. There was a significant ($P < 0.05$) difference between the age group pair in shoulder width but there was no significant ($P > 0.05$) difference between age group 19-24 and 25-35 months. This result is however not surprising since the size and shape of the animal is expected to increase as the animal is growing with age. There was wide variation as the age of the animals increased in the live body weight.

This result is in line to the finding of Khan et al. (2006) and Alemayohu et al. (2012). However, the variability among the age group at maturity sharply reduced between age groups (Fajemilehin and Salako, 2008). In some linear measurement, the difference between age group 2 and 3 was not significant as the body condition of

the animal affects the consistent growth of the animal and then the measurements (Devendra and Burns, 1983). Most of the linear body measurement of the sampled indigenous goat significantly ($P < 0.05$) increased with age, the older animals (25 months and above) being heavier and larger than the kids (04-12 months), with the growers being intermediate. The current study observed that growth rate from 0 to 1 PPI was higher than as compared to that from 1 to 2 PPI and 2 \geq 3PPI in live body weight of the highland sheep population (Figure 3).

The indigenous Maefur goat has the following key identifying features

83 and 16% have concave and flat (straight) facial profile respectively, with narrow face. Ear is laterally oriented for about 92% of the sampled population. Maefur indigenous goat has been classified as short earned goat. Maefur indigenous goat has the body conformation in- between lanky and compacted (76%) and lanky (20%). It has rectangular body shape. Straight (81%) and spiral (13%) horn shape with Upright (41%) and backward (45%) horn orientation. Polledness occurred at 3% of the flock and 6% in male with thick and long horn Mean horn length 15.8 cm (Male 17 cm). Spotty (33%) with gray (white) and black, pied (27%) white on black, uniform (25%) black or white (rare) and shaded 15% with beige like pall brown. Variable hair coat length: Medium (64%), short (29%) and long (7%) hair coat length. Hair type smooth (50.7%) and glossy (34.3%), straight (6.7%), curly (3%) and dull (5.7%). Variable body colors: White (9.5%), beige (light brown 29.6%), black (20%), and brown (17.5%), blue gray (8%). Long hair is present in neck 44%, tail 56% head 38%, chest 33%, thigh 32%, back 30% and leg 28

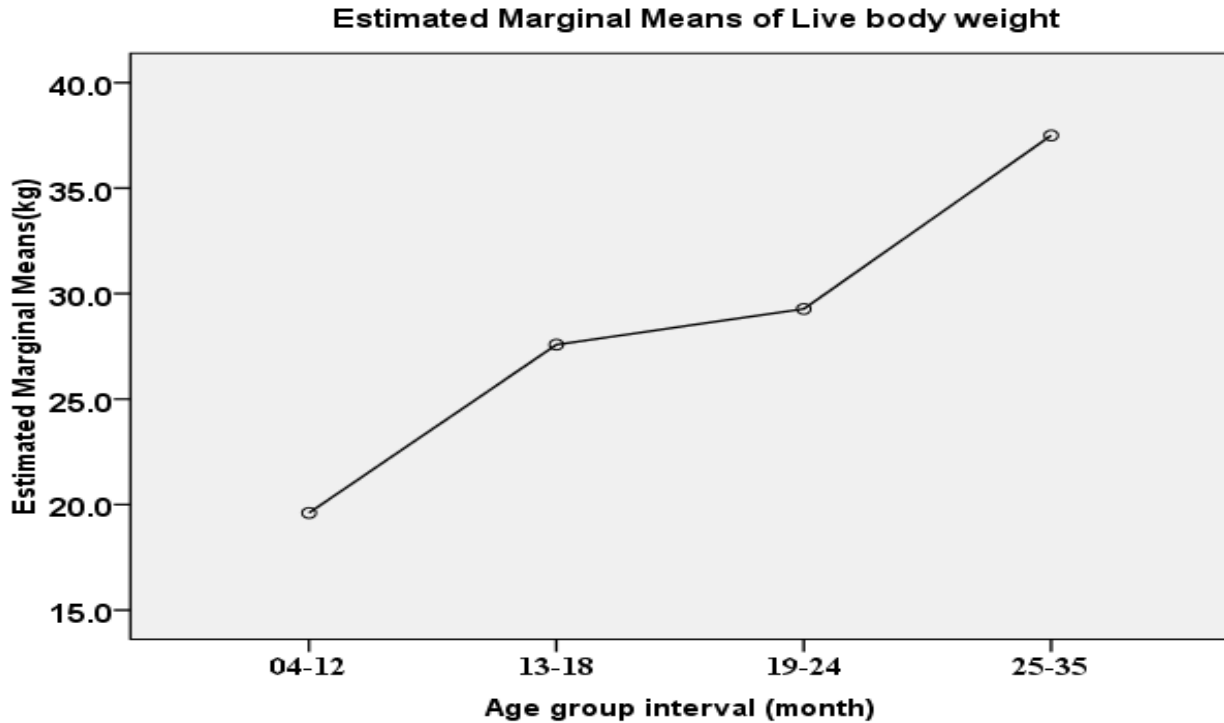


Figure 3. Effect of age on live body weight in relation to growth rate in Maefur goat.

of the goats. Beard is present in male (83%) and uncommon for female. Wattles are rare (29%). Toggle is present in 45% of the flock. It is used for Function: Milk and Meat production. It adapted drought and mountainous topography features.

Conclusion

Maefur indigenous goat populations adapted to the mountainous topographical features and survived through utilizing browsed indigenous plant species around the hillside of Erob district eastern Tigray. The analyses of data on body measurements provide quantitative measure of body size and shape. Body measurements provide quantitative measure of body size and shape. It has an identified body characteristic from other indigenous goat found in the regional government of Tigray by its conformation (rectangular shape), large heart girth (82.1 cm for adult male and 73.4 cm for adult female), thick and long horn in male, variable coat color and concave facial profile. Accordingly, the indigenous Maefur goats breed is characterized as medium-size breeds (42.8 kg for adult male and 32.7 kg for adult female). Based on this evidence, male goat is larger than female goat. It has distinguished feature from Afar (dwarf goat) by its large size (has large heart girth) in between the compacted and leggy body confirmation. Afar goat is in habited in the regional government of Afar around the

lowland but Maefur is inhabited in the mountainous highland area of Tigray. In addition, to increase the validity of this on farm preliminary study, it is important to undertake well planned on station study for phenotypic and genetic characterization of the goat under study within breeds and then to improve their genetic potential. Community based breed improvement through selection should be designed for proper mating superior male and female goat. It is better to make a group of households of the same village in a local, small-scale community-based indigenous goat breeding organization.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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APPENDIX

Table 1. Data collection format for linear body measurement (LBM).

S/N	Name of the owner	Sex (1=M; 2=F)	*Age group	value of LBM in cm											
				BW	HG	HW	RH	SW	BL	CD	EL	Ew	HL	TL	
1															
2															
3															
4															
5															
6															

*age group for 04-12months=A, for 13-18 months=B, for 19-24months=C and for 25-35 months= D For age grouping use milk and permanent teeth pair (milk teeth= Group A, for 1pair of permanent teeth=Group B, for 2 pair of permanent teeth=Group C and for >=3pair of permanent teeth =D). BW=Body weight, HG=Heart girth, HW=Height at wither, RH=Height at Rump, SW=Shoulder width, BL=Body Length, CD=Chest Depth, E L=Ear length, Ew=Ear Width, HL=Horn length and TL=Tail length.

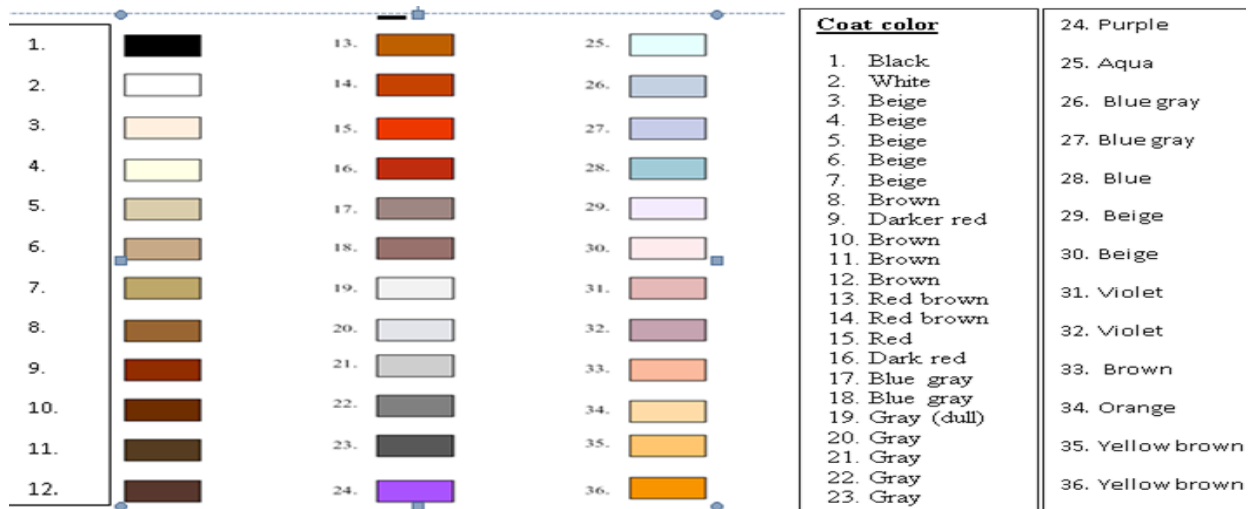


Figure 1. Chart of body coat color and pattern.

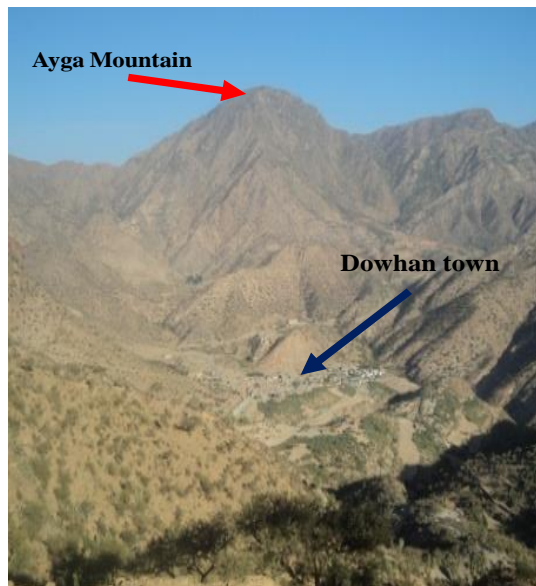


Figure 2. Typical mountain landscape "Ayga Mountain".

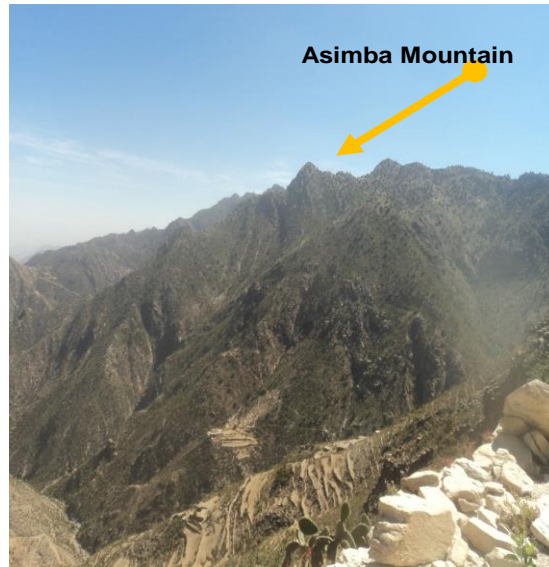


Figure 3. Typical mountain landscape (Asimba Mountain).



Figure 4. Working downhill towards the targeted HH.



Figure 5. Moving uphill from one respondent to the next for personal interview.



Figure 6. Personal interview with Ato Kabsay residence of Haraze-Sabata..



Figure 7. Personal interview with Ato Sibhat residence of Haraze-Sabata



Figure 8. Focus group discussion with goat owner.



Figure 9. Indigenous browse plant species.



Figure 10. Maefur goat flock in the study area.

Full Length Research Paper

Uses of *Haematostaphis barteri* Hook.f. among the Waaba and Bètamaribè in North-Benin and impact on the species vulnerability

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Haematostaphis barteri Hook.f. is an endemic plant species with a high economic potential that mostly grows on rocky soils in the Sudanian zone from Ghana to Sudan. In Bénin, the species is found only around the commune of Natitingou, but there is little knowledge on its uses by the local populations and how these uses potentially affect its conservation status. This study aimed to evaluate the vulnerability of *H. barteri* in its natural range in Benin, based on the assessment of its indigenous uses and its population inventory. An ethnobotanical survey was conducted in eight villages of the commune of Natitingou from eighty people belonging to the Bètamaribè and Waaba ethnic groups, to identify their knowledge and usage of the species. The species population inventory was also carried out to estimate the frequency and density of *H. barteri* populations. The species' vulnerability score was determined using results from the ethnobotanical survey, population inventory and information in the literature. Rural populations in Natitingou use *H. barteri* mainly for food (100% of interviewees), traditional medicine (76.3%) and wood fuel (37.5%). Most of the respondents (91.3%) usually harvest immature fruits so as to preserve them, both for their consumption and for commercialization. Twenty-nine populations of *H. barteri* were identified with densities averaging 46.6 adult individuals per hectare and a regeneration of 9.7 individuals per hectare. The average vulnerability score for *H. barteri* was estimated at 2.4 on a scale of 1 (not vulnerable) to 3 (highly vulnerable). *H. barteri* is thus a vulnerable species that deserves to be included in Benin's list of endangered species.

Key words: West Africa, Atacora mountains, ethnobotany, endemic species, exploitation, vulnerability, non timber forest products (NTFP).

INTRODUCTION

Non timber forest products (NTFP) are a potential source of income that allows human communities to meet

several of their socio-economic needs (Laird and Pierce, 2002; Vodouhê et al., 2009; Moupela et al., 2011).

NTFP constitute a set of various products including fruits, nuts, seeds, latex, resin, gum, medicinal herbs, spices, dyes, decorative plants, firewood and bamboos (Sodhi, 2010) to name a few. In south Saharan Africa, several and well-diversified wild plants have been identified as contributing significantly to the diet balance and improvement of rural population health (Eyog Matig et al., 2002). This crucial importance prompted reflections on the possibility of domesticating multi-purpose species to ensure their sustainable conservation (Assogbadjo et al., 2002; Codjia et al., 2003; Dossou et al., 2004).

Haematostaphis barteri Hook.f. (Anacardiaceae) is a woody plant species typical of tropical Africa and which distribution spans from Ghana to Sudan (Arbonnier, 2002). The species is endemic to the Sudanian zone and mostly grows on rocky soils (Adomou, 2005). In Benin, it is specifically found around the commune of Natitingou (Adomou, 2005; Akoègninou et al., 2006). The species limited geographic range and its high socio-economic importance for human communities, particularly the high consumption of its fruits (Umaru et al., 2007; Atato et al., 2010), might be prejudicial to its survival. Indeed, several studies showed that harvesting of organs or parts of plants can compromise species dissemination and reproduction (Betti, 2001; Gaoué and Ticktin, 2007; Krishnamurthy et al., 2013) and then increase their vulnerability (Betti, 2001; Dibong et al., 2011). Multiple uses, in particular, create many stresses to the plant that can affect the overall population dynamics (Gaoué and Ticktin, 2007; Hawkes and Sullivan, 2010; Allred et al., 2012).

Uncontrolled harvesting of NTFP can even sometimes give rise to the disappearance of species, especially when such species are not abundant (Akpagana and Bouchet, 1995). Apart from the direct damages to the integrity of the plant and its vital functions, the exploitation of NTFP could also contribute to the loss of diversity by altering the abundance and distribution of species as well as reduce their genetic base (Papy and Goldringer, 2011). This applies in particular where farmers select and conserve a small number of species to maintain the functions they deem useful in their agro-ecosystems such as soil fertility, production of firewood, leaves, fruits or other products. Hence, biodiversity conservation involves the identification of species sensitive to exploitation and anthropization of ecosystems, and which require conservation actions. This study aimed to evaluate the vulnerability of *H. barteri* based on the assessment of its indigenous uses and its population inventory in the natural range of the species in Northern Benin.

MATERIALS AND METHODS

Study area

The study was conducted in the commune of Natitingou (10°19' North and 1°29' East), in northwestern Benin (Figure 1). Natitingou is located in the vicinity of the Atacora mountain chain and is characterized by an accidental relief, with altitudes ranging from 400 to 650 m. The climate is of the sudanian type with a rainfall between 1,000 and 1,400 mm, and two seasons: the rainy season from April to October and the dry season from November to March. The dry season is marked by the harmattan, a cold-dry and dusty northeast wind which blows from the Sahara desert. The average temperature is 27°C but can reach 37°C in March and April. Soils are of the tropical ferruginous type and mostly rocky and shallow throughout the mountain chain (Azontondé, 1991). The vegetation is dominated by tree and shrub savannah. The dominant woody species are *Parkia biglobosa*, *Vitellaria paradoxa*, *Adansonia digitata*, *Bligia sapida*, *Tamarindus indica*, *Bombax costatum* and *Khaya senegalensis* (Wala, 2005).

The commune of Natitingou covers an area of 3,045 km² and counts nine arrondissements (four urban and five rural), which contain 39 villages and 26 urban districts. The population was estimated at 103,843 inhabitants in 2013 (INSAE, 2013) and is dominated by the Waaba (or Yoabou) and Bètammaribè ethnic groups which live around the Atacora mountain chain (Biaou, 2006). Other ethnic groups in the commune include the Dendi, Batombou, Peuhl, Yoruba, Fon and Natimba. The majority of the population, including the Bètammaribè and Waaba, believe in animist practices and worship divinities represented by physical elements such as clumps of natural stones, large sized trees or other specific constructions. Agriculture is the principal economic activity in the commune and farmers produce mostly maize, sorghum, millet and yam (Biaou, 2006).

Study species

Haematostaphis barteri Hook.f. (Anacardiaceae) is a shrub up to 8 m tall and can reach 35 cm in diameter (Kpemissi Amana, 2007). It is found in the Guinean and Sudanian savannas on rocky soils, in tropical Africa. It has been observed in Ivory Coast, Ghana, Togo, Nigeria, Benin, Gabon, D.R. Congo (Zaire) and Cameroon (GBIF Secretariat, 2016) but the populations are mostly scarce and isolated. The crown is spread out and open (Figure 2A), and the leaves are grouped at the ends of the branches. The leaves are alternate, imparipinnate, glabrous and 20-35 cm long, with 17 to 25 alternate or subopposed leaflets, narrowly elliptic or oblong. The bark is scaly and brown - gray. *H. barteri* is a dioecious species with a glabrous pendant inflorescence in the terminal panicle, and up to 30 cm long. The infructescence is made of long hanging clusters composed of glabrous ellipsoid drupes, purple at maturity and 2 cm long (Figure 2B). Flowering and fruiting occur at the end of the dry season, generally before the first leaves appear.

Overview of the study method

To assess the uses and the vulnerability of *H. barteri* in North-Benin, four complementary approaches were combined:

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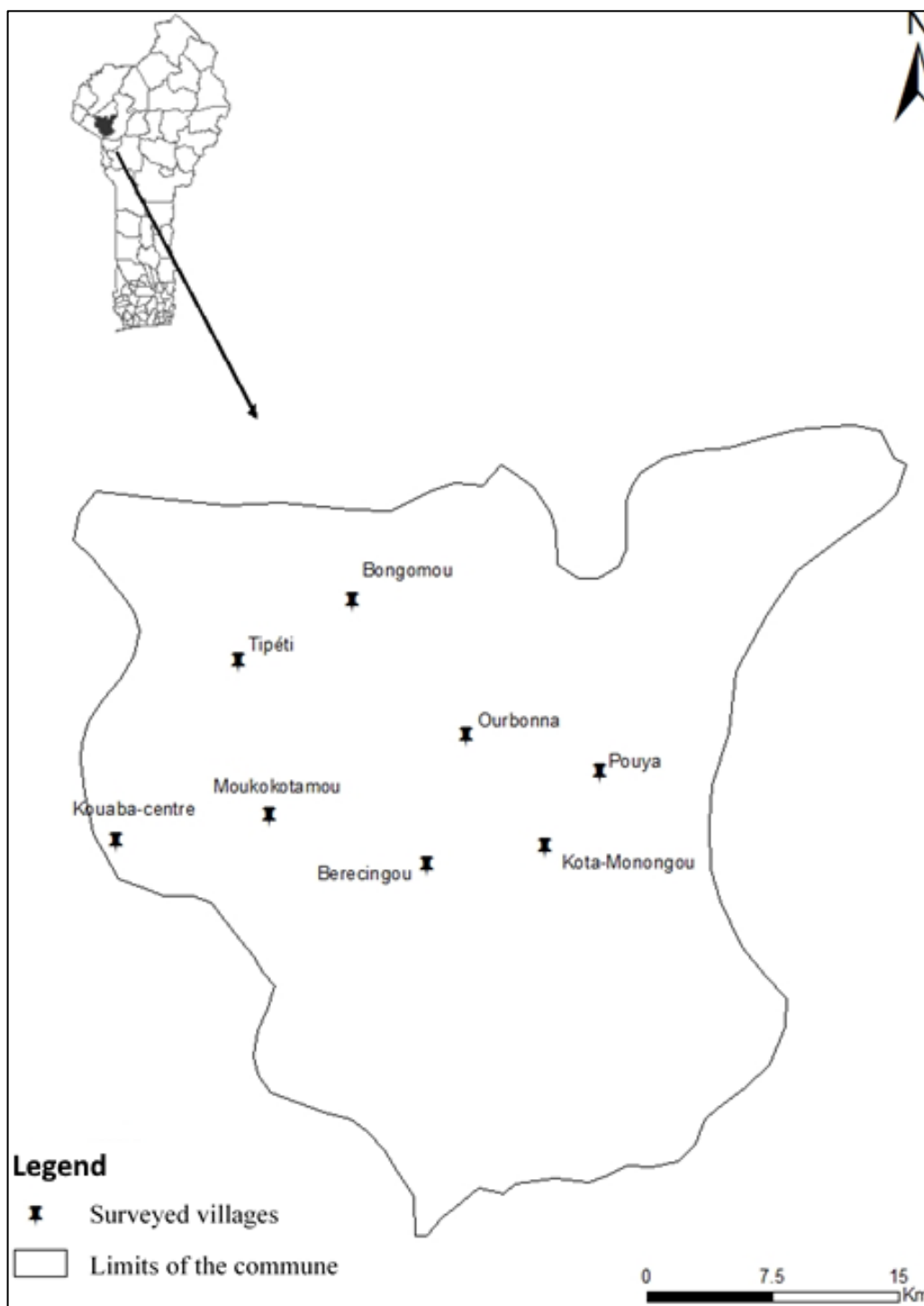


Figure 1. Location of the commune of Natitingou in Benin and the surveyed villages for the ethnobotanical study of *H. barteri*.

1. Exploratory survey to identify and select localities where *H. barteri* is present for further characterization of the species population and ethnobotanical surveys;
 2. Detailed inventory of the selected *H. barteri* populations to

estimate the density and frequency of the species populations;
 3. Ethnobotanical study of *H. barteri* in the selected localities to identify current uses of the species in the study area; and
 4. Assessment of *H. barteri* vulnerability through the calculation of a



Figure 2. *H. barteri* shrub on a rocky outcrop (A) and mature fruits (B) in the commune of Natitingou (Benin). Photo credit: Moutouama (2011).

vulnerability score derived from the information gathered during both the species population inventory and the ethnobotanical survey.

Exploratory survey and localization of *H. barteri* populations

An exhaustive list of localities where *H. barteri* is present was established in July 2011 through an exploratory survey combined with road transects across the commune of Natitingou and two neighboring communes (Boukombé and Toucountouna). The populations of the species were identified with the aid of agents from the local forestry and agriculture departments, as well as traditional health practitioners and farmers, by showing them a fresh specimen collected in the wild. Based on this exploratory survey, *H. barteri* presence was confirmed in 25 villages, including 20 in the commune of Natitingou, 3 in the commune of Boukombé and 2 in the commune of Toucountouna. The commune of Natitingou was eventually maintained for the ethnobotanical survey since the species was more abundant and more frequent in this area.

Characterization of *H. barteri* populations

Individuals of *H. barteri* were counted systematically within all the populations identified, including the neighboring communes of Boukombé and Toucountouna, so as to estimate the density and frequency of *H. barteri* populations. The species sometimes grows in clumps because it resprouts after periodic fires or other wounds. In these cases, each clump was counted as one individual. The environmental characteristics of each site were also noted for each population. These included the type of vegetation, type of soil, presence of rocky outcrop and presence of streams. All the surveyed populations were georeferenced using a Garmin 60 GPS to establish the distribution map of the species populations using the software Quantum GIS.

Ethnobotanical study of *H. barteri*

Ethnobotanical surveys were conducted in eight villages (Table 1)

randomly sampled out of twenty where the species was recorded in the commune of Natitingou. A total of 80 people (40 men and 40 women) were interviewed based on five men and five women per village. Interviewees are individuals aged between 36 and 80 years and belonging to the two dominant ethnic groups (Bétammaribè and Waaba) in the study area. Interviewees also belong to socio-professional groups that may be familiar with the species, including farmers, NTFP sellers, quarrymen and traditional health practitioners (Table 1).

Based on a semi-structured questionnaire, the indigenous names of the species, its potential uses (food, medicine, construction, art and wood energy) as well as the most used organs and diseases treated were collected. Fisher's exact test in R.3.2.2 software (R Core Team, 2015) was used to evaluate the relation between the ethnic groups and the use categories of *H. barteri*, organs used or diseases treated. Fisher exact test was preferred because some of the expected frequencies were less than five (Crawley, 2007).

Assessment of the species vulnerability

H. barteri vulnerability was assessed based on nine parameters (Betti, 2001). These include the popularity of the species, the organs harvested, the stage of development of these organs, the mode of collection of the organs, the pharmaceutical forms used, the plant biotope, the mode of seed dissemination, the plant morphological type and the species frequency in the area. For each of these parameters, a vulnerability score (V_i) was assigned a scale from 1 (species not vulnerable for the parameter considered) to 3 (highly vulnerable), with 2 corresponding to a moderate vulnerability. These scores were deduced from:

1. The ethnobotanical study (popularity of the species, organs harvested, stage of development of these organs, mode of collection of the organs and pharmaceutical forms used)
2. *H. barteri* populations inventory (plant biotope and frequency in the area)
3. Information from the literature (mode of seed dissemination and plant morphological type).

By combining the vulnerability scores of all the parameters, an average index of vulnerability (V) was calculated using the equation:

Table 1. Number of people interviewed in the ethnobotanical study of *H. barteri* in the commune of Natitingou and characteristics of the species local populations.

Localities	Number of interviewees	Ethnic groups		Age		Socio-professional groups				Characteristics of <i>H. barteri</i> populations	
		Be	Wa	30 to 49	≥ 50	F	H	M	O	Number of populations recorded (and ID)	Density /ha (dbh ≥ 5 cm)
Berecingou	10	10		3	7	9		1		1 (P11)	120
Bongomou	10		10	4	6	2	2	5	1	1 (P02)	40
Kotamonongou	10		10	4	6	7		2	1	1 (P12)	20
Kouaba-Centre	10	10		8	2	6	3	1		1 (P17)	20
Moukokotamou	10	10		5	5	8		2		2 (P05 & P06)	50
Ourbonna	10		10	4	6	6	1		3	1 (P08)	20
Pouya	10		10	5	5	7	3			1 (P13)	20
Tipeti	10	10		5	5	5	4		1	1 (P29)	20
Total	80	40	40	38	42	50	13	11	6	9	

Be (Bètamaribè); Wa (Waaba); (F) farmer; (H) housewife; M (merchant of NTFP), O (other); ID (population identification number "Pxx", used also in Figure 3); dbh (diameter at breast height).

$$V = \sum V_i \times 1/n$$

where V_i is the vulnerability score for the parameter i , and n is the total number of parameters.

RESULTS

Localization and characterization of *H. barteri* populations

29 populations of *H. barteri* were identified, of which 22 were in the commune of Natitingou and the remaining in the communes of Boukombé and Toucountouna (Figure 3A). The density of *H. barteri* was in average 46.6 stems/ha for adults (dbh ≥ 5 cm) and 9.7 stems/ha for the regeneration (dbh < 5 cm). The regeneration was inexistent in 19 (65.5%) of these populations, for example at Kounitchankou

(P03), Katagnika (P19), Koussantikou (P07), Kotamonongou (P12), Pouya (P13), Moukokotamou (P05) and Ourbouga (P26) in the commune of Natitingou, and Peperkou (P20) and Takissari (P14 and P15) in the commune of Toucountouna (Figure 3B).

Also, there is no significant plantation of the species in the surveyed area, and only two (2.5%) of the interviewees stated they have once planted a few individuals of the species.

Indigenous names of *H. barteri*

The language spoken by the Waaba is called Waama, while the language of the Bètamaribè is called Tammari or Ditammari. All (100%) the interviewees know *H. barteri*. Only one name is used in each of the two ethnic groups surveyed to designate the tree and its fruit

indiscriminately. *H. barteri* is locally named "Yinrinyinrinbou" (singular) or "Yinrinyinrina" (plural) by the Waaba and "Mouyinyinrinmou" (singular) or "Deyinrinyinride" (plural) by the Bètamaribè, thereby indicating similarities in the consonances between the two languages.

Uses of *H. barteri* and most sought plant parts

The Waaba and Bètamaribè of Natitingou use *H. barteri* primarily for food (100% of the interviewees), traditional medicine (76.25%) and wood fuel (37.5%) (Figure 4A). The proportion of the respondents using the species for food (fruits) is the same among the Waaba (100%) and Bètamaribè (100%). However, its use in traditional medicine is more important among the Bètamaribè (87.5%) than the Waaba

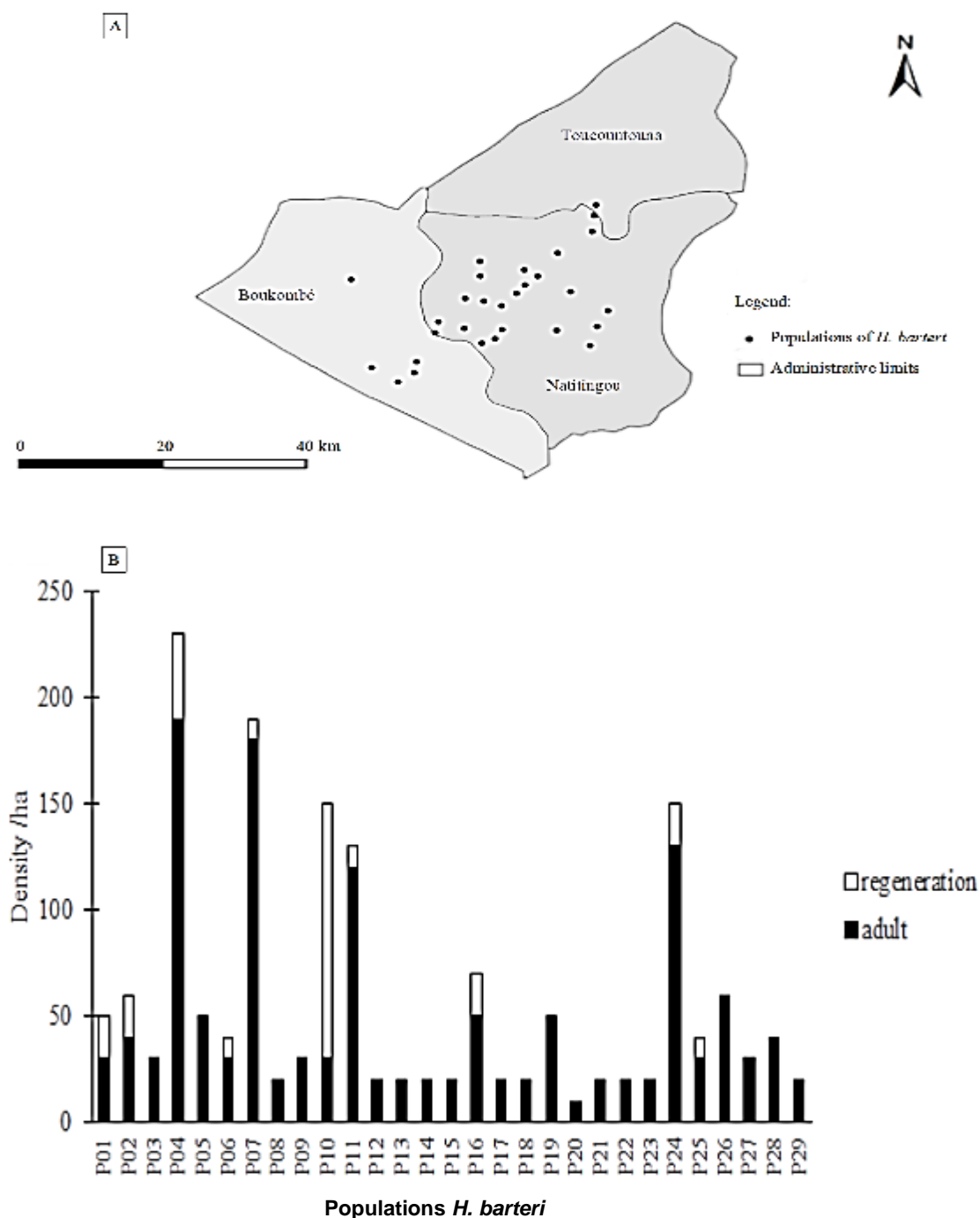


Figure 3. Characteristics of *H. barteri* populations inventoried in North Benin: (A) localization in the communes of Natitingou, Boukoubé and Toucountouna; and (B) Density of the regeneration and adult trees.

(65%). Also, ritual use is limited (1.25%) and was noted only among the Waaba. The species is not used at all as craft wood, timber or construction wood.

The most sought parts of *H. barteri* in both ethnic groups are fruits (100% of interviewees), stems (98.75%) and leaves (82.5%) (Figure 4B). Most of the respondents

(91.3%) usually harvest immature fruits to preserve them, both for their consumption and for commercialization. On the contrary, both ethnic groups rarely use barks (22.5%), roots (20%) and flowers (12.5%). Still, the Waaba use more, the flowers (25%), barks (27.5%) and roots (27.5%) of the species than Bètammaribè (0, 17.5 and

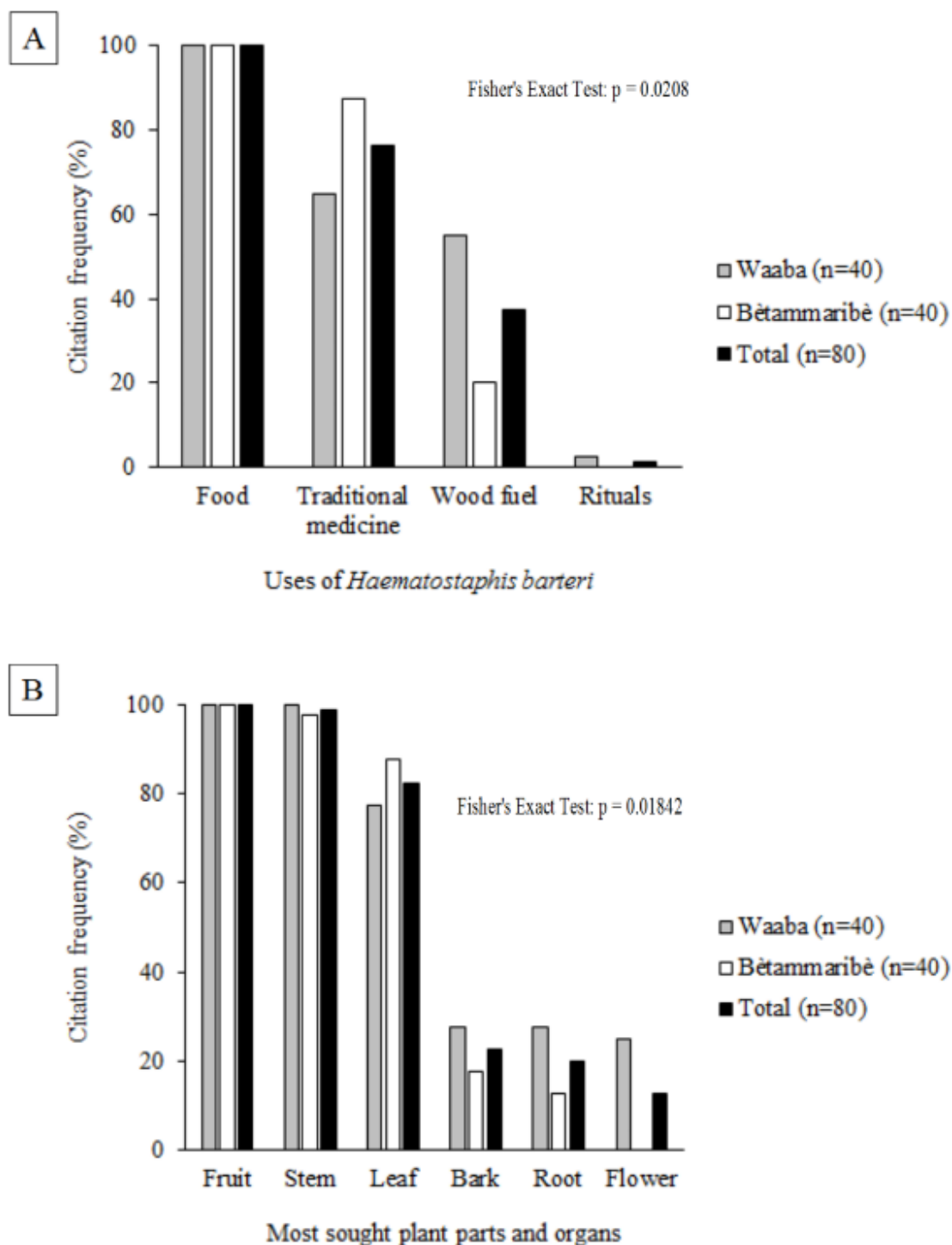


Figure 4. Uses of *H. barteri* by the Waaba and Bètammaribè of the commune of Natitingou: (A) most common uses and (B) most sought plant parts and organs.

12.5%, respectively). In contrast, the Bètammaribè (87.5%) use more, the leaves of the species than Waaba (77.5%).

There were significant differences between the Waaba and Bètammaribè for both the uses of *H. barteri* (Fisher's Exact Test, $p = 0.0208$) and the plant parts collected

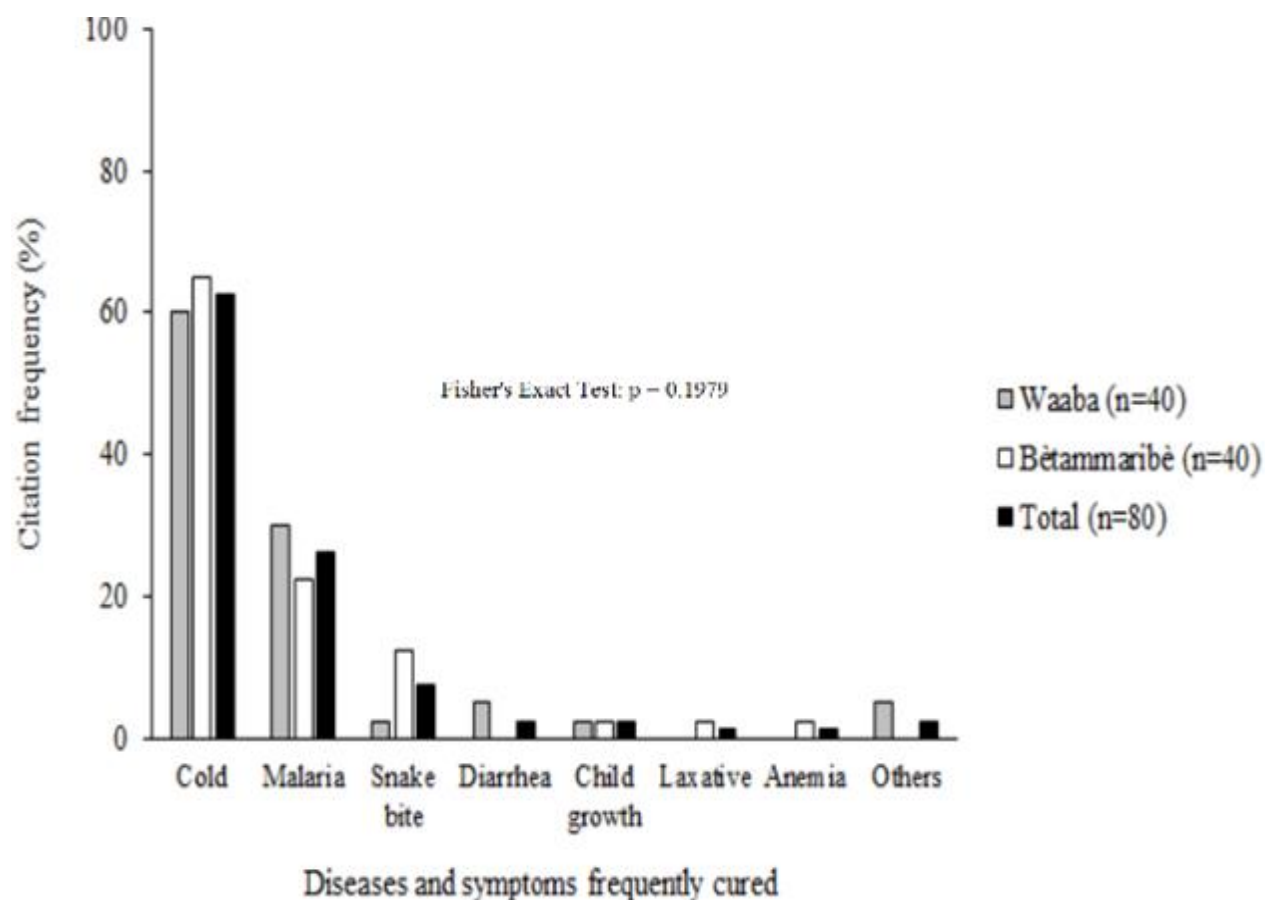


Figure 5. Diseases and symptoms frequently cured with *H. barteri* organs.

(Fisher's Exact Test, $p = 0.01842$).

Diseases and symptoms treated with *H. barteri* organs

There was no difference between the Waaba and Bètammaribè regarding the use of *H. barteri* in traditional medicine (Fisher's Exact Test, $p = 0.1979$). The majority (86.75%) of the interviewees quoted at least one disease or symptom treated with *H. barteri* organs. The plant can be used solely or in combination with other plants for the treatment of more than seven diseases or symptoms (Figure 5). Diseases treated with *H. barteri* include cold (62.5% of the interviewees), malaria (26.25%), snake bite (7.5%), diarrhea (2.5%) and child growth (2.5%). It is used to a smaller extent as laxative (1.25%) or to treat anemia (1.25%). Also, the cooking of the wild yam (*Dioscorea* sp.) in combination with the leaves of *H. barteri* makes it more pleasant to eat, thus enabling poor households to survive during the lean season with this occasional meal.

Vulnerability of *H. barteri*

The average vulnerability score for *H. barteri* was estimated at 2.4, thus indicating that the species is vulnerable (Table 2 and Figure 6). Factors contributing to the species vulnerability include its popularity, the harvesting of its immature fruits by locals, its biotope restricted to rocky soils on the Atacora mountain chain, the scarcity of its populations, and its dependence on external factors (animals and human) for seed dissemination.

DISCUSSION

The understanding of local populations needs in term of NTFP is essential for establishing sustainable conservation policies and for biodiversity conservation (Vodouhê et al., 2009). Also, to be effective, efforts to conserve biodiversity must ideally be based on endogenous knowledge and local mechanisms of resource management (Camou-Guerrero et al., 2008).

Table 2. *H. barteri* vulnerability score established for nine ecological and ethnobotanical parameters.

Vulnerability assessed	parameters	Score	Score justification
Popularity of the species		3	100% of the interviewees (Waaba and Bètamaribè) know <i>H. barteri</i> , and 100% use either its fruits or other plant parts.
Organs harvested		2	The mostly used organs by locals are fruits (93% of citation) and leaves (83%). The harvesting of these organs does not necessarily lead to the death of the plant individuals.
Development stage of organs harvested		3	91.3% of the interviewees harvest fruits of <i>H. barteri</i> before maturation while leaves, roots, and barks are harvested at a mature stage. Harvesting of immature fruits can compromise the species regeneration.
Mode of collection of the organs		2	The majority of the interviewees (87.5%) rely on the harvesting of <i>H. barteri</i> fruits while 12.5% combine collecting fallen fruits and harvesting.
Pharmaceutical forms used		2	Roots and barks are dried for their conservation. However, fruits are directly consumed.
Biotope		3	<i>H. barteri</i> is restricted to rocky soils on the Atacora mountain chain
Morphological type		1	<i>H. barteri</i> is a woody plant species with many stems and is then less vulnerable than species with single stem
Seed dissemination mode		3	Seeds of <i>H. barteri</i> are disseminated by animals and human, making the species dependent on external factors and thus vulnerable
Frequency/abundance of the plant in the area		3	<i>H. barteri</i> is an endemic and uncommon species which distribution is restricted to the commune of Natitingou. Its populations are presently isolated
Average vulnerability score (V)		2.4	Vulnerable species

Vulnerability score = 1 (not vulnerable); = 2 (moderately vulnerable); = 3 (highly vulnerable).

This study enabled understanding the importance of *H. barteri* for the human communities living along Atacora chain and to assess the species status of conservation which was found critical in Benin.

Uses and importance of *H. barteri*

Significant differences were found between the Waaba and Bètamaribè for both the uses of *H. barteri* and the collected plant parts. Although, the two ethnic groups have been living closely for a long time and could consequently share similar knowledge, only the diseases and symptoms cured with the species in traditional medicine were similar in the two ethnic groups. There are indeed cultural connections between the Waaba and Bètamaribè, and both of their spoken languages (Waama and Tammari) belong to the Oti-Volta languages, a subgroup of the Gur languages spoken in northern Ghana, Benin and Burkina Faso (Williamson and Blench, 2000). This is also evidenced by the similarities in the consonances of the species local names between the two languages. Still, it seems that there have been some differentiations between the two groups about the use of the plant in traditional medicine, in rituals or as wood fuel. This differentiated uses could also explain the differences between the two groups concerning the most sought plant parts.

The fruits and leaves of *H. barteri* are widely used by the communities living in the vicinity of the Atacora mountain chain. On the other hand, the roots and the bark are less used. The same findings regarding food and therapeutic uses of *H. barteri* by local populations were made in Nigeria (Eromosele and Eromosele, 2002; Umaru et al., 2007; Kubmarawa et al., 2009) and Togo (Kpemissi Amana, 2007). However, it is only in Benin that the species is reported as wood fuel. The contribution of *H. barteri's* wood to domestic energy in the survey area increases its socio-economic interest but might also pose serious problems for its conservation.

Besides, *H. barteri* bear fruits at the end of the dry season (Arbonnier, 2002), which corresponds to the lean period in the study area, and makes the species a subsistence food of high importance for local poor communities. Indeed, the commune of Natitingou, where the species is found, belongs to the Benin communes having the highest food insecurity rates. In this commune, the proportion of households with poor or limited food consumption was estimated at 50% (PAM, 2014). Their poorly diversified diet is characterized by major deficiencies (lack of foods rich in animal proteins, fruits, milk and dairy products), as cereals (millet, sorghum, and maize) and yam form the basis of the diets. In this context, NTFP and fruit trees like *H. barteri* can contribute significantly to the diet balance of poor households.

Also, the level of poverty of the population greatly

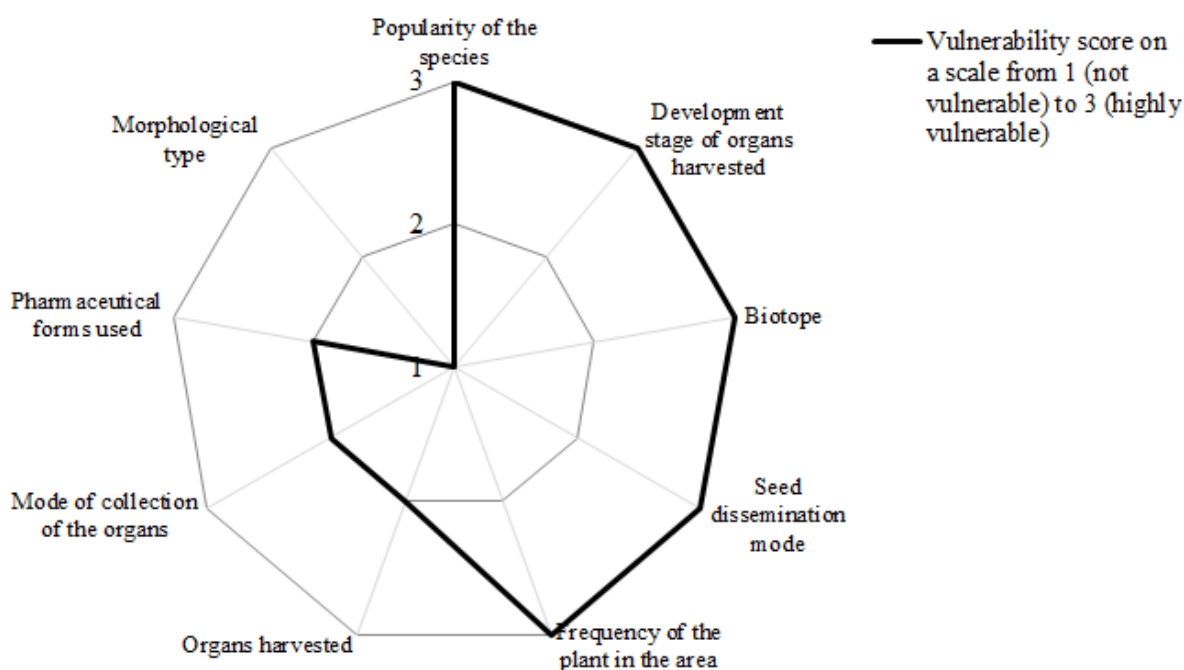


Figure 6. Vulnerability indicators for *H. barteri*.

reduces its accessibility to modern health facilities and increases the use of flora and fauna species for health care. The leaves, roots and barks of *H. barteri* contain substances like tannins, saponins and flavonoids (Eromosele and Eromosele, 2002; Kpemissi Amana, 2007; Umaru et al., 2007; Kubmarawa et al., 2009) and explains the interest of traditional healers in using *H. barteri* for treating several diseases. These chemical substances have anti-inflammatory and analgesic properties and could account for the fact that *H. barteri* is used for treating snakes bites and attenuating headaches. Tannins favor the inhibition of intestinal motility and justify the utilization of the species as anti-diarrheic (Djemai, 2009). Likewise, *H. barteri* leaves are known to be excellent sources of nutrients for human, and its organs contain proteins such as leucine, tyrosine and phenylalanine at a higher rate than WHO's recommended standards for human (Kubmarawa et al., 2009) with potentially interesting effects on child growth.

Vulnerability of *H. barteri*

In this study, *H. barteri* was found vulnerable due to its popularity, the harvesting of its immature fruits by locals, its uncommon biotope, the scarcity of its populations, and its dependence on external factors for seed dissemination. *H. barteri* is well known and widely used in the commune of Natitingou for multiple purposes such as food, traditional medicine and wood fuel. Locals often

harvest immature fruits so as to be among the first to collect them, and for preserving them long enough. This practice demonstrates a high demand for the species as compared to the relatively low availability of the resource, and one potential consequence could be the lack of regeneration we observed within the majority of the species populations, as also noted in Togo (Agbogon et al., 2015). The availability of a resource and types of use are important criteria for assessing the vulnerability of a species (Dibong et al., 2011). Indeed, a strong pressure on a species can increase its vulnerability (Traoré et al., 2011) and the irrational harvest of certain parts can negatively affect the survival of the species (Gaoué and Ticktin, 2007). In the actual context of the commune of Natitingou, which is mostly composed of poor populations (PAM, 2014), the high dependence of the population on flora and fauna species for food and health care suggests that the level of *H. barteri* vulnerability is likely to increase (Betti, 2001; Dassou et al., 2014). The results of this study thus call for more attention regarding the conservation status of *H. barteri* in Benin and particularly its inclusion in the Benin's list of threatened species.

Conclusion

H. barteri is a multi-purpose use plant species of high importance for the populations living along the Atacora mountain chain in Benin. It contributes significantly to food subsistence and health care for the local people. It

also provides wood energy which is a vector for the socio-economic development in rural areas. However, the current uses of the species make it vulnerable and can compromise its persistence in Benin. Consequently, there is a need to include *H. barteri* in the local list of threatened species, and to develop methods for the species conservation and sustainable management, such as artificial regeneration and plantation techniques. Also, future studies need to assess and monitor the dynamics of this restricted-range and highly demanded species in the context of climate change.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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