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The economic potential of *Echinochloa pyramidalis* (Lam.) Hitchc & Chase forage plant used in liquid waste treatment in Cameroon: opportunity to link sanitation to food security

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ABSTRACT

Cameroon, like other developing countries, faces major problems in the urban centres such as high rate of population increase, food and ruminant feed shortages as well as inadequate access to sanitation. However, *Echinochloa pyramidalis*, well-known forage adapted to the drying vegetated beds for wastewater and faecal sludge treatments with similar characteristics as *Typha* sp., *Phragmites* sp., might be used in the dual purpose as animal feed and as support material in sanitation treatment. This study aimed at linking sanitation technology to forage production. A socio-economic survey conducted in Douala, Yaoundé and Garoua to evaluate the economic potential of *E. pyramidalis* showed the daily quantities of marketed forage between 5 and 8-tons of fresh weight (FW) respectively during dry and rainy season. The forage price varies with season and species from USD 0.1–0.2 to USD 0.2–0.3/kg FW with daily income of USD 800–1’600 and USD 500–1’500 respectively to rainy and dry season. While comparable to most tropical forages, the nutritional values of *E. pyramidalis* after 45 and 100 days of wetland treatment were only affected by the advancing maturity. Thus, *E. pyramidalis* can be easily grown in wetland systems and sold for animal feeding in the local market.

Keywords: *Echinochloa pyramidalis*, economic potential, forage production, nutritional values, sanitation technology, vertical-flow constructed wetlands.

INTRODUCTION

Cameroon, like other developing countries, faces major problems in the urban centers such as high rate of population increase, shortage of food and ruminant feed as well as inadequate access to sanitation which affects human health and environmental safety. However, the developments of constructed wetlands (CWs) are currently recognized as a cost-effective and technically feasible approach to domestic and industrial wastewater treatment, faecal sludge dewatering, stabilization, and humification (Koottatep et al., 2005).

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Although this eco-technology raised substantial interest in its potential use for beneficial purposes, it is well-known that the plants commonly used in CW such as *Typha* sp., *Phragmites* sp. which enhanced their biomass productivity while treating human waste and wastewater are not always available and their economic or energetic reuse potential is very limited (De Maesener, 1997; Zurita et al., 2009). However, with similar characteristics as the macrophytes traditionally used, *E. pyramidalis* revealed high yielding potential in constructed wetlands. This aquatic plant has also raised substantial interest in its pollution removal capacity and it has been successfully used for wastewater and faecal sludge dewatering in constructed wetlands (Bojcevska and Tonderski, 2007; Kengne et al., 2008).

Echinochloa pyramidalis (Lam.) Hitchc & Chase is a perennial herb belonging to the Poaceae family. This plant of tropical Africa origin is widely distributed in tropical regions of Africa, America, Asia and Australia (Yabuno, 1968; Rosas et al., 2006; De Abreu et al., 2006). Commonly called antelope grass, it is generally soil-attached, but also found floating or submerged (Adebowale, 1988). The plant is favored by humid environments mainly swampy areas, floodplains and along many rivers such as River Niger in Mali and the Southern lagoon Coast (Adebowale, 1988; Anderson and Cameron, 2006). It forms a dense, pure stand with a leaf table at 120 cm to 2 m (Vesey-Fitzgerald, 1963).

E. pyramidalis is well-known to be both good green as well as hay fodder for livestock (Adebowale, 1988; De Abreu et al., 2006; Scholte, 2007). Also called antelope grass, it is noted as an excellent and important source of dry-season grazing forage; the land surfaces it covers are commonly used as pastures and young plant shoots, grown after the action of fire when shifting cultivation, are more nutritious and very palatable (Anderson and Cameron, 2006). Indeed, as regards the ruminant production, the tropical regions are characterized by forage shortage during the dry season (4-8 months) despite the fact that most ruminants subsist wholly on forage. Forage purchase is one of the feeding strategies intensively used during the critical period of forage shortage and the forage trade has always played an important role in the economic and social lives of some Cameroonian. In Cameroon, 150–240 tons DM/ha/y of *E. pyramidalis* cultivated on faecal sludge dewatering beds have been reported (Kengne et al., 2008). Comparative studies under the same climatic conditions carried out with manure application exhibited high productivity of *E. pyramidalis* (27 t DM/ha/y) compared to 5.4 t DM/ha/y in natural environments (Onana et al., 2003). According to FAO's grass data collection, it achieved a green matter yield of up to 25 tons/ha in Malawi in February.

Besides the yielding potential of this plant, there are many challenges such as the maturity effect on its feeding value which need to be addressed with in deep investigation. Many studies reported that as the plant ages, its morphological and histological development decreases and consequently the nutritional values reduced (Van Soest, 1982; Van Soest, 1994; Adebowale, 1988; Gulsen et al., 2004)). In addition, protein content and digestibility of forages are often related negatively to maturation stage (Van Soest, 1982; Van Soest, 1994; Gulsen et al., 2004). To the extent of our knowledge, there are no studies on the effect of maturity and wetland treatment processes on the nutritive potential of macrophytes. In addition, the income generated by the forage trade in Cameroon is largely unknown. All these reasons contributed to strengthen the increased interest on *E. pyramidalis*. The present study was particularly initiated to (1) estimate the market potential of forages in Cameroon with a comparison of the cost-effective technology which might result from forage production as the forage trade exists, (2) examine the effect of maturity and wetland treatment processes on the forage composition which may help determining its harvest timing.

MATERIALS AND METHODS

Location of the survey areas

The survey was conducted in the three urban cities of Cameroon (Douala, Garoua and Yaoundé); there are of different agro pastoral or economic importance and considering their sanitation situations: (1) Yaoundé, the administrative and political capital with about 2 millions inhabitants, is located in the centre province of the country at 760 m above the sea level (3°45 N and 11°32 E). It has a typical equatorial Guinean climate characterized by two rainy seasons (from September to mid-November and from mid-March to June) and two dry seasons (from mid-November to mid-March and from July to August). Annual rainfall amounts to about 1600 mm, and the daily temperatures vary between 23 and 32 °C; (2) Douala, the economic capital, principal port on the estuary of Wouri and most industrialised city is situated at 24 km from the ocean (4°03'N and 9°42'E). With about 3.5 million inhabitants, of its humid equatorial climate and long rainy season, the Yaoundé vegetation mainly consists of mangrove swamp species, such as *Rhizosphora racemosa*; (3) Garoua is the first economic centre of the northern part of Cameroon with several production facilities, such as oil, milk industry and breweries. It is situated in a Sudano-Sahelian zone (9°18'N and 13°24' E) at an average elevation of 400 m above sea level and have 313 000 inhabitants. The climate can be divided into three seasons: dry and hot from February to May, wet and mild from June to September, dry and cold from October to January.

Survey design

The study was based on formal and informal interviews through structured and semi-structured interviews. The structured and semi-structured interviews were done with aid of questionnaires designed to obtain basic information (Table 1). They also involved on-farm direct observation. The units of investigations were the urban livestock keepers or animal breeders and forage seller. Before the study, contacts were established with farmers/livestock keepers and forage sellers through field visits (animal farms and forage market points), presentation, introduction or explanation of the purpose of our study. Accordingly, the livestock keepers or forage sellers were randomly selected on the basis of their willingness for cooperation.

A total of 170 randomly selected livestock keepers or animal sellers engaged in livestock farming and/or milk production and 83 randomly selected forage sellers were interviewed on farms or at the local markets of Douala, Garoua and Yaoundé from May to August 2007. Fifty and seventy farmers representing 25 % and 20 % of the livestock keepers respectively in Douala, Yaoundé and Garoua while 20 and 63 forage sellers respectively in Yaoundé and Garoua representing 50 % of forage sellers in both cites were individually interviewed. Before, the questionnaires were tested in Yaoundé and readjusted. Both closed and open-ended questions were included in the questionnaires administered to the respondents via individual interviews. The questionnaires were designed to seek information mainly on forage offer and demand of with special focus on three major points: (1) the socio-economic profile of urban stakeholders (primary occupation, professional experience, age, gender, level of education, size of herd, breeding system, types of animal bred, family income, major source of income, major farming activities); (2) the forage demand (distance between forage site, the nearest market and main constraints to the development of this activity, general information on the diet of the herd, such as preferred animal fodder, fodder usually available throughout the year, forage purchasing price); (3) fodder supply as well as supply methods, economic value, forage species, periods of feed shortage and types of forage commonly present at the markets. To determine the income generated by forage selling, a quick appraisal and study of the economic activity were also conducted in the main forage trade markets of the studied cities. The forage varieties and daily forage quantities sold at markets as well as their variability in terms of price and quantity were evaluated.

Experimental set up of CWs, planting and harvesting

The designs of vertical-flow constructed wetlands (VFCW) with a media arrangement adapted from Koottatep et al. (2005) were set-up. This VFCW consisted of 03 units of 50-litre capacity and 0.78 m^2 size each. A completely randomised design with three replicates was used for the experiments. The units were equipped with a drainage pipe connected to a tap allowing vertical free drainage of the percolate through the media. Young shoots of *E. pyramidalis* were collected in the surrounding natural wetlands and transplanted the same day in the 03 VFCW units. Seven plants, each with about 20-cm long rhizomes and stems, were planted in each bed. After planting, the beds were flooded with raw wastewater to about 5-cm above the gravel layer and the plants were allowed to establish themselves in raw wastewater. After 8 weeks of acclimatisation, the faecal sludge supernatant (FSS) replaced the raw wastewater in irrigating the pilot-scale units of VFCWs. Each VFCW unit was fed twice a week with 15-L of FSS regularly analyzed before (Table 2). In all the experiments, the plants were harvested at two different periods (45 and 100 days) after the start of sludge treatments. The harvested periods were based on the study of Adebowale (1988).

Analysis of the composition of *E. pyramidalis*

The nutritive value of *E. pyramidalis* was assessed for dry matter (DM), ash, crude protein (CP), lipids, ADF (acid detergent fibre), and NDF (neutral detergent fibre), hemicellulose and cellulose in the fresh leaves and stems harvested in the experimental units and in the natural wetland of Yaoundé after 45 and 100-day periods of wetland sludge treatments. At the 45- and 100-day periods of sludge treatments, *E. pyramidalis* was cut 25-cm from the soil, separated into leaves and stems and dried at 65 °C until constant weight. Dried samples were grounded to pass through a 1-mm sieve. Dry matter (DM) was determined by oven drying the samples at 105 °C for 6h and the ash determined at 550 °C for 6h. Total N was analysed by the Kjeldahl method (AOAC, 2000) and crude protein (CP) calculated by multiplying N×6.25. Acid detergent fibre (ADF), including ash residues, were analysed by the standard AOAC methods (AOAC, 2000), neutral detergent fibre (NDF), including residual ash and acid detergent lignin (ADL) were determined by standard methods (Van Soest et al., 1991). Total lipids were extracted from dried ground samples according to the Soxhlet's procedure by repeated washing (percolation) with organic solvent, petroleum ether under reflux in glassware apparatus. The content of lignin was determined by solubilising cellulose with sulphuric acid. Forage cellulose and hemicellulose concentrations were estimated as ADF minus sulfuric acid detergent lignin (ADL) and as NDF minus ADF, respectively (Van Soest and Robertson, 1980).

Data analysis

Data were analyzed using Excel software and SPSS 15.0 for Windows (SPSS, 2006). Descriptive statistics such as frequency and percentage were used to draw the general information of the survey questionnaires. The quantitative variables were analyzed using analysis of variance procedure and when the F-*test* declared significant differences for certain parameters, Tukey test was used to separate the group means.

Paired Student's t-Test was used to compare the compositions of *E. pyramidalis* at different ages grown on CWs, natural wetlands between them and those of the same age to those of different growing media. Data of the antelope grass presented are means of four replicates (n = 4).

RESULTS

Socio-economic profile of the respondents

General Profile

The major socio-economic characteristics of the respondents are presented in Table 3. Globally, most of the farmers were males (92%) and this general pattern of gender distribution showed that men are more involved in livestock keeping than females (8%). These characteristics closely followed those of Shenkute et al. (2010) who reported 94.4% of male against 5.6% of female livestock farmers. There was however, no statistical significant variations (P = 0.470) between the sex proportions in the three different cities. Over 60 year-old, the farmers represent 7%. They were within the age range of 41 to 60 years (39%), while 14% were between 30 and 40 years. Less than 13% of the farmers were below 30 years (Figure 1). This may imply that the young were less involved in livestock production and that livestock farming is a common practice of old people in these cities.

The educational status (Table 3) of the respondents showed that 71% of the farmers had formal education while 29% had no formal education. Thirty-nine percent of those who were formally educated attended primary classes or fast breeding training and 22% attended secondary school while 10% had university formation. The high percentage of those with formal education with no differences (P = 0.622) between the three cities (Table 3) indicates high academic standard may be due to lack of opportunities for employment in the cities (Rischkowsky et al., 2006). The 36 % of respondents reported that they had been keeping cattle for a period ranging between 1-5 years, 30% for 6-10 years, 23% for 11-15 years, 3.2% for 16-20 years and 7.8% for 21-25 years. A significant difference between the three cities in terms of experience in livestock keeping was noticed (P = 0.005); the experience in Douala was in the range of 0-10 years although in Yaoundé and Garoua; it was ranged between 6-20 years. While the respondents were divided into low-income groups (88.4%) with a monthly salary between 35,000-70,000 CFA Francs (US$ 70-140) and wealthy groups (11.6%) with 104,000-139,000 CFA Francs (US$ 210-280), the respondents of Garoua are characterized by low-incomes and the income generation was significantly different between the cities (P = 0.000).

Their major sources of incomes were livestock production, livestock and crop productions, sale of livestock products and others. Livestock productions were reported to be the major source of income by 67% of the farmers, followed by sale of livestock products (17%), livestock and crop productions (10.6%) and others globally with a significant difference (P = 0.000) in the three cities. However, the major economic activities in these three cities were reported to be livestock keeping (64.7%) and the combination of livestock keeping with crop production (32.4%) in the overall three cities with no statistical difference (P = 0.307), indicating that majority of livestock keepers are also involved in cropping. The study also showed that the respondent’s main occupation in the three cities were ranged from livestock keepers (37.6%), traders or self-employed (22.4%), manual workers (17.1%), crop producers (14.7%), unemployed or retired (3.5%) and civil employed (4.7%) and there was significant variations (P = 0.000) of these proportions with cities.

Production systems, feed resources and forage species

In Yaoundé, Douala and Garoua, the overall individual interviews revealed that urban livestock production included extensive or traditional (15.3%), semi-intensive (44.1%) and intensive (40.6%) production systems. These production systems included small-scale ruminant production dedicated to the commercial, semi-commercial or subsistence goals while most of the time the large-scale ruminant production is entirely dedicated to the commercial purposes. However, the extensive production system generally in small-scale is characterized by the animal feeding on open spaces, road-side grazing, cut-and-carry forage, household wastes, scavenging, tethering, fattening and compound dairying and no supplementation with feed concentrates; the number of animals is usually small. The animals in such system are either stall-fed or grazed close to the compounds in the day and confined in the night. The semi-intensive are mainly operated for commercial purposes in the large or small-scale; farms are generally located in peri-urban areas with or no natural grazing areas or land available to cultivate forage, which constitutes the main feeding source and supplementation with feed concentrates. The intensive production systems were mostly relied on zero-grazing using the cut-and-carry system where animals are housed and supplemented with feed concentrates; they were used by a few modern commercial farms.

In Cameroon, although a great deal of effort has been done in the feed production research, the estimates (data) on the fodder production are not update and the forage utilization varies widely in the cities. Animals fed various feed materials in the three study areas depending largely on the availability and; on the socioeconomic conditions and the type of livestock. The feed resources were classified in to six classes: foraging/grazing (on natural pastures), hay (based on natural pastures), green feeds/forages (legumes, grass, legume/fodder trees for leaves and pods), crop residues (sorghum and maize stover, wheat straw), concentrate (grains, oil seed cakes, wheat bran, stalks, commercial mix, brewery or distillery spent grain, millet grain, cotton seed, cotton seed cake and molasses) and non-conventional feeds (household wastes) (Table 4).

Regarding the green feeds, 56 species of plants distributed in 40 genera and 9 families were mentioned by the respondents to be the forage crops used locally in livestock production. Family Poaceae contains the greatest number of forage species (37) followed by Fabaceae family with 11 species, while Cyperaceae (1), Convolvulaceae (2), Commelinaceae (1), Malvaceae (1), Meliaceae (1), Moraceae (1) and Onagraceae (1) were least represented (Table 5). The genera with highest number of forage species are *Echinochloa* and *Pennisetum* with 4 species each, followed by *Brachiaria* and *Setaria* with 3 species each whereas *Andropogon*, *Loudetia*, *Ipomoea*, *Hyparrhenia*, *Tephrosia*, *Vetiveria*, *Sesbania* show 2 species each and all the rest of genera present 1 species each. While shrubs, trees and crops are also represented, the forage growth forms recorded in majority are grasses. Almost all species grow wild except crops such as *Arachis hypogeae*, *Pennisetum americanum*, *Vigna unguiculata*, *Zea mays*, *Sorghum bicolor* which mainly in the food consumption purposes are cultivated species. However, all these 56 species mentioned by respondents were not found in the forage market during the study.

Herd size and composition in the city

The opinions among respondents in the three cities regarding the herd size (Figure 2) did not differed between the three cities (P = 0.375); 76.5% of the respondents owned on average 1-50 animals ranged in 45.3% for 1-10 animals, 20.6% for 11-20 animals, 10.6% for 21-50 animals while 23.5% keep up to 50 animals. Different animal species were kept in the urban and peri-urban centres in the proportion of 22.4% for large ruminants, 52% for small ruminants and 17% for rodents. Large ruminants comprised cattle (beef and dairy cows) and horses while sheep and goats were grouped as small ruminants and rabbits, guinea pigs and cane rats/ aulacaudes (*Thryonomys swinderianus*) as rodents. In relative numbers, goats rank first (37%), closely followed by sheep (30%), cattle (16%), and other animals (17%).

Purposes of keeping livestock in these urban centers

In general, the incentives behind urban livestock keepers were ranged from hobby, tradition (cultural value), religion (sacrifices), food security (subsistence, home consumption), and financial security to profit-oriented aspects (income generation). However, the income generation (97%) was the real motivation behind urban stakeholders aside from other reasons (3%) globally in the three cities with non significant difference between the cities (P = 0.128). These results also confirm what was found as reason for keeping cattle in many developing countries (Waters-Bayer, 1996).

Main constraints on livestock production in these urban centres

Overall the three cities, the study revealed that shortage of feeds/grazing land, livestock diseases and high cost of veterinary drugs were ranked as the first (50.6%), second (24.1%) and third (20.6%) most important constraints (Figure 3). In the individual cities, 61.4%, 44% and 42% of respondents respectively in Garoua, Yaoundé and Douala stated that shortage of feeds/grazing land were the first important constraints, followed also by livestock diseases and high cost of veterinary drugs. The other problems such as theft and lack of market for livestock and livestock by-products were almost the same and inconsistent between cities.

Correlations between some socioeconomic variables

There were significant relationships between cities, main activities, age of livestock keepers, major sources of incomes, livestock herd size, motivations of keeping livestock in the urban areas, educational level of livestock keepers, income generation, experience on livestock keeping and constraints of livestock production (Table 6). The linear relationship (R = 0.155; P< 0.05) was noticed between the educational status of livestock keepers and the incentive of keeping livestock in the urban centers (Table 6). A highly significant positive correlation were shown between the cities and the sources of income (R = 0.283; P = 0.000). There were significant relationships between the major constraints to livestock production and the major sources of income generation (R = -0.214; P<0.01) and between the major constraints to livestock production and the main occupation or economic activity (R = -0.196; P<0.05) (Table 6). This implies that these variables may have significant influence on the livestock production.

Offer and demand of forage

Actors of forage market

The forage markets were found only in Yaoundé and Garoua although the livestock keepers in Douala expressed the need to be supplied with forage. Almost all forage species found in the markets are not cultivated, they grew wild mainly in the humid environment (wetlands, along the rivers) and in abandoned lands. The forage trader actors are forage producers (harvesters), forage transporters, forage traders (wholesalers, semi- wholesalers and retailers) and forage consumers. In Yaoundé, forages species are harvested around the city, in the wetlands and peri-urban areas such (Soa, Mvan, Bankomo, Obala, etc.) and the forage is transported from the farms to urban markets mainly by cars, usually ordered by the harvesters for the deliveries to the market. Each the harvesters purchased their forage themselves at the different market points such as "marché à bétail d'Etoudi", "marché du huitième" at Tsinga and "marché Fanta Citron" at Mvog-ada. In Garoua, although forage species are mainly harvested along the borders of Bénoué Rivers, many rural towns also supplied forages to the city through transport. Most of the times, the transporters are those who have harvested the forage species and who will also trade. The forage producers are the harvesters which deliver their goods to the given market places. Forages are transported on the head, by bicycle, "pousse-pousse" or by car in Garoua while in Yaoundé, there are mainly transported by car.

According to the study, forage trader is ranged from the permanent to casual activity, for several sellers it is a seasonal activity of inter season. Some sellers stay in their villages during the growing season and travel to the city during the dry season for forage harvests. For others it is the permanent activity which is almost their only source of income. The study revealed two marketing strategies; home-delivery sales (5%) and market sales (95%).

Profile of the main actors of forage market

From the survey, it appeared that the main actors involved in the forage market were forage producers/harvesters, forage transporters, forage traders and forage consumers (livestock keepers and livestock sellers). In the two cities, almost all the forage traders were male and originated from the Adamaoua, North and Far North Cameroon and did have the educational status. The majority of the forage traders interviewed were less than 25 years old (45%), 20% were between the ages of 25-35 whilst 17% were between the ages 35-45 and 18% were above 45 years old. From the results, forage trader is considered as a business for the youth. However, to meet forage supply, 82% of the traders harvest the plants within a distance of 5-15 km from the market place. A few have their harvesting site at an accessible distance of less than 5 km (13%) or more than 15 km (4%). This means that the forage trade is an activity mainly undertaken by young people as it requires most of the times to travel the very large distances to find the marketable species.

Green feeds/forages available in the market

In the three cities, natural pastures or forage species which grow wild were shown to be the principal animal feeding grounds that represent 80% of the daily diet. As the numbers of herds increased, the pressure on natural forage plants also increased and the animal feeding habits relied mainly on the availability of forage. Natural pastures are composed of herbaceous species, mostly annual and perennial grasses, though non-gramineae herbs are sometime used in Douala and Yaoundé, and herbaceous, tree and shrub leaves and pods in Garoua. Household waste is sometime fed as forage cultivation areas are scarce in urban centers, and the forage plants commonly used are those growing naturally on waste or roadsides, rivers, banks, open spaces or wetlands or those coming from rural areas. The plant species are harvested in the natural areas and traded as forage crops at the markets. In Garoua, a large variety of forage species were recorded although there were not always available in sufficient quantities. However, most livestock keepers preferred *E. stagnina* for their animal feeding, as it is the most abundant and available species on the market over the year. *E. stagnina, E. pyramidalis, F. sycomorus, I. aquatica, Oryza barthii* were indicated to be the permanent species in the market during the year. In Yaoundé, *E. pyramidalis, H. rufa, P. maximum, P. purpureum,* and *S. barbata* are the most important forage species sold at the local markets. As illustrated in Table 7, the traded forage plant species vary from one locality to another. According to 85% of the respondents, the marked forage species are characterized throughout the year by a seasonal variation in their availability. A significant shortage of forage is noted during the dry season. Moreover, the reason mentioned regarding this forage shortage was that the widely fluctuating and scarce amount of rainfall. Seventy-four percent of the respondents reported that the rainy season (June–August) favoured forage supply although the amount of forage available for livestock production is even during this season quantitatively insufficient. However, the dry season especially September to May was pointed out as the most critical months of forage shortage. The locally marketed forages and crop residues are scarce during some period of the year. Owing to the acute shortage of forage plants during the dry season, availability rather than nutritive value is the decisive factor in commercial species. The most prominent available forages during the year were *Echinochloa stagnina*, *E. pyramidalis*, *Oryza barthii* and *Ipomoea aquatica* in Garoua while the most representative marketed fodder trees were *Ficus sycomorus*.

Estimation of the forage supply in the markets

According to 85% of the respondents, forage quantity and price marked throughout the year by a seasonal variation in their availability and quality. A significant shortage of forage is noted during the dry season. The important forage need has contributed to a change in feeding behavior of the animals in these cities. As regards forage management during the dry season, the survey revealed that forage conservation is not a common practice in Douala nor in Yaoundé, though occasionally practiced in Garoua. In Garoua, to solve the problem of forage shortages in the dry season, crop residues, tree leaves, industrial by-products as food supplement are commonly used (59%) since farmers do not favor mixed concentrate feeds. Among other, high costs are the main reason for a reduced use of concentrated feed in animal production. The main crop residues are annual plants, such as residues of *Sorghum bicolor, Vignia unguiculata, Arachis hypogeae, Zea mays, Pennisetum americanum,* and *Oryza barthii* associated with the use of tree leaves such as those of *Ficus sycomorus*. Especially in Garoua, crop residues (32%) and agro-industrial by-products (64%) mainly cotton seed and cotton seed cake are by far the main feeds.

The forage cultivation is scarce; the widespread practice consists at harvesting the naturally grown fodder rather than cultivating. The study revealed that the quantities of fodder marketed vary according to season and species. Moreover, during the year, availability of green forage at markets is dependent on forage species and their favorite environments. By weighing the daily quantities of forages reaching at the different market points during our study period, the estimated daily average quantity of forage available at the Garoua market was around 8 tons of fresh matter.

Since the forage transport in Garoua is mainly by head or by "pousse-pousse” (rickshaw) for the permanent fresh green forage sellers, according to our study the estimated quantities of fodder contained in the rickshaw revealed an average weight of 240 kg. Loading a rickshaw was on average made up of six bundles of fresh green forages with an average weight of 40 kg/bundle. From January to May, 63.5% of forage sellers claimed to harvest at least one bundle per day which gives by calculation according to the average weight 1600 kg/day while 36.5% mentioned a daily quantity of 3 bundles at least which gives 3680 kg/day.

In the same order, from June to December 63.5% of those forage sellers also claimed to have at least 2 bundles per day (3200 kg/day) while rest declared to have at least one rickshaw loading per day which gives 5520 kg/day. According to these estimations, it is obvious that the daily average quantity of forage available at the Garoua market varies from 5-tons of fresh matter in the dry season to 8-tons of fresh matter in the rainy season. The evaluation of the quantities of the different species at the different market points of Garoua showed that *E. stagnina* represents the most widespread and well-known forage with about 3 tons/day of fresh matter (FM) followed by *E. pyramidalis* with a daily quantity of about 2 tons of FM . Both species are present in this region over the year. Furthermore, the study showed that *E. stagnina*, *E. pyramidalis, E. colona, Oryza barthii*, *Ipomoea aquatica* and the leaves of *Ficus sycomorus* are among the most widely available forage trade species in Garoua. The other species are generally absent or less represented, and their daily quantities vary seasonally and range from 0.5 to 1 ton of FM. In Yaoundé the quantity estimated to 3-5 tons/day of fresh matter (FM) of the marketed forage species with Etoudi livestock market representing the most supply market in the city. This biomass of forage can be used to feed at least 250 L.S.U. (Livestock Standard Unit) in the maintenance feeding system (6.25 kg DM/day) over a year. However, in general these forages are usually given as an additional feed, less than 6 kg per day. In addition, the amount of the forage biomass flowing through the year may explain the importance of this trade.

Income generated from forage trade

The business of selling forage is not a new activity, 69.8% of the sellers have been conducting this activity for about 20 years. Forage selling activity ranges from a seasonal (part-time) to a full-time year-round occupation. About 15.9% of the forage sellers and retailers spent not more than one month per year in this activity; nearly 44.4% spent less than four months per year and 39.7% were involved in forage selling permanently. Based on data collected, 87% of the forage sellers said that forage selling activities are intense during the rainy season when forage is available and also during the dry season, the period of acute forage shortage. Forage sales make significant contributions to cash incomes. Forage was sold using the small bundle of 1kg in Garoua and 8-10 kg in Yaoundé Etoudi market (not the bundle used after harvesting for transportation) as the measuring unit. Each bundle weight varies from 5-15 kg FM and retailers reorganized in the very small bundle of the mean weights of 1kg. The price varies according to many factors such as forage species, availability and seasons (Table 8). The retail price per kilogram varied with species, location, quantity of the sale, special relationships between the sellers and the buyers. Generally the forage price ranged from FCFA 50-100 (USD 0.1-0.2) per kg of fresh matter in the rainy season and FCFA 100-150 (USD 0.2-0.3) per kg of fresh matter in the dry season. According to the available quantity of daily forage on the market (about 5-tons of fresh matter in the dry season to 8 tons of fresh matter in the rainy season), the forage income is estimated to vary between FCFA 400’000-800’000 (USD 800-1’600) in the rainy season and FCFA 500’000-750’000 (USD 1’000-1’500) in the dry season.

Relative knowledge on *E. pyramidalis*

The antelope grass forms part of the diet of several animals, such as large and small ruminants and rodents. It is one of the forage species used to feed horses, goats, sheep, dairy cattle, rabbits, cane rats (*Thryonomys swinderianus*) and guinea-pigs (Figure 4). Similar to other forages, *E. pyramidalis* is sold in the urban and peri-urban centers and the mean price varies over the year accordingly with its form (hay or fresh matter), quantity and availability. A great number of the farmers (78.8%) reported that the high nutritive value of *E. pyramidalis* is the main reason for using this particular forage plant in animal nutrition. This farmers’ knowledge on *E. pyramidalis* quality was based on the palatability of the forage by animals, ability to satisfy animals’ appetite and hunger, ability of the forage to improve the animal weight body and growth rate, the effects of forage on the milk production and health improvement. Knowing that natural forages’ important role in sustaining animal productivity, the results of this study shows that the available amount of forage is insufficient for animal nutrition (Figure 5). Besides, according to international standard of breeding, a L.S.U. (Livestock Standard Unit) is defined as an animal having at least 250 kg of weight, must consume for its maintenance 6.25 kg DM per day. According to the interview, the quantity of forage used for animal feeding is not depending to the weight reference and the type of animal production. An average daily quantity of forage supply ranged from 5-15 kg of fresh matter was given to animals most of the times without taking into account the type of animal production (dairying, preservation, fattening, etc.).

Though, the availability factor constitutes an essential forage selection criteria, it appears that *E. pyramidalis* is used in the three Cameroonian cities. The quantity of feed used in animal nutrition depends very often on the forage availability in the market and financial means of the livestock keepers. According to the respondents, the daily quantity of forage used for livestock consumption is not based on the weight reference of animals or on the type of production. An average daily quantity of forage consumption (Figure 5) ranged from 5-15 kg FM was fed to animals most of the time without taking into account the type of animal production (preservation, fattening, etc.).

Constraints on forage supply

According to the information obtained, it appears that constraints in livestock production are mainly attributed to: (1) diseases; (2) poor management (land availability) and (3) seasonal quantitative and qualitative feed shortages. During the dry season, forage availability is depleted and market access to forage turns to be the most prominent means of supply (Figure 6). The problems related to forage supply comprise: (1) low productivity of the natural species; (2) inaccessibility of fodder during the rainy and dry season (long distance, flooding of wetlands) and (3) tedious harvesting. Indeed, in cities like Garoua and Yaoundé, this activity generated many other small parallel activities like the sale of fodder trees and crop residues. Although fodder trees are popular and likely appreciated, they were characterized by scarcity in the market. This scarcity can be explained by the existence of taxes for the exploitation which cost FCFA 3000 per month to pay at the Ministry of Environment and Forests (MINEF) funds and the farmers consider being very high. Often the forage sellers do not pay and prefer an illegal logging which may sometimes caused seizures Among the expenses related to the marketing of forage crops, our study revealed other fees that should be pay to the municipality such the place right for rickshaw parking which is 1000 FCFA per month, the market place right that is 100 FCFA per day, the place right for bicycle parking rising from 50 FCFA per day and the rickshaw hiring which is 200 FCFA per day. Although fodder supply in Douala is especially covered by natural pastures and cut-and-carry forages from the uncultivated land, more than 50% of the forage users have expressed the need to buy some forage. As a result of permanent flooding during the rainy season, access to forage is also far more difficult than in the dry season and that means pasture and fodder crops are difficult to obtain even if there is money to buy. In urban centers, various types of forage supplies were reported, such as cutting, free grazing and forage purchased (Figure 6). As indicated in Figure 6, the best way to cover forage supply is through purchase (81% in Garoua and 71% in Yaoundé), although forage crops are almost non-existent. In Cameroon, even under the intensive concentrate feeding systems of ruminant production, forages continue to represent the primary most important feed resource and this places the forage trade as one of the most profitable economic activities in urban centers (Garoua and Yaoundé).

Chemical compositions of *E. pyramidalis*

Tables 9 and 10 contain details on the mean concentration of cell wall constituents respectively in the leaves and stems of *E. pyramidalis* at two different periods of wetland treatment processes (45- and 100-day periods). The CP content of leaves decreased with advancing age and the highest value was recorded at 45-day period in the samples grown in CWs with samples of 45-day period significantly higher than those of 100-day period. The cell-wall composition increased with advancing age and the 100-day contents were significantly higher than those of 45-day period. The lipid contents of leaves decreased slightly from the 45-day to the 100-day period while ash content increased from the 45-day to the100-day. The slight increase of hemicellulose was noticed from the first period to the second period without statistical significant at $P<0.05$. The increase of cellulose from 20 to about 22% DM was highly significant ($P<0.05$).

The stem parts of *E. pyramidalis* (Table 10) showed the same trend with the CP content higher at 45-day period than those of 100-day period. In CWs, the CP content in leaves and stems were both significantly higher than those of NWs and the cell-wall (NDF, ADF, ADL) contents were also significantly increased in NWs ($P<0.05$).

Table 1: Methodical approaches and their functions.

Type	Approach	Function/Information
Interview	Semi-Structured	Identifying key questions and indicators
Interview	Structured	Get quantifiable information on the socio-economic characteristics and constraints to cattle and forage productions
Observation	Direct observations	Relative available amounts of forage sold in the market, their variability in terms of price and quantity

Table 2: Physicochemical compositions of the faecal sludge supernatant used in the VFCW units as influent.

Parameters	**pH**	**T (°C)**	**Eh (mV)**	**EC (dS/m)**	**TDS**	**Ca^{2+}**	**Mg^{2+}**	**Na^{+}**	**K^{+}**	**Cl^{-}**	**NO_3^{-}**	**SO_4^{2-}**	**Total N**	**PT**
					(mg/l)									
Means	6.9	26.3	9.9	3	1522.5	133.6	86	0.01	0.2	47.8	381	991	979.2	490.7
S.D.	1.2	2.9	69.4	0	28.5	173.8	156.4	0.01	0.6	51.9	11.6	89.1	177.1	35.3

Table 3: Socio-economic characteristics of the respondents in the three cities (Douala, Garoua and Yaoundé).

Variable	**Overall cities (%)**	**Douala (%)**	**Garoua (%)**	**Yaoundé (%)**	***P-value***
Sex					***0.47***
Male	91.8	88	94.3	92	
Female	8.2	12	5.7	8	
Educational Status					***0.622***
No formal education	42.9	10	37.1	36	
Primary school/fast breeding training	38.8	68	24.3	30	
Secondary school	12.9	10	28.6	26	
University	5.3	12	10	8	
Experience in cattle keeping					***0.005****
< 5 years	35.9	52	35.7	20	
6-10 years	30.0	34	24.3	34	
11-20 years	22.9	6	27.1	34	
21-25 years	3.5	4	4.3	2	
> 25 years	7.6	4	8.6	10	
Main Occupation					***0.000****
Livestock keepers	37.6	62	25.7	30	
Traders/self-employed	22.4	6	37.1	12	
Manual workers	17.1	13	1.4	30	
Crop producers	14.7	0	24.3	16	
Unemployed /Retired	3.5	0	0	12	
Civil employed	4.7	0	11.4	0	
Major farming activities					***0.307***
Livestock Keeping	64.7	58	67.1	68	
Livestock keeping and crop production	32.4	36	32.9	28	
Others	2.9	6	0	4	
Major source of income					***0.000****
Livestock production	67.1	100	42.9	68	
Livestock and crop productions	10.6	0	22.9	4	
Sale of livestock products	17	0	28.6	18	
Others	5.3		5.7	10	

Table 4: Major production systems practiced and the utilization frequency of feed resources in the three surveyed cities.

Variables	**Douala**	**Yaoundé**	**Garoua**
***Production systems* (% of respondents)**			
Extensive/traditional	20	30	1.43
Semi- intensive	20	50	57.14
Intensive	60	20	41.43
***Main feed types used* (+)**			
Grazing/ Foraging	++	++	++
Hay	+	+	+++
Green feeds	+++	+++	+++
Crop residues	+	+	+++
Concentrates	+++	++	+++
Non conventional feeds	+++	+++	+

Frequency of feed used: + (sometimes/rarely); + + (often); + + + (usually) when more than 50% responded.

Table 5: Forage species as reported by respondents globally in the three cities of Cameroon.

Scientific name	**Family**	**Status**	**biological type**	**Other uses**
Andropogon pinguipe	Poaceae	Wild	Grass	Fiber use, medicinal use and human consumption
Andropogon gayanus	Poaceae	Wild	Grass	Use for coarse matting (weaving grass mats and thatching). Anti-tick repellent effect.
Arachis hypogeae	Fabaceae	Introduced	Crop	Human consumption
Brachiaria jubata	Poaceae	Wild	Grass	Land conservation, human consumption
Brachiaria stigmatisata	Poaceae	Wild	Grass	/
Brachiaria ruziziensis	Poaceae	Introduced	Grass	/
Calliandra calothyrsus	Fabaceae	Introduced	Shrub	Honey production, soil improvement (green manure)
Chloris pilosa	Poaceae	Wild	Grass	Alkaloid and socio-cultural uses
Cynodon dactylon	Poaceae	Wild	Grass	/
Cyperus esculentus	Cyperaceae	Wild	Grass	/
Commelina benghalensis	Commelinaceae	Wild	Herb	Use as famine food
Echinochloa colona	Poaceae	Wild	Grass	
Echinochloa obtusiflora	Poaceae	Wild	Grass	Human consumption (grains)
Echinochloa pyramidalis	Poaceae	Wild	Grass	
Echinochloa stagnina	Poaceae	Wild	Grass	

Eragrostis gangetica	Poaceae	Wild	Grass	
Eriosema glomeratum	Poaceae	Wild	Grass	
Faidherbia albida (syn. Acacia albida)	Fabaceae	Wild	Tree	/
Ficus sycomorus (Syn. Ficus gnaphalocarpa)	Moraceae	Wild	Tree	Veterinary uses
Gliricidia sepium	Fabaceae	Introduced	Shrub	Domestic uses (firewood), living fences, soil fertility (green manure), and medicinal uses.
Hyparrhenia bracteata	Poaceae	Wild	Grass	
Hyparrhenia rufa	Poaceae	Wild	Grass	Use as material of construction
Ipomoea aquatica	Convolvulaceae	Wild	Grass	/
Ipomoea batatas	Convolvulaceae	Introduced	Crop	Human consumption
Jardinea congoensis	Poaceae	Wild	Grass	Medicinal use, building materials, aromatic substances
Khaya senegalensis	Meliaceae	Wild	Tree	Veterinary uses
Leersia hexandra	Poaceae	Wild	Grass	/
Leucaena leucocephala	Fabaceae	Introduced	Shrub/Tree	Maintenance of soil fertility (green manure), firewood , Human nutrition
Loudetia simplex	Poaceae	Wild	Grass	Domestic uses
Loudetia togoensis	Poaceae	Wild	Grass	Domestic uses
Ludwigia abyssinica	Onagraceae	Wild	Grass	/
Panicum maximum	Poaceae	Wild	Grass	Medicinal use
Paspalum sp.	Poaceae	Wild	Grass	
Pennisetum americanum	Poaceae	Introduced	Crop	Human consumption
Pennisetum pedicellatum	Poaceae	Wild	Grass	Valuable soil stabilizer (erosion control)
Pennisetum polystachion	Poaceae	Wild	Grass	Medicinal uses
Pennisetum purpureum	Poaceae	Wild	Grass	Used as material of construction
Phragmites karka	Poaceae	Wild	Grass	Phytoremediation
*Oryza barthii (*Syn.*O. longistaminata)*	Poaceae	Wild	Grass	Human consumption
Prosopis Africana	Fabaceae	Wild	Shrub/Tree	Medicinal and domestic uses, human consumption (spices)
Rottboellia exaltata	Poaceae	Wild	Grass	/
Saccharum spontaneum	Poaceae	Wild	Grass	Medicinal uses, soil-erosion control, thatching, cordage and broom uses of leaves, allelopathic

				and allelochemical properties
Setaria barbata	Poaceae	Wild	Grass	/
Setaria sphacelata	Poaceae	Wild	Grass	/
Setaria pumila	Poaceae	Wild	Grass	/
Sesbania sesban	Fabaceae	Introduced	Shrub/Tree	Maintenance of soil fertility (green manure), wood as living fences, Human nutrition (flowers), medicinal uses
Sesbania pachycarpa	Fabaceae	Wild	Shrub/Tree	Maintenance of soil fertility
Sorghum bicolor	Poaceae	Introduced	Crop	Human consumption
Tephrosia bracteolata	Fabaceae	Wild	Shrub	/
Tephrosia pedicellata	Fabaceae	Wild	Shrub	Medicinal use, fish-poisons
Trypsacum laxum	Poaceae	Introduced	Grass	/
Urena lobata	Malvaceae	Wild	Grass	Medicinal use
Vetiveria fulvibarbis	Poaceae	Wild	Shrub	Human consumption (infusion drink)
Vetiveria nigritiana	Poaceae	Wild	Shrub	Use of the straw in the roof making
Vigna unguiculata	Fabaceae	Introduced	Crop	Human consumption
Zea mays	Poaceae	Introduced	Crop	Human consumption

Table 6: Relationships (Pearson correlation analysis) between some variables.

Variables	**[1]Coef.**	***P-Value***	**Decision**
Survey cities and the main activities	0.278	0.000	**
Age of respondents and the major sources of incomes	-0.377	0.000	**
The major sources of incomes and the main activities	0.388	0.000	**
Survey cities and the major sources of incomes	0.283	0.000	**
The major sources of incomes and livestock herd size	0.159	0.038	*
Motivations of keeping livestock in the urban areas and the educational level of livestock keepers	0.196	0.010	*
Income generation and cities	0.238	0.002	**
Constraints of livestock production and the major sources of income	-0.214	0.005	**
Constraints of livestock production and the main activities	-0.196	0.010	*
Experience on livestock keeping and the major sources of income	0.155	0.043	*
Experience on livestock keeping and cities	0.241	0.002	**
Experience on livestock keeping and the motivations in livestock keeping	0.155	0.043	*
Experience on livestock keeping and income generation	0.226	0.003	**
Experience on livestock keeping and constraints of livestock production	-0.168	0.028	**

[1]Pearson correlation coefficient; **Highly significant (<0.01); *Significant (<0.05).

Table 7: Relative percentage of the forage species sold in the local.

Forage crops	Marketed forages in %			
	Local name	**Garoua**	**Yaoundé**	**Douala**
Andropogon chinensis	Houdo hossere	5.4	0	0
Cynodon dactylon	Tregueguel	0.7	4	0
Cyperus esculentus	Goye	5	0.4	0
Echinochloa pyramidalis	Taagol	12.1	15.6	0
Echinochloa stagnina	Bourgou	17.2	0	0
Echinochloa colona	Kayari	5.2	0	0
Ficus sycomorus	Ibbi	11.2	0	0
Hyparrhenia rufa	/	0	14.5	0
Ipomoea aquatica	Boore	9.6	2.4	0
Ludwigia abyssinica	Haako ndiam	6.2	1	0
Oryza barthii	Nanare	7.4	0	0
Panicum maximum	/	0.4	19	0
Paspalum sp.	Boungo	5.8	5.1	0
Pennisetum pedicellatum	Woulouko	4.2	0	0
Pennisetum purpureum	/	0	17.6	0
Setaria barbata	Gaouri tcholi	4	16.7	0
Setaria pumila	Witchouwandou	3.3	0	0
Tephrosia bracteolata	Lekoi-lekoi	2.3	0	0
Trypsacum laxum	/	0	3.7	0

Marketed forages in % refer to the percent of respondents that mentioned the species to be present in the forage markets.

Table 8: Mean price of *E. pyramidalis* in function of respondents.

Survey areas	USD < 1	USD 1–2	USD > 2	No opinion
	per kg of wet forage (fresh forage)			
Douala (%)	0	2	0	0
Garoua (%)	24	56	5	15
Yaoundé (%)	8.6	51.4	5.7	34.3
	per kg of hay (dried forage)			
Douala (%)	0	0	0	0
Garoua (%)	7	56	0	37
Yaoundé (%)	0	26	0	74

Table 9: Compositions (% DM) of *E. pyramidalis* of leaves harvested at 45-and 100-day of wetland treatment.

Treatment condition	Treatment period	DM (%)	Ash	CP	ADF	NDF	ADL(sa)	Lipids	Hemicellulose	Cellulose
			(% DM)							
NWs	**Ctrl1**	92.5±0.6	9.6± 1.6	15.6±1	29.2±2.6	59.9±0.9	9±0.5	2.4±0.1	27.7±1.7	20.2±2.2
	Ctrl2	92.0±0.5	8.6±1.1	12.8±1.7	37.5±1.3	65.1±1.1	12.9±0.6	3.9±1	27.6±2.4	24.6±1.9
CWs	**45-days**	93.8±0.8	6.6±0.2	18.4±0.1	30.6±0.7	59.2±1.1	10.6±0.3	4.4±0.5	28.5±0.5	20.0±0.4
	100-days	92.8±0.4	9.7±0.4	12.1±0.3	34.4±0.9	63.3±1.4	12.5±0.8	4.1±0.1	28.8±2.2	21.9±0.1
Age and growing environment effects										
Ctrl1 *vs* **Ctrl2**		*	*	*	*	*	*	*	NS	NS
45-days *vs* **100-days**		NS	*	*	*	*	*	NS	NS	*
Ctrl1 *vs* **45-days**		NS	*	*	NS	NS	*	*	NS	NS
Ctrl2 *vs* **100-days**		*	NS	NS	*	*	NS	NS	*	NS

NWs: Natural wetlands; CWS: Constructed wetlands; Ctrl1: control of 45-day treatment; Crtl2: control of 100-day treatment. CP: Crude Protein; NDF: Neutral Detergent Fiber; ADF: Acid Detergent Fiber; ADL: Acid Detergent Lignin; NS: Not significant; *: Significant response at P< 0.05.

Table 10: Compositions (% DM) of *E. pyramidalis* of stems harvested at 45- and 100-day of wetland treatment.

Treatment condition	Treatment period	DM (%)	Ash	CP	ADF	NDF	ADL(sa)	Lipids	Hemicellulose	Cellulose
			(% DM)							
	Ctrl1	94.8±1.4	10.5± 0.8	11.85±1.2	39.6±2.2	68.9±1.2	13.1±0.7	2.4±0.1	3.7±0.7	26.5±1.5
NWs	**Ctrl2**	94.1±1.3	10.8±1.3	8.0±0.6	45.6±0.6	74.5±0.7	16.8±0.1	3.9±1	28.9±0.1	28.9±0.6
	45-days	92.4±0.3	8.3±0.9	10.6±0.2	35.2±0.4	73.6±2.4	15.4±0.1	2.1±0.1	38.4±2.0	19.8±0.5
CWs	**100-days**	93.3±0.5	11.0±0.4	8.8±0.1	43.4±0.3	73.8±1.4	19.0±0.7	2.8±0.3	30.4±1.1	24.3±0.4
Age and growing environment effects										
Ctrl1 *vs* **Ctrl2**		*	NS	*	*	*	*	NS	*	*
45-days *vs* **100-days**		*	*	*	*	NS	*	*	*	*
Ctrl1 *vs* **45-days**		NS	NS	NS	*	NS	*	*	*	*
Ctrl2 *vs* **100-days**		NS	NS	NS	*	NS	*	NS	NS	*

NWs: Natural wetlands; CWS: Constructed wetlands; Ctrl1: control of 45-day treatment; Crtl2: control of 100-day treatment; CP: Crude Protein; NDF: Neutral Detergent Fiber; ADF: Acid Detergent Fiber; ADL: Acid Detergent Lignin; NS: Not significant; *: Significant response at P< 0.05.

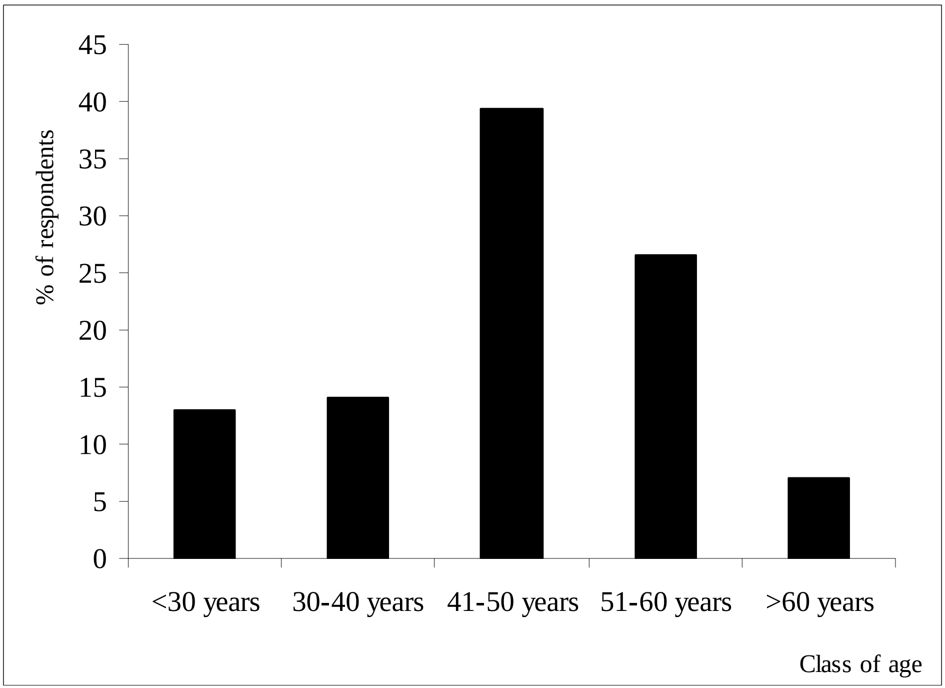

Figure 1: Age distribution of the respondents in the three cities of Cameroon.

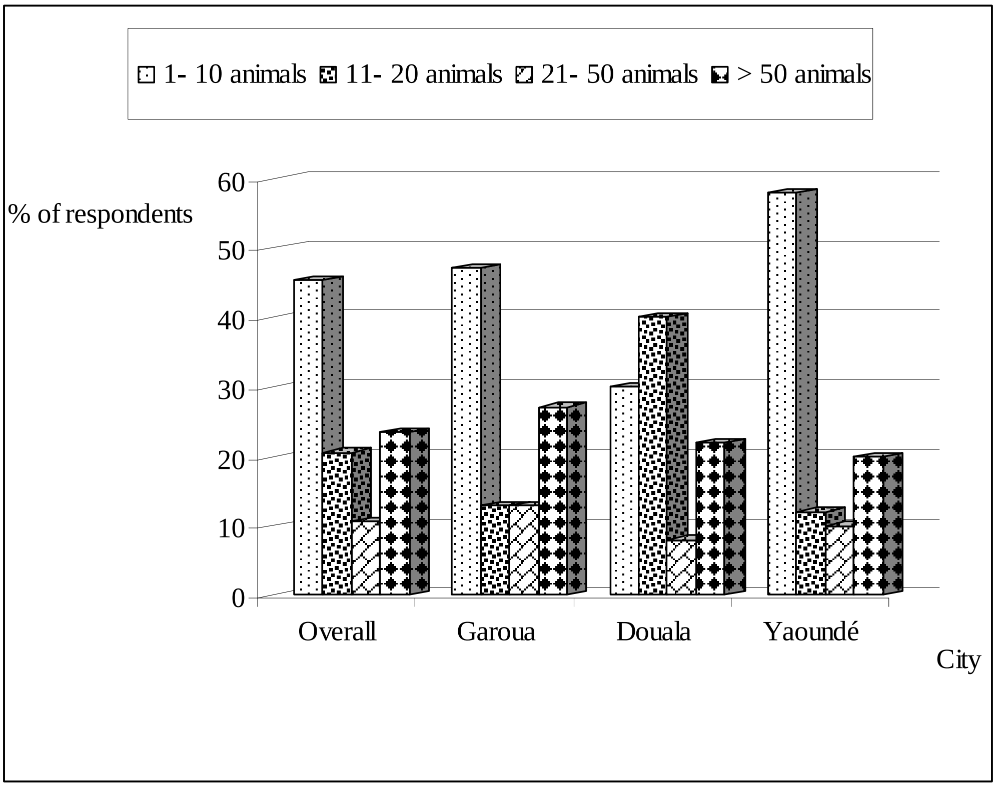

Figure 2: Proportions of animals herd size grouped as a whole and by city.

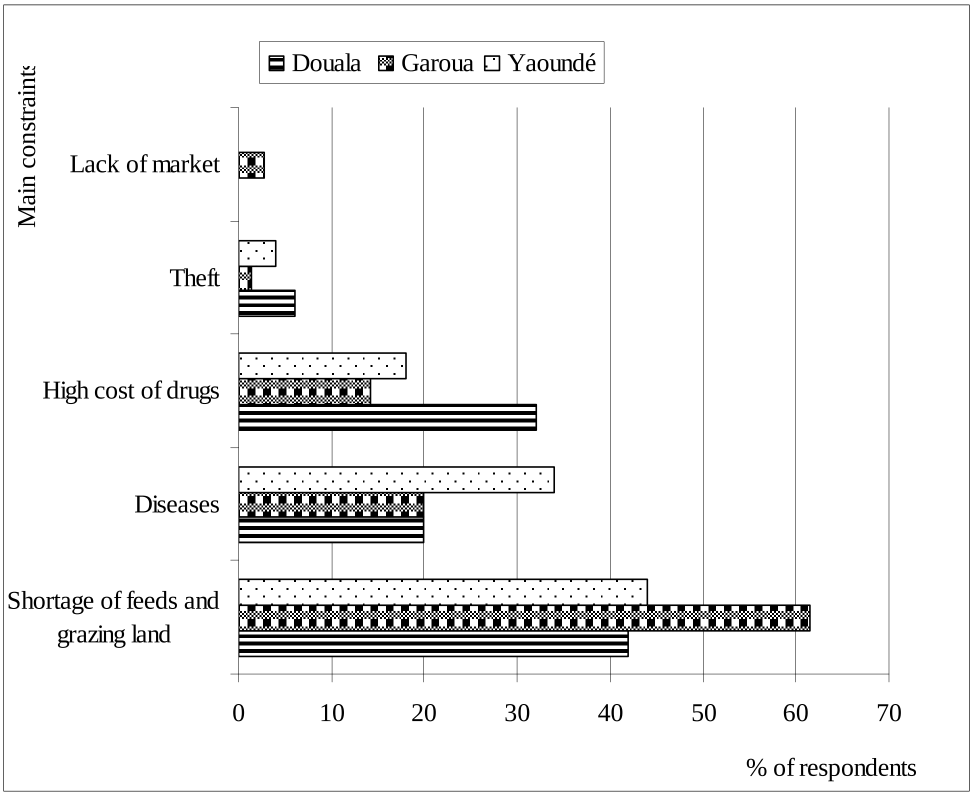

Figure 3: Production constraints identified by the respondents in the three cities.

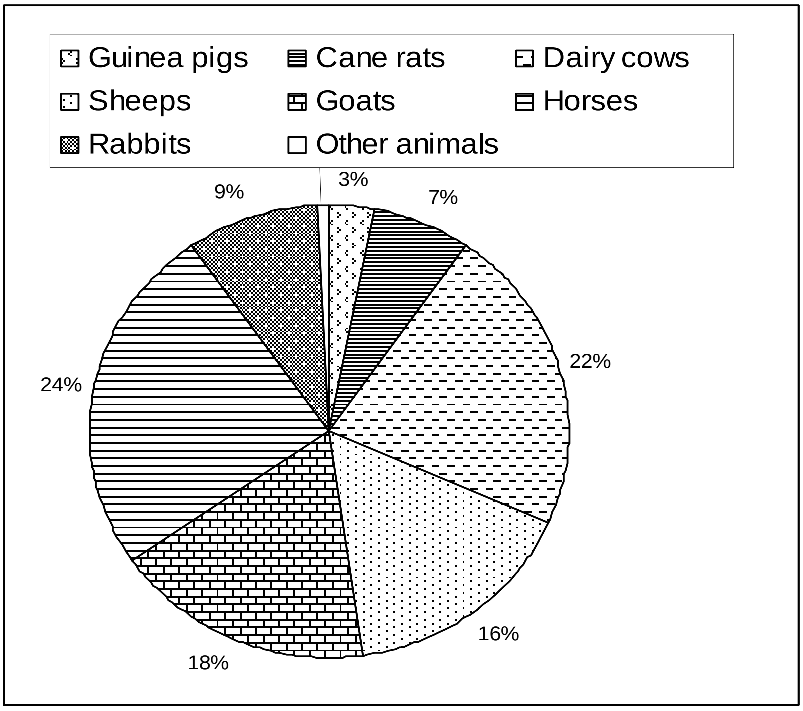

Figure 4: Consumption potential of *E. pyramidalis* by livestock.

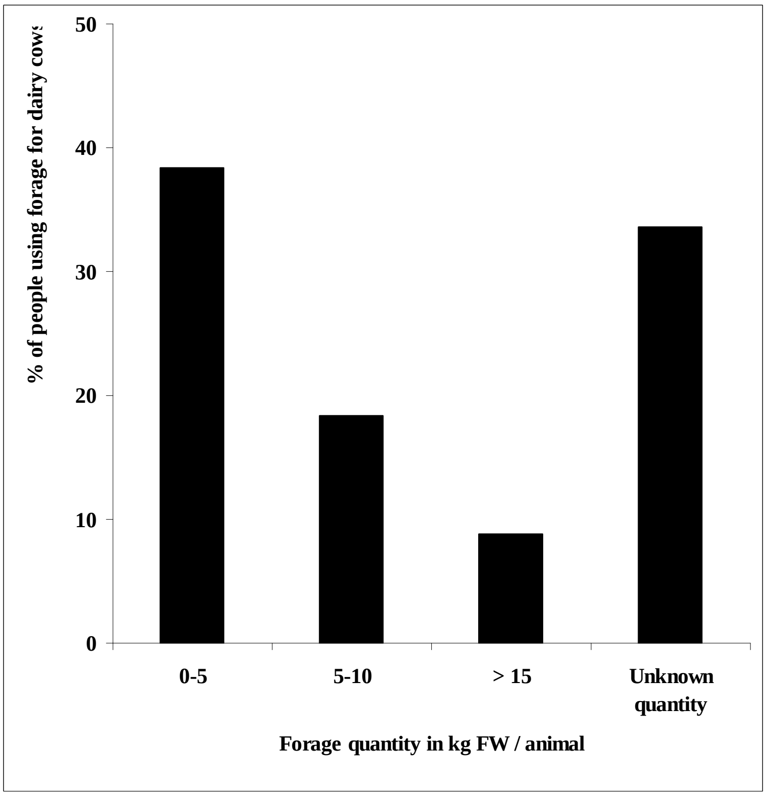

Figure 5: Daily quantity of forage (kg FW/animal) used by breeders for dairy farming in the three studied cities.

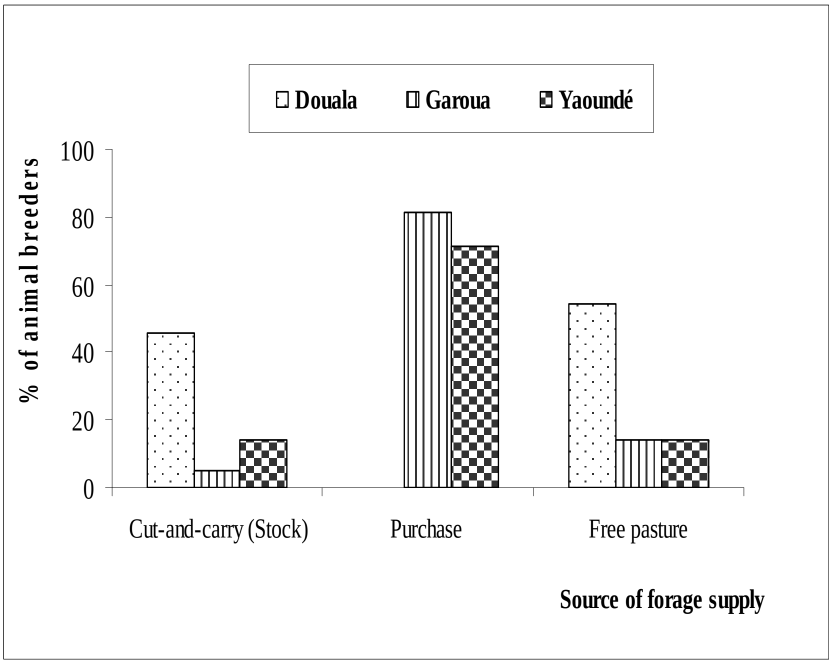

Figure 6: Different sources of forage supply in the three cities of Cameroon in the three survey cities.

DISCUSSION

Opportunity to produce forage CWs

Wastewater and excreta are rich sources of organic and inorganic matter (nitrogen, phosphorus and potassium) for plant nutrition. These materials have been used for centuries to fertilise fields, fishponds and to maintain the soil organic fraction (Strauss, 2000). In treatment processes, they may enhance the nutritive value and productivity of plants by acting as a fertilizer, allowing optimum recycling of nutrients by plants. Thus, by integrating sanitation techniques and forage production, CWs could improve the forage supply in the cities. For example, knowing that the mean volume of human excreta is 1L/cap day FS which represents about 30 kg TS/m^3 (Heinss and Strauss, 1999), a city having 100’ 000 inhabitants may show an annual faecal sludge production of 1095 tons TS (total solids). Hence, the estimated required surface for sanitation treatment in the Cameroonian context with a loading rate capacity of 200 kg TS/m^2/y would be equivalent to 5475 m^2. Taking into account that appropriate treatment consists of two stages, i.e. dewatering and percolate treatment on an equal surface, the full-scale treatment system will require 11000 m^2 surface areas. As regards the yielding potential of *E. pyramidalis* in CWs, production is estimated to vary from 165 to 264 tons DM/m^2/y on an annual three-harvest basis (Kengne et al., 2008).

Income generation potential from trade of forage grown in CWs

Generally, environmental factors, such as water scarcity (season), soil fertility and stages of growth influence the quality and quantity of natural pastures throughout the year in tropical regions (Newman et al., 2007). The integrated system of sanitation treatment and forage production could be an opportunity to enhance forage availability during the dry season. Based on the sub-mentioned estimation, the full-scale treatment units of 11 000 m^2 offered the income potential generated from forage trade of about FCFA 6187’500-19800’000 (USD 12’375-39’600) in the dry season and FCFA 12375’000-29700’000 (USD 24’750-59’400) in the rainy season. Likewise, the authors (unpublished data) have evaluated the annual operating costs for drying vegetated beds in constructed wetlands of Dakar with an overall surface capacity of 130 m^2 and optimal daily faecal sludge loading rate of 200 kg TS/m^2/y to be around FCFA 7500’000 (USD 15’000). Relating the operational costs only to the faecal sludge dewatering process, the income generated by the forage trade could provide cash to improve maintenance and operation of the systems. Since municipal sanitation is mainly lacking in developing countries, appropriate solutions should be developed to facilitate not only the development of the technology, but also to ensure their sustainability. The sanitation technology could act as a forage-based production site, allowing optimum recycling of nutrients by plants to promote their growth and productivity and provide a good forage supplement for animal breeders, despite the progressive scarcity of forage in urban and peri-urban areas.

Feeding potential of *E. pyramidalis*

The content of CP determined in *E. pyramidalis* grown in CWs was higher than those reported by Adebowale (1988) and those of NWs; this confirmed that the alternative production of this forage in CWs might contribute efficiently to the livestock productions. The decrease of protein content of different parts of forage plants with advanced maturity, were higher than the critical level of 7% DM, below which the forage intake of animal is depressed (Van Soest, 1994). These CP ranges were sufficiently high to warrant utilization as protein supplement to low-quality diets and for maintenance and growth of small ruminants with their proper rumen-bacteria functioning (Van Soest, 1994). The proportion of NDF was higher than those reported by (Adebowale, 1988). These NDF ranges in our results can be explained mainly by age of the forage used; here the plants were acclimatized for eight weeks and subjected to 45- and 100-

day wetland treatment period. These increase fibre contents may be attributed to their increasing age and their nature as tropical forage. In addition, the tropical forages generally showed an increase in cell wall components such as NDF, ADF and ADL with increasing maturity (Cherney et al., 1993). In orchard grass, 72.4 and 43.8% DM respectively for NDF and ADF were recorded (Bourquin et al., 1994). The study of three tropical grasses commonly used in traditional small farms of Burundi showed 85.1, 69.5 and 70.5% DM for NDF against 45.4, 37.4 and 37.1% DM for ADF respectively for *Eragrostis olivacea*, *Setaria sphacelata* and *Tripsacum laxum* (Nivyobizi et al., 2010). In fact, maturity was mainly considered to be the key factor affecting forage quality, and many reports have focused on season and growth stage of forage since some factors affect its feeding value (Minson, 1990; Borreani et al., 1998). Few differences were found between the antelope grass grown in NWs and those grown in CWs showing that these compositions could be improved in CWs. For all the samples, the ADF fraction was a large proportion of the NDF, which indicate high content of cellulose and lignin and low levels of hemicellulose. These results do not substantiate those of Adebowale (1988) who, working with the same plant, found that the ADF content in the whole stem with leaves ranged from 41.4 to 50.8% for 3 and 12-week old forage, respectively. However, this high content of cell walls and lignin is typical of tropical forages (Van Soest, 1982). The considerable difference between leaves at 45-day and those of 100-day period as regards ADF, ADL (sa) and NDF can be attributed to the maturity effect. Higher fibre concentrations in stems occurred because stems contain more structural and conducting tissues than leaves, while a larger part of the leaves is occupied by thin-walled mesophyl (Van Soest, 1994). Besides, Buxton (1996) also reported that stems of most forage have a higher concentration of cell walls than leaves and; as plant advance in maturity, the cell wall concentration within stems declines more rapidly than does than of leaves. Many studies have shown that fibre concentrations increased as plants matured (Cherney et al., 1993; Buxton and Redfearn, 1997). The highest fibre concentration in this forage could be explained by the anatomical feature of *E. pyramidalis,* as it is a tropical C4 photosynthetic pathway forage. This forage has thinner leaves, more bundled sheaths and smaller interveinal distance, corresponding to the higher cellulose and higher lignin content. Since lignification is more pronounced in stems than in leaves, it may explain why leaves are very good in quality compared to stems. Maturation of stems results in the accumulation of parenchyma, sclerenchyma and vascular tissues such as xylems, which are rich in cellulose and lignin. In addition, the results of this study were in the same line with those of Cherney et al. (1993) and Kamalak et al. (2005a, 2005b) who also showed an increase of all fiber constituents with advancing age. Buxton (1996) reported that the maximum cell wall concentration of diets that will not hinder intake and animal production can be as high as 700-750 g NDF kg^{-1} dry matter for mature beef cows; this means that even in these studied stages, *E. pyramidalis* could be used in cow production or supplementation. Globally, the values of chemical compositions of this studied forage were within the range of values reported for tropical regions (Dean et al., 2008, Pamo et al., 2007).

Conclusion

These investigations aimed at (1) assessing the income generated from forage trade in the three different cities (Douala, Yaoundé, Garoua) of Cameroon; with an evaluation of the economic potential which may be derived from forage production in CWs and (2) examining the effect of maturity and wetland treatment processes on the feeding qualities of *E. pyramidalis*. From the results obtained, the following conclusions can be drawn:

- The business of forage trade is an economic activity, which could generate a daily income of USD 800–1’600 in the rainy season and USD 500–1’500 in the dry season, depending on the forage availability. By extrapolation, a city of 100’ 000 inhabitants which requires a surface areas of 11000-m^2 for full-scale sanitation treatment system, the forage production estimated to vary from 165 to 264 tons DM/m^2/y on an annual three-harvest basis and the potential income generated from forage selling is estimated at about USD 12’375–39’600 in the dry season and USD 24’750–59’400 in the rainy season.

- The CP contents of *E. pyramidalis* decline with time however, the potential nutritive value is comparable to that of most tropical forage. Much would be gained if this forage could be utilized in the early stage of maturity as animal feeds.
- The cell-wall composition of *E. pyramidalis* (ADF, ADL (sa) and NDF) at 45 and 100-day period with the additional eight week period of acclimatization showed its advancing maturity and suggested the need to use this forage at an earlier stage of maturity.

This work represents one of the attempts to link the sanitation technology to forage production development in sub-Saharan countries. To improve sanitation conditions in developing countries, treatment strategies and technological options will have to be adapted to local situation and needs. For example, urban and peri-urban agriculture in African cities is increasingly accepted and used as a tool in sustainable city development because of its multiple functions. Urban agriculture has been adopted to achieve food and health security, alleviate poverty through income generation from economic opportunities arising from agriculture. To adapt sanitation technology to local needs may consists of supplying healthy wastewater for urban irrigation, provide forage for animal nutrition and compost as fertiliser, thus contributing to improving the urban agricultural sector. Careful research on the management of this integrated system of sanitation treatment and forage production to cover the forage requirements should be promoted with the most suitable harvesting periods determined over the year with regards to the public health risks, period of optimum nutritional forage value and production planning focus on the period of forage shortage.

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