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Le Point sur :

Some suitable grasses and legumes for ley pastures in Sudanian Africa: the case of the Borgou region in Benin

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In Sudanian region of Africa, agricultural systems are under increasing pressure because of human and animal population growth, climate changes, extensive practises, decreasing prices for cash crops, etc. Possibilities of intensification in smallholder farming systems of the Borgou region in Benin are limited due to difficulties to pay for external inputs. Therefore, rural communities rely heavily on low input technologies to increase crop production and animal feed. Cultivated forages are of better-feed quality for ruminants compared to weed fallows. Their integration in cropping system through ley pastures has the potential to increase not only animal feed availability but also to improve soil fertility. This paper reviews some possible grass and legume species that can be used for that purpose with a special focus on the strengths and weaknesses of the species in terms of soil and climate suitability, forage production, nutritive value and soil fertility restoration. The choice of one or several among them as leys in pure stands or mixed forage crops must be taken carefully considering the balance between advantages and disadvantages of the species, the available financial and technical inputs and the adaptation to the local environment.
Keywords. West Africa, Sudanian regions, ley pasture, forage, legumes, grasses.

Graminées et légumineuses adaptées à la jachère fourragère des régions soudaniennes de l'Afrique de l'Ouest : le cas du Borgou au Bénin. Dans la région soudanienne de l'Afrique, les systèmes de production agricole sont sous pression en raison de l'augmentation de la population humaine et animale, des changements climatiques, des modes extensifs de production agricole, de la chute des coûts des produits d'exportation, etc. Les possibilités d'intensification des systèmes de production agricole dans le Borgou au Bénin sont limitées notamment à cause des faibles capacités d'investissement financier des paysans. Par conséquent, les communautés rurales comptent sur des technologies relativement peu coûteuses pour accroître les productions et assurer l'alimentation des animaux. Les cultures fourragères sont des aliments de bonne qualité en comparaison avec les jachères naturelles. Leur intégration dans les systèmes de production sous forme de jachère fourragère offre des possibilités d'augmenter non seulement les disponibilités alimentaires du bétail mais aussi d'accroître la fertilité des sols. Ce document présente une gamme de graminées et de légumineuses susceptibles d'être utilisées en jachère fourragère, mettant l'accent sur les forces et faiblesses de ces espèces en termes d'adaptation au climat, de leur production fourragère, de leur valeur alimentaire et de la restauration de la fertilité des sols. Le choix d'une ou de plusieurs de ces espèces pour les utiliser en mono-culture ou en mélange sous forme de jachère fourragère doit être fait avec précaution en tenant compte des avantages et inconvénients de ces espèces, de la capacité financière des paysans et de leur adaptation à l'environnement local.
Mots-clés. Afrique de l'Ouest, régions soudaniennes, jachère fourragère, fourrage, légumineuses, graminées.

1. INTRODUCTION

In Sudanian regions such as the Borgou region in Benin, land cropping is practised by small-farmers according to the traditional method of slash-and-burn cultivation. The fields are cropped for 3 to 4 years and, afterwards, the land is left in a weed fallow with many unpalatable species (Nye et al., 1960). Originally, the fallow duration ranged from 10 to 20 years in the Borgou (Floret et al., 1999), while in other Sudanian zones of West Africa fallow periods up to 30 years are reported (Klein et al., 1999; Somé et al., 2007). Today, the increased population densities and the development of cash crops have drastically reduced land availability, leading to a net reduction of the fallow period with dramatic consequences on soil fertility (Mapongmetsem, 1999; Rethman, 2000; Koutika et al., 2002; Nikiema, 2005).

On another hand, livestock owners in their search for ruminant feeds intensively overexploit the natural vegetation as well as the weed fallows, and the availability of the natural forage has currently become the main constraint to ruminant production (Peters et al., 2003; Carr et al., 2005). This is especially the case during the dry season when the low nutritive value of forages induces loss of ruminants body weight, reduces milk production and increases calf mortality as well as nutritional anoestrus (McIntire et al., 1992; Gbangboché, 2005).

This conjunction of over-cultivation and grazing has gradually led to depletion of soil fertility, deterioration of its structure, increased erosion, lower biological activity and higher incidence of crop diseases and pests (Dalal et al., 1986; 1991). There is an urgent need to adopt fertility restorative practices to maintain the sustainability of the farming and livestock systems.

Opportunities for intensification in smallholder farming systems in Borgou, like in other extensive systems, are however limited due to difficulties to pay for external inputs. Ley pasture integrated in farming systems can produce synergistic effects with minimal inputs (Humphreys, 1994; Peters et al., 2001; Clem, 2004). The versatility of forages allows them to be used in different ways in the complex production systems of the tropics and the sub-tropics (Schultze-Kraft et al., 1997): grazing, cut-and-carry, hay and silage. Moreover, they can have direct and indirect effects in increasing resource and land use efficiency (Humphreys, 1994; Somé et al., 2006). Indeed most forages, in particular legumes, are also multi-purpose plants.

When integrated in the rotation, direct effects on crop production include plant-water availability, weed suppression, pest and disease reduction and improved fallows (Cullen et al., 2006; Mapiye et al., 2007). Cultivated forages are also of better-feed quality for ruminants compared to weed fallow and the possibility to maintain animals on the farm improves soil fertility through manure production.

For the Borgou and the Sudanian region of Africa in general, scientific results and knowledge on well-adapted forage species or cultivars are very limited today. Therefore, this paper reviews the forages that could be used for ley pastures in these regions, with a special focus on the strengths and weaknesses of the species in terms of ecology forage production, nutritive value and soil fertility management.

2. PHYSICAL AND SOCIO-ECONOMIC CHARACTERISTICS OF THE BORGOU REGION

2.1. Climate, soils and vegetation

The Borgou is located in Benin between 8°45'-12°30'N and 2°-3°15'E with an altitude varying from 200 to 300 m asl. The region covers about 52,093 km^2 (46% of the country) with a population evaluated to 1,052,600 hbts in 1999 and an annual increasing rate of 3% (CARDER, 2005). The region can be divided from North to South into three ecological zones that are related to mean annual rainfall: Sudano-Sahelian, Sudanian and Sudano-Guinean zones. From the Northern Sudano-Sahelian zone to the Southern Sudano-Guinean, annual rainfalls increase from 900 to 1,200 mm (**Figure 1**). The rainy season lengthens from

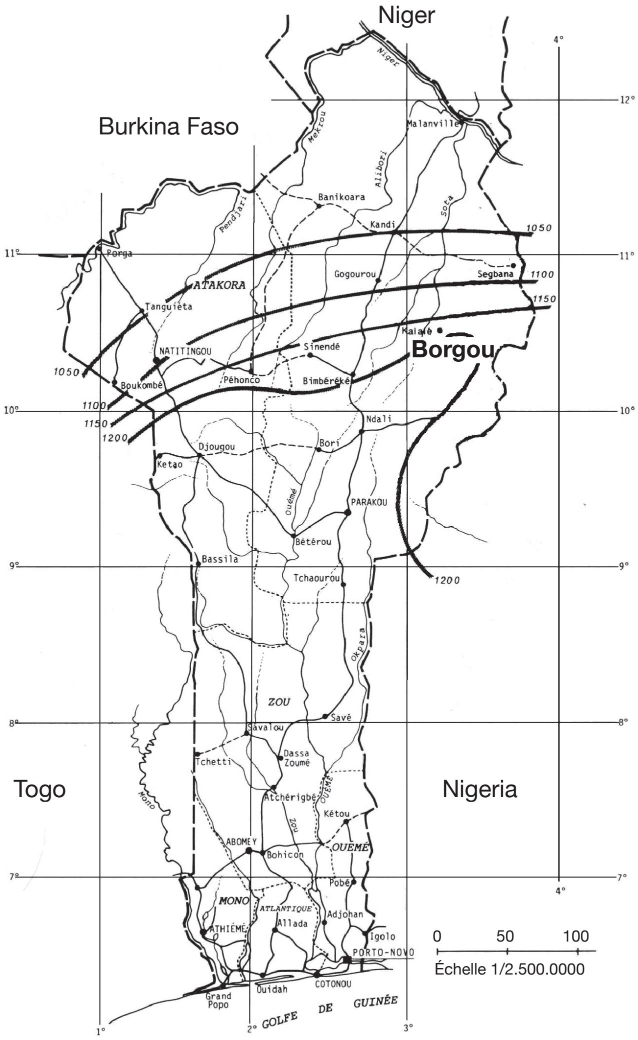

Figure 1. Annual rainfalls distribution (in mm) in Borgou region (Benin, West Africa) — *Répartition de la pluviométrie annuelle (en mm) dans la region du Borgou (Bénin, Afrique de l'Ouest).*

5 to 7 months (April-October) and July-September is generally the wettest period of the year (**Figure 2**). Annual rainy days average 65 days with high variations from year to year. Within these above mean rainy conditions, local variations in ecosystems exist depending on soil and relief conditions (CARDER, 2005). The monthly and annual mean temperatures are between 21-34°C and 27-28°C, respectively. Monthly relative humidity and evaporation are between 40-90% and 3-6 mm per day respectively. Annual solar radiation average is slightly above 2,500 hours.

A marking characteristic of the climate in Borgou is the temporal variability of annual rainfalls, with a general trend to lower rainfall and an increased mean temperature since the past decades (**Figures 3** and **4**). Some years have a total rainfall that significantly exceeds the long-term average, whereas others are far below. Years of abundant rainfall are generally followed by years of drought. These meteorological changes in the Borgou region agree with the trend observed in whole West Africa reported by Sultan et al. (2004) and Bigot et al. (2005). Such climatic changes have certainly an impact on the environment and the livelihoods of people through the plant growth and dry matter production and changes in land-use patterns (Russell, 1991).

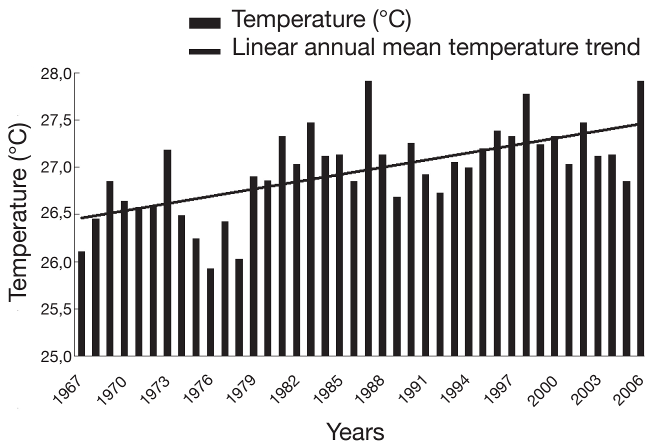

Figure 4. Annual mean temperature and trend between 1967-2006 in Parakou (Borgou region, Benin) — *Température annuelle moyenne et sa tendance entre 1967-2006 à Parakou (Borgou, Bénin).*

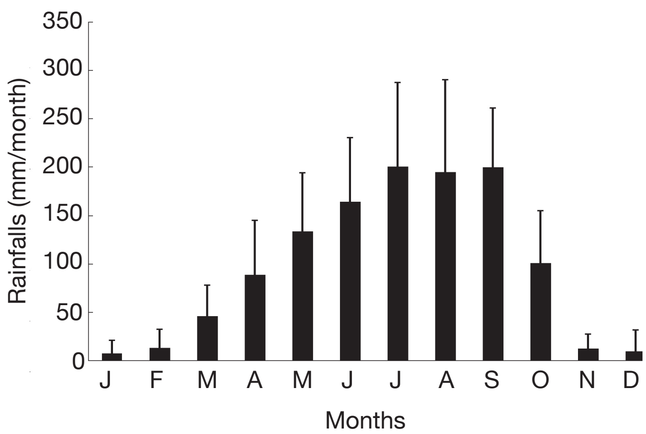

Figure 2. Means and standard deviations of the monthly rainfalls observed between 1967-2006 in Parakou (Borgou region, Benin) — *Moyennes et écarts-types de la pluviométrie mensuelle entre 1967-2006 à Parakou (Borgou, Bénin).*

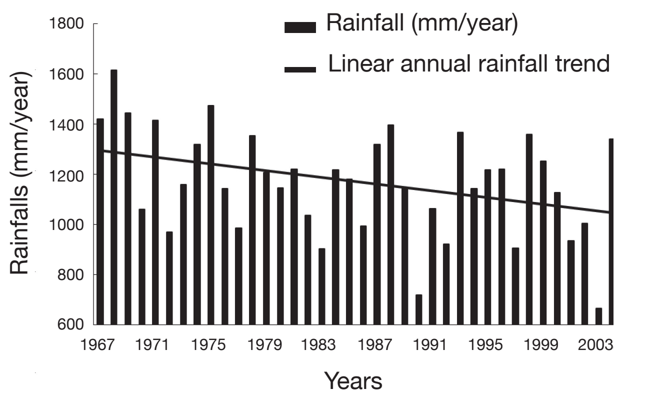

Figure 3. Annual rainfalls and trend between 1967-2003 in Parakou (Borgou region, Benin) — *Pluviométrie annuelle et sa tendance entre 1967-2003 à Parakou (Borgou, Bénin).*

The region is characterized by ferruginous tropical soils (87%), ferralitic soils (10%) and vertisols (3%). According to FAO (1965) and CPCS (1967) soil classification, ferruginous tropical soils in Borgou are skeletal chromic-luvisoil or tropical concretionary ferruginised soil (Youssouf et al., 2002). Most lands have a slope varying from 1 to 10%, sometimes with a slightly undulating topography and granite or gneiss as parent material. Soil texture consists of friable gravely sand to gravely sand-loam and is highly leached in most of the region. Their deepness is highly variable (0.40-2 m) with reddish colour more pronounced in some sites and they increase in ferruginous gravel content with deep. Soils have a low water-holding capacity and are generally medium to well drained. The reaction is slightly acid to neutral (pH_{water} 6.0-6.7) in the surface layers (0-20 cm), decreasing slightly to acid in the lower layers. The chemical composition of these substrates shows an accumulation of ferric oxides and hydrates with low concentrations of aluminium oxide and low exchangeable cations capacity (2-5 $cmol^{+}$ per 100 g), but with high base saturation (80-95%). Organic matter content is very low (0.5-1.5%) and soils are deficient in N (0.01-0.03%) and assimilable P (1-3 ppm Bray) (Youssouf et al., 2002).

The natural vegetation in Borgou changes with the rainfall from wooded savannahs in the South to semi-desert steppes in the North. Some bush lands are also confined to rocky soils. Grasslands are dominated by *Loxodera ledermannii* (Pilg.) Clayton ex Laurent, *Andropogon* and *Brachiaria* species. Other species such as *Setaria pallide-fusca* (Schumach.) Stapf. and C.E.Hubb., *Aristida adscensionis* L., *Aristida hordeacea* Kunth, *Axonopus compressus* (Sw.) P.Beauv., *Axonopus flexuosus* (Peter) C.E.Hubb. ex Troupin are widespread (Sinsin et al., 1989). All the natural forests in Borgou have been destroyed by fire or cultivation. In the grasslands, woody species (*Adansonia digitata* L., *Parkia biglobosa* (Jacq.) R.Br. ex G.Don, *Vitellaria paradoxa* C.F.Gaertn., *Mangifera indica* L., etc.) are highly valued by the farmers because of the various products they benefit from: fruits, vegetable, cooking oil, firewood, spices, medicines, etc. (Adjanohoun et al., 1989; Sinsin et al., 1989; Bosch et al., 2002) and their positive influence on soil fertility maintenance (Traoré et al., 2004).

2.2. Livestock

The cattle breeds present in Borgou are called the Borgou cattle, a crossing between zebu (*Bos indicus* L.) and taurine (*Bos taurus* L.). They can withstand heat, are medium trypano-tolerant, they tolerate humidity and graze year round on hard feed conditions. Borgou cattle are also good draught animals given their small size. About 960,000 heads are present in the Borgou. It represents 70% of the stock in Benin (CARDER, 2005). Domestic sheep (*Ovis aries* L.) belong to Dwarf type of West Africa. With an estimated total of some 300,000 units in the region, sheep slightly outnumber goats (*Capra hircus* L.) (CARDER, 2005). Both have low reproduction ratio and productivity (CARDER, 2005).

In Borgou, different livestock production systems coexist: transhumant herders, sedentary agropastoralists and farmers using animal power. However, since the majority of the herd is held in the transhumant system, there is a real lack of integration with the cropping systems.

2.3. Farming systems

Most land in Borgou belong to a family clan or a village community (95%) and is transmitted through generations (CARDER, 2005). Family size varies between 5 and 10 persons exploiting 5-10 ha. Agriculture is dominated by cereals, yam (*Dioscorea batatas* Decné.), cassava (*Manihot esculenta* Crantz), sweet potato (*Ipomoea batatas* (L.) Lam.), cotton (*Gossypium hirsutum* L.) and few tree crop productions. Maize, sorghum, pearl millet, groundnut and cowpea are other important grain crops. Typically, the cultivated land is constituted of 1.5-2 ha of maize in association with or without cassava, 1-1.5 ha sorghum and millet, 1 ha yam and 1 ha for cash crop, cotton or groundnut. Rice is cultivated on limited areas corresponding to hydromorphic soils. Pepper, tomato and bitter-leaf are generally grown around the houses. Clearing starts around January and February and tilling is done between March and April. Planting starts with the rains, between April and May, but installation of some later varieties of yam might take place already in December. Harvesting happens between August and December. The same area is cropped for 3 to 4 years, alternately with a weed fallow of 2 to 3 years to recover fertility. However, due mainly to population growth and the development of cash crops (cotton and groundnut), cultivation periods are more and more prolonged and fallow periods shortened, leading to a decrease in soil fertility.

3. IDENTIFICATION OF THE SUITED FORAGE SPECIES

The role of temporary pastures to improve soil fertility, increase land-use efficiency and produce synergistic effects in agricultural systems is highly documented (Buldgen et al., 1997; Muyekho et al., 2003; Mapiye et al., 2007). The main prerequisite to obtain efficient forages is however to choose the appropriate species and cultivars, for which the following basic aptitudes are requested:

- the adaptability to the local environmental conditions, mainly climate and soils,
- the capability to ensure high yields in palatable materials with acceptable nutritive value,
- the maximum efficiency in soil fertility improvement.

The choice of possible species of forages was first done by consulting the Tropical Forages Database version 1.1 (Cook et al., 2005), which offers an interactive tool to identify adapted species in specific environments. The main environmental conditions taken into account in this database are: altitude, temperature and rainfall ranges, length of dry season, preferences for substrate structure and texture, requirements for soil ecology such as acidity, Al saturation, drainage, flooding or waterlogging and salinity tolerance and the adaptation of the species to low soil fertility level. The selection was thereafter refined by using our own observations about species behaviour in savannah regions of West Africa, the opinion of crop-livestock producers and other useful information given by the scientific literature. For the forage grasses and legumes presented in **tables 1** and **2**, the following attributes were especially targeted: the survival of the species and the yields with minimum 1,000 mm of annual rainfall, the aptitude for soil fertility improvement, the

Table 1. Characteristics of some suited tropical grasses for Borgou region (West Africa) — *Caractéristiques de quelques graminées tropicales adaptées à la région du Borgou (Afrique de l'Ouest).*

	Requirement for altitude, rainfall and temperature	Requirement for soil pH, texture, drainage, fertility and tolerance for Al saturation and waterlogging	Installation	Forage and seed production	Nutritive value	Drought and defoliation tolerance	Sources
Panicum maximum Jacq.	< 1500 m asl. > 1000 mm rainfall but < 800 mm for some ecotypes 19-23°C	pH 5.5-6.5, sand to slightly clay and medium to well-drained, Al tolerance< 60%, medium to good fertility, good drainage and generally poor waterlogging and salinity tolerance	Seed: 2-7 kg·ha^{-1} > 80% germination or splits	3-15 t·ha^{-1} DM 50-150 kg·ha^{-1} seed	5-13% CP, 51-65% digestibility, 0.17% P, high palatability before flowering, LWG* = 100-400 kg per ha per year	Medium but good for *Panicum maximum* C1	(1) (2) (3) (4) (5) (6) (7) (8)
Andropogon gayanus Kunth	< 1000 m asl. > 900 mm but < 500 mm for some ecotypes 23-27°C	pH = 4-7.5, sand to clay, low fertility adaptation, medium to well drained soils, Al saturation tolerance < 80%, medium to poor salinity and poor waterlogging tolerance	Seed: 5-7 kg·ha^{-1} or 1-5 kg de-awned seed, or splits	4-30 t·ha^{-1} DM 20-350 kg·ha^{-1} seed	7-15% CP, 63% digestibility, high palatability, LWG: 100-250 kg per ha per year	Very good but depending to ecotypes	(1)(2) (3) (9) (10) (11) (12) (13) (14) (15) (16)
Pennisetum purpureum Schum.	< 2000 m asl. > 1000 mm rainfall but 800 mm for some ecotypes 25-40°C	pH = 4.5-8.2, friable loam soil, high soil fertility and water demand, moderate flooding and waterlogging tolerance	Seed but usually cutting or splits	2-50 t·ha^{-1} DM Seed rarely harvested	4-18% CP, 68-74% digestibility, high palatability LWG: 50-550 kg per ha per year	Low to medium but very good for some ecotypes	(1) (2) (3) (14) (17) (18) (19) (20) (21)
Brachiaria ruziziensis R.Germ. & C.M. Evrard	< 1000 m asl. > 1200 mm rainfall 20-36°C	pH = 5-6.8, sand to loam, high fertility and well-drained soils, Al tolerance < 87% but poor tolerance for flooding and waterlogging	Seed: 3-10 kg·ha^{-1} or splits rooting nodes	3-25 t·ha^{-1} DM 50-200 kg·ha^{-1} seed	5-15% CP, 55-75% digestibility, very high palatability, photosensitization, LWG > 200 kg per ha per year	Low tolerance in thin and light textural soils	(1) (3) (18) (22) (23) (24) (25)

*LWG = liveweight gain with approximately 2 animal units·ha^{-1}.

(1) Cook et al., 2005 (2) CIAT, 1978 (3) Bodgan, 1977 (4) Middleton et al., 1975 (5) Messager, 1984 (6) Santos et al., 2006 (7) Roberge et al., 1999 (8) Loch et al., 1999 (9) Buldgen et al., 1997 (10) Toledo et al., 1990 (11) Haggar, 1966 (12) Jones, 1979b (13) Bowden, 1963 (14) Adegbola, 1964 (15) Mandret et al., 1999 (16) Gobius et al., 2001 (17) Tudsri et al., 2002 (18) Miyagi, 1980 (19) Phaikaew et al., 1993 (20) Peake et al., 1990 (21) Muia et al., 1999 (22) Hopkinson et al., 1996 (23) Miles et al., 1996 (24) Hare et al., 2007 (25) Häussler et al., 2006.

Table 2. Characteristics of some suited forage legumes for the Borgou region (West Africa) — *Caractéristiques de quelques légumineuses fourragères adaptées à la région du Borgou (Afrique de l'Ouest).*

	Requirement for altitude, rainfall and temperature	Requirement for soil pH, texture, drainage, fertility and tolerance for Al saturation and waterlogging	Installation	Forage and seed production	Nutritive value	Drought and defoliation tolerance	Sources
Aeschynomene histrix Poir.	< 1400 m asl. 800-2800 mm rainfall 19-26°C	pH = 5-7.5, sandy to clay with medium drainage, adaptation to low fertility, Al saturation tolerance > 70% and poor waterlogging tolerance	Seed: 4-8 kg·ha^{-1}, sowing after dormancy broken (usually hot water)	2-8 t·ha^{-1} DM 90-200 kg·ha^{-1} seed	20% CP, 53-66% digestibility, very high palatability, LWG* > 200 kg per ha per year	Medium for drought and defoliation tolerance	(1) (2) (3) (4) (5) (6) (7)
Aeschynomene americana L.	< 1200 m asl. 600-800 mm rainfall 20-25°C	pH 5.5-7, gravel sand to clay, tolerant to low fertility, high saturation for Al, good tolerance for flooding and waterlogging	Seed: 4-6 kg·ha^{-1} after dormancy removed	3-5 t·ha^{-1} DM 0.5-1 t·ha^{-1} seed	10-28% CP, 60-70% digestibility, moderately to high palatability and LWG: 500 g per head per day	Moderate drought and defoliation tolerance	(1) (8) (9) (10) (11) (12)
Aeschynomene indica L.	< 1500 m asl. > 1200 mm rainfall 17-27°C	pH 4.5-8, sand loam to clay, tolerant to low fertility, medium tolerant for Al saturation, good tolerance for flooding and waterlogging	Seed: 5-8 kg·ha^{-1} after dormancy removed	Not sufficiently evaluated but may be acceptable	Not sufficiently evaluated but may be acceptable	Low drought and defoliation tolerance	(1) (10) (12) (13) (14)
Stylosanthes hamata (L.) Taub.	< 1500 m asl. 500-2000 mm rainfall 23-27°C	pH 5.4-8.0, coarse sand to heavy clay soils, tolerance for low soil P content and some ecotypes have good waterlogging tolerance	Seed: 3-5 kg·ha^{-1} after heat treatment	1-6 t·ha^{-1} DM 50-500 kg·ha^{-1} seed	CP > 17-24%, 66-72% digestibility, very good palatability	Good drought tolerance but low defoliation tolerance	(1) (15) (16) (17) (18) (19) (20)
Stylosanthes fruticosa (Retz.) Alston	< 2000 m asl. > 300 mm rainfall 23-27°C	pH = 4-8, sandy to clay, tolerance for low soil P content and high Al saturation, well drained soils, medium flooding and waterlogging tolerance	Seed: 3-7 kg·ha^{-1} after heat treatment	3-5 t·ha^{-1} DM 15-100 kg·ha^{-1} . seed	CP > 8%, 66% digestibility, high palatability	Highly drought tolerance but medium defoliation tolerance	(1) (21) (22) (23) (24)
Stylosanthes guianensis (Aublet) Sw.	< 2000 m asl. 800-1500 mm rainfall 25-30°C	pH = 4-8.3, sandy to clay, tolerance for low soil P content and medium Al saturation and Mn tolerance, low to medium flooding and waterlogging tolerance	Seed: 3-6 kg·ha^{-1} after heat treatment	3-5 t·ha^{-1} DM 300-700 kg·ha^{-1} seed	10-15% CP, 60% digestibility, low palatability in early growing season, 0.2-0.6% P, 0.6-1.6% Ca, LWG: 300-500 kg per ha per year, fed to pigs	Medium for drought and defoliation tolerance	(1) (21) (25)

Centrosema pubescens Benth	< 1000 m asl. > 1500 mm but 1000 mm rainfall for some ecotypes 20-30°C	pH, 4-8,5; sandy to clay, medium to well-drained, Al saturation tolerance > 80%, medium flooding tolerance	Seed: 3-5 kg·ha^{-1} after dormancy broken or rooted runners	2-7 t·ha^{-1} DM 50-375 kg·ha^{-1} seed	13-26% CP, 54-65% digestibility, 0.15-0.21% P, 0.5-0.8% Ca, 0.32% Mg, 1.5% K, high palatability, LWG*: 100-650 kg per ha per year	Medium to good for drought and defoliation tolerance	(1) (26) (27) (28) (29) (30) (31)
Mucuna pruriens (L.) DC.	< 1600 m asl. > 1000 mm rainfall 20-27°C	pH = 5-7, sandy to loam, moderate to high fertility, medium to well-drained, low waterlogging tolerance	Seed: 20-40 kg·ha^{-1}	2-10 t·ha^{-1} DM 200-2000 kg·ha^{-1} seed	11-26% CP, 60-65% digestibility and high mineral content, medium to high palatability but seeds contain L-Dopa acids, LWG is good	Annual plant	(1) (32) (33) (34) (35) (36)
Macroptilium atropurpureum (DC.) Urb.	< 1600 m asl. 700-1600 mm rainfall 25-30°C	pH 5.5-8, various soil types, slightly acid but well drained. Low soil fertility tolerance, high tolerance to Al and Mn but poor tolerance to waterlogging	Seed: 2-6 kg·ha^{-1}	5-8 t·ha^{-1} DM 100-300 kg·ha^{-1} seed	12-25% CP, 50-55% digestibility, medium to high palatability, 0.26% P, and LWG: 50-150 kg per head per year	Medium tolerance for drought and defoliation but highly sensitive to insects	(1) (21) (37) (38) (39) (40)
Cajanus cajan (L.) Huth	< 3000 m asl. 600-1500 mm rainfall 18-35°C	pH 4.5-8.4, sand to heavy clay, low to high fertility and well drained, medium tolerance for Al saturation and low waterlogging tolerance	Seed: 5-20 kg·ha^{-1}	2-25 t·ha^{-1} DM 0.5-2 t·ha^{-1} seed	10-25% CP, palatability increase with plant age, LWG: 200-500 kg per ha per year	Very good for drought but low for defoliation tolerance	(1) (41) (42) (43) (44)
Leucaena leucocephala (Lam.) de With	< 1800 m asl. > 400 mm rainfall 25-30°C	pH 5-7.5, sand to clay, low to high fertility, medium to well drained, moderate tolerance for salinity and flooding	Seed: 2-4 kg·ha^{-1}	1-33 t·ha^{-1} DM 0.3-2 t·ha^{-1} seed	25-30% CP, 55-70% digestibility, very high palatability, 0.8-1.9% Ca, 0.23-0.27% P, 0.01-0.05% Na, LWG: 200-1700 kg per ha per year	Very good for drought and defoliation tolerance	(1) (45) (46) (47) (48) (49) (50)
Gliricidia sepium (Jacq.) Walp.	< 1600 m asl. 650-3500 mm rainfall 21-29°C	pH 4.5-8.7, sand to clay, tolerant to low fertility, medium to well drained, poor tolerance for Al saturation or waterlogged tolerance	Seed but quickly by cutting stakes	2-20 t·ha^{-1} DM 75-180 kg·ha^{-1} seed	18-30% CP; 60-65% digestibility; increase of 25% LWG per year, very low palatability and high toxicity	Very good for drought and defoliation tolerance	(1) (51) (52) (53) (54) (55)

*LWG = liveweight gain with approximately 2 animal units·ha^{-1}.

(1) Cook et al., 2005 (2) Tarawali et al., 1995 (3) Merkel et al., 2000 (4) Adjei et al., 1985 (5) Olanite et al., 2004 (6) Barnes et al., 1996 (7) Muhr et al., 1999 (8) Bishop, 1992 (9) Bishop et al., 1985 (10) Bishop et al., 1988 (11) Hodges et al., 1982 (12) Kretschmer et al., 1980 (13) Rudd, 1955 (14) Bielig, 1997 (15) Roberge et al., 1999 (16) Cameron, 1985 (17) English, 1999 (18) Jones et al., 2003a (19) Jones et al., 2003b (20) Loch et al., 1999 (21) Stace et al., 1984 (23) Gillett et al., 1971 (24) Skerman et al., 1988 (25) Hakiza et al., 1987 (25) 't Mannetje, 1992 (26) Valarini et al., 2006 (27) Omokanye, 2001 (28) Bogdan, 1977 (29) Muhr, 1998 (30) Schultze-Kraft et al., 1990 (31) Fantz, 1996 (32) Buckles et al., 1998 (33) Capo-Chichi et al., 2001 (34) Carsky et al., 1998 (35) Eilittä et al., 2003 (36) Whitbread et al., 2004 (37) Bray et al., 1994 (38) Hall et al., 2004 (39) Pengelly et al., 2004 (40) McKeon et al., 1984 (41) Vandenbeldt, 1988 (42) Ong et al., 1990 (43) Skerman, 1977 (44) Dommergues et al., 1999 (45) Kaminski et al., 2005 (46) Wandera et al., 2005 (47) Lalljee et al., 1998 (48) Mugwe et al., 1998 (49) Dzowela et al., 1998 (50) McNeil et al., 1998 (51) Anoka et al., 1991 (52) Atta-Krah, 1987 (53) Bray et al., 1993 (54) Cobbina et al., 1992 (55) Ella et al., 1989.

requirements in fertilisation, the palatability and the feeding value and, finally, the availability of seeds or planting material.

3.1. Adaptability of the species to the environmental conditions of the Borgou region

Grasses. All grasses presented in **table 1** are perennial with erect or creeping growth habit. They can grow in sandy soils, since they are adapted to a wide range of textures: gravel, sand or clay, provided that the soils are medium to well drained and not flooded or waterlogged for a long period (Bodgan, 1977; Rao et al., 1996; Cook et al., 2005). They are all adapted to tropical regions with a maximal altitude of 1,000 m asl and an average annual temperature varying from 20 to 30°C (Cook et al., 2005). They require generally mean annual rainfalls between 800 and 1,000 mm. However, drought tolerance varies widely between species and accessions. *Panicum maximum* Jacq. C1 and *Andropogon gayanus* Kunth are without any doubt the best adapted grasses to the drought years (600-700 mm) occurring in the Borgou (Messager, 1984; Buldgen et al., 1997; Geerts et al., 1998; Cook et al., 2005). On the contrary, *Brachiaria ruziziensis* R.Germ. & C.M.Evrard is a shallow rooted species and needs high soil water holding capacity due to the dry season length in Borgou. Its suitability seems therefore limited to deep soils.

Differences in low soil fertility tolerance are also observed between species and accessions. *Pennisetum purpureum* Schum. and *B. ruziziensis* are generally weak for that point of view and particularly demanding for water, N, P and K. For example, the available P levels in the substrate must be maintained above 8 ppm for *P. purpureum* (Falade, 1975; Cook et al., 2005). In Borgou, P content of the soils ranges between 1 and 3 ppm (Youssouf et al., 2002). On the opposite, *A. gayanus* accessions are particularly adapted to low soil fertility and seasonal fires as observed in the West-African savannahs (CIAT, 1978).

Legumes. The legumes selected in this review (**Table 2**) are adapted to a wide range of ecological situations (Bodgan, 1977; Cook et al., 2005). They grow in soils from sandy to clay, although they prefer generally a medium soil texture. Most species are successfully planted in situations receiving ideally from 1,000 to 1,500 mm. Some species, such as *Stylosanthes fruticosa* (Retz.) Alston, can however survive on field in very low rainfall areas (300 mm per year), with a pronounced dry season up to 6 months (Cook et al., 2005). The ideal average annual temperature of the selected legumes ranges from 20 to 30°C but selected shrub species, particularly *Cajanus cajan* (L.) Huth, are very heat-tolerant. *C. cajan* prefers hot moist conditions, such as those prevailing in Borgou, and grows at temperatures above 35°C under adequate soil conditions (Cook et al., 2005). All the selected legumes request medium substrate fertility. However, some accessions of *Stylosanthes* or *Centrosema* genus can grow in low soil fertility (Stace et al., 1984; Omokanye, 2001). Conversely, *Macroptilium atropurpureum* (DC.) Urb. requires P fertilisation if soils P contents are less than 8 ppm (Cook et al., 2005).

3.2. Dry matter production and nutritive value of the species.

Grasses. Forage dry matter (DM) production is highly variable depending on species, accessions and growing conditions, particularly when N fertilisers are applied. Commonly and under extensive cultivation, DM of 3-10 $t \cdot ha^{-1}$ can be achieved for *Panicum*, *Andropogon*, *Brachiaria* and *Pennisetum* accessions in typical West-African environments (Buldgen et al., 1997; Buldgen et al., 2001; Cook et al., 2005). All accessions of the selected species require high N fertiliser levels (up to 100-400 $kg \cdot ha^{-1}$) to reach dry matter yields up to 25-40 $t \cdot ha^{-1}$ DM and to persist under frequent cutting or grazing (Cook et al., 2005). When highly fertilised, DM production of *A. gayanus* and *P. maximum*. C1 can reach up to 30 and 50 $t \cdot ha^{-1}$ DM, respectively (Roberge et al., 1999; Cook et al., 2005). *P. purpureum* is one of the most productive grass crop in the world and DM yields of 10-30 $t \cdot ha^{-1}$ DM per year are common. For this species to 85 $t \cdot ha^{-1}$ per year DM can be achieved under heavy fertilisation (Adegbola, 1964; Walmsley et al., 1978). Nevertheless, DM yield declines rapidly if fertility is not maintained. Generally, except for *P. purpureum,* the selected grasses must be cut or grazed at 3-4 weeks intervals and 15-20 cm height to obtain a best balance between persistency on field and feed quality and quantity. To maximize the leafy material, *P. purpureum* should not be allowed to grow more than 1.5 m before cutting at 30-40 cm above ground (Cook et al., 2005).

The digestibility of the selected grasses are in the range of tropical pasture (50-80%) and the ingestion varies between 30 and 70 $g \cdot kg^{-0.75}$ (Babatoundé, 2005; Alkoiret, 2007). They support animal productions of 100 to 500 kg per ha per year and up to 800 or even 1,000 $kg \cdot ha^{-1}$ when high N is applied or when the grasses are mixed with legumes and exploited with moderate stocking rate (Toléba, 2001; Sidi-Imorou, 2002; Cook et al., 2005). On average, the nutritive value of *B. ruziziensis* is higher compared to the other selected grasses, but one must mention the risks for photosensitization and goitre when *B. ruziziensis* is fed alone to ruminants (Hare et al., 1997).

Legumes. Annual yields of the selected legumes range from 2 to 6 t·ha^{-1} DM (**Table 2**). Under ideal conditions, *Aeschynomene histrix* Poir. and *Centrosema pubescens* Benth. yield more than 17 t·ha^{-1} DM in pure stands, but their contribution corresponds to 3 to 5 t·ha^{-1} DM in mixed pastures (Cook et al., 2005). If cutting is practised as frequently as for grasses, the main problem with herbaceous legumes lies in the reduction of regrowths and of seed production, decreasing finally the capacity of the pasture to persist, even under a vegetative form (Olanite et al., 2004). Tree legumes are generally more productive than herbaceous legumes. As an example, Jones et al. (1982) report 25 t·ha^{-1} DM for *C. cajan*.

The palatability of the selected legumes strongly differs between the species. Cook et al. (2005) report that some legumes such as *Leucaena leucocephala* (Lam.) de Wit are eaten the yearlong. Conversely, others such as *C. cajan* present a seasonal palatability and are readily eaten after flowering. *M. atropurpureum* has also a low palatability and needs some adaptation before acceptance by animals. *S. fruticosa* is reported to have high DM digestibility and voluntary intakes, 66% and 71 g·kg$^{-0.75}$, respectively, indicating that the species could have reasonable potential for livestock production (Cook et al., 2005). The main weakness of *Stylosanthes hamata* (L.) Taub. and *Stylosanthes guianensis* (Aublet) Sw. lies in their sensitiveness to anthracnose (*Colletotrichum gloeosporioides*) (Edye et al., 1997; Hall et al., 2004).

The tannin content of the selected legumes is generally low. Nevertheless, some species contain antinutritive and toxic compounds. This is for example the case for *Mucuna pruriens* (L.) DC. that must be limited in the diet as seeds contain L-Dopa (D'Mello, 1995). *L. leucocephala* is highly nutritive for all livestock species (ruminants, pigs and chickens) (McNeill et al., 1998). However, its mimosine content has an antimitotic and depilatory effect on all animals when fed at high levels (Hegarty et al., 1976; Jones, 1979a; 1986). Low cost techniques exist for ruminants to overcome this constraint by introducing mimosine-degrading bacteria in the rumen once during the life of the animals (Jones, 1986).

3.3. Soil fertility improvement

Grasses. Except for *A. gayanus*, results of the positive role of tropical or subtropical grasses alone (without legumes) on soil fertility are scarce. In mixture with legumes, some grasses have however shown a faculty in soil fertility restoration. Compared to natural fallow, Klein et al. (1999) reported an increase from 0.7 to 1% of the organic matter content of the soil, 0.38 to 0.58% for N, 1.8 to 2.4 units of exchangeable cations and 2 to 2.5% of CEC under pasture of *P. maximum* and *S. hamata* mixture grazed during 10 years. When ploughed for later grain crop, this ley pasture mixture yielded 75% crop grain more than after natural fallow. *A. gayanus* is also used as an indicator of good soil fertility by rural people (Saïdou, 2006; Somé et al., 2006) and shows good potential for the rehabilitation of degraded pastures in many tropical areas, without weed control or fertilisation (Mitja et al., 1998; Mullen et al., 2005; Bilgo et al., 2007). When incorporated into the rotation, Buldgen et al. (1997) observed that, beside a positive influence on fertility, *A. gayanus* also decreased soil erosion. These findings were confirmed by Somé et al. (2006; 2007) who recorded a significant effect of a 3-year *A. gayanus* ley pasture on soil carbon content and yields of subsequent crops.

Legumes. Many experiences were conducted with legumes to improve soil fertility. Cereal crops in rotation with herbaceous legumes yield higher net returns than those gained from cereal-production practices based on commercial fertilizers (Mohamed-Saleem, 1986; Tarawali et al., 1995; Muhr, 1998; Muhr et al., 2002). *A. histrix* is recognized as improving fallow systems in West Africa (Becker et al., 1998). Some of its accessions also act as a trap crop for the parasitic plant *Striga hermonthica* Benth. (Weber et al., 1995).

Many authors (Mohamed-Saleem, 1986; Bayer et al., 1989; Becker et al., 1998) showed also that *Stylosanthes* fallows improve yields of subsequent cereal crops between 50 and 100%, due sometimes to more than 100 kg·ha^{-1} N fixed annually (Vallis et al., 1984; Sanginga et al., 1996). Three years *S. hamata* fallow in Nigeria produced a total N accumulation of 91 kg N·ha^{-1} with 60-70% being derived from N fixation (Tarawali et al., 1995; Becker et al., 1998). Other legumes such as *C. pubescens*, *M. pruriens* and *M. atropurpureum* have been successfully tested in Sub-Saharan Africa with a valuable contribution as forage legume to soil structural stability, microbial activity and fertility (Sanginga et al., 1996).

For tree legumes, a significant increase in soil cation capacity exchange (ranging from 6 to 12 cmol^{+}·kg^{-1} dry soil) has been reported (Gichuru et al., 1989). *C. cajan* and *L. leucocephala* are excellent green manure for improving soil structure and quality and *C. cajan* has a useful fertiliser value, greater than natural regeneration or bush fallow (Dennison, 1959). One year of *C. cajan* growth increased the maize yield by a similar amount compared to high level of fertilisers (125 kg N, 30 kg P and 30 kg K·ha^{-1}) (Shehu et al., 1997). Grain yields can be doubled after 2-3 years of *L. leucocephala* ley pastures (Mullen et al., 2005; Piggin et al., 2005).

3.4. Other characteristics to fit in the agricultural systems

Grasses. In the Borgou region, all grass species presented in **table 1** could be established by seed with sowing rates varying between 3 and 10 kg·ha^{-1} depending on seed quality and purpose of the pasture. Sowing must take place at the beginning of the rainy season and seed should be sown in hole at no more than 1-2 cm deep or broadcast on a well prepared seedbed and lightly covered (Cook et al., 2005). Except for *A. gayanus*, the grasses can also be established successfully by rooted tillers, particularly *P. maximum* species, with high success. Sowing density for selected grasses can be 50 cm to 60 cm in and between rows, or as close as 40 cm × 40 cm if a faster cover is required (Bogdan, 1977; Cook et al., 2005). *P. purpureum* can be established from seed although it is generally planted from cuttings about 20-30 cm length at 1 m × 1 m inter- and within-rows spacing.

The selected grasses have different flowering behaviour, but they are all sensitive to short-days. Seed yields depend on accessions and plant management, particularly N and P applications (Noirot et al., 1986; Cook et al., 2005). For *P. maximum* the low germination rates, from 10 to 40%, is however a major limitation (Mandret et al., 1999). *A. gayanus* and *Brachiaria* spp. are high seed producers but their seed dormancy must be overcome through at least 6 months conservation (Grof, 1968; Miles et al., 1996; Cook et al., 2005). These grasses produce however a high soil-seed reserve with good potentiality for natural vegetation improvement.

The selected grasses can also be cut-and-carried or grazed. However, *B. ruziziensis* is less tolerant to frequent cutting compared to *P. maximum*, *A. gayanus* and *P. purpureum* and may therefore not be suited for ley pasture if high productivity is required. Grasses can also be conserved successfully as hay for the dry season (Roberge et al., 1999) excepted for *B. ruziziensis*. Some accessions of *P. maximum* such as ‘ Mombaça ’, ‘ Tanzania ’ and ‘ C1 ’ produce silage of good quality and can withstand heavy grazing. *A. gayanus* resists to fire much more than the other grasses, especially *B. ruziziensis*. After fire, it develops rapidly new tillers or seedlings (Jones, 1979b). Its thick stems are widely used as thatch in rural Africa.

Stylosanthes, *Centrosema*, *Aeschynomene* and *Macroptilium* species have also been grown successfully in association with the selected grasses. Some shade tolerant grasses such as *P. maximum* cv. ‘ C1 ’ can also be mixed with selected ligneous legumes like *C. cajan* or *L. leucocephala* (Bodgan, 1977; Jones, 1979a).

Legumes. Most of legumes are short-day flowering and can be used for grazing or cutting during some months before seed production phase occurs from September to November. Herbaceous legumes can also contribute to soil protection. Early in the growing season, they are generally not palatable and stocking rate should be adjusted to control associated grasses if they appear to be too competitive. *A. histrix*, *S. fruticosa*, *C. pubescens* and *M. pruriens* show high coverage. In a cropping system with maize, *Mucuna* plays also an important role in soil protection against erosion and weed control (*Imperata cylindrica* (L.) Raeusch.) (Sanginga et al., 1996; Buckles et al., 1998). Its weakness lies in the fact that it dies during the dry season. However, it can self-resow each year if exploitation is stopped once the plants start to flower. *A. histrix* is suited to a short-term fallow. It remains in the field throughout the years but is easily removed by ploughing. Conversely, because of its ligneous roots, *L. leucocephala* is not easy to eradicate and requires to be slashed-and-burned. It however allows wood yield of 10-40 t·ha^{-1} DM (Gichuru et al., 1989).

4. CONCLUSION

The integration of forage agricultural systems in savannah regions of West Africa is a means to increase sustainability of animal and crop production, but it involves the adoption of new crops by smallholders. The possibility for forages to be installed during cultural calendar, the household resources, seed availability for pasture establishment and farmer’s perception for each forage are important factors that must be taken into consideration in practice.

Based on this review, when introducing a new forage resource, attention must be paid, especially in the Borgou region, on the dry years, with only 600 to 700 mm annual rainfalls. Under such situations, *P. maximum* cv. ‘ C1 ’, some strains of *A. gayanus* or annual (*S. fructicosa* and *S. hamata*) and ligneous legumes (*L. leucocephala*) seem the most adapted solutions. The low financial capacity of many farmers also limits the possibility to introduce soil-fertility demanding plants such as *P. purpureum* or *B. ruziziensis*.

Finally, considering advantages and disadvantages of the proposed forage species, the climatic change in West Africa, the opinion of the smallholders and the need of soil fertility improvement in extensive agricultural systems, a mixture of well-adapted grass and legume forages will probably lead to an optimal solution.

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