Trees dynamics (1955-2012) and their uses in the Senegal's Ferlo region: insights from a historical vegetation database, local knowledge and field inventories

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Photograph 1.
Tree stand of *Balanites aegyptiaca*, *Acacia senegal* and *Acacia tortilis* at the beginning of the rainy season.
Photograph M. Dendoncker.

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RÉSUMÉ

CONNAISSANCE DE LA DYNAMIQUE DU COUVERT ARBORÉ (1955-2012) ET UTILISATIONS DES ESSENCES DANS LA RÉGION DU FERLO AU SENEGAL : APPORTS D'UNE BASE DE DONNÉES HISTORIQUE, DE CONNAISSANCES LOCALES ET D'INVENTAIRES SUR SITE

Les écosystèmes sahéliens sont soumis à des pressions anthropiques et climatiques croissantes, avec des conséquences durables pour la végétation ligneuse. Les arbres jouent un rôle vital pour la population locale, et leur pérennité doit être assurée. La présente étude vise à caractériser la végétation ligneuse, ses utilisations et sa dynamique sur le long terme (1955-2012) dans la région sablonneuse du Ferlo au Sénégal, dans une zone anthropisée à proximité de deux forages. En 2012, des inventaires ont été réalisés dans 30 placettes, ainsi que des enquêtes auprès d'éleveurs issus de 30 camps sur la dynamique de la végétation et l'utilisation des essences. Une base de données historique a permis d'obtenir des données complémentaires sur l'évolution de la diversité des essences ligneuses depuis 1955. Par ailleurs, une étude de la bibliographie a permis de recenser toutes les utilisations potentielles des essences. Ces données ont été analysées pour en extraire la dynamique des services d'approvisionnement, en calculant des indices d'utilisation pour les essences et des indices de services pour l'écosystème. En 2012, pour un couvert arboré de 3 % et une diversité spécifique de 12 essences différentes, les peuplements étaient dominés par deux essences sahéliennes, *Balanites aegyptiaca* et *Boscia senegalensis*. Le rapport entre arbres jeunes et adultes atteignait 70,5 %, ce qui pouvait indiquer un bon équilibre des essences dans les peuplements, mais 95 % des jeunes plants correspondaient à trois essences seulement, *Balanites aegyptiaca*, *Boscia senegalensis* et *Acacia tortilis*. Concernant la valorisation des différentes essences, les plus couramment utilisées étaient *B. aegyptiaca* et *B. senegalensis*, mais aussi *A. senegal*, une essence rare, *Adansonia digitata* et *Ziziphus mauritiana*. Les données indiquent un déclin de la diversité spécifique et du nombre de jeunes arbres entre 1955 et 2012, accompagné d'une proportion croissante d'essences sahéliennes. Les indices d'utilisation et de service suggèrent une dégradation des services d'approvisionnement, ce qui pourrait indiquer une vulnérabilité croissante de ces écosystèmes.

Mots-clés : services écosystémiques, sylviculture, savoir pastoral local, végétation ligneuse, Sahel, Sénégal.

ABSTRACT

TREE DYNAMICS (1955-2012) AND THEIR USES IN SENEGAL'S FERLO REGION: INSIGHTS FROM A HISTORICAL VEGETATION DATABASE, LOCAL KNOWLEDGE AND FIELD INVENTORIES

Sahelian ecosystems are undergoing increasing anthropogenic and climatic pressures with long-lasting consequences for woody vegetation. As trees play a vital role for the local population, the main challenge is to ensure that they will endure. This study characterizes the woody vegetation, its uses and its long-term dynamics (1955-2012) in Senegal's sandy Ferlo region, in an anthropized zone near two boreholes. In 2012, inventories were made of 30 plots and surveys on vegetation dynamics and uses of tree species were conducted among herders from 30 camps. A historical vegetation database provided further information about the species diversity of the woody vegetation since 1955, and all potential uses of the species were listed through a review of the literature. We then attempted to convert these data in terms of the dynamics of provisioning services, by calculating use indices for the species and service indices for the ecosystem. With 3% tree cover in 2012, made up of 12 different tree species, the tree stands were dominated by two Sahelian species, *Balanites aegyptiaca* and *Boscia senegalensis*. The ratio between saplings and adults was up to 70.5%, which seemed to indicate a good balance among trees in the stands, but 95% of the saplings belonged to the species *Balanites aegyptiaca*, *Boscia senegalensis* and *Acacia tortilis*. Regarding the use value of woody species, the most commonly used were *B. aegyptiaca* and *B. senegalensis*, but also the rare *A. senegal*, *Adansonia digitata* and *Ziziphus mauritiana*. The data showed a decline in species diversity and numbers of saplings from 1955 to 2012 with a shift towards Sahelian species, while the uses and services trends suggest a decline in provisioning services. This could indicate an increase in the vulnerability of these ecosystems.

Keywords: ecosystem services, forestry, local pastoral knowledge, woody vegetation, Sahel, Senegal.

RESUMEN

CONOCIMIENTO DE LA DINÁMICA DE LA COBERTURA ARBÓREA (1955-2012) Y DEL USO DE ESPECIES EN LA REGIÓN SENEGALESA DE FERLO: APORTES DE UNA BASE DE DATOS HISTÓRICA, DE CONOCIMIENTOS LOCALES E INVENTARIOS DE CAMPO

Los ecosistemas del Sahel están sometidos a crecientes presiones antrópicas y climáticas con impactos duraderos para la vegetación leñosa. Los árboles desempeñan un papel vital para la población local y se debe garantizar su perdurabilidad. Este estudio tiene como objetivo caracterizar la vegetación leñosa, sus usos y dinámica a largo plazo (1955-2012) en la región arenosa de Ferlo en Senegal, en un área antropizada cerca de dos pozos de perforación. En 2012, se hicieron inventarios en 30 parcelas y encuestas a pastores de 30 campamentos sobre la dinámica de la vegetación y el uso de las especies. Mediante una base de datos histórica se obtuvieron datos complementarios sobre la evolución de la diversidad de las especies leñosas desde 1955. Por otra parte, gracias al estudio de la bibliografía se pudieron identificar todos los usos potenciales de las especies. El siguiente paso consistió en analizar dichos datos para caracterizar la dinámica de los servicios de aprovisionamiento, calculando los índices de uso de las especies y los índices de servicios para el ecosistema. En 2012, con una cobertura arbórea del 3% compuesta por 12 especies diferentes, las masas estaban dominadas por dos especies del Sahel, *Balanites aegyptiaca* y *Boscia senegalensis*. La relación entre árboles jóvenes y adultos alcanzaba el 70,5%, lo que parecía indicar un buen equilibrio de las especies en las masas, pero el 95% de los árboles jóvenes pertenecía sólo a tres especies, *Balanites aegyptiaca*, *Boscia senegalensis* y *Acacia tortilis*. En cuanto al valor de uso de las distintas especies, las más utilizadas eran *B. aegyptiaca* y *B. senegalensis*, pero también *A. senegal*, una especie rara, *Adansonia digitata* y *Ziziphus mauritiana*. Los datos muestran una disminución de la diversidad específica y del número de árboles jóvenes entre 1955 y 2012, con una proporción creciente de especies del Sahel. Los índices de uso y servicio sugieren una degradación de los servicios de aprovisionamiento, lo que podría indicar un incremento de la vulnerabilidad de estos ecosistemas.

Palabras clave: servicios ecosistémicos, silvicultura, conocimiento pastoral local, vegetación leñosa, Sahel, Senegal.

Introduction

Research on Sahelian semi-arid ecosystem ecology, dynamics and productivity has been carried out intensively, particularly since the drought episodes of 1972-1973 and 1983-1984 (Nicholson *et al.*, 1998; Vetter, 2005). Even though high spatial and interannual variability of rainfall is characteristic in those regions, these extreme droughts, together with an increasing anthropogenic pressure, have had some long lasting consequences on these ecosystems, raising the issue of desertification (Nicholson *et al.*, 1998). Even if there has been some debate about the causes of this degradation (Breman and de Wit, 1983; Westoby *et al.*, 1989), it is now recognized that degradation and land use changes result from a multitude of feedback mechanisms involving various socio-economic and bio-physical components (Briske *et al.*, 2003; Rasmussen *et al.*, 2012). These ecosystems are now viewed by scientists as complex landscapes, constantly transformed by human actions (besides climate influence), in which the pastoralists, accustomed to changes, show great flexibility and absorptive capacity (Batterbury and Warren, 2001).

Today, the major challenge is to ensure the long term productivity of these ecosystems. Indeed, as a major part of the Sahelian population relies on livestock husbandry to live, vegetation plays a great role in this area. Woody species, for example, are highly valuable as they are used by local population for food, forage, medicine and firewood. In the Ferlo, the Sahelian zone in Senegal, woody vegetation is crucial during the dry season to supply food for livestock when the herbaceous layer becomes scarce. These benefits that pastoralists obtain from ecosystems are called ecosystem services (MEA, 2005) and they are often classified in four categories: provisioning services, regulating services, cultural services and supporting services.

As productivity relies on vegetation, its characteristics were studied by focusing either on the herbaceous layer (Valenza and Diallo, 1972; Cornet and Poupon, 1977) and/or on the woody vegetation, which is a more robust indicator for long term trends (Poupon and Bille, 1974; Gonzalez, 2001; Wezel and Lykke, 2006; Hiernaux *et al.*, 2009; Vincke *et al.*, 2010). During the past few years, some studies have demonstrated a decreasing trend in woody species (Wezel and Lykke, 2006; Gonzalez *et al.*, 2012). Gonzalez *et al.* (2012) noticed a diminution in woody plant density across Senegal and a decrease in the specific richness across all the Sahel. In Fété-Olé (Senegal), a site relatively preserved from human pressure, Vincke *et al.* (2010) observed a 82.4% mortality rate for *Acacia senegal* (L.) Willd. from 1976 to 1995. In addition to these changes in structure, a southward

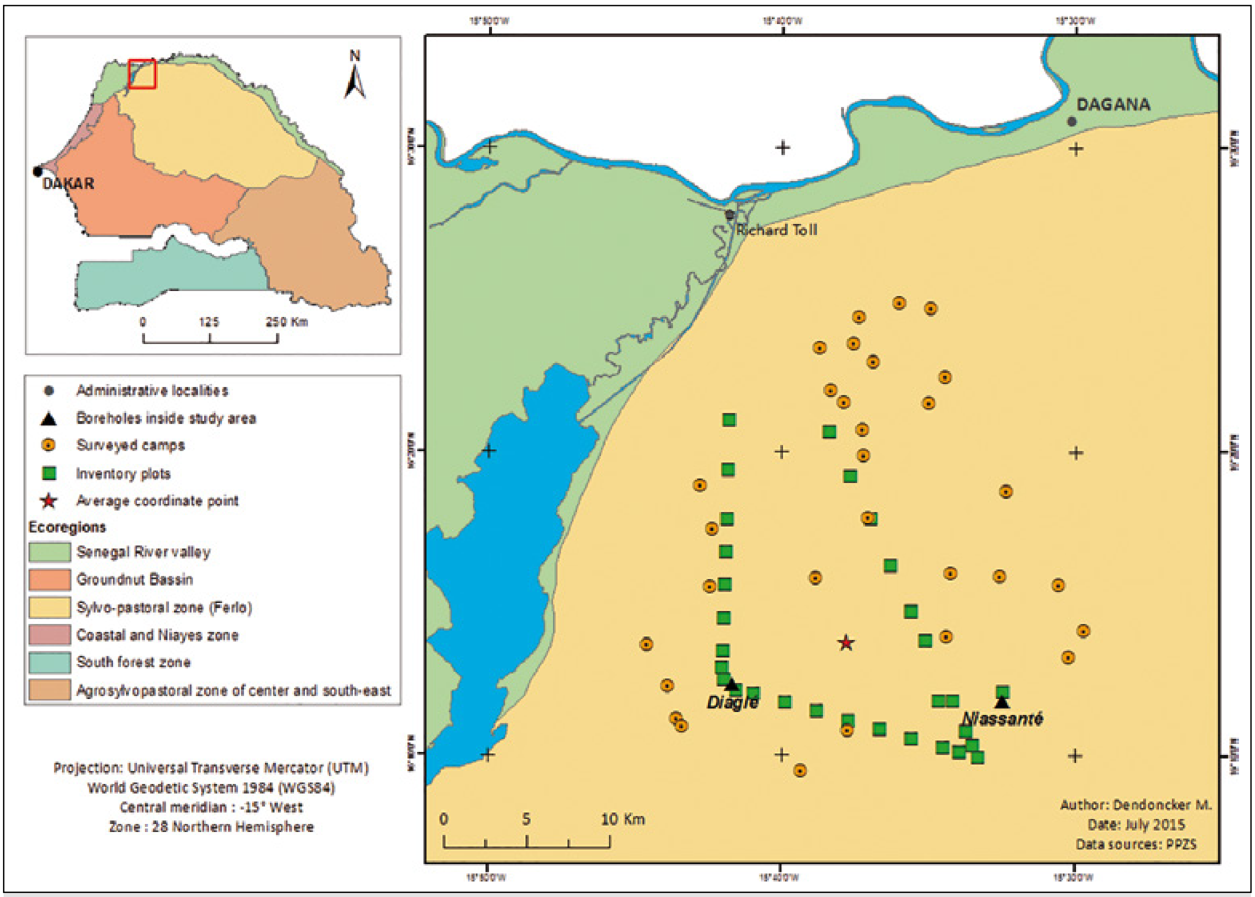

Figure 1.
Location of the study area in the ecoregion of Ferlo in Senegal (author: M. Dendoncker; data sources: PPZS).

shift in vegetation zones was found by Gonzalez (2001) and Herrmann and Tappan (2013) pointed out a shift towards more xeric species composition in several sites of central Senegal. However, some reservations were expressed by Hiernaux *et al.* (2009) as they noted some diversification in the flora in the mid-1990s in Gourma (Mali), that could indicate the resilience of Sahel vegetation to human pressure and climatic variability in some cases. Nevertheless, the vulnerability of these ecosystems still needs to be documented with regards to their role in the primary subsistence sectors.

In northern Ferlo, an industrial dairy, the "Laiterie du Berger" was established in 2006 in the city of Richard Toll (figure 1) with the aim of collecting the daily milk production from the local pastoralists, transforming it and ensuring its commercialization in several cities throughout the country, this way boosting local capacity and supporting pastoralists' welfare. During the dry season, the dairy sells food for the animals at a stable and competitive price. As a consequence, some pastoralists choose to stay in the collection area during the whole year. This intensification raised questions about the positive and/or negative consequences that it could imply regarding the woody vegetation, and in a broader view, in terms of long-term sustainability.

The aims of the present study are i) to characterize the current state and uses of the woody vegetation in terms of provisioning services in the collection area of the dairy, ii) to describe the long term trend in species diversity within this zone and iii) to attempt to convert these information in terms of provisioning services evolution. The first objective was achieved by associating data from field inventories carried in 2012 with local knowledge from pastoralists. The second objective, the study of temporal dynamics of tree stands in the same zone since 1955, was addressed through a historical metadata base.

Materials and methods

Study area

The Sahel is a biogeographic zone of Africa whose limits are determined by annual rainfall (Le Houerou, 1989; Hiernaux and Le Houerou, 2006). Its northern and southern boundaries match the isohyets of 200 and 600 mm of annual rainfall respectively.

The tropical arid to semi-arid climate is characterized by a long dry season from November to June, followed by a rainy season from July to October. The high spatio-temporal variability of rainfall makes the drought a substantial climatic risk in the Sahel. The latest drought episode, known as the great drought, began in the early 1970s. Affecting all Sahelian countries, it lasted until 1984 (figure 2). From 1985 to 2010, a slight recovery in regards to the great drought has been noted (Nicholson, 2013).

In Senegal, the Sahelian domain covers approximately the Ferlo ecoregion, also called the sylvo-pastoral zone as the population often relies on livestock for living. The sylvo-pastoral zone is formed by two morphopedological subsets: the Sandy Ferlo and the Ferruginous Ferlo (Diop, 1989a).

The present study was carried out in the north of the Sandy Ferlo, 30 km south of the Senegal River and the city of Richard Toll, in the collection area of the "Laiterie du Berger" (figure 1). This zone was one of the study sites of the MOUVE project[1], which was launched in 2010 for a duration of four years. The predominant soils encountered in the study area are Ferric Luvisols and Cambic and Luvic Arenosols (Le Houerou, 1989; Tappan *et al.*, 2004).

[1] "The interactions Livestock – Local Development and the dynamics of the ecological intensification". https://www1.clermont.inra.fr/mouve/

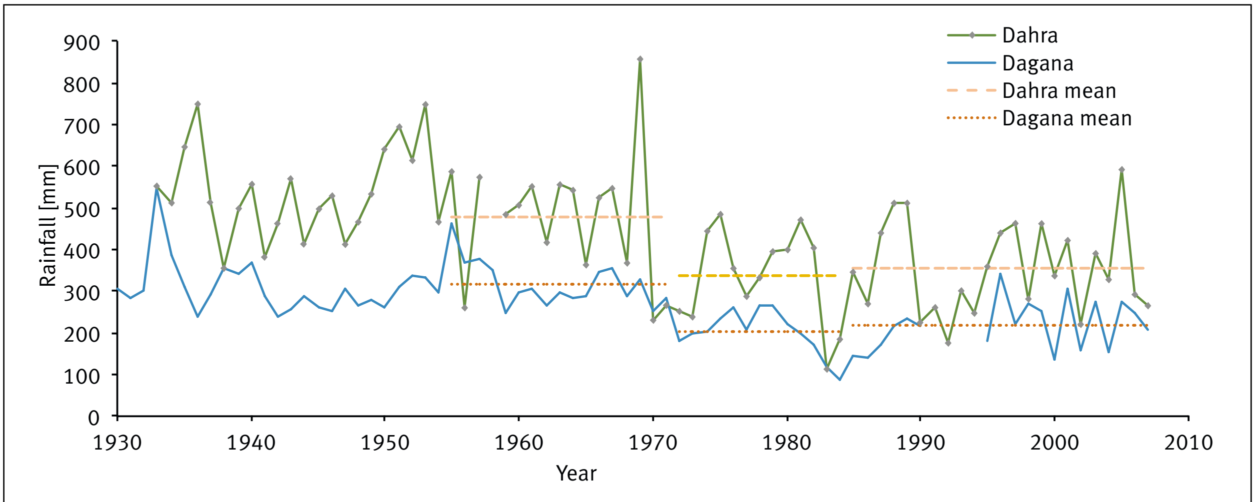

Figure 2.
Annual rainfall in Dagana (16° 31'N, 15° 30'W) and Dahra (15° 20'N, 15° 28'W), from the ANAMS (Agence Nationale de la Météorologie du Sénégal). The horizontal lines represent the mean for the climatic series of 1955-1971, 1972-1984 and 1985-2007.

Superficial water resources include: the Senegal River to the north, the Lac de Guiers to the west and the many temporary ponds formed in the Ferlo by the accumulation of rainfall in small depressions. These ponds are extremely important in the Sandy Ferlo as they supply water during the first months of the dry season. The Maastrichtian aquifer provides water to more than 70 boreholes, most of them dug in the 1950s (Le Houerou, 1989). The study area includes two of them (figure 1): Diaglé (16.21°N, 15.69°W) and Niassanté (16.20°N, 15.54°W).

The Ferlo region is inhabited by the nomadic pastoralists Fulani with livestock raising as their main activity. The Fulani used to practice transhumance and move with their herds over the year to find grazing pastures and water. The permanent access to water offered by the drilling of boreholes has had multiple consequences. The transhumance towards the Senegal River decreased with the Fulani settling permanently around boreholes, the pressures on vegetation increased and the number of animals rose considerably between 1950 and 1980 (Touré, 1990; Ndiaye, 2003; Cesaro *et al.*, 2010).

Photograph 2.
Tree stand of *Balanites aegyptiaca*, *Boscia senegalensis* and *Acacia tortilis* in the background near a temporary pond at the beginning of the rainy season.
Photograph M. Dendoncker.

The vegetation of the Ferlo can be described as savannas or tree and shrub (pseudo)-steppe (Tappan, 1986). In the study area, the tree layer is dominated by *Balanites aegyptiaca* (L.) Del., *Acacia tortilis* subsp. *raddiana* (Savi) Brenan and a few *Adansonia digitata* L. whereas *Acacia senegal* (L.) Willd., *Boscia senegalensis* (Pers.) Lam. ex Poir., *Commiphora africana* (A. Rich.) Engl., and *Ziziphus mauritiana* Lam. are present in the shrub layer.

Acacia seyal Del., *Guiera senegalensis* J. F. Gmel., *Grewia bicolor* Juss., *Acacia nilotica* (L.) Willd. ex Del. and *Sclerocarya birrea* (A. Rich.) Hochst. can be found in the interdunal depressions (Tappan, 1986).

The herbaceous layer is mainly composed of grass species such as *Cenchrus biflorus* Roxburgh, *Chloris prieurii* Kunth., *Dactyloctenium aegyptium* (L.) Beauv., *Eragrostis tremula* (Lam.) Steud. and *Schoenefeldia gracilis* Kunth. and other herbaceous species such as *Alysicarpus ovalifolius* (Schumach.) J. Léonard., *Tribulus terrestris* L. and *Polycarpaea linearifolia* (DC.) DC. (Valenza and Diallo, 1972).

The inventoried plots as well as the surveyed camps were established between two axes of collection of the dairy, near the boreholes of Niassanté and Diaglé (figure 1).

Data collection and analysis

To characterize the woody vegetation and its uses in 2012 along with their temporal dynamics since 1955, we used a diversified set of data sources, including i) field inventories, ii) local pastoralists' knowledge and iii) large data sets on previous field inventories in this region (the Flotrop database; Daget and Gaston, 1999). This database gathers information about vegetation studies (concerning woody or herbaceous layers) carried out in northern tropical Africa for the past sixty years.

Ecological approach: inventory of woody vegetation

The current structure and composition of Sahelian woody vegetation was determined within the collection area of the Laiterie du Berger. Thirty square plots of 0.25 hectares each were established along 3 axes connecting the boreholes, Niassanté and Diaglé, with the city of Richard Toll (figure 1). As the axes are the shortest ways from the boreholes to the city, woody vegetation on the immediate surroundings undergoes more anthropogenic constraints than the rest of the study area. No relief element stratification was applied as the axes were chosen to study the influence of the distance to the city and boreholes on woody vegetation.

Characterization of woody population

In each plot, every shrub and tree were recorded and identified following the nomenclature of Arbonnier (2009). For all trees and shrubs, we measured the height with a Blume Leiss for trees and with a tape measure for shrubs; the circumference at a height of 30 cm or at ground level for the multi-stemmed individuals; and the diameter of the crown in two perpendicular directions. The saplings (circumference < 10 cm) and the dead trees were also counted. The regeneration rate is expressed as the ratio between the number of saplings and the total number of individuals inventoried (number of saplings and number of adults).

Circumferences were gathered in classes of 10 cm range to visualize the woody vegetation structure. Damage observed on adult trees was recorded and classified in four types: cutting and pruning; livestock damage; fire; and termites.

The following parameters were calculated for each species, and for the entire stand: the density (N/ha), the crown cover of a tree or a bush (C_i, m²/ha; Equation 1), the canopy or woody cover (C, m²/ha; Equation 2) and the basal area (G, m²/ha).

Table I.
The Importance Value Index (IVI), its components and their formulas.

IVI and its components	Formulas	
Importance Value Index IVI	$IVI = F_r + D_r + Dom_r$ [-] (3)	
Relative frequency F_r	$F_r = \frac{F_i}{\sum F_i} \times 100$ [%] (4)	Ratio between the frequency of the species F_i and the sum of the frequencies of all species in all plots $\sum F_i$
Relative density D_R	$D_r = \frac{N_i}{N} \times 100$ [%] (5)	Ratio between the number of individuals of a species N_i and the total number of individuals N
Relative dominance Dom_r	$Dom_r = \frac{G_i}{G} \times 100$ [%] (6)	Ratio between the total basal area of a species G_i and the total basal area of all species G

$$C_i = \left(\frac{\bar{d}}{2}\right)^2 \times \pi \text{ [m²] (Equation 1)}$$

$$C = \frac{\sum_i C_i}{Surface} \text{ [m²/ha] (Equation 2)}$$

With d: average diameter of the crown (mean of the two measured diameters).

To highlight the ecological importance of a species, the Importance Value Index (IVI, Equation 3 in table I; Curtis and McIntosh, 1951) was calculated for a given species, the IVI equals the arithmetical average of the species relative frequency (Equation 4 in table I), the relative density (Equation 5 in table I) and the relative dominance (Equation 6 in table I). The IVI ranges from 0 (absence of dominance) to 100% (mono-dominance; Ngom, 2008).

The frequency of a species is defined according to Roberts-Pichette and Gillespie (1999) as the ratio between the number of plots in which the species is encountered and the sum of the plots (30 in the present study).

Dynamics of tree stands

To study the woody vegetation dynamics since 1955, the Flotrop database (Daget and Gaston, 1999) was consulted. The studies located in a radius of 40 km around the study area centre were selected, with the exception of the Senegal River and the Lake Guiers surrounding areas. Above this distance, we entered the influence area of other boreholes (Tatki 16° 00' N, 15° 20' W; and Widou Thiengoly, 15° 57' N, 15° 18' W). The plots selected were then split into three groups corresponding to three climatic periods: before, during and after the great drought (1955-1971; 1972-1984; 1985-2012).

For each period, species composition was established by taking account of all the species encountered in the plots during one period and was then compared to the current composition. The numbers of studied plots available for each period (1955-1971; 1972-1984; 1985-2012) are respectively 38, 262 and 104. We have integrated our plots to the third period. As the inventoried plots for one period do not match those for the other two periods, the results will not show any standard deviation. This sort of meta-analysis of a heterogeneous data set allows the establishment of a long term tendency within the zone of interest, which was not achievable by other ways.

Evolution of provisioning services in the study area: sociological approach by survey

The aims of the survey of local population were to collect data concerning the uses of woody species along with the evolution of woody resources and of the provisioning services. We applied a principle of data saturation, which means that we stopped the collection of data once the last questionnaire brought no new information.

A total of 30 persons, all camp leaders, were interviewed in the influence zone of the boreholes (figure 1). The distance between two surveyed camps did not exceed 30 km.

Respondents were requested to cite the species they value in six categories of provisioning services: food, forage, firewood, construction, medicine and veterinary use. However, the distance at which the products were collected remained unknown. Other questions were asked to document the current and the past composition of woody stands inside the collection area of the dairy. Respondents were asked which species composed the current ecosystem and the ecosystem in 1982; whether some species had disappeared and if they knew why.

Table II.
The Use Index, its components and the ecosystem indices.

Indices	Equation
Current Use (for one species)	$U_c = \sum_{uses} (\textit{current uses x rating})$ (7)
Potential Use (for one species)	$U_{pot} = \sum_{uses} (\textit{literature uses x rating})$ (8)
Use Index	$I_u = \frac{U_c}{U_{Pot}}$ (9)
Potential provisioning services of the ecosystem (for different periods)	$S_{potentials} = \sum_{\substack{encountered \\ species}} U_{pot}$ (10)
Current provisioning services of the ecosystem of 2012	$S_{2012} = \sum_{\substack{inventoried \\ species\ (2012)}} U_c$ (11)

To express the evolution of species uses, a Use index was created (I_u, Equation 9 in table II) based on the comparison of species use according to the 2012 survey and potential use according to literature. Such an index is related to the Relative Cultural Importance (RCI) indices used in ethnobotany to attribute a value to a species (Hoffman and Gallaher, 2007).

Basically, the method for the creation of the Use Index consisted in attributing points to each species encountered, based on the number of provisioning services categories in which the species is used and a weighting of these services. The points were given according to two criteria. The first one states that a provisioning services used daily (food, fodder and firewood, according to the surveys) will be given more points than a service used less regularly. The second criterion gives more points to the services for which there is less or no alternative, which explains why food and fodder services gain more points. As it was mentioned during the interviews that finding an alternative to fodder during the dry season was more difficult than finding an alternative for food, the weighting of the fodder is higher compared to food. We then obtained the following rating scale: 10 points for the fodder, 8 points for the food, 6 points for the firewood, 4 points for the construction wood, medicine and veterinary use. The indicator created express a species potential based on the number of provided services, without taking account of the abundance of the species (because we didn't have the data except for 2012) or the herders' preferences for a species inside a particular service.

For each species, the next step was then to calculate a *current use* (U_c; Equation 7 in table II) corresponding to the list of uses in which the species was valued (food, fodder etc.) according to the interview conducted in 2012, multiplied by their respective rating. A *potential use* (U_{pot}; Equation 8 in table II) was also calculated by multiplying the rating by uses of the species according to a literature review on "woody species uses in West Africa" (appendix A). We assumed that literature would reflect all potential uses of a species, as if these uses where the ones of an "ideal" ecosystem where the structural and diversity features are such that they give the user the possibility of picking up the best species for a particular use.

In addition, to evaluate the capacity of the current and past ecosystem to provide such services, we created two other indices on the ecosystem scale ($S_{potentials}$ and $S_{current}$; Equation 10 and 11 in table II). For each period selected for the analysis of the Flotrop database, (1955-1971; 1972-1983; 1984-2012) and for 2012, the potential of the studied zone to provide the selected services was calculated by adding up the potential use of the species present during the period. The species list for the three periods came from the Flotrop database and those for 2012 from the field inventory.

The capacity of the current ecosystem (S_{2012}) to provide services in 2012 was obtained by adding up the current uses (from interviews) of the species inventoried in the field. The change in the provisioning capacity of the ecosystem was emphasized by the comparison of the two indices.

The indices $S_{potential}$ for the three periods are hypothetical, as they are based on the specific composition of each period and on the potential uses identified by a literature review. With this method, we attempted to express the dynamics of woody species diversity in terms of the evolution of ecosystem services.

Results and discussion

Characterization of woody population in 2012 inside the collection area of the "Laiterie du Berger"

The structural characteristics of the woody plant population are shown in table II along with the encountered species. Overall, 12 species belonging to 10 genera and 7 families were inventoried in the plots. Most of them are Sahelian species, four are Sudanian and one, *Prosopis juliflora* (Sw.) DC. is a pantropical species, frequently planted in the neighbourhood of villages. The mean density of adults was 47.2 trees/ha with a mean basal area of 1.6 m²/ha and a canopy cover of 3%. Saplings were found at a density of 33.2 individuals/ha or 224 stems/ha. The average height of the four most abundant species was calculated: *Boscia senegalensis* (1.6 m; CI of 95% = 0.1), *Balanites aegyptiaca* (4.6 m; CI = 0.5), *Leptadenia pyrotechnica* (Forssk.) Decne. (2.2 m ; CI = 0.6 m), *Acacia tortilis* (3.1 m; CI = 3.1).

Woody vegetation is largely dominated by two species, the shrub *Boscia senegalensis* and the tree *Balanites aegyptiaca*, with an Importance Value Index (IVI) of 40.21 and 31.16% respectively. We must stress that the IVI of *Adansonia digitata* L. is not representative of its abundance. Indeed, only one individual was inventoried with a circumference above 6 m which explain the relatively high value of its index. With an IVI of 4.42 and 3.08%, *Leptadenia pyrotechnica* and *Acacia tortilis* were the next most encountered species (*Adansonia digitata* not taken into account for the reason cited above).

The results probably reflect a very anthropised ecosystem as the inventory plots were located on axes between the two boreholes and the city of Richard Toll (see Materials and methods).

Amongst these four abundant species, only *Leptadenia pyrotechnica* was not reported by the respondents of the survey as an abundant species in the study area. This discrepancy could be explained by its herbaceous appearance and its low woody biomass. *Maerua crassifolia* Forssk. and *Salvadora persica* L. were reported as abundant species by respondents but the IVI results do not reflect this assumption. This can be caused by a bias in the results due to the unknown maximum distance at which the interviewed herdsmen collect their wood products. Therefore, some species that were still abundant in some specific sites of the study area but not necessarily widespread across it could have been cited by respondents as abundant in the entire area.

The structure of the stand, considering all species (figure 3), was quite balanced as the ratio between saplings and adults was up to 70.5% and the regeneration rate up to 41.3%. The regeneration ability of trees can be used as an ecological indicator to assess the degradation of semi-arid systems (Retzer, 2006 in Vincke *et al.*, 2010). 95 % of the saplings belonged to *Acacia tortilis*, *Boscia senegalensis* and *Balanites aegyptiaca*.

The population above the circumference class of 50 cm was essentially composed of *Balanites aegyptiaca* and *Boscia senegalensis*. The others species were scarce. The linear regression showed that the adults and the saplings are not necessarily found on the same plots (the coefficients of determination R^2 did not exceed 0.4) and therefore woody cover appears not to impact the distribution of the saplings.

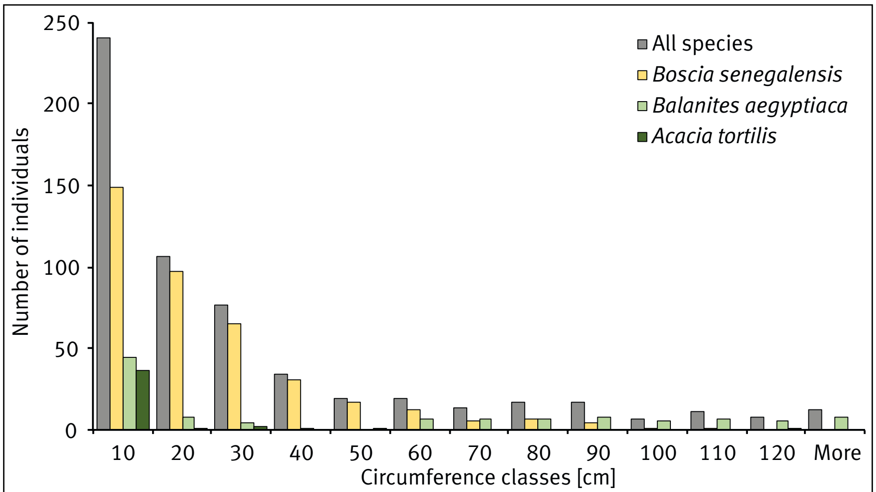

Figure 3.
Woody vegetation structure for all species and population structure of *Boscia senegalensis*, *Balanites aegyptiaca* and *Acacia tortilis* subsp. *raddiana* (Savi) Brenan. The class [0 - 10 cm] represents the saplings.

This could be explained by the high number of *Boscia senegalensis*, which, by its growth form does not offer much cover for the saplings.

Amongst the 583 inventoried trees (saplings and adults), we counted 189 trees that were affected by one or several types of damage (i.e. fire; cutting or pruning; livestock damage; termites). The most frequent was cutting and pruning (37% of the damage) followed by livestock damage (33%). These two types are due to human activity, in contrast to the damage caused by termites (28%). Only 2% of the damage was due to fire.

As the plots were located at increasing distances from boreholes, they were gathered in distance classes according to the nearest distance between the plots and the boreholes or the city of Richard Toll. A one-way Anova was carried out to ensure that no distance classes show statistically significant differences with each other, considering average basal area, canopy cover, and density of adults and saplings. The results (not shown) produced no evidence of any distance effect on woody vegetation. This is probably due to the numerous locally dispersed camps that could blurr the distance effect.

The dominance of *Balanites aegyptiaca*, *Boscia senegalensis* and *Leptadenia pyrotechnica* in the woody population, along with the high regeneration of *Acacia tortilis* could be explained by the climatic conditions of the study area (for vegetation zone, see table III). These dominant species are known to be resistant to extreme climatic conditions and to have strong regeneration ability. Indeed, Poupon (1980; cited in Diop, 1989b) points out that *Boscia senegalensis* and *Balanites aegyptiaca* are very resistant to drought because they are highly sclerophyllous and that would enhance their development. In addition, *Balanites aegyptiaca* would stand against bushfires (Stancioff *et al.*, 1986). After the 1983-1984 drought, Hiernaux *et al.* (2009) observed in several sites in the Sahelian zone of Mali, a strong development of *Leptadenia pyrotechnica*, a Saharo-Sahelian species, on sandy soils and a high density of *Acacia tortilis* saplings. According to the edaphic chart of dominant species in the North Sahel from Hiernaux and Le Houerou (2006), the current composition indicates that the study area soils are disturbed (e.g. high trampling, roads sites).

The species richness of the study area (12 species) appears to be quite poor compared with some other sites in the North Ferlo. Diouf (2011) has studied the woody vegetation around Tatki borehole and has inventoried 18 species, also noticing the dominance of the shrub *Boscia senegalensis*. In our case a stratified sampling, with relief elements as factor, would have given a more complete picture of the woody vegetation. Indeed, the microrelief impacts greatly woody vegetation distribution, in some cases, more than the anthropogenic constraint (Bondé *et al.*, 2013).

A posteriori classification of the plots has been made regarding the micro-topographic position based on field notes and satellite imagery (Bing map aerial, (c) 2010 Microsoft Corporation and its data suppliers). Seven plots are located in depression and we noticed that all the individuals of *Salvadora persica*, *Maerua crassifolia* and *Acacia senegal* have been inventoried in those plots.

Table III.
Structural characteristics of the woody plant population and list of the species surveyed in the 30 plots in 2012 (G, basal area; C, canopy cover; D, density), their botanical family and vegetation zone (after Aubréville, 1950 and Trochain, 1940), the Importance Value Index (IVI). The column "survey" highlights the species which were reported by respondents as an abundant species in the study area in 2012.

Structural characteristics of the woody plant population	
G ($m^2.ha^{-1}$)	1.6
C ($m^2.ha^{-1}$)	331.4
Density ($N.ha^{-1}$)	
Adult trees (D)	47.2
Saplings (D_{sap})	33.2
Dead trees	2.2

Species	Family	Vegetation zone+	IVI [%]	Survey
Acacia tortilis subsp. *raddiana* (Savi) Brenan	Mimosaceae	Sahel	3.08	+
Acacia senegal (L.) Willd.	Mimosaceae	Sahel	0.80	
Adansonia digitata L.	Bombacaceae	Sudan	9.03	+
Balanites aegyptiaca (L.) Del.	Balanitaceae	Sahel	31.16	+
Boscia senegalensis (Pers.) Lam. Ex Poir.	Capparidaceae	Sahel	40.21	+
Combretum glutinosum Perr. Ex DC.	Combretaceae	Sudan	2.72	
Faidherbia albida (Del.) A. Chev.	Mimosaceae	Sudan	2.14	
Leptadenia hastata (Pers.) Decne.	Asclepiadaceae	Sudan	0.67	
Leptadenia pyrotechnica (Forssk.) Decne.	Asclepiadaceae	Sahel	4.42	
Maerua crassifolia Forssk.	Capparidaceae	Sahel	0.83	+
Prosopis juliflora (Sw.) DC.	Mimosaceae	(exotic)	2.20	
Salvadora persica L.	Salvadoraceae	Sahel	2.73	

+ According to *Aubréville* (1950) and *Trochain* (1940) cited in Gonzalez, 2001.

Even though saplings density may vary between years, based on literature and our observations, it seems that saplings have decreased in this part of Ferlo. In Fété-Olé (16° 14' N, 15° 06' W; East to Niassanté) Cornet and Poupon (1977) counted 709 stems of saplings/ha and in 1995; on the same site, Vincke *et al.* (2010) found a sapling density of 156 individuals/ha. In 1990, Lawesson observed in Diaglé, that the number of adults was three time less than the saplings (with a circumference threshold below ours). As a reminder, in 2012, the number of adults is 1.5 time higher than the saplings.

Trends in the evolution of woody vegetation from 1955 to 2012

Figure 4 highlights trends and progressive changes in the diversity of the ecosystem during the last 60 years. From 1955 up to the great drought, 30 species were encountered in the inventories. During the great drought and after it, this number fell from 30 to 24.

During the same time span, we observed a shift to more xeric species in the study area (figure 5). The chart shows that the proportion of Sahelian species rose from 43% in 1955 to 58% during the period 1985-2012 whereas the Sudanian species fell from 53% to 42%. As for the Guinean species, they seem to disappear after the great drought. The detailed list of species (and their vegetation zone) encountered during each period is given in table IV.

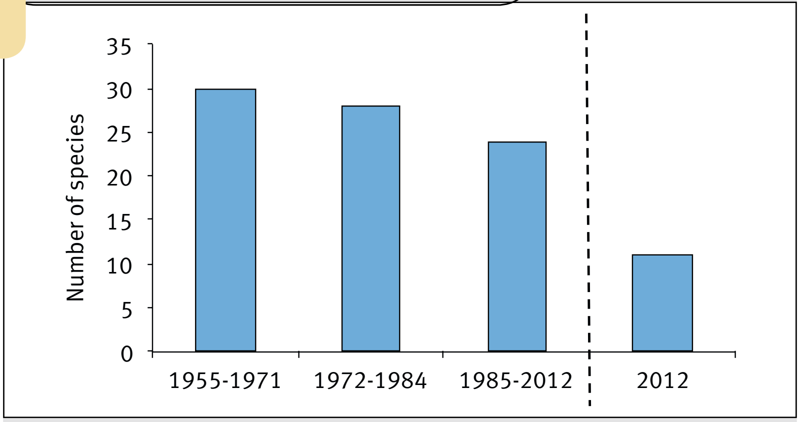

Figure 4.
Evolution of species richness from 1955 to 2012, in a radius of 40 km from the study area central point (calculated after the average coordinates of the 30 plots; see figure 3). The list of species found in the ecosystem for each period is given in table IV.

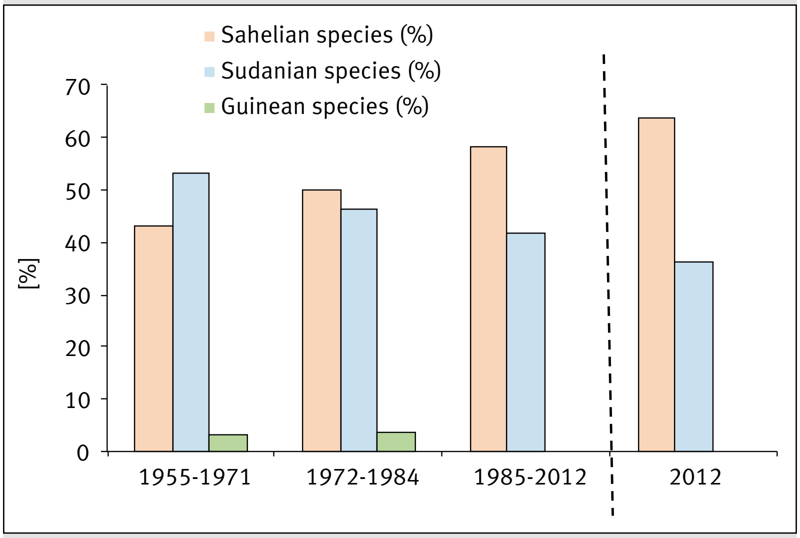

Figure 5.
Evolution of Sahelian, Sudanian and Guinean species from 1955 to 2012 in a radius of 40 km from the study area central point (calculated after the average coordinates of the 30 plots).

These results have to be interpreted with caution, as we are not certain that the data from the Flotrop database covers all relief elements. Hence, although the numerous plots are distributed evenly throughout all the study area, we cannot infer that they are representative of all the variability of the woody vegetation.

The study of the Flotrop database was useful to provide the information concerning the specific composition of woody vegetation during the past 60 years. However, the database does not include some other vegetation features such as basal area, woody cover and saplings which would have been helpful to get a clearer picture of the dynamics. Due to the lack of spatially defined permanent observation plots in the study area, we have compared our results with other works carried out in the northern Ferlo in order to get a global trend of the evolution of these features.

Similar decrease in species richness has been observed in central Senegal by Herrmann and Tappan (2013) who used a combination of inventory, perceptions of population and repeat photography to document changes in woody vegetation. They also reported a shift toward Sahelian species since 1983.

As the Sahelian species tend to become dominant, there is a shift for this kind of species, more resistant to semi-arid conditions. This observation is consistent with climate evolution during the past few decades. Water is becoming scarcer either because of a decrease in average annual rainfall or by the influence of soil-climate interaction. According to Sarr (2009), despite the improvement in the rainfall quantities observed in the Ferlo since the mid-80s, we stay far from the amount of the 50s and early 60s. He also notes an increase in the mean annual temperatures.

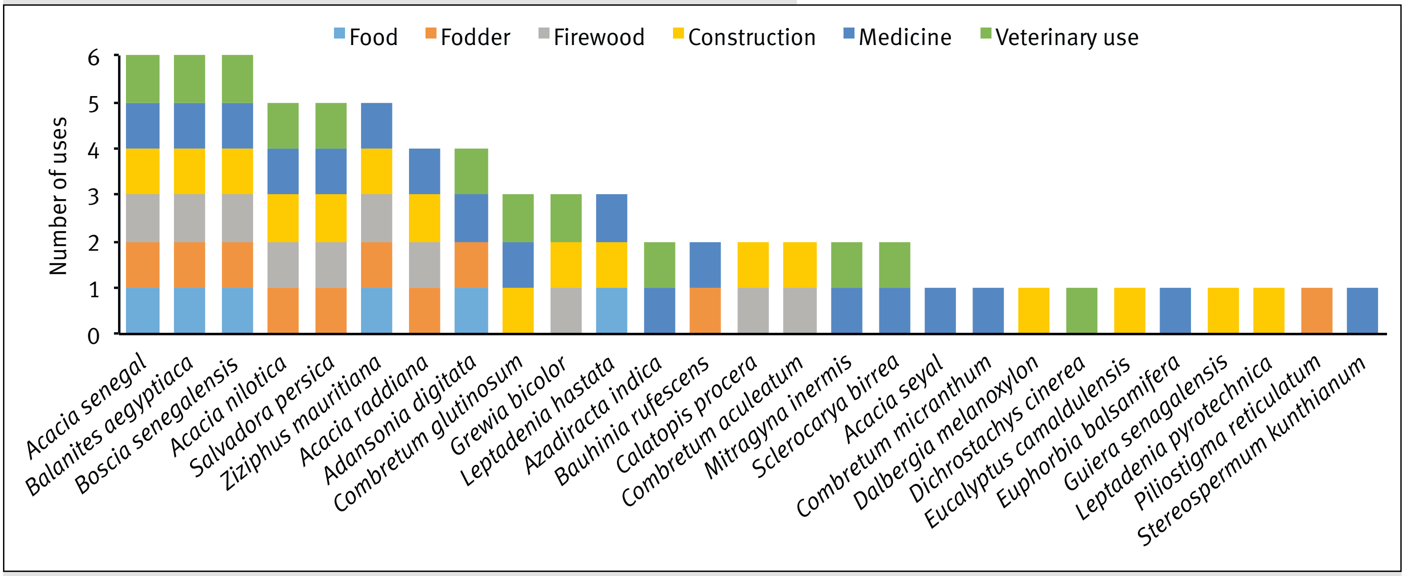

Figure 6.
Number of use categories (provisioning services) being valued per species, with the details on what provisioning services are concerned. The detailed list of species used in the 6 categories is in Appendix A.

Table IV.
Species composition in a radius of 40 km from the study area central point (calculated after the average coordinates of the 30 plots) for the 3 climatic periods and 2012. Note: *Prosopis juliflora* was not taken into account as it is an exotic, planted species.

Species	Vegetation zone	Period 1 1955-1971	Period 2 1972-1984	Period 3 1985-2012	2012
Acacia erythrocalyx Brenan	Sudan	+			
Acacia nilotica (L.) Willd. ex Del.	Sahel	+	+	+	
Acacia senegal (L.) Willd.	Sahel	+	+	+	+
Acacia seyal Del.	Sahel	+	+		
Acacia tortilis subsp. *raddiana* (Savi) Brenan	Sahel		+	+	+
Adansonia digitata L.	Sudan	+	+		+
Adenium obesum (Forssk.) Roem. et Schult.	Sudan	+	+		
Anogeissus leiocarpa (DC.) Guill. et Perr.	Guinea	+			
Balanites aegyptiaca (L.) Del.	Sahel	+	+	+	+
Bauhinia rufescens Lam.	Sudan	+	+	+	
Borassus aethiopum Mart.	Sudan	+			
Boscia senegalensis (Pers.) Lam. ex Poir.	Sahel	+	+	+	+
Cadaba farinosa Forssk.	Sahel	+			
Calotropis procera (Ait.) Ait. F.	Sahel	+	+	+	
Cissus quadrangularis L.	Sudan			+	
Combretum aculeatum Vent.	Sahel	+	+	+	
Combretum adenogonium Steud. ex A. Rich.	Sudan		+		
Combretum glutinosum Perr. ex DC.	Sudan	+	+	+	+
Commiphora africana (A. Rich.) Engl.	Sahel	+	+	+	
Crossopteryx febrifuga (Afzel. ex G. Don) Benth.	Sudan	+			
Dalbergia melanoxylon Guill. et Perr.	Sudan	+			
Dichrostachys cinerea (L.) Wight et Arn.	Sudan	+			
Faidherbia albida (Del.) Chev.	Sudan			+	+
Feretia apodanthera Del.	Sudan			+	
Grewia bicolor Juss.	Sahel	+	+	+	
Guiera senegalensis J. F. Gmel.	Sudan	+	+	+	
Lannea acida A. Rich.	Guinea		+		
Leptadenia hastata (Pers.) Decne.	Sudan	+	+	+	+
Leptadenia pyrotechnica (Forssk.) Decne.	Sahel	+	+	+	+
Maerua angolensis DC.	Sudan	+			
Maerua crassifolia Forssk.	Sahel			+	+
Maytenus senegalensis (Lam.) Exell	Sudan		+		
Mitragyna inermis (Willd.) Kuntze	Sudan	+	+	+	
Piliostigma reticulatum (DC.) Hochst.	Sudan	+	+		
Salvadora persica L.	Sahel		+	+	+
Sclerocarya birrea (A. Rich.) Hochst.	Sudan	+	+	+	
Sterculia setigera Del.	Sudan	+	+	+	
Tamarindus indica L.	Sudan		+	+	
Tamarix senegalensis DC.	Sahel	+			
Terminalia avicennioides Guill. et Perr.	Sudan		+		
Ziziphus mauritiana Lam.	Sahel	+	+	+	
Number of species in the ecosystem		**30**	**28**	**24**	**11**
Number of plots		**36**	**265**	**104**	**30**

Table V.
Current use (U_c), Potential Use (U_{pot}) and Use Index (I_u) for some species used in the study area.

Species	U_c	U_{pot}	I_U
Group 1 – $I_U > 100$			
Salvadora persica	28	22	127
Boscia senegalensis	36	32	113
Group 2 – $I_U = 100$			
Acacia tortilis	24	24	100
Acacia senegal	36	36	100
Balanites aegyptiaca	36	36	100
Ziziphus mauritiana	32	32	100
Group 3 – $I_U < 100$			
Adansonia digitata	26	32	81
Acacia nilotica	28	36	78
Leptadenia hastata	16	26	62
Grewia bicolor	14	36	39
Combretum glutinosum	12	36	33

Table VI.
Assessment of the provisioning services of the current ecosystem (2012) compared with the reference ecosystem (period 1955-1971) (Equation 10 and 11).

$S_{potential}$ (ecosystem from 1955-1971 : reference)	886
$S_{potential}$ (ecosystem from 1972-1984)	760
$S_{potential}$ (ecosystem from 1985-2012)	800
$S_{current}$ (ecosystem from 1985-2012)	346
Assessment: $S_{potential}$ for 1955 compared to $S_{potential}$ for 1985-2012	- 9.7 %
Assessment : $S_{potential}$ for 1955 compared to $S_{current}$	- 60.9 %

Whereas the presence of *Balanites aegyptiaca*, *Boscia senegalensis* and *Leptadenia pyrotechnica* is already reported in 1955, *Acacia tortilis* is absent from the inventories of the first period (1955-1971). Valenza and Diallo (1972) did not recognize this species as characteristic in contrast to Tappan (1986) who considered it in his vegetation classification. Hence, we can assume that the population of *Acacia tortilis* has grown in the study area during the past 30 years. The drought, combined with the drilling of the boreholes that allow livestock to spread seeds over large distances (Diop, 1989b), could explain the establishment of this species in the study area.

Use of woody species and provisioning services in the study area

According to the survey, for the six chosen provisioning services (food, fodder, firewood, construction, medicine and veterinary use), 27 species were valued and among them, 17 species were valued in more than one category (figure 6). *Balanites aegyptiaca* and *Ziziphus mauritiana* were the two most cited species for providing of human food (31% and 23% of citations), fodder (35% and 16%) and medicine (19% and 16%). For firewood, *Balanites aegyptiaca* and *Boscia senegalensis* were the most used at 41% and 26%; for the construction *Balanites aegyptiaca* (24%) and *Eucalyptus camaldulensis* (17%), which is bought at market as this species is planted on the riverbank of the Senegal River; for veterinary use, *Acacia senegal* (25%), along with *Acacia tortilis* and *Sclerocarya birrea* (both 15%).

Acacia senegal, *Balanites aegyptiaca* and *Boscia senegalensis* were valued in all six categories of provisioning services, meaning that the most common species (except for the rare *Acacia senegal*), also have the most diversified uses. Amongst the species valued in five categories, *Acacia nilotica* and *Ziziphus mauritiana* were not encountered in the inventoried plots, which indicates that they have low frequencies.

If we consider the Use Index (Equation 9; partial results are shown in table V), we can distinguish groups with growing uses ($I_U > 100$), stable uses ($I_U = 100$) and decreasing uses ($I_U < 100$). As the literature uses should be considered as most complete, a Use Index above 100 could indicate that some uses have become essential because the more suitable alternative have disappeared. Amongst the species with a Use Index equal or above 100 (group 1 and 2), we can distinguish two sorts of species according to their abundance in the ecosystem. The first includes species well represented in the woody population, such as *Balanites aegyptiaca* and *Boscia senegalensis*. The second is constituted by species with very low abundance or not inventoried, such as *Acacia senegal* and *Ziziphus mauritiana*. Herrmann and Tappan (2013) also observed in central Senegal that many species with high livelihood importance are perceived to be decreasing. It shows the pressure that such species undergo and the potential consequences on the livelihood of the population should these species disappear. For the species in group 3, the less diversified use probably results from species decrease (e.g. *Grewia bicolor*) in the study area.

To highlight the evolution of provisioning services provided by woody resources within the study area, we compared ecosystems indices from the different periods (table VI). If we consider the list of species in 1985-2012 with their potential and current uses, the indices $S_{potential\ (1985\text{-}2012)}$ and $S_{current\ (1985\text{-}2012)}$ define a range of values in which the quantity of the services provided during the period 1985-2012 by woody vegetation should stand. $S_{current}$ could be seen as the likely minimum of services provided by the ecosystem given the location of the study area, in a very anthropised zone and the non-stratified sampling. Hence, the 61% loss observed should be the maximal potential loss.

These results are therefore only valid on strong assumptions: the results are valid for the rating scale created under the two criteria cited before; the area of application is limited to the study area; we assume that the survey is representative of the local population; only six provisioning services were covered; woody resources are substitutable. However, one should regard the highlighted decreasing trend as the main result, more than the values themselves. This is also valid for the observed decrease of the specific richness between 1955 and 2012.

Future researches could include the abundances of the species in the ecosystem along with the preferences for some species for provisioning services.

As we applied the saturation principle and did not carry out a representative sampling of the population, the survey results do not, from a strictly statistical point of view, reflect the population of northern Ferlo. Therefore, the conclusions drawn here cannot be extended to a larger zone or only with extreme caution. In addition, only a few ecosystem services have been explored, so the effective value of the woody population in this area is still unknown. However, this method has the advantage of attributing a value, albeit arbitrary, to woody species according to their importance for the livelihood of the local population.

Photograph 3.
An isolated blooming *Acacia senegal* at the beginning of the rainy season.
Photograph M. Dendoncker.

Conclusion

Through this study we attempted to value heterogeneous sources such as historical database, field inventories, bibliographic record of species use categories and herders' knowledge, in order to (i) indicate a long-term tendency in woody vegetation with no distinction between climatic and human causes, and (ii) to present a lumped methodology to evaluate the evolution of some provisioning services.

The analyses of historical inventories have highlighted a decreasing trend in the specific diversity since 1955 that cannot be overlooked along with a shift toward more xeric species. In 2012, tree stands in the anthropized study area were highly dominated by two Sahelian species, *Balanites aegyptiaca* and *Boscia senegalensis* in the adults phase but also in the sapling phase.

With respect to the presented methodology, it appeared that, amongst the 27 species valued by the Fulani, six are intensively used: two are the dominant species cited above, two are present in low abundance (*Acacia tortilis* and *Salvadora persica*) and the last two are very rare (*Acacia senegal* and *Ziziphus mauritiana*).

Given the current composition of woody vegetation in the anthropised zone inventoried, the intensive uses of some rare species and the likely highlighted loss in provisioning services during the last decades, the question of the capacity of the ecosystem to maintain such services may be raised. In case of major changes in specific composition and density, the ability of local rural population to adapt and modify their uptakes will be crucial. The establishment of the "Laiterie du Berger" could induce changes in the surrounding ecosystem (e.g.: by increasing the number of cows that stay in the collect area throughout the year). This requires vigilance and a long term monitoring in this area could be useful given the complexity of the driving forces of change within this region.

To improve the accuracy of the estimation of specific diversity and provisioning services evolution, future researches concerning woody vegetation should be based on a stratified sampling. More research should also be done regarding the links between woody vegetation dynamics and the provided ecosystem services (e.g. by improving the calculation of Use indices).

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Appendix A.
Uses of woody species in 6 categories of provisioning services according to a literature review (first line) and in 2012, according to the survey (second line). The species were either present inside the study area during at least one period, or cited during the interviewed as being used in 2012. The number in brackets indicates the group of Use Index (see table II for formulas and table V for groups) to which the species belongs to.

Species	Food	Fodder	Firewood	Construction	Medicine	Veterinary use
Acacia erythrocalyx Brenan (3)		+	+		+	
Acacia nilotica (L.) Willd. ex Del. (3)	+	+	+	+	+	+
		+	+	+	+	+
Acacia tortilis subsp. *raddiana* (Savi) Brenan (2)		+	+	+	+	
		+	+	+	+	
Acacia senegal (L.) Willd. (2)	+	+	+	+	+	+
	+	+	+	+	+	+
Acacia seyal Del. (3)	+	+	+	+	+	+
					+	
Adansonia digitata L. (3)	+	+	+		+	+
	+	+			+	+
Adenium obesum (Forssk.) Roem. et Schult. (3)					+	
Anogeissus leiocarpa (DC.) Guill. et Perr. (3)	+	+	+	+	+	+
Azadirachta indica A. Juss. (3)	+	+	+	+	+	+
				+	+	
Balanites aegyptiaca (L.) Del. (2)	+	+	+	+	+	+
	+	+	+	+	+	+
Bauhinia rufescens Lam. (3)	+	+	+	+	+	+
		+			+	
Borassus aethiopum Mart. (3)	+	+		+	+	
Boscia senegalensis (Pers.) Lam. ex Poir. (1)	+	+	+		+	+
	+	+	+	+	+	+
Cadaba farinosa Forssk. (3)	+	+			+	
Calotropis procera (Ait.) Ait. F. (3)	+	+	+		+	+
			+	+		
Cissus quadrangularis L. (3)					+	+
Combretum aculeatum Vent. (3)		+			+	
			+	+		
Combretum adenogonium Steud. ex A. Rich. (3)	+	+	+	+	+	
Combretum glutinosum Perr. ex DC. (3)	+	+	+	+	+	+
				+	+	+
Combretum micranthum G. Don (3)	+	+	+	+	+	+
					+	
Commiphora africana (A. Rich.) Engl. (3)	+	+		+	+	+
Crossopteryx febrifuga (Afzel. ex G. Don) Benth. (3)	+		+	+	+	+
Dalbergia melanoxylon Guill. et Perr. (3)		+		+	+	
				+		

Species	Food	Fodder	Firewood	Construction	Medicine	Veterinary use
Dichrostachys cinerea (L.) Wight et Arn. (3)		+	+	+	+	+ +
Eucalyptus camaldulensis Dehnh. (3)		+	+	+ +	+	
Euphorbia balsamifera Ait. (3)		+			+ +	+
Faidherbia albida (Del.) A. Chev. (3)	+	+	+	+	+	
Feretia apodanthera Del. (3)	+	+	+	+	+	
Grewia bicolor Juss. (3)	+	+	+ +	+ +	+	+ +
Guiera senegalensis J. F. Gmel. (3)		+	+	+ +	+	+
Lannea acida A. Rich. (3)	+	+	+	+	+	+
Leptadenia hastata (Pers.) Decne. (3)	+ +	+		+	+ +	+
Leptadenia pyrotechnica (Forssk.) Decne. (3)	+	+	+	+	+	+
Maerua angolensis DC. (3)	+	+			+	+
Maerua crassifolia Forssk. (3)	+	+	+	+	+	
Maytenus senegalensis (Lam.) Exell (3)	+	+	+		+	+
Mitragyna inermis (Willd.) Kuntze (3)		+	+	+	+ +	+ +
Piliostigma reticulatum (DC.) Hochst. (3)	+	+ +	+	+	+	+
Prosopis juliflora (Sw.) DC. (3)	+	+	+	+	+	
Salvadora persica L. (1)	+	+ +	+	+	+ +	+
Sclerocarya birrea (A. Rich.) Hochst. (3)	+	+	+	+	+ +	+ +
Sterculia setigera Del. (3)	+	+	+	+	+	+
Stereospermum kunthianum Cham. (3)	+	+		+	+ +	
Tamarindus indica L. (3)	+	+	+	+	+	+
Tamarix senegalensis DC. (3)				+	+	
Terminalia avicennioides Guill. et Perr. (3)		+	+	+	+	+
Ziziphus mauritiana Lam. (2)	+ +	+ +	+ +	+ +	+ +	

Literature list for the Appendix A
(Arbonnier, 2009; Ayantunde *et al.*, 2009; Becker, 1983; CSE, 2010; Diop *et al.*, 2011; Ganaba *et al.*, 2005; Grouzis and Le Floc'h, 2003; Kuhlman *et al.*, 2010; Lykke *et al.*, 2004; Ngom, 2008; Sagna *et al.*, 2014; Sop *et al.*, 2012; Vassal, 1998).