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Vulnerability assessment of medicinal tree species in Benin (West Africa): *Zanthoxylum zanthoxyloïdes* (Lam.) and *Morinda lucida* Benth

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Abstract Many causes are suspected to explain the decline of medicinal plant species. This study aims to understand the threats on *Zanthoxylum zanthoxyloïdes* and *Morinda lucida* in Benin in order to plan sound conservation strategies. A total of 247 respondents of the Southern and Central Zones of Benin were interviewed based on the uses of each target species, their perceptions about species availability in the natural vegetation and the farming operations (clearing and uprooting) that destroy plant species. In the field, 130 plots were established in various habitats where at least one plant of the two species was found, to assess the abundance of each targeted species. Traditional medicinal uses were recognized by respondents as the most important and preferred use of the target species based on the cultural importance index (1.86–2.50) within each zone. *Zanthoxylum zanthoxyloïdes* and *M. lucida* were both available in Southern Benin but were threatened by farming operations in this zone. The findings indicate that the ecological impacts of medicinal uses of the two tree species are minor compared to the effects of pineapple production. The findings also suggest the need for conservation actions and further researches in this area of pineapple production in Southern Benin to reconcile the issue of pineapple production with the need for biodiversity conservation.

Keywords Threats · Preferred uses · Farming operations · Conservation · Benin

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Introduction

Human-driven habitat degradation and loss is a great threat to plant diversity throughout the world, it and jeopardizes conservation efforts (Maunder 2013). Among the human activities that destroy plant diversity, agriculture is often first mentioned, because it converts a wild habitat with species richness into mono-specific lands (Sulieman et al. 2012). Concerning some useful species such as medicinal plants, their harvest for traditional medicinal use is sometimes reported to be the main cause of their decline in the natural vegetation (Delvaux et al. 2009; Gaoue and Ticktin 2007). Elsewhere, many other factors such as wildfire, grazing, deforestation and urbanization have been cited to impact negatively the availability of medicinal plant species in the field (Delvaux et al. 2009; Djego et al. 2011). In view of these various causes suspected to explain the decline of medicinal plant species, it is important to discern the real cause of a given useful plant species in a particular locale because harvest and sustainability practices vary by region and culture.

In Benin, people possess a traditional knowledge of medicinal uses of numerous plants as reported by previous studies (Deleke Koko et al. 2011; Djego et al. 2011; Allabi et al. 2012; Yetein et al. 2013). Some of these species are commercialized for their medicinal uses (Vodouhè et al. 2008; Quiroz et al. 2014). However, there is a clear relationship between the widespread commercial harvesting of a given species and its vulnerability status (Jusu and Sanchez 2013; Quiroz et al. 2014). Therefore, great quantities of some plant products are frequently sold on Benin's urban markets (Quiroz et al. 2014). Among these species widely sold, *Zanthoxylum zanthoxyloïdes* and *Morinda lucida* have anthelmintic effects, which have been highlighted in several studies (Hounzangbé-Adoté et al. 2005a, b; Azando et al. 2011; Olounladé et al. 2012). Consequently, these species could become potential sources for production of improved traditional drugs for treatment of animal diseases, and this could lead to their overexploitation. Indeed, *Z. zanthoxyloïdes*, listed as a threatened species (Adomou et al. 2011), was frequently marketed. *M. lucida* is not yet listed as a threatened species, but traders perceive that species as being rare in natural vegetation (Quiroz et al. 2014). Apart from this extinction risk assessment by International Union for Conservation of Nature (IUCN) in Benin targeted on *Z. zanthoxyloïdes* (Adomou et al. 2011), little is known about the ecological impacts of various uses of these species. However, such details are essential to improve suitable strategies for their conservation. Indeed, apart from the high traditional medicinal uses widely brought up as the main vulnerability indicators of these tree species (Adomou et al. 2011; Djego et al. 2011), other social and economic factors could lead to a high impact on their availability in the field.

The species vulnerability can be assessed using the demand for medicinal uses, the plant parts used and their availability/scarcity in the field (Cunningham 1996). To ensure the conservation of *Z. zanthoxyloïdes* and *M. lucida* in Benin, this work aimed to understand the potential drivers of their overexploitation in Benin. The specific objectives of the study were (i) to determine the pattern of use of *Z. zanthoxyloïdes* and *M. lucida* and (ii) to evaluate the ecological impacts of the various uses of these species.

Materials and methods

Sampling and study area characteristics

This study was conducted using the central axis from the southern (Guineo-Congolian zone) to the central (Sudano-Guinean zone) part of the country, according to phytogeographical zoning of Benin (Fig. 1) into vertical bands from south to north (Adomou et al. 2006).

From November 2013, we undertook an exploration in each zone to select where target species (*Z. zanthoxyloïdes* and *M. lucida*) were well represented. Indeed, in each of the two phytogeographical zones of Benin, three communes where involved in data collection. This choice was facilitated by forest officials' guidance, accessibility and direct vegetation observation in the field. The exploratory survey lead to the inclusion of the three communes covered by the study in the Department of Atlantique, including Allada's commune, which is the greatest provider of the roots of tree species to marketing actors in Cotonou, the most populated city of the country and its vicinities. In summary, the selected communes were Ouidah, Tori-Bossito and Allada in Southern Benin; Abomey, Agbangninzoun and Djidja in Zou's Department; and Dassa, Savalou and Savè in Collines' Department. The Department of Atlantique is in the Southern zone or Guinea-Congolian zone, and Collines and Zou are located in the Central zone or Sudano-Guinean transition zone in Benin (Adomou et al. 2006). In terms of plant vegetation, all study areas were characteristic of a mosaic of lowland rain forests and secondary grasslands, with most of the original vegetation replaced by thickets and farmland (White 1983).

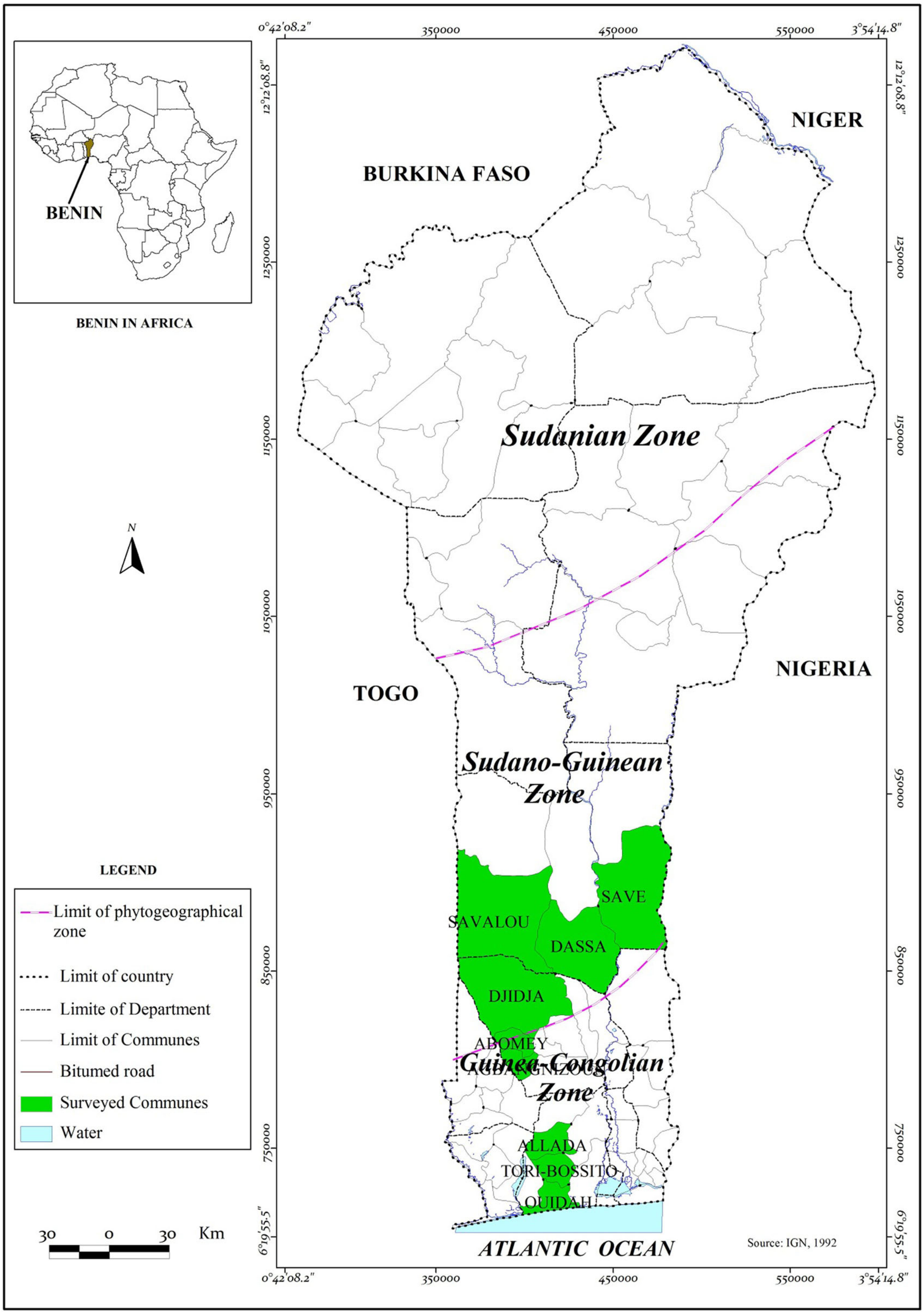

Fig. 1 Study sites localization

The Guineo-Congolian zone has two wet and two dry seasons, with a mean annual rainfall varying between 900 and 1300 mm. The relative humidity varies between 69 and 97%, and soils are either deep ferralitic or rich in clay, humus and minerals. The main crops produced in this zone are maize, cassava and peanuts. Particularly in Allada Commune, pineapple (*Ananas comosus*) is widely cultivated following the uprooting of wild tree species.

As for the Sudano-Guinean transition zone, its climate is unstable and complex, due to the climate influence of the Guinea-Congolian and Sudanian zones. Indeed, the Sudanian climate has only one wet and one dry season (annual mean rainfall varying between 900 and 1110 mm), and the relative humidity varies from 31 to 98%. The soils in the Sudano-Guinean transition zone are ferruginous with variable fertility and are generally adapted for cereal (millet, sorghum and maize), yam and cotton cultivation. The production of cotton leads to the use of shifting agriculture on a large expanse of land.

Data collection

From July to November 2014, interviews and vegetation surveys were carried out under authorization of local administrators (the village head) in all the sampled villages. In order to determine the pattern of use of the two species, heads of the households sampled were interviewed individually based on their willingness to participate in the study. A total of 247 respondents were interviewed using a questionnaire based on the uses of each target species and their perceptions about species availability in the field. Concerning the uses, informants were asked to arrange them by relative importance (in the order of first, second and third importance). The different uses were medicinal, carpentry, fuel, construction, fodder and craft. Among these informants, 121 farmers were additionally interviewed with the aim to obtain their points of view about farming operations (clearing and uprooting) related to *Z. zanthoxyloïdes* and *M. lucida* harvesting.

A vegetation survey was carried out in each phytogeographical zone to assess the availability of each targeted species. In all, 130 plots of 30 m × 30 m were established in various habitats where at least one plant of the two species was found. Based on the difficulty to find uprooted species in the field, the numbers of plants and plant stumps were counted within each plot.

Moreover, 60 medicinal plant sellers were interviewed in the markets of Dantokpa, Gbegamey, Cococodji, Allada and Ouidah about the origin of *Z. zanthoxyloïdes* and *M. lucida* roots being commercialized. This investigation allowed us to identify the species' roots trading channels.

Data analysis

Information collected from the respondents on the uses of each target species (*Z. zanthoxyloïdes* and *M. lucida*) was used to calculate the cultural importance index ($IP_{i,j}$) following Houehanou et al. (2011) for each commune (i) and for a given use (j) within each zone.

$$IP_{i,j} = \frac{\sum n_i \times x_j}{N}$$

where n_i = number of informants who preferred to use a species with j importance; x_j = score attributed to each level of use importance as follows: 1st importance: $x_1 = 3$, 2nd: $x_2 = 2$ and 3rd: $x_3 = 1$; N = total number of informants in each commune. The values of $IP_{i,j}$ ranged from 0 to 3.

This cultural importance index ($IP_{i,j}$) enabled us to identify the preferred uses among medicinal, carpentry, fuel, construction, fodder and craft uses within each zone and to test for a given use that was different between the two zones by using a suitable statistical analysis: Kruskal–Wallis tests (Höft et al. 1999). These tests were performed in R software.

The fidelity level (FL) was calculated for each medicinal use following (Friedman et al. 1986):

$$FL\,(\%) = \frac{si}{N} \times 100$$

where si = number of informants who reported a given medicinal use i, and N = total number of informants.

Recording of the numbers of plants and plant stumps of each targeted species in the field permitted us to calculate the density/100 m^2 (D) following (Mueller-Dombois and Ellenberg 1974).

$$D = \frac{z}{A} \times 100\ \mathrm{m}^2$$

where z = number of plants of a species in a given space (group of plots), and A = total area (m^2) of plots considered.

This density (D) was used to evaluate the availability of each targeted species within the two zones and the various habitats (built-up: i.e. "area covered by houses", fallow, farm, plantation).

The farmer's declaration about farming operations (clearing and uprooting) related to harvesting of *Z. zanthoxyloïdes* and *M. lucida* in the three communes of the Department of Atlantique was assessed.

Results

Use patterns of *Z. zanthoxyloïdes* and *M. lucida*

From the Southern to Central zones of Benin, the two species (*Z. zanthoxyloïdes* and *M. lucida*) were well recognized for various uses (Fig. 2). These species were commonly used for traditional medicine (cultural importance index: IP: 1.86–2.50), fuel (IP: 0.89–1.42), fodder (IP: 0.96–1.35), construction (IP: 0.01–0.49) and carpentry (IP: 0.03–0.08), whereas *Z. zanthoxyloïdes* was particularly used for craft (IP: 0.21–0.55).

The main craft use reported by the respondents was as a hoe handle. On average, medicinal use was the most preferred among all the uses reported by the respondents. Certainly, use as fuel and fodder were ranked second and third, respectively, but construction and carpentry were placed at the back of the list. Considering the medicinal use, the highest cultural importance was obtained in Central Benin for *Z. zanthoxyloïdes* and in Southern Benin for *M. lucida*. The variation in cultural importance of the medicinal use of *M. lucida* between the two zones was not significant ($p = 0.56$). As for *Z. zanthoxyloïdes*, the cultural importance of the medicinal use obtained in Central Benin was significantly greater than that observed in Southern Benin ($p = 0.04$). The medicinal use has the highest cultural importance among the other uses in the Southern and Central zones of Benin.

Indeed, concerning the medicinal use, respondents demonstrated important traditional knowledge about the two species. The various diseases treated by using each of the two species are presented in Table 1. Overall, 27 and 26 medicinal properties were attributed to *Z. zanthoxyloïdes* and *M. lucida*, respectively. The fidelity level (FL) showed that dental decay (FL = 44.13%) was the most common use of *Z. zanthoxyloïdes*, whereas malaria (FL = 59.66%) was the most reported ailment treated by using *M. lucida*. Each of the two main medicinal uses were followed by stomachache for *Z. zanthoxyloïdes* (FL = 6.07%) and *M. lucida* (FL = 27.84%). Several medicinal uses were reported by a few respondents, and one informant reported numerous uses. Among these, the medicinal uses were FL = 0.41% for *Z. zanthoxyloïdes* and FL = 0.57% for *M. lucida.* Certain medicinal uses reported by respondents including malaria, stomachache, diarrhoea, animal diarrhoea, vomiting, worms, gonorrhea, impotence, dysmenorrhoea, sterility, care of breastfeeding women, hypertension and tiredness were common to the two species. Therefore, malaria, which was the main reported medicinal use of *M. lucida*, was also reported for *Z. zanthoxyloïdes* with FL = 1.62%. However, jaundice, which could be linked with malaria, was reported only for *M. lucida.*

The treatment of the reported diseases reflects the harvesting pressure on the target species. Concerning *Z. zanthoxyloïdes*, the main medicinal uses such as

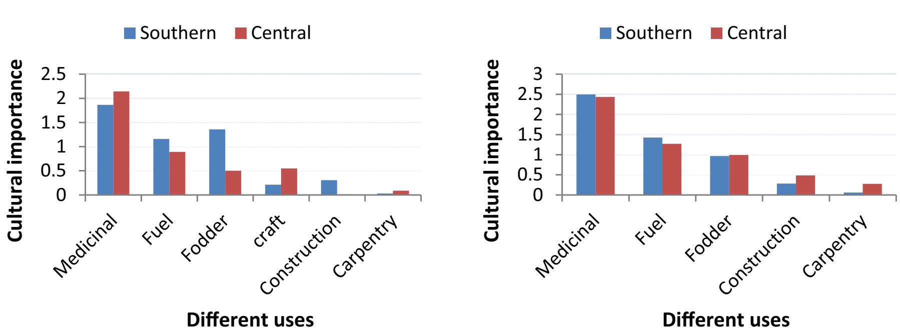

Fig. 2 Cultural importance of different uses of *Z. zanthoxyloïdes* and *M. lucida* in Southern and Central of Benin

Table 1 Medicinal uses of *Z. zanthoxyloïdes* and *M. lucida*

Medicinal uses	Plant parts	FL (%)
(A) *Z. zanthoxyloïdes*		
Dental decay	Rt, St, Bk	44.13
Stomachache	Rt, St	6.07
Constipation	Rt, Bk	1.62
Malaria, insect bite	Lf	1.62
Hypertension	Lf, Rt, Fr	1.22
Worm	Rt	1.22
Cough, animal diarrhoea	Lf	0.81
Animal infection, vomiting, diarrhoea, galactogogue, tiredness, reminder, care of breastfeeding women, oral hygiene of baby	Lf	0.41
Gonorrhoea, dysmenorrhoea, oral infection, sterility, infection, ulcer, sickle cell disease, hemorrhoids, impotence	Rt	0.41
Throat infection	St	0.41
(B) *M. lucida*		
Malaria	Lf, Rt, Bk	59.66
Stomachache	Lf, Rt, Bk,	27.84
Gonorrhoea	Lf, Rt	3.41
Jaundice	Lf, Rt, Bk	2.84
Abortion, dysmenorrhoea	Lf, Rt	1.70
Sterility, care of baby	Lf, Rt	1.70
Animal diarrhoea	Lf	1.14
Care of breastfeeding women	Lf, Rt	1.14
Hypertension	Rt, Bk	1.14
Child's fever, sinusitis	Bk	0.57
Diarrhoea, vomiting, measles, care of pregnancy, worm	Lf	0.57
Laxatif, difficult conception, diabetes, tiredness, anemia, snake bite, impotence, precocious menopause	Rt	0.57

Plant parts: *Bk* bark, *Fr* fruit, *Lf* leaf, *Rt* root, *St* stem

dental decay, stomachache and constipation were attributed to the roots, stems and bark with regular harvests impacting negatively on plant survival. In addition, a total of 11 medicinal uses were attributed to the roots of *Z. zanthoxyloïdes*. As for *M. lucida*, 18 medicinal uses including malaria, stomachache, gonorrhea and jaundice were attributed to the roots. Given these requirements for those parts of the plants, mainly the roots for the treatment of diseases, the availability of the concerned parts of the species for the benefit of the people in urban areas was assured by trade.

Availability of *Z. zanthoxyloïdes* and *M. lucida*

In the field, *Z. zanthoxyloïdes* and *M. lucida* were more available in the south than in the central zone of Benin (Table 2). The density of either of the two species and the perception of people about their availability were in congruence. Indeed, most respondents in Southern Benin (62.31%) perceived that *Z. zanthoxyloïdes* was available. Concerning *M. lucida*, the majority of people in Southern Benin (54.32%) trusted that this species was scarce. In Central Benin on the other hand,

Table 2 People's perception about the availability versus the density of *Z. zanthoxyloïdes* and *M. lucida* in Southern and Central of Benin

Zone	Number of informants (%)		Density/100 m^2 ± SD
	Scarce	Available	
(A) *Z. zanthoxyloïdes*			
Southern	37.69	62.31	2.05 ± 1.92
Central	79.58	17.65	0.11
(B) *M. lucida*			
Southern	54.32	45.68	0.99 ± 1.21
Central	87.78	12.22	0.22 ± 0.08

SD standard deviation

the number of people who perceived the scarcity of these species was significantly greater. Overall, the vegetation survey showed that both *Z. zanthoxyloïdes* and *M. lucida* were more available in Southern than in Central Benin. In fact, in Southern Benin, where the two species were relatively most abundant, they were recorded in diverse habitats including farms, fallows, plantations and built-up areas (Fig. 3). Overall, the greatest densities of individual plants of these species were collected from fallows, whereas the plant stumps were more frequent within the farms than fallows. Because fallows become cultivated through agricultural operations, numerous individual plants observed within a fallow can disappear, converting them to stumps (Fig. 4).

Morinda lucida was most especially recorded inside of the built-up areas, indicating that some people were well aware of its usefulness and conserved it for eventual use. However, the negative effects of agricultural operations on the tree species seemed to distort this awareness for the conservation of plants in the field. Thus, all farmers surveyed affirmed to have cleared at least 1 ha of fallows within the last 2 years (Fig. 5). If only the clearing operation were performed, the regeneration of plant stumps would be possible. But in addition to clearing, some farmers equally uprooted the stumps in order to install specific cultures including pineapple cultivation. Thus, the main percentage of farmers who engaged in this operation of uprooting was recorded at Allada (24%) compared to about 3% in the other two communes of the Department of Atlantique.

In the pineapple farms surveyed in Allada, very few or no plants (< 0.64 plants/100 m^2) of the two species were recorded (Fig. 6). The few recorded plants were the stumps that were found at the edges of the pineapple farms. Consequently, pineapple production, for which the uprooting of plants is necessary, was

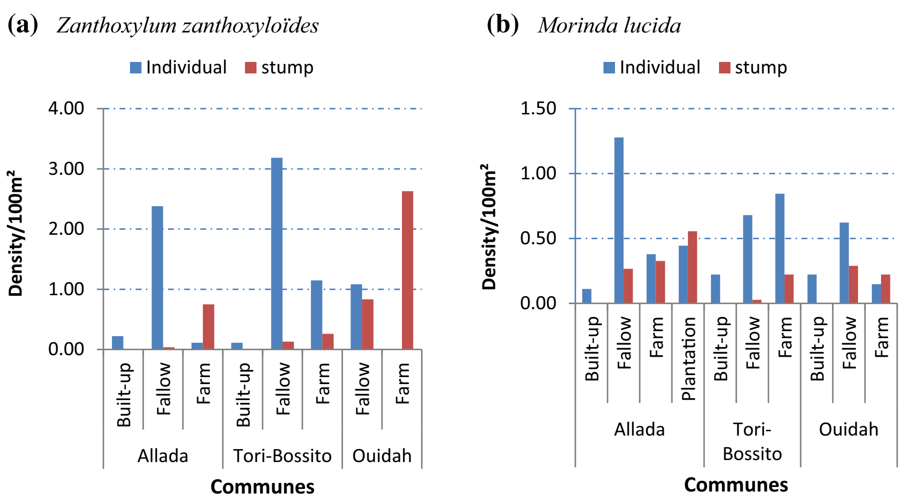

Fig. 3 Variation of density of *Z. zanthoxyloïdes* and *M. lucida* within different habits in three communes of Department of Atlantique (Southern Benin)

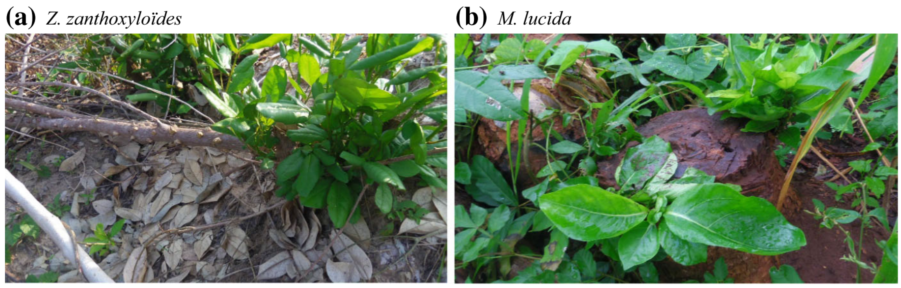

Fig. 4 Stumps of *Z. zanthoxyloïdes* and *M. lucida* after clearing operations

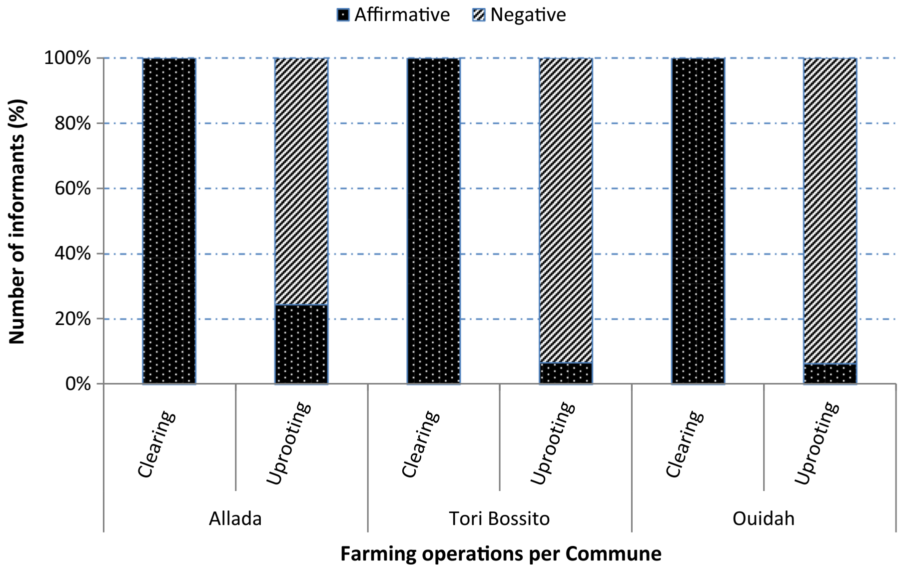

Fig. 5 Farmer's declaration about clearing operations affecting *Z. zanthoxyloïdes* and *M. lucida* in three communes of Department of Atlantique (Southern Benin)

observed to be the main destroyer of plants in the commune of Allada but, the roots obtained were recuperated for trade in the direction of medicinal plants commercialization in Cotonou and markets in its vicinity including Dantokpa, Gbegamey and Cococodji (Fig. 7).

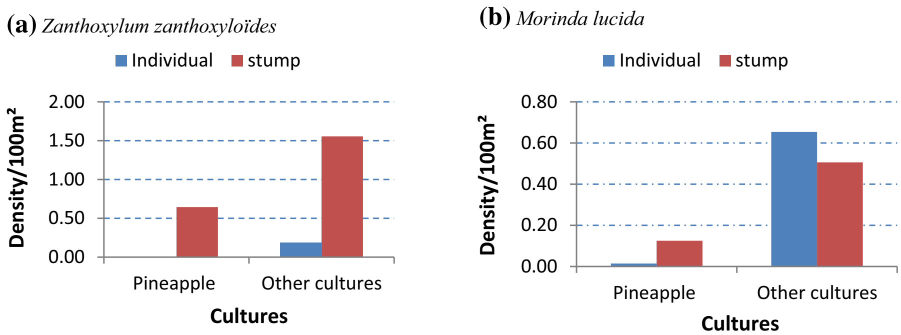

Fig. 6 Compared densities of *Z. zanthoxyloïdes* and *M. lucida* within Pineapple and other cultures' farms in commune of Allada in Department of Atlantique (Southern Benin)

In the trading system, four channels were distinguished (Fig. 8): (a) Vendors from Cotonou and its vicinities traveled to the villages of Allada and its vicinities to meet the suppliers and bought a large quantity of roots. They came back to Cotonou to sell the roots on retail. (b) The suppliers collected the roots and travelled from the villages of Allada to markets in Cotonou and its vicinities for delivery to the vendors. (c) In this channel, a middleman/woman was inserted between the suppliers and the vendors and was in charge of escorting the roots between the suppliers in the villages of Allada and the vendors in markets in Cotonou and its vicinities. (d) There were also the local markets where the suppliers and vendors met to undertake the transaction. These local markets were positioned at the centre of Allada and Pahou in the Commune of Ouidah.

Finally, a bunch of roots (200 ± 52 g of dry matter) of one of the two species (*Z. zanthoxyloïdes* or *M. lucida*) was sold to consumers at 100 Fcfa (1.15 USD per kilogram).

Fig. 7 Medicinal plant roots recuperated from farming operations for commercialization

Discussion

Agricultural pressure on medicinal tree species

The present study showed how far the agricultural operations impinged on the survival of *Z. zanthoxyloïdes* and *M. lucida* in Southern Benin, where the species are more available. They are found mainly in young and old fallows, which are in perpetual rotation into crop lands. In the southern part of Benin, due to an increasing population density, farmers have limited land to extend their fields. Pineapple production has increased and reached 315,000 tons in 2015 contributing to 1.2% to Benin's Gross Domestic Product (MAEP 2015). Contrary to other crops such as maize or peanuts, in pineapple production systems, all trees are uprooted because pineapple needs a high level of sunshine for the best yields. Generally, few individual plants are spared during the clearing operations, but some stumps regenerate to ensure the survival of the species in the field. This explains the fact that the densities of individual plants of these species collected from fallows were greater than those within the farms, and the density of plant stumps in farms was greater than that within fallows.

When considering a given agricultural production such as maize, forests are cleared, and the maize is seeded during the first year with or without plowing. Over the years, the process of soil manipulation carried out by plowing leads to gradual uprooting, starting with the less robust stumps in order to ensure the availability of nutrients and provide aeration of soil layers (Bajwa 2014). None of the main crops such as maize, cassava or peanuts cultivated in Southern Benin require the systematic uprooting of plants. The presence of one stump or an individual plant does not prevent those crops from producing high yields. The plant stumps are often left on the spot and regenerate later. However, when necessary, the larger and stronger stumps are one by one uprooted or burnt when they are very abundant or prevent easy plowing.

Especially in the case of pineapple production, in the Plateau of Allada in Southern Benin where pineapple is widely cultivated, the whole uprooting operation starts from the first year with no stumps or individual plants remaining on the farm. The potential explanations of this practice could be the need for direct and full sunlight for enhancing the yield and coloration of pineapple on one hand and the need for

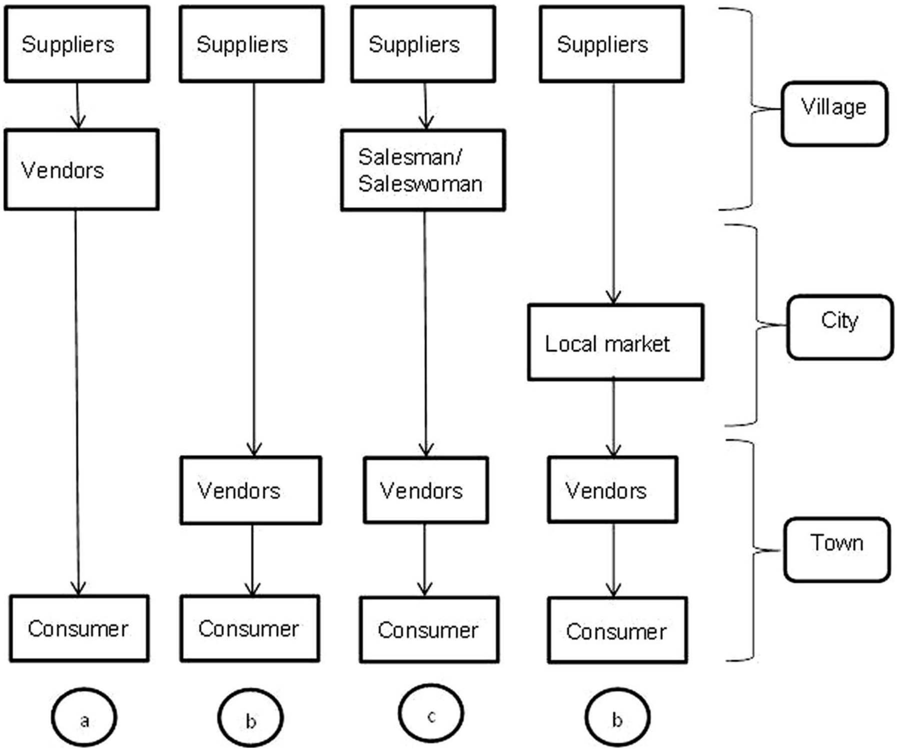

Fig. 8 Trading channels of the roots of *Z. zanthoxyloïdes* and *M. lucida*

soft ground for the superficial and fragile root system of pineapple on the other hand. The whole uprooting operation makes the plant roots available for medicinal uses in households and mainly for commercialization. Thus, after the uprooting operation, the roots of *Z. zanthoxyloïdes* and *M. lucida* are picked throughout the farm and commercialized. This may be by the farmer himself, his wife, the recruited maneuvers or somebody else whose goal is the collection of roots for sale in the village, because the roots have little value for farmers, who are occupied by agricultural production. For the pineapple producers in this case, the roots become an inconvenience and could be used as fuel in the household. Certainly, collectors are interested in the roots and make a little money by selling them.

The average price per kilogram of the two species was 1.15 USD (vs. 50–80 USD for pineapple; Miko Gohoun 2013). Compared with the prices found by Quiroz et al. (2014) for plant roots sold in general (2.21 USD), it seems that the two species are among those that are less expensive and more available, given that the threatened species price is 16 USD per kilogram (Quiroz et al. 2014). But although, the price is not the best indicator of medicinal plant availability (Botha et al. 2007), it could allow us to appreciate the difficulty of obtaining and harvesting the plant roots (in the case of this study). The current study provided further information on how the harvesting of roots is organized concerning specifically *Z. zanthoxyloïdes* and *M. lucida*. Indeed, when considering the number of actors in the supply-chain, we could speculate on what price the collectors must sell the roots to allow retailers to sell a kilogram at 1.15 USD. Concerning the roots of *Z. zanthoxyloïdes*, Vodouhè et al. (2008) revealed that the retailers have per unit a gross margin that is 2 or 8 times higher compared with the collectors. Because the collectors harvest the roots directly in vegetation without paying any royalties (Vodouhè et al. 2008), their income may be at most 0.58 USD (250 Fcfa) per kilogram. Consequently, it would not be profitable for farmers to devote themselves to roots harvesting and leave their agricultural activities. Even if the demand for medicinal roots were high, the hard efforts of uprooting and selling the product combined with the loss of the contribution from pineapple production may make the activity unprofitable. In summary, species roots availability as a result of pineapple production seem to be the main destructive factor of these species' populations.

Without this demand for medicinal use, the roots released from pineapple production would be available for something else and used for fuel.

As part of the activities of pineapple production, the uprooting is more easily done during the rainy season. Because the released roots have little value for farmers, they would not give up their agricultural activities for medicinal plants trade. This explains the fact that even though the roots become scarce during the rainy season in the market as reported by Vodouhè et al. (2008), they might still be available in the field. Elsewhere, to circumvent the scarcity of medicinal roots in the markets at Cotonou and its vicinities, some vendors traveled to the villages of Allada or local markets to meet the suppliers. This explains why there were four channels in this study, whereas Vodouhè et al. (2008) found only two. Nowadays the medicinal roots are available in the markets during all seasons.

Medicinal uses versus uprooting of tree species

Could the availability of the roots in markets mean that the demand for medicinal uses is so high? In fact, concerning the two targeted medicinal plants (*Z. zanthoxyloïdes* and *M. lucida*), medicinal use was recognized by people as the most important and preferred use of these plant species. The types of diseases widely treated by each species were somewhat variable. The frequent diseases such as malaria were widely treated by *M. lucida*, and that could result in a high demand. But, the main organs used for this purpose were the leaves and sometimes the bark and roots. The same organs of *M. lucida* were also used for treatment of jaundice. However, for the other current medicinal uses including the treatment of dysmenorrhoea, difficulties with conception and the care of pregnant and breastfeeding women, the roots of *M. lucida* are the most sought after parts. As such, the demand for the roots of *M. lucida* could be high. As far as the uses of *Z. zanthoxyloïdes* are concerned, dental decay treatment was the use widely reported by people. Thus, one could consider that if dental decay were a widespread disease, the bark and roots of *Z. zanthoxyloïdes* traded at local and international levels could be recognized as medicinal treatments (Adomou et al. 2011). Even if dental decay were not widespread, everybody has a need for oral hygiene, and thus the multiplicity of improved traditional toothpastes found in the markets nowadays could mean that they were made from *Z. zanthoxyloïdes* roots. But, we cannot be certain about their ingredients, because the manufacturers keep them a secret. What we can certify is the existence of anti-sickling drugs made from *Z. zanthoxyloïdes* roots such as VK500, Drepanostat and Faca (Matu 2011). But strangely, sickle cell disease widely treated by *Z. zanthoxyloïdes* roots in Africa (Matu 2011) was reported by only one informant in this study. Because this disease is very recurrent in Africa (Matu 2011), that could explain the local and international translation of *Z. zanthoxyloïdes* roots (Adomou et al. 2011; Djego et al. 2011; Quiroz et al. 2014). Regarding the high demand of the roots accompanied by international translation, it is usual for *Z. zanthoxyloïdes* to be on the IUCN Red List in Benin (Adomou et al. 2011). But, *M. lucida*, for which extinction risk has not yet been evaluated, seems less available than *Z. zanthoxyloïdes*, for which the status is vulnerable. Most people also perceived the scarcity of this species, which was consistent with the density results. Elsewhere, the scarcity of *Z. lucida* was also perceived by vendors interviewed by Quiroz et al. (2014). Consequently, these authors suggested to consider the priority conservation of species for which scarcity has been reported at least once any region. In addition, because *Z. zanthoxyloïdes* share the same habitat with some non-red-listed plants such as *M. lucida* and are subject to the same agricultural pressures, mainly from pineapple production, it is recommended to consider this species for the list of threatened species in Benin. Future researches could focus on this and show the real threat status of the species.

Elsewhere, this study has found that in Southern Benin, where the two target species were more abundant, pineapple production was the main destroying factor; thus, because it has been shown that human-managed ecosystems could contribute to conservation of biodiversity (Houehanou et al. 2013), the agronomic requirement and trade scope of pineapple production in Benin run counter. In fact, the production of other crops such as maize seems to be less destructive because they are compatible with agroforestry. So, further studies are needed to identify the impact of agricultural activities, mainly pineapple production, on vegetation composition and regeneration ability.

Implication for species conservation strategies

How should we reconcile pineapple production with the need of biodiversity conservation? At the scale of Benin's country, the Plateau of Allada, which is a hotspot of pineapple production, is at the same time a pool of medicinal plant diversity. For example, Yetein et al. (2013) reported 82 anti-malaria species in this area.

Without knowing the havoc caused by pineapple production in this area, the authors suggested the promotion and increased availability of those plants in the sites of collection, including the fallow. At this moment where the fallows in the Allada region could likely become pineapple fields without any agroforestry practice, it would be better to find alternative solutions to suppression of the plant species. Indeed, it would be better to encourage agricultural diversification than expect plant conservation to occur on human-managed ecosystems. Such agricultural diversification could permit the adoption of agroforestry tools for conservation of biodiversity in other fields. In view of the high sunlight requirements of pineapple production, the research could help in the selection of pineapple cultivars that are less dependent on sunlight and are tolerant of tree shade in agroforestry systems. In addition, we recommend a study to identify the threshold density and coverage of trees whcth tolerate a better pineapple production. In this context, one can advise the pruning of lateral roots and maintaining the main root of the saved trees in the pineapple fields. Because pineapple is produced for export, it becomes a matter of national sovereign and so it would be important to integrate it to the promotion system of agricultural sectors. Likewise, because Benin has ratified the Convention for Biological Diversity, it has a duty to conduct the actions for conservation of plants destroyed through pineapple production. Thus the actions based on conservation of biodiversity within the sacred forests, which are common in Southern Benin, could be strengthened in this Plateau of Allada and its surroundings. At last, the awareness of actions could be initiated on the threatened species which must be spared during the agricultural activities.

Conclusions

This study has permitted us to advance the knowledge on the use of two tree species, namely *Z. zanthoxyloïdes* and *M. lucida*. Medicinal use is the main use of the two species. These species are mainly used for treatment of human diseases and as an accessory for treatment of animal diarrhoea and feeding. The two species were most available in Southern Benin but were subject at the same time to agricultural pressure through uprooting of wild species for pineapple production, providing the medicinal roots for trade. This study showed that the real cause of vulnerability of most medicinal plants including *Z. zanthoxyloïdes* and *M. lucida* in southern Benin is rather pineapple production not automatically the demand for medicinal use. As such, it suggested that the non-red-listed plants such as *M. lucida* should be considered in the list of threatened species in Benin. Regarding the findings of this study, conservation actions are needed, and future researches could be targeted on the impact of agricultural activities (mainly the pineapple production) on vegetation composition and regeneration ability of destroyed vegetation.

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