INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 18, No. 3, p. 31-46, 2021
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Review on reported importance and previous conservation investigations of a threatened food tree species *Pentadesma butyracea*

M. Mouyohoun Kouagou*[1], Honore SS Biaou[1,2], Imorou Ouorou Barre Fousseni[1,2], Jonas A Djenontin[1,2], Armand K Natta[1,2]

[1]*Laboratory of Ecology, Botany and Plant Biology, Parakou, Republic of Benin*

[2]*Faculty of Agronomy, University of Parakou, Parakou, Republic of Benin*

Article published on March 30, 2021

Key words: Effective conservation strategy, Optimal habitat size, Synergetic disturbances, *Pentadesma butyracea*

Abstract

Most of multi-use species are declining in the wide habitat in spite of the variety of the conservation recommendations formulated by researchers. This may be due to the fact that a large part of researches focused on their socio-economic importance than the conservation of those species. *Pentadesma butyracea* is a multi-uses tree species that occurs from Sierra Leone to Gabon in dense Guineo-Congo rainforest and in gallery forests in the Dahomey-Gap of the dry corridor. This work used 56 studies to synthetize the importance of *Pentadesma butyracea*, enumerate the main threats to species persistence and test if probability of suggesting conservation strategies varied according to main fields of research, the conservation focus and the statement of conservation aim in the study. Our synthesis showed that although 68.75% asked conservation questions, only 43.75% suggested strategies for conservation of *Pentadesma butyracea* species and/or its habitat, gallery forests. We found 11 combinations of disturbances and 3 isolated disturbances which can simultaneously occur in the wild. We recommended for *Pentadesma butyracea* and it habitat effective conservation to limit gallery forest width reduction and fragmentation, to enforce the law regarding the minimum distance between farmer field and the gallery forest. Studies on multi-uses trees species must explicitly involve the viability of remnant populations and set the threshold viable habitat size. We also recommend to disentangle drivers of *Pentadesma butyracea* populations decline using update and accurate mathematical and statistical tools.

***Corresponding Author:** M' Mouyohoun Kouagou ✉ mkouagou@gmail.com

Introduction

Threatened species conservation is the main goal of most biological conservation and related field researches (Sutherland *et al.*, 2009, Wintle *et al.*, 2019). However, with increasing researches in biological conservation, many species are still facing high risk of extinction. Most of plant species in the tropics are under several threats including unsustainable harvest of timber and non-timber forest products, habitat loss and fragmentation, fire, and climate change. Populations of many species are reducing, leading to the extinction of some species (Mora *et al.*, 2007). This biodiversity decline is due to multiple human causes. Human activities and climate change are the leading causes of this decline (Burney and Flannery 2005). Human-induce disturbances are often non-independent (Taubert *et al.*, 2018).

For example, habitat size reduction can change fine scale climate and favor the spread of invasive species (Brook *et al.*, 2008) and recurrent fire can favor the spread of exotic species (Baker, 2006). Moreover, the increase of edge effects is often associated with the increase livestock incursion, wildfire, logging, and human-wildlife conflicts (Goswami *et al.*, 2014), and it can also facilitate further habitat loss (Laurance and Useche, 2009, Fletcher *et al.*, 2018a). Harvest of non-timber forest products may be higher fragmented habitats, since harvesters can easily access to small habitats than large and intact landscape (Tabarelli *et al.*, 2004).

Habitat fragmentation can reduce seed dispersal (Fletcher *et al.*, 2018b), the probability of seed germination (Rutledge, 2003) and plant recruitment in small and isolated fragments (Bruna, 2003). The reduction of recruitment is most common for shade-tolerant or forest understory species (Lemire and Tabarelli, 2007). Habitat size reduction and an increase of spatial isolation between fragments can also interrupt mechanisms of seed dispersal (Poschlod and Bonn, 1998) and increase seed predation (Curran and Webb, 2000). This can then limit seedling density (Bruna, 2003). Fragmentation increases plant mortality in small and isolated fragments *(Laurance et al.*, 2002, Rutledge, 2003). Fragmentation can especially reduce offspring survival (Kolb, 2005). Fragmentation can either increase plant growth at the forest edges (Sizer and Tanner, 1999) or decrease plant growth (Bruna *et al.*, 2009, Bruna and Oli, 2005). Habitat loss and fragmentation can alter abiotic and biotic environment that could limit plant population dynamics in fragments (Bruna and Oli, 2005).

Pentadesma butyracea is one of the most important tree species in West-Africa. It belongs to the 106 vulnerable species of the red list of Benin (Neuenschwander *et al.*, 2011). It occurs in gallery forests of the center and northern part of Benin (Natta, 2003). This species is widely used by local people (Avocèvou-Ayisso *et al.*, 2011, Houédjissin *et al.*, 2016, Natta *et al.*, 2010, Schreckenberg 1996).

Its butter is mostly used (Aissi *et al.*, 2011, Ayegnon *et al.*, 2015a,b, Ayegnon *et al.*, 2009, Badoussi *et al.*, 2016, Tchobo *et al.*, 2007). *Pentadesma butyracea* is under several pressures such as fruit overharvesting (Avocèvou-Ayisso *et al.*, 2009, Gaoue *et al.*, 2018), fragmentation of gallery forests (Kouagou *et al.*, 2018) gallery width reduction (Gaoue *et al.*, 2017) and so many threats (Dicko *et al.*, 2016). Yet, there is a need to design an effective conservation plan for the species and its habitat.

It is important to synthetize the reported uses and threats of *P. butyracea* in order to suggest conservation strategies and to guide further studies. This study aims to synthesize the work already done one *P. butyracea* for its effective conservation purposes. Specific objectives are:

(i) to synthesize the reported importance of *Pentadesma butyracea,* (ii) to enumerate the main threats to *Pentadesma butyracea* persistence, and (iii) to test if probability of suggesting conservation strategies varied according to main fields of research, the conservation focus (species or habitat) and the statement of conservation aim in journal papers (Yes or No).

Materials and methods

Study species description and its reproductive biology

Pentadesma butyracea Sabine is a Clusiaceae tree which belongs to the Pentadesma genus, the Symphonieae tribe, the subfamily of the Moronobeoideae. It is a wild mesophanerophyte woody species from the dense evergreen forests of Central and West Africa from Guinea-Bissau to the West of the Democratic Republic of Congo (Akoègninou *et al.*, 2006, Sama *et al.*, 2007). It occurrence in Benin may be due to the critical West African forest fragmentation (Salzmann and Hoelzmann, 2005). In that country, *P. butyracea* is a gallery forests typical species and is found in the soudano-guinean in the communes of Bassila and Tchaourou and in the sudanian zone in the communes of Kandi, Ségbana, Natitingou, Boukombé, Toucountouna, Kouandé and Tanguiéta (Natta, 2003). The soudano-guinean zone seems to be its ecological optimum with high probability of occurrence (Avocèvou-Ayisso, 2011). *P. butyracea* is found in 42 riparian forest with a total of 2559 adult trees (diameter at breast height, DBH ≥ 10cm) in the dry region (Natta *et al.*, 2011a) and in 76 riparian forest in moist region with an abundance of 1132 stems (Natta *et al.*, 2011b). *P. butyracea* is a long-lived canopy tree with height that can reach 15 m to 35 m and its DBH can reach 80cm to 150cm (Akoègninou *et al.*, 2006, Sama *et al.*, 2007). The species has a straight cylindrical trunk and horizontal branches. Its entire leaves which measure 10 to 25cm of length and 3.5 to 7cm of width are simple petiolate, persistent and opposite. Their limb glabrous, tough dark shining on the top with many fine and parallel side veins, not very visible. The side veins are joined together close to the margin of the limb by an inter-marginal vein. Leaves petioles measure 1 to 1.5cm (Avocèvou-Ayisso, 2011).

Its flowers are large, yellowish white or whitish red, solitary or in cluster (2 to 6). *P. butyracea* is an outbreeding species and it spatial distance of pollen dispersal is less than 100 m (Ewédjè *et al.*, 2017). High inbreeding depression was observed in small populations suggesting that gallery forest fragmentation is one of the leading causes of its genetic diversity reduction (Ewédjè *et al.*, 2017). *P. butyracea* has both sexual and asexual reproduction (Avocèvou-Ayisso, 2011, Gaoue *et al.*, 2018). Asexual reproduction is common in high fruit harvest populations (Gaoue *et al.*, 2018). Zeatin (3.5mg/L) appeared to be the best suited to budding and leafing of apical buds for i*n vitro* regeneration (Houédjissin *et al.*, 2015).

Reproductive biology of *Pentadesma butyracea* is fully presented be (Ewédjè *et al.*, 2015). *Pentadesma butyracea a* self-compatible mainly allogamous tree species flowers once a year during the dry season from September to December. It is pollinated by two sunbirds (*Cyanomitra verticalis*, *Cinnyris coccinigastrus*) and three Hymenoptera (*Apis mellifera*, *Meliponula togoensis*, *Hypotrigona* sp.).

Pollen-ovule ratio was 577±213 suggesting facultative xenogamy. The fruit ripe from March to May with approximately 6.5-12.5cm of width and 9-15cm of length. A fruit can weight from 50 to 1500g, and contain between 1 to 25 seeds. Seeds are large and contain darkred embryos. Seeds of *P. butyracea* have a pyramidal shape, at flattened sides or irregular, of 3-4cm × 2.5-3cm, brown dark and often confused with Cola nut, because of their resemblance appearance and color (Ewédjè *et al.*, 2012).

Data collection

During December 2018, we searched published papers on the web dealing with P. butyracea using the following search strings: "threat*and Pentadesma butyracea", "*Pentadesma butyracea*", "*P. butyracea*". From the resulting list of studies, we identified papers in which the authors included *Pentadesma butyracea* name in the title, abstract or key-word. We also got the dissertations of five graduated PhD who investigated various aspects on *P. butyracea* in the Republic of Benin. We considered unpublished PhD dissertation chapters like a papers.

From each paper, we recorded the name of first author, the year of publication, and the threats mentioned in the paper. Each paper was classified in one of five research domains: Phytochemistry, Food technology, Ecology, Genetics, Ethnobiology and Biology. We considered Ecology, Genetics, Ethnobiology and Biology as the fields of research that must focus on the conservation of *P. butyracea* and/or its habitat.

In each of those papers from conservation field, we checked whether or not the conservation of the species (*P. butyracea*) and/or its habitat (gallery forests) was mentioned as an important aspect of the research. Finally, we recorded the tagged conservation focus (habitat or species) mentioned in papers. Reported importance of *P. butyracea* were recorded from the papers published in the fields of Phytochemistry, Food technology, and Ethnobiology.

Statistical analysis

We counted the number of published journal papers for each year and for each of the six identified fields of research (Biology, Ecology, Genetics, Ethnobiology, Phytochemistry, and Food technology). Fisher's exact test was performed to test the null hypothesis of independence of fragmentation and gallery width reduction as the main threat to *P. butyracea* persistence and the independence between the formulation of conservation strategies for the species and its habitat.

The logistic regression was used with a binomial distribution to test if the probability of suggesting conservation or management strategies varied according to three main fields of research (Ecology, Genetics and Ethnobiology), the conservation focus (species and habitat), and according to the statement of conservation importance. We included the random effect of the leading author to account for the fact that many papers can be led by the same author. Then, we compare fixed and mixed effect models. Mixed model was performed with the *glmmTMB* package (Brooks *et al.*, 2017). All analyses were performed with the statistical software R version 3.5.1 (R Core Team 2018).

Results

Publication trend, main fields of research, and reported ethnobotanical uses of P. butyracea

We recorded 56 publications (45 published peer reviewed papers and 11 PhD dissertation chapters) that investigated diverse aspects on *P. butyracea* around the world (Figure Fig.1A and B). Our first recorded paper on *Pentadesma butyracea* was published in 1972 by Bamps (1972). Most studies (23.21%) on the species were published in 2015.

Around 57% (32/56) of published papers were in conservation biology i.e. ecology (32.14%), genetics (7.14%), ethnobiology (16.07%) and biology (1.79%). *Pentadesma butyracea* is a nutritional, socio-economic and cultural tree species in West-Africa (Table 1). Different parts of *P. butyracea* are used as food, cosmetic and medicine. Natta *et al.* (2010) reported 27 uses. Only women are involved in fruit harvest and seed transformation into butter (Sinsin and Sinadouwirou 2003). This butter resembles the shea butter (Badoussi *et al.*, 2014) by its point of flow, its index of saponification, and its composition in fatty acids, but with less odor (Sinsin and Avocevou 2007). It butter has higher quality than that of the shea tree (Ayegnon *et al.*, 2015b). The physicochemical composition of butter is influenced by the duration and the temperature of almonds torrefaction (Aissi *et al.*, 2011, Badoussi *et al.*, 2016, Badoussi *et al.*, 2015a, b).

Reported threat of P. butyracea and it habitat

We found in published papers five main threats: (1) Fruit harvest, (2) tree logging, (3) gallery forest fragmentation, (4) gallery forest size reduction and (5) recurrent fire (Fig. 2A). Fruit harvest was the main threat of P. butyracea (22/32, 68.75%) following by the recurrent fire (15/32, 46.88%), then gallery forest width reduction (13/32, 40.63%), ending by fragmentation (12/32, 37.5%) and tree logging (12/32, 37.5%). Among then only three were single disturbance (Harvest, fragmentation and tree logging) others co-occurred (78.57%, Fig. 2B). We found five categories of papers based on reported disturbances.

Table 1. Main uses of *Pentadesma butyracea*.

Organs	Uses	References	Intensity of ecological sustainability
Seed	Consumed like Cola nut	Avocèvou-Ayisso, 2011, Sinsin and Sinadouwirou, 2003	High
	Manufactured into butter for Cosmetics, Medicinal	Aissi *et al.*, 2011, Tchobo *et al.*, 2007, Natta *et al.*, 2010, Avocèvou-Ayisso, 2011	
	Extracts used for menopausal and hormone-sensitive diseases	Tindano *et al.*, 2017	
	For sell around 99.85-150 CFA/Kg	Avocèvou-Ayisso *et al.*, 2009, Natta *et al.*, 2010, Sinsin and Sinadouwirou, 2003.	
Mesocarp of mature fruit	Fruit juice	White and Albernethy, 1996	Very high
Bark	Macerated and used against skin parasitic diseases and as antidiarrhoeatic	Raponda-Walker and Sillans, 1961	Low
Roots	Decoction to fight intestinal worms	Abbiw, 1990	Low
Roots and bark	Xanthone used for antiproliferative, cytotoxic and antiplasmodial activities against microbe proliferation and breast cancer cell line (MCF-7)	Lenta *et al.*, 2011; Wabo *et al.*, 2010; Zelefack *et al.*, 2009, Ning-Hua *et al.*, 2015, Tala *et al.*, 2013	Moderate
Fruit pericarp	Antiplasmodial compounds	Lenta *et al.*, 2011	Very high
Leaves and Roots	A prenylated xanthone (butyraxanthone F) and 20 antiproliferative compounds	Tala *et al.*, 2013, Wabo *et al.*, 2010	Moderate
Leave, bark and root	Treat the fever, cough, the constipation, bronchitis and the venereal diseases	Alitonou *et al.*, 2010, Noudogbessi *et al.*, 2013, Sinsin and Sinadouwirou, 2003, Tchobo *et al.*, 2007, Wabo *et al.*, 2010	Moderate
Wood	Sculpture, boring, mortise, turning and sandpapering	Rachman and Balfas, 1987	Very low

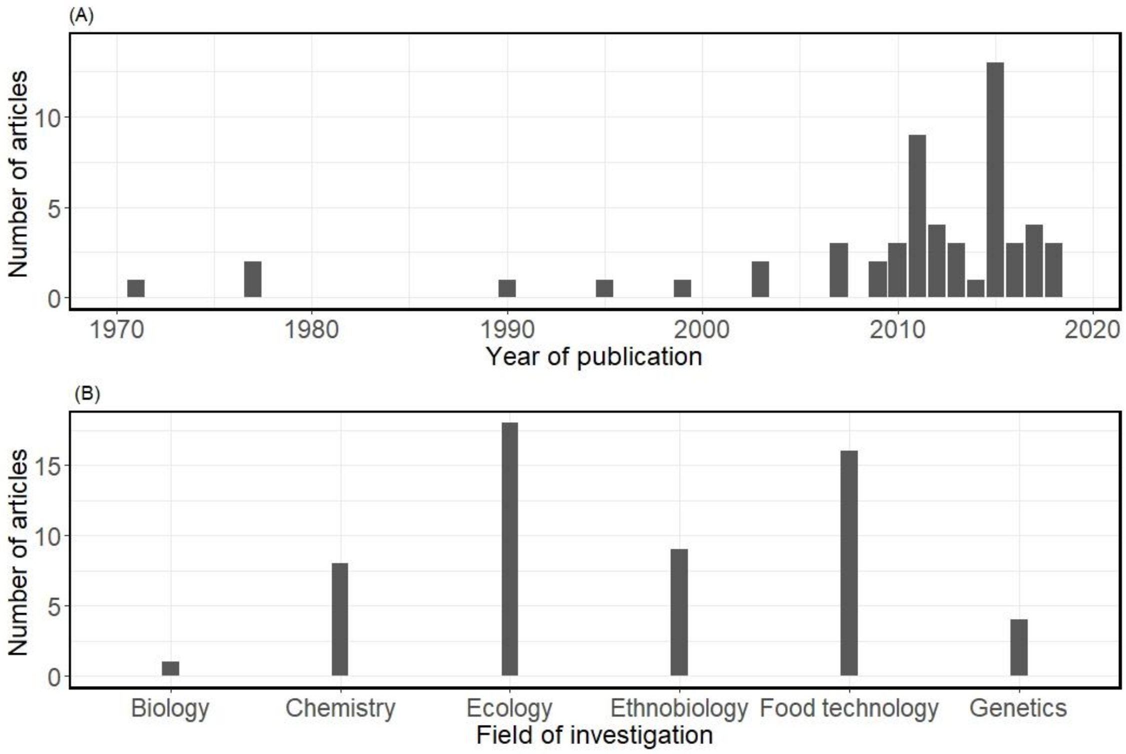

Fig. 1. Trend of published papers on *P. butyracea* with years (A) and with fields of study (B).

The first category mentioned single disturbance: (1) logging (Lo), (2) fruit harvest (Ha) and (3) fragmentation (Fr). The second category mentioned two synergistic disturbances: (4) fruit harvest and logging (HaLo), (5) fragmentation and habitat size reduction (FrRe), and (6) fire and fruit harvest (fiHa). The third category mentioned three synergistic disturbances: (7) fire, fruit harvest and habitat size reduction (fiHaRe), (8) fire, fruit harvest and logging (fiHaLo), (9) fire, fragmentation, harvest and logging (fiFrLo). The fourth category that mentioned four synergistic disturbances: (10) Fragmentation, fruit harvest, habitat size reduction and logging (FrHaReLo), (11) fire, fruit harvest, habitat size reduction and logging (fiHaReLo), (12), fire, fragmentation, fruit harvest and habitat size reduction (fiFrHaRe) and (13) fire, fragmentation, fruit harvest and logging (fiFrHaLo) and the fifth category of papers which simultaneously mentioned five synergistic disturbances: (14) fire, fragmentation, fruit harvest, habitat size reduction and logging (fiFrHaReLo) (Fig. 2B). About the quarter of papers (23.08%, Fig. 2B) belong to the fifth category. Papers that reported fragmentation as threat also reported gallery forest width reduction as threat of *P. butyracea* (Fisher's exact test, odds ratio=10.85, CI=[1.73 - 95.19], p = 0.004).

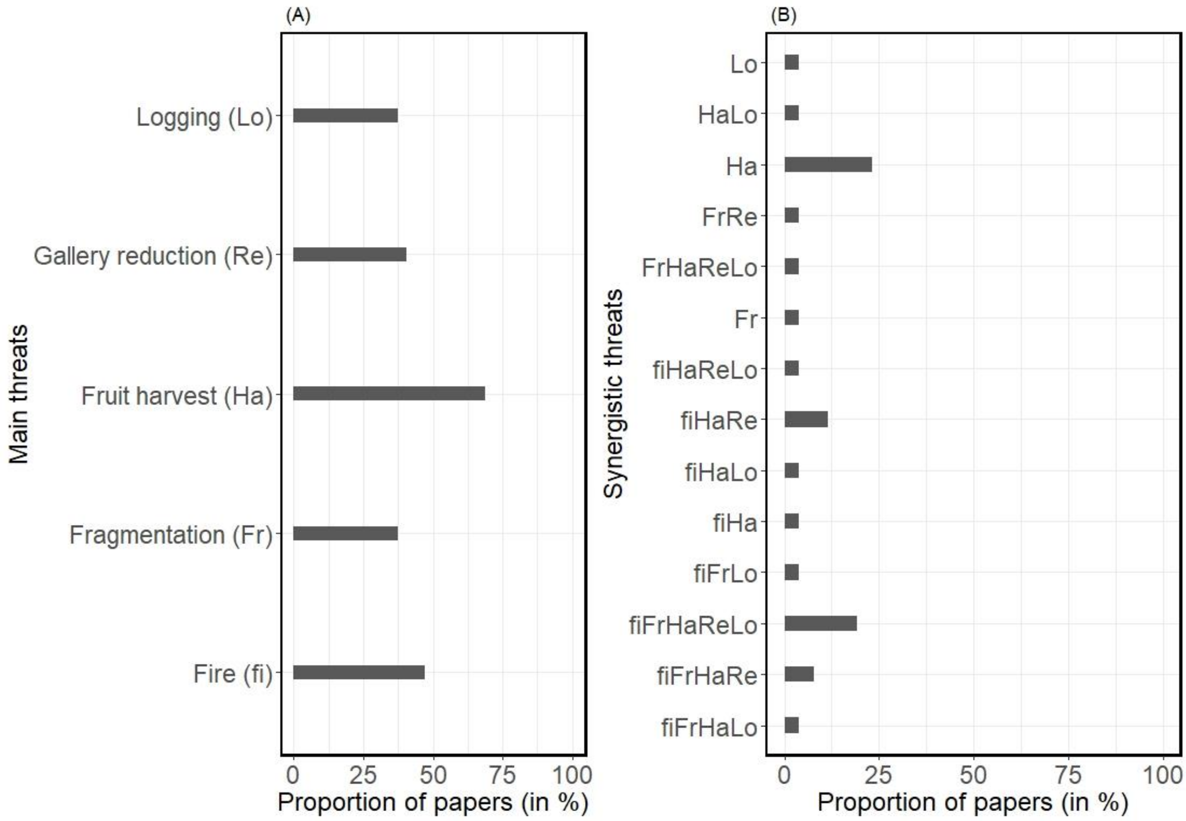

Fig. 2. Percentage of published papers that mentioned main and synergistic threats to the persistence of *P. butyracea* and its habitat.

Conservation investigations of P. butyracea and it habitat

Published papers less suggest conservation or management strategies (β =-1.47±0.7, Z=-2.097, p=0.0360). However, its suggested more likely conservation strategies when the conservation aim was clearly stated in the research (β =1.4082 ±0.6980, Z=2.017, p= 0.0436, Figure Fig. 3B). The result also showed that the probability of suggesting conservation strategies in published papers on *P. butyracea* was high for genetics (β =2.37±1.09, Z=2.19, p=0.029) and ecological (β =1.64±0.75, Z=2.18, p=0.029, Fig. 3A) field researches than for ethnobiological researches. The probability of recommending conservation strategies was high for genetics research than for ecology but the difference was not significant (β =0.73±0.93, Z=0.79, p=0.431, Fig. 3A). However, researchers suggested more likely conservation strategies for the species *P. butyracea* than for the conservation or restoration of its habitat (gallery forests) (β =0.98±0.59, Z=1.67, p=0.095, Fig. 3C, see Table 2 for some example of conservation strategies).

Table 2. Suggested conservation strategies for species (*Pentadesma butyracea*) and for its habitat (Gallery forests).

Conservation strategies	Species	Habitat
Reduction of fruit harvest intensity	+	
Prohibiting fire	+	
Establishment of orchards outside gallery forest such as at Ahozon, Republic of Benin (02°22'59.0"N, 02°09'38.7"E) and in Seychelles in the upper part of the Rivière Cascade and elsewhere.	+	
Enforcement of forest law	+	+
Prohibiting establishment of farm in gallery forest	+	+
Restoration of degraded gallery forests		+
Enrichment of gallery forests with *P. butyracea* seedling	+	+
Prohibiting pasture in gallery forests		+
Prohibiting of *P. butyracea* tree logging	+	
Reduction of the intensity of bark of *P. butyracea* harvest	+	
Reduction of the intensity of root of *P. butyracea* harvest	+	
Stopping cutting of young stems of *P. butyracea*	+	
Creation of connectivity between gallery forest		+
Storage of gene bank	+	

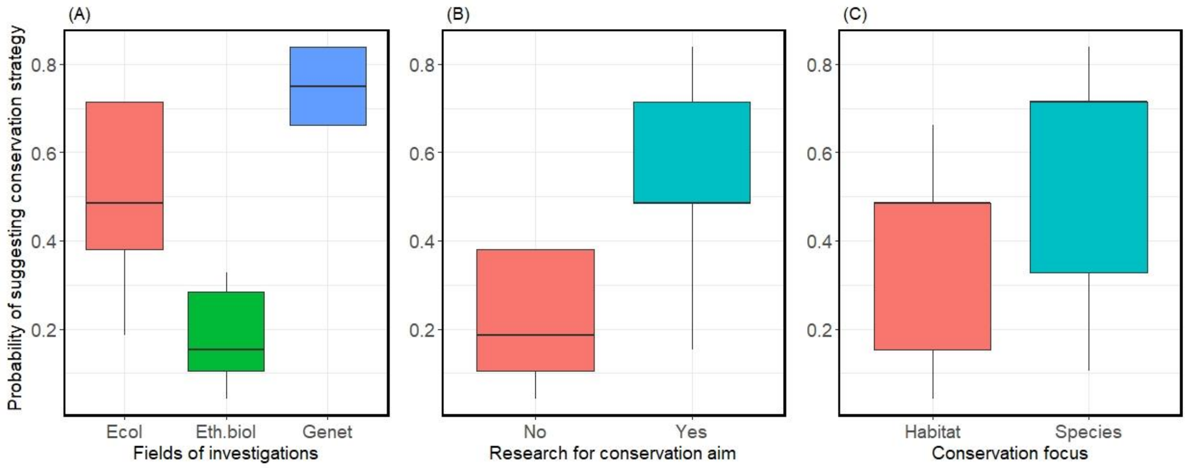

Fig. 3. Variation of probability of suggesting conservation strategy with the main field of investigation (A), the statement of conservation aim or not (B) and with conservation focus either for the species or its habitat (C).

Discussion

Ethnobotanical uses, domain of published journal papers and it ecological implications

Our review showed that P. butyracea is used for multiple reasons including medicinal, food and revenue. All its organs (leaves, bark, roots, stems, fruits, mesocarp and pericarp) are used. Additionally, timbers are harvested from *P. butyracea* (Neuenschwander *et al.*, 2011) especially trees with about 80cm of DBH (Natta *et al.*, 2011b). It importance in medicine motivated the investigation of the chemical composition of its roots, leaves, bark, and fruit pericarp (Lenta *et al.*, 2011, Noudogbessi *et al.*, 2013, Tala *et al.*, 2013, Ning-Hua *et al.*, 2015). The use of its organs had motivated its ethnobotanical studies (Natta *et al.*, 2010, Avocevou Ayisso *et al.*, 2011, Badoussi *et al.*, 2014, Houedjissin *et al.*, 2016). Its biology was well described by Ewedje *et al.*, (2015) and its ecology by many authors (Natta 2003, Sinsin and Avocevou 2007, Ewédjè *et al.*, 2012, Natta *et al.*, 2013, Gaoue *et al.*, 2018, Kouagou *et al.*, 2018). Most of ecological studies deal with how *P. butyracea* respond to disturbances and variation in ecological conditions (Dicko *et al.*, 2016, Gaoue *et al.*, 2018, 2017, Kouagou *et al.*, 2018). The increase of the intensity of gallery forest fragmentation, gallery width reduction and fruit overexploitation led to its genetic conservation studies (Ewedje *et al.*, 2017).

Our finding showed that fruit harvest is the main threat often mentions in studies despite of the reported ecological sustainability of fruit harvesting (Ticktin, 2004, Emanuel *et al.*, 2005; Ticktin *et al.*, 2012, Gaoue *et al.*, 2017). More than 80% of fruit can be harvested in a sustainable way (Ticktin, 2004). For example, 92% of fruits can be harvested from *Sclerocarya birrea* (Emanuel *et al.*, 2005). However, fruit harvest can alter recruitment and population structure (Avocèvou-Ayisso *et al.*, 2009) and increase clonal production (Gaoue *et al.*, 2018). Moreover, high fruit harvest of *P. butyracea* in Bassila region reduced long term population growth (Avocèvou-Ayisso, 2011). The negative impact of fruit harvest is highly expected when harvest take place in context of multiple stressors such as habitat size reduction (Gaoue *et al.*, 2018, Taubert *et al.*, 2018).

Interaction effect among threats of Pentadesma butyracea

Most forest habitats even in protected area are under multiple sources of disturbances. We found that published journal papers reported simultaneously some disturbances such as fragmentation and habitat size reduction (*FrRe*). Habitat loss and fragmentation may interact synergistically affect persistence of *P. butyracea* (Fletcher *et al.*, 2018a, Fahrig *et al.*, 2019, Sharp *et al.*, 2019). Despite this, most conservation researches focus on isolated effect of habitat size or fragmentation (Fahrig *et al.*, 2019). We also found three levels of interaction of disturbances such as fire, fruit harvest and habitat size reduction (*fiHaRe*). Fruit harvest in small habitat size often affected by fire can have a severe impact on population size and density of reproducing trees (Mora *et al.*, 2007, Pivello, 2011). All these finding suggest that synergistic effect of all threats should be investigation to prevent biodiversity declines (Brook *et al.*, 2008; Malcolm *et al.*, 2006). Due to the fact that interaction effects are often non-additive, it can be challenging to accurately predict the effect of more than one type of disturbance (Didham *et al.*, 2007).

Identified threats of *P. butyracea* can also interact with climate conditions to shape its response to those threats (Mora *et al.*, 2007, Karp *et al.*, 2018). For instance, worst ecological conditions can reduce plant growth which will return affect directly or indirectly seed production which often increase with the diameter (Lankoande *et al.*, 2017). The density, basal area and the diametric structure of *P. butyracea* vary according to the ecological region and to the anthropogenic disturbance intensity (Natta *et al.*, 2011a,b, Dicko *et al.*, 2016). Ecological or environmental conditions can also affect plant demographic performance. For example, *Pentadesma butyracea* produced more and big fruits and seeds in moist ecological region than in dry region (Ewédjè *et al.*, 2015).

Pentadesma butyracea Sabine and it habitat conservation

In situ conservation of *P. butyracea* is feasible than ex situ conservation (Ewedje 2012). Thus, most conservation strategies should act for the conservation of its habitat and the creation of orchards than the storage of its organs. Gallery forests are the most critical areas for high conservation priority in West-Africa (Natta *et al.*, 2002). They play socioeconomic, cultural and ecological roles (Ceperley *et al.*, 2010). In Benin, they are refugee of more than 1000 species of plants which represents about the third of the total flora of the country (Natta, 2003). They also are the refugee of threatened species (Natta *et al.*, 2002). Unfortunately, their sizes are reducing (Sinsin and Sinadouwirou, 2003). The enforcement of the forest law regarding the protection of gallery forest as *P. butyracea* habitat will help to fully protect at risk species habitat (Natta *et al.*, 2011a,b). *In situ* conservation strategies must limit it habitat reduction and for *ex situ* conservation, *P. butyracea* is suitable for orchards establishment (Ewédjè *et al.*, 2015). *P. butyracea* has the high spread ability in plantation in Seychelles in the upper part of the Rivière Cascade

(Richardson *et al.*, 2000). In Benin, there is an orchard plantation within the coastal forest at Ahozon (02°22'59.0″N, 02°09'38.7″E).

Ewédjè (2012) pointed out three main actors in effective conservation of *P. butyracea* and its habitat: Local communities, researchers and legislators of forest laws. For him, the first must interact with *Pentadesma butyracea* and its habitat in sustainable way, the second must undertake researches that will lead to effective conservation and the third design appropriate laws to effectively conserve *P. butyracea* habitat. Regulation can effectively stop gallery forests deforestation (Busch and Ferretti-Gallon, 2017). Natta *et al.* (2011b) suggest to promote in situ and ex situ conservation, to undertake domestication trials, and to raise awareness among local people as a means to reduce anthropogenic disturbance and preserve remnants populations of *P. butyracea*.

Some future conservation researches on Pentadesma butyracea

Threat to persistence of *P. butyracea* are high intensities of fruit harvest, logging, fragmentation, fire and gallery forest width reduction. How isolated threat affect plant population structure, demography, dynamic and genetic are largely investigated. However, how threat synergistically affect plant populations are poorly understood. Testing how those threats can synergistically affect demography and population growth rate will provide optimal conservation strategies than testing the effect of each single threat. The fitness consequence of clonal reproduction can also highlight how clonal plants adapt and spread in changeable environment. The study of genetic implication of increasing clonal offspring for a multi-use tree species with both clonal and sexual reproduction can help to identify more genetically diversify populations for effective conservation (Gaoue *et al.*, 2013).

Although there is an investigation of how fruit harvest can alter *P. butyracea* dynamic in moist ecological region (Avocevou-ayisso, 2011). However, the findings of a study may be ecological context dependent (Ticktin, 2004) requiring new studies at new environment or ecological conditions (Isaza *et al.*, 2017). A demographic study in both the dry and the moist ecological regions can improve our understanding of how variation of ecological conditions can mitigate the effect of non-timber forest product harvest (Ticktin, 2004). Moreover, methodological choices may bias the analysis output in demographic studies (Caswell, 2001). Matrix models are widely used to elucidate the effect of non-timber forest products harvest on demography of harvested populations (Schmidt *et al.*, 2011). Unfortunately, they are being criticized (Picard and Liang, 2014). Integral projection models (IPM) are new more robust methods (Easterling *et al.*, 2000).

They are built from continuous functions that describe size-dependent growth, survival, and fertility (Easterling *et al.*, 2000) and, as such, represent an advance over traditional matrix models (Ticktin *et al.*, 2016). It performs better for small demographic data than Matrix projection modeling (MPM) and put forward as a solution to the arbitrariness of the class division (Easterling *et al.*, 2000, Ellner and Rees, 2007, Metcalf *et al.*, 2013). Integral projection models can be used to investigate the effect of interactions between multiple forms of disturbance (Mandle *et al.*, 2015). On can use IPM to evaluate the effect multiple stressors on population growth rate of *P. butyracea* in both dry and moist regions.

Conclusion

Conservation researches are crucial in identifying key threats and suggesting conservation strategies. Here, we focused on a threatened food tree species, *P. butyracea* to showed that contrary to the fact that some authors considered *P. butyracea* like under studied species we need to guide our research toward an effective conservation researches. Most of the researches focused on its socioeconomical important and phytochemical composition with fewer investigations on conservation aspects. Fruit harvest was identified like the main threat to the persistence of *P. butyracea*. Journal papers mentioned four categories of threats which co-occur in the wild.

We suggested focusing on disentangling threats which driver *P. butyracea* population decline. This will provide useful information to practitioners and decision/policy makers. Then gallery forest restoration can help protecting the species.

Acknowledgements

This work was financially supported by the International Foundation for Science (Grant n° D/6092-1 to M.K) and IDEA WILD provided equipment to M.K.

References

Abbiw DK. 1990. Useful plants of Ghana: African uses of wild and cultivated plants (Intermedia). London: Kew.

Aissi MV, Tchobo FP, Natta A, Piombo G, Villeneuve P, Sohounhloue DCK, Soumanou MM. 2011. Effet des prétraitements post-récolte des amandes de *Pentadesma butyracea* (Sabine) sur la technologie d'extraction en milieu réel et la qualité du beurre. OCL **18(6),** 384-392.

Akoègninou A, Van der Burg W, Van der Maesen LJ. 2006. Flore Analytique Du Bénin.

Alitonou G, Avlessi F, Sohounhloue DCK, Bessière JM, Menut C. 2010. Chemical and biological investigation on volatile constituents of *Pentadesma butyracea* sabine (Clusiaceae) from Benin. Journal of Essential Oil Research **22(2),** 138-140.

Amissah L. 2014. Functional traits, drought performance, and the distribution of tree species in tropical forests of Ghana. PhD Thesis. Wageningen University, Wageningen, NL.

Avocèvou-Ayisso C. 2011. Etude de la viabilité des populations de Pentadesma butyracea Sabine et de leur socio-économie au Bénin. Thèse de Doctorat. Université d'Abomey-Calavi, Republique du Benin.

Avocèvou-Ayisso C, Avohou TH, Oumorou M, Dossou G, Sinsin BA. 2011. Ethnobotany of Pentadesma butyracea in Benin: A quantitative approach. Ethnobotany Research and Applications **9,** 151-166.

Avocèvou-Ayisso C, Sinsin BA, Adeagbidi A, Dossou G, Van Damme P. 2009. Sustainable use of non-timber forest products: Impact of fruit harvesting on Pentadesma butyracea regeneration and financial analysis of its products trade in Benin. Forest Ecology and Management (**257**), 1930 1938.

Ayegnon BP, Kayodé APP, Gnanvi G, Madodé Y, Balbine A, Azokpota P, Soumanou M, Hounhouigan JD. 2015a. Screening of the kernels of *Pentadesma butyracea* from various growing sites of Benin and evaluation of their antioxidant pigments content. African Journal of Biotechnology **14,** 1- 10.

Ayegnon BP, Kayodé APP, Nassia I, Barea B, Tchobo FP. 2009. Effects of storage conditions on the fatty acid composition of the butter of tallow tree (*Pentadesma butyracea*). Journal of Applied Biosciences 8630-8638.

Ayegnon BP, Kayodé AP, Tchobo FP, Azokpota P, Soumanou M, Hounhouigan DJ. 2015b. Profiling the quality characteristics of the butter of *Pentadesma butyracea* with reference to shea butter. Journal of Science of Food and Agriculture, DOI 10.1002/jsfa.7052

Badoussi E, Azokpota P, Madodé YE, Kayodé PAP, Dossou A, Soumanou M, Hounhouigan DJ. 2014. Variations in the traditional processing methods of *Pentadesma butyracea* butter in northern Benin. Food Chain **4(3),** 261-274

Badoussi E, Azokpota P, Madodé YE, Amoussou BF, Tchobo FP, Kayodé APP, Dossou A, Soumanou MM, Hounhouigan DJ. 2015a. Effet des opérations unitaires d'extraction sur le rendement et la qualité du beurre de Pentadesma butyracea produit en milieu traditionnel au Bénin. Journal of Applied Bioscences **86,** 7976-7989.

Badoussi E, Azokpota P, Madodé YE, Tchobo FP, Fagla B, Kayodé APP, Soumanou MM, Hounhouigan DJ. 2015b. Cooking and drying processes optimization of *Pentadesma butyracea* kernels during butter production. African Journal of Biotechnology **14,** 2777-2785.

Badoussi E, Madode YE, Amoussou BF, Azokpota P, Tchobo FP, Kayode APP, Soumanou MM, Hounhouigan JD. 2016. Optimisation de la torréfaction des amandes de P. butyracea pour la production du beurre. Annales Des Sciences Agronomiques **20(2),** 107-123.

Baker WL. 2006. Fire and restoration of sagebrush ecosystems. Wildlife Society Bulletin **34,** 177-185.

Bamps P. 1972. Répartition de Pentadesma en Afrique. Bulletin Du Jardin Botanique National de Belgique **41,** 430-432.

Brook B, Sodhi N, Bradshaw C. 2008. Synergies among extinction drivers under global change. Trends in Ecology and Evolution **23(8),** 453-460.

Brooks ME, Kristensen K, van Benthem KJ, Magnusson A, Berg CW, Nielsen A, Skaug HJ, Maechler M, Bolker BM. 2017. Glmmtmb Balances Speed and Flexibility Among Packages for Zero-inflated Generalized Linear Mixed Modeling. The R Journal **9(2),** 378-400.

Bruna E, Fiske I, Trager M. 2009. Habitat fragmentation and plant populations: is what we know demographically irrelevant. Journal of Vegetation Science **20,** 569-576.

Bruna EM. 2003. Are plant populations in fragmented habitats recruitment limited? Tests with an Amazonian herb. Ecology **84,** 932-947.

Bruna EM, Oli MK. 2005. Demographic effects of habitat fragmentation on a tropical herb: Life-table response experiments. Ecology **86(7)**, 1816-1824.

Burney DA, Flannery TF. 2005. Fifty millennia of catastrophic extinctions after human contact. Trends in Ecology and Evolution **20,** 395-401.

Busch J, Ferretti-Gallon K. 2017. What drives deforestation and what stops it. A metaanalysis. Review of Environmental Economics and Policy **11,** 3-23.

Caswell H. 2001. Matrix population models: Construction, analysis, and interpretation (2nd Ed.). Sunderland, Massachusetts: Sinauer Associates.

Ceperley N, Montagnini F, Natta AK. 2010. Significance of sacred sites for riparian forest conservation in Central Benin. Bois et Forets Des Tropiques **303,** 5-23.

Cote I, Darling E, Brown CJ. 2016. Interactions among ecosystem stressors and their importance in conservation. Proceedings of the Royal Society of London B: Biological Sciences **283**.

Curran L, Webb C. 2000. Experimental tests of the spatiotemporal scale of seed predation in mast-fruiting Dipterocarpaceae. Ecological Monographs **70,** 129-148.

Dencausse L, Nsourankoua H, Artaud J, Clamou JL. 1995. Comparison of the lipidic compositions of butters of *Pentadesma* and the shea tree. OCL **2,** 143-147.

Dicko A, Sorotori S, Honoré B, Natta A, Gado C, Kouagou M. 2016. Influence des pressions anthropiques sur la structure des populations de *Pentadesma butyracea* au Bénin. VertigO **16,** 0-21.

Didham R, Tylianakis J, Gemmell N, Rand T, Ewers R. 2007. Interactive effects of habitat modification and species invasion on native species decline. Trends in Ecology & Evolution **22,** 489-496.

Dosso K, Konate S, Akoua T, Kouakou M. 2011. The study of unburned savanna sections serving as temporary refuges for insects . An experiment in a tropical humid savanna in Côte d' Ivoire. Journal of Applied Biosciences **39,** 2607-2617.

Easterling MR, Ellner SP, Dixon PM. 2000. Size-specific sensitivity: applying a new structured population model. Ecology **81,** 694-708.

Ellner SP, Rees M. 2007. Stochastic stable population growth in integral projection models: theory and application. Journal of Mathematical Biology **54,** 227-256.

Emanuel PL, Shackletoncm, Baxter JS. 2005. Modeling the sustainable harvest of *Sclerocarya birrea* subsp. caffra fruits in the South African lowveld. Forest Ecol ogy and Management **214,** 91-103.

Ewédjè E-EBK. 2012. Biologie de la reproduction, phylogéographie et diversité de l'arbre à beurre *Pentadesma butyracea* Sabine (Clusiaceae) - implications pour sa conservation au Bénin. PhD Thesis. Université Libre de Bruxelles, Brussels, Belgium.

Ewédjè E-EBK, Ahanchédé A, Hardy OJ, Ley AC. 2015. Reproductive biology of *Pentadesma butyracea* (Clusiaceae), source of a valuable non timber forest product in Benin. Plant Ecology and Evolution **148(2),** 213-228.

Ewédjè E, Ahanchédé A, Hardy O. 2017. Breeding system, gene dispersal and small-scale spatial genetic structure of a threatened food tree species, *Pentadesma butyracea* (Clusiaceae) in Benin. Conservation Genetics **18(4),** 799-811.

Ewédjè E, Parmentier I, Natta A, Ahanchédé A, Hardy O. 2012. Morphological variability of the tallow tree, *Pentadesma butyracea* Sabine (Clusiaceae), in Benin. Genetic Resources and Crop Evolution **59,** 625-633.

Fahrig L. 2003. Effects of habitat fragmentation on biodiversity. Annual Review of Ecology and Systematics **34,** 487-515.

Fletcher RJ, Didham RK, Banks-Leite C, Ewers RM, Rosindell J, Holt RD, Haddad NM. 2018a. Is habitat fragmentation good for biodiversity. Biological Conservation **226,** 9-15.

Fletcher RJ, Reichert BE, Holmes K. 2018b. The negative effects of habitat fragmentation operate at the scale of dispersal. Ecology **99(10),** 2176-2186.

Frank B, Piccolo J, Baret P. 2011. A review of ecological models for brown trout: towards a new demogenetic model. Ecology of Freshwater Fish **20,** 167-198.

Fritts T, Rodda G. 1998. The role of introduced species in the degradation of island ecosystems: A case history of Guam. Annual Review of Ecology and Systematics **29,** 113-140.

Gaoue OG, Gado C, Natta AK, Kouagou M. 2018. Recurrent fruit harvesting reduces seedling density but increases the frequency of clonal reproduction in a tropical tree. Biotropica **50(1),** 69-73.

Gaoue OG, Horvitz CC, Ticktin T, Steiner UK, Tuljapurkar S. 2013. Defoliation and bark harvesting affect life-history traits of a tropical tree. Journal of Ecology **101(6),** 1563-1571.

Gaoue OG, Ticktin T. 2010. Effects of harvest of nontimber forest products and ecological differences on the demography of African mahogany. Conservation Biology **24(2),** 605-614.

Gaoue OG, Kouagou M, Natta A, Gado C. 2017. Response of a tropical tree to non-timber forest products harvest and reduction in habitat size. PLoS ONE **12(8),** e0183964.

Gaoue O, Ticktin T. 2008. Impacts of bark and foliage harvest on *Khaya senegalensis* (Meliaceae) reproductive performance in Benin. Journal of Applied Ecology **45,** 34-40.

Goswami VR, Vasudev D, Oli MK. 2014. The importance of conflict-induced mortality for conservation planning in areas of human-elephant co-occurrence. Biological Conservation **176,** 191-198.

Guedje NM, Lejoly J, Nkongmeneck BA, Jonkers WBJ. 2003. Population dynamics of *Garcinia lucida* (Clusiaceae) in Cameroonian Atlantic forests. Forest Ecology and Management **177,** 231-244.

Houédjissin SS, Azokpota P, Assogbadjo A, Ahanhanzo C, Hounhouigan JD. 2016. Traditional classification, perception, and preferences for tallow tree (*Pentadesma butyracea* Sabine) Organs in Benin: Implications for domestication and conservation. Ethnobotany Research & Applications **503,** 491-503.

Houédjissin SS, Dangou SJ, Azokpota P, Cacaï G, Agbidinoukoun A, Hounhouigan DJ, Ahanhanzo C. 2015. Régénération in vitro de l'arbre à suif (*Pentadesma butyracea* Sabine), une espèce ligneuse à usages multiples (LUM) vulnérable au Bénin. European Scientific Journal **11(21),** 150-167.

Isaza C, Bernal R, Galeano G, Martorell C. 2017. Demography of Euterpe precatoria and Mauritia flexuosa in the Amazon: application of integral projection models for their harvest. Biotropica **49(5),** 653-664.

Karp DS, Frishkoff LO, Echeverri A, Zook J, Juárez P, Chan K. 2018. Agriculture erases climate-driven β-diversity in Neotropical bird communities. Global Change Biology **24,** 338-349.

Kolb A. 2005. Reduced reproductive success and offspring survival in fragmented populations of the forest herb Phyteuma spicatum. Journal of Ecology **93(6)**, 1226-1237.

Kouagou M, Ahoundjinou O, Biaou S, Keita N, Natta A. 2018. Impact of fragmentation on tree diversity, density and structure of *P. butyracea* Sabine Clusiaceae population in Benin (West-Africa). International Journal of Biology and Chemical Sciences **12(5),** 1965-1975.

Lankoande B, Ouedrago A, Boussim IJ, Lykke AM. 2017. Identification of determining traits of seed production in *Carapa procera* and *Pentadesma butyracea*, two native oil trees from riparian forests in Burkina Faso, West Africa. Biomass and Bioenergy **102,** 37-43.

Laurance WF, Useche DC. 2009. Environmental synergisms and extinctions of tropical species. Conservation Biology **23,** 1427-1437.

Laurance W, Lovejoy T, Vasconcelos H, Bruna E, Didham R, Stouffer P, Sampaio E. 2002. Ecosystem decay of Amazonian forest fragments: A 22-year investigation. Conservation Biology **16,** 605-618.

Lawes MJ, Adie H, Russell-Smith J, Murphy B, Midgley JJ. 2011. How do small savanna trees avoid stem mortality by fire. The roles of stem diameter, height and bark thickness. Ecosphere **2,** 1-13.

Lefcheck J. 2016. PIECEWISESEM: Piecewise structural equation modelling in R for ecology, evolution, and systematics. Methods in Ecology and Evolution **7,** 573-579.

Lenta BN, Kamdem LM, Ngouela S, Tantangmo F, Devkota KP, Boyom FF, Tsamo E. 2011. Antiplasmodial constituents from the fruitpericarp of *Pentadesma butyracea*. Planta Med **77,** 377-379.

Malcolm J, Liu C, Neilson R, Hansen L, Hannah L. 2006. Global warming and extinctions of endemic species from biodiversity hotspots. Conservation Biology **20,** 538-548.

Mandle L, Ticktin T, Zuidem PA. 2015. Resilience of palm populations to disturbance is determined by interactive effects of fire, herbivory and harvest. Journal of Ecology **103,** 1032-1043.

Melo FPL, Lemire D, Tabarelli M. 2007. Extirpation of large-seeded seedlings from the edge of a large Brazilian Atlantic forest fragment. Ecoscience **14,** 124-129.

Metcalf CJE, McMahon SM, Salguero-Gomez R, Jongejan E. 2013. IPMpack: an R package for integral projection models. Methods in Ecology and Evolution **4,** 195-200.

Mora C, Metzger R, Rollo A, Myers RA. 2007. Experimental simulations about the effects of overexploitation and habitat fragmentation on populations facing environmental warming. Proceedings of the Royal Society of London B: Biological Sciences **274,** 1023-1028.

Natta A. 2003. Ecological assessment of riparian forests in Benin: phytodiversity, phytosociology and spatial distribution of tree species. PhD. Thesis. Wageningen University.

Natta AK, Adomou AC, Tchabi VI, Sogbegnon AR, Mensah GABA. 2011a. Inventaire, typologie et structure des populations naturelles de *Pentadesma butyracea* (Clusiaceae) de la chaîne de l'Atacora au Nord-Ouest du Bénin. Bulletin de Recherche Agronomique du Bénin **70,** 10-24.

Natta A, Yedomonhan H, Zoumarou-Wallis N, Houndehin J, Ewédjè E, Glele Kakai RL. 2011b. Typologie et structure des populations naturelles de *Pentadesma butyracea* dans la zone soudano-guineenne du Benin. Annales Des Sciences Agronomiques **15(2),** 217-243.

Natta AK, Sogbégnon R, Tchobo F. 2010. Connaissances Endogènes et Importance du *Pentadesma butyracea* (Clusiaceae) pour les Populations Autochtones au Nord-Ouest Bénin. Fruit, Vegetable and Cereal Science and Biotechnology **4,** 18-25.

Natta A, Sinsin B, van der Maesen L. 2002. Riparian forest, a unique but endangered ecosystem in Benin. Notulae Florae Beninensis 4. Botanische Jahrbucher **124,** 55-69.

Natta A, Zoumarou-Wallis N, Akossou AY, Houndehin J. 2013. Effets de l'eau et de la lumière sur la germination des graines de *Pentadesma butyracea* Sabine au centre Bénin. Annales de l'Universite de Parakou, Série : Sciences Naturelles et Agronomiques **2(2),** 9-15.

Neuenschwander P, Sinsin BA, Goergen G. 2011. Protection de la nature en Afrique de l'Ouest: une liste rouge pour le Benin. Nature conservation in West Africa: Red List for Benin. International Institute of Tropical Agriculture, Ibadan, Nigeria.

Ning-Hua T, Chang-Jiu J, Tala FM, Wabo KH, Zeng G, Tane P. 2015. A prenylated xanthone and antiproliferative compounds from leaves of *Pentadesma butyracea*. Phytochemistry Letters 326-330.

Noudogbessi J, Natta A, Tchobo F, Bogninou G, Bothon F, Bossou A, Figueredo G, Chalard P, Chalchat JC, Sohounhloue D. 2013. Phytochemical screening of *Pentadesma butyracea* Sabine (Clusiaceae) acclimated in Benin by GC/MS. ISRN Analytical Chemistry 1-8.

Picard N, Liang J. 2014. Matrix Models for Size-Structured Populations: Unrealistic Fast Growth or Simply Diffusion? PLoS ONE **9(6)**.

Pivello V. 2011. The use of fire in the Cerrado and Amazonian Rainforests of Brazil: Past and present. Fire Ecology **7,** 24-39.

Poschlod P, Bonn S. 1998. Changing dispersal processes in the central European landscape since the last ice age: An explanation for the actual decrease of plant species richness in different habitats. *Acta* Botanica Neerlandica **47,** 27-44.

Pounds JA, Bustamante MR, Coloma LA, Consuegra JA, Fogden MPL, Foster PN, La Marca E, Masters KL, Merino-Viteri A, Puschendorf R, Ron SR, Sánchez-Azofeifa GA, Still CJ, Young BE. 2006. *Widespread amphibian* extinctions from epidemic disease driven by global warming. Nature **439,** 161-167.

Price S, Gittleman J. 2007. Hunting to extinction: Biology and regional economy influence extinction risk and the impact of hunting in artiodactyls. Proceedings of the Royal Society of London B: Biological Sciences **274,** 1845-1851.

R Core Team. 2018. R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from https://www.r-project.org/.

Rachman O, Balfas J. 1987. Machining properties of wood species from West Java. Journal-Penelitian-Hasil-Hutan **4,** 54-64.

Raponda-Walker A, Sillans R. 1961. Useful plants of Gabon (Paul Leche). Paris, France.

Richardson DM, Pyšek P, Rejmánek M, Barbourmg, Panetta FD, West CJ. 2000. Naturalization and invasion of alien plants: Concepts and definitions. Diversity and Distributions **6(2),** 93-107.

Rutledge D. 2003. Landscape indices as measures of the effects of fragmentation: can pattern reflect process. Department of Conservation, Wellington: Science Internal Series 98.

Salzmann U, Hoelzmann P. 2005. The Dahomey Gap: an abrupt climatically induced rain forest fragmentation in West Africa during the late Holocene. The Holocene **15(2),** 1-10.

Sama B, Sacandé M, Schmidt LH. 2007. Pentadesma butyracea Sabine. Seed Leaflet.

Schmidt I, Mandle L, Ticktin T, Gaoue O. 2011. What do matrix population models reveal about the sustainability of non-timber forest product harvest. Journal of Applied Ecology. **48,** 815-826.

Schreckenberg K. 1996. Forest, fields and markets: A study of indigenous Tress products in the Woody savannas of the Bassila region. University of London, UK.

Sharp AC, Barclay MVL, Chung AYC, Ewers RM. 2019. Tropical logging and deforestation impacts multiple scales of weevil beta-diversity. Biological Conservation **234,** 172-179

Sinsin BA, Sinadouwirou A. 2003. Valorisation socio-économique et pérennité du Pentadesma butyracea Sabine en galeries forestières au Bénin. Cahiers Agricultures **12,** 75-79.

Sinsin B, Avocévou C. 2007. *Pentadesma butyracea Sabine*. (van der Vossen HAM, Mkamilo GS, Eds.) (PROTA 14:).

Sizer N, Tanner E. 1999. Responses of woody plant seedlings to edge formation in a lowland tropical rainforest, Amazonia. Biological Conservation **91,** 135-142.

Sutherland WJ, Adams WM, Aronson RB, Aveling R, Blackburn TM, Broad S, Ceballos G, Côté IM, Cowling RM, Da Fonseca GAB, Dinerstein E, Ferraro PJ, Fleishman E, Gascon C, Hunter Jr M, Hutton J, Kareiva P, Kuria A, Macdonald DW, Mackinnon K, Madgwick FJ, Mascia MB, McNeely J, MilnerGulland EJ, Moon S, Morley CG, Nelson S, Osborn D, Pai M, Parsons ECM, Peck LS, Possingham H, Prior SV, Pullin AS, Rands MRW, Ranganathan J, Redford KH, Rodriguez JP, Seymour F, Sobel J, Sodhi NS, Stott A, Vance-Borland K, Watkinson AR. 2009. One hundred questions of importance to the conservation of global biological diversity. Conservation Biology **23,** 557-567.

Tabarelli M, Cardosa da Silva JM, Gascon C. 2004. Forest fragmentation, synergisms and the impoverishment of neotropical forests. Biodiversity and Conservation **13,** 1419-1425.

Tala MF, Wabo HK, Zeng GZ, Ji CJ, Tane P, Tan NH. 2013. A prenylated xanthone and antiproliferative compounds from leaves of Pentadesma butyracea. Phytochemistry Letters **6,** 326-330.

Taubert F, Fischer R, Groeneveld J, Lehmann S, Müller MS, Rödig E, Wiegand T, Huth A. 2018. Global patterns of tropical forest fragmentation. Nature **554,** 519-522.

Tchobo FP, Natta AK, Barea B, Barouh N, Piombo G, Pina M, Villeneuve P, Soumanou MM, Sohounhloue DCK. 2007. Characterization of *Pentadesma butyracea* sabine butters of different production regions in Benin. Journal of American Oil Chemical Society **84,** 755-760.

Ticktin T. 2004. The ecological implications of harvesting non-timber forest products. Journal of Applied Ecology **41(1),** 11-21.

Ticktin T, Ganesan R, Paramesha M, Setty S. 2012. Disentangling the effects of multiple anthropogenic drivers on the decline of two tropical dry forest trees. Journal of Applied Ecology **49(4),** 774-784.

Ticktin T, Mondragón D, Gaoue O. 2016. Host genus and rainfall drive the population dynamics of a vascular epiphyte. Ecosphere **7(11),** e01580.

Tindano B, Bayala B, Doukoure M, Belemtougri R, Tamboura H, Sawadogo L. 2017. Phytochemical composition, acute toxicity and phytohormonal activity of hydroalcoholic extract of *Pentadesma butyracea* (Clusiaceae Sabine (1824)) seeds. Journal of Medicinal Plants Research **11(42),** 656-664.

Wabo HK, Kikuchi H, Katou Y, Tane P, Oshima Y. 2010. *Xanthones* and *Abenzophenone* from the roots of *Pentadesma butyracea* and their antiproliferative activity. Phytochemistry Letters **3,** 104-107.

White L, Albernethy K. 1996. *G*uide de la végétation de la Réserve de la Lopé. Gabon. Libreville: ECOFAC.

Wintle BA, Kujala H, Whitehead A, Cameron A, Veloz S, Kukkala A, Gordon A, Lentini PE, Cadenhead NCR, Bekessy SA, Moilanen A. 2019. Global synthesis of conservation studies reveals the importance of small habitat patches for biodiversity. PNAS **116(3),** 909-914

Zelefack F, Guilet D, Fabre N, Bayet C, Chevalley S, Ngouela S, Dijoux-Francamg. 2009. Cytotoxic and antiplasmodial *Xanthones* from *Pentadesma butyracea*. Journal of Natural Products **72,** 954-957.