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TESIS DOCTORAL:

Participation of society in breeding and conservation programs for food tree species in Niger (West Africa)

Participación de la sociedad en programas de mejora y conservación de especies forestales alimenticias en Níger (África Occidental)

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A Antonio y María Cristina, siempre fieles a mi vocación por África. A mis hermanos, María Cristina, Juan y Daniel, y especialmente a Antonio. Te fuiste sin entender bien qué hacía yo allí, ahora ya lo sabes.

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SUMMARY

This thesis seeks as main objective to encourage the participation of society in its own development. More specifically, to involve the rural population, whose livelihood is found in low productivity agroforestry systems, in the promotion and improvement of their quality of life, nutritional and food security. Agroforestry systems of the Republic of Niger (West Africa), are based on (i) an arboreal and shrubby stratum remaining from the original forests, (ii) the extensive cultivation mainly of millet, and (iii) the livestock production also extensive and predominantly transhumant. The Sahel region, and Niger in particular, has seen its woody cover reduced due to worsening environmental conditions and unsustainable management practices, aggravated by the increase in population pressure. This has resulted in a problem of land availability, which, together with low agricultural productivity, causes populations to experience annual periods of food shortages that can range from 5 to 8 months, depending on the regions of the country. This, in turn, has led to a phenomenon assumed currently as usual, such as the seasonal migration of men and young to other countries in the sub region during a period from harvest until the new sowing.

This study takes two agroecological regions of Niger as a model for the conservation and improvement of food forest resources, within the production system in which they are found. The non-wood forest products (NWFP) have great importance as a source of food as part of the diet and even replacing the basic food in times of crisis. Trees in marginal lands and agroforestry systems have great ecological, economic, medicinal and nutritional value for rural populations. Some of these products, such as the leaves of *Adansonia digitata* (baobab) used daily in rural households, have become a priority sector for the Niger economy.

The thesis analyzes the social preferences for programs of conservation and improvement of woody food species in agroforestry systems. The problem (above all in the arid regions) has been that traditional management can't adapt to the current conditions arising from climate change and increased human pressure. Furthermore, changes that affect the density, quality, and composition of the tree cover have a direct impact on the genetic

resources of the species. But, if we merely proposed the recovery of the arboreal part of the system, then the system would tend to revert to the current situation. We therefore want to incentivize farmers so that they participate in designing and implementing a sustainable program that all the players involved can agree upon: farmers, merchants, consumers, civil society, and the local and national administrations.

For that purpose, based on focus groups and individuals questionnaires (i) in study 1, local communities have prioritized the species and evaluated their current conservation status, (ii) in study 2, farmers have stated their willingness to work to perform conservation and breeding programs, and (iii) study 3, consumers have shown a positive willingness to pay to preserve and improve these natural resources.

Different statistical analyses gives us a general view of the perception of a declining occurrence of food woody species. A complex system of common threat factors emerges but not providing a univocal explanation for all species investigated, being the main ones identified overexploitation, pests and diseases, and drought.

Environmental economics methods showed that farmers and consumers would participate in the conservation and improvement of food tree species. Farmer's preferred scenario for the recovery and improvement of the production system was that one based on the species conservation and breeding of *A. digitata*, by plantation of selected material in half-moons, with a 49% of the farmers participating for a minimum of 5 years and a 38.75% for an indefinite period. The reasons of consumers participating in the program are because of the tradition of using baobab products, which are good for health, because the conservation and improvement of baobab is important, and to ensure the availability of the leaves of baobab in the market.

Based on results of previous studies and on the existing knowledge about *A. digitata*, the main actions, tools and actors for achieving a sustainable management and conservation program of a valuable food tree species are proposed in the application of the results.

RÉSUMÉ

Cette thèse a pour objectif principal d'encourager la participation de la société à son propre développement. En d'autres termes, impliquer la population rurale, dont les moyens de subsistance se trouvent dans des systèmes agroforestiers à faible productivité, dans la promotion et l'amélioration de leur qualité de vie, et dans leur sécurité alimentaire et nutritionnelle. Les systèmes agroforestiers de la République du Niger (Afrique de l'Ouest), un des pays les plus pauvres du monde, sont basés sur une strate arborée et arbustive originaire des anciennes forêts, sur la culture extensive principalement de mil, et un élevage aussi extensif et surtout transhumant. La région du Sahel, et le Niger en particulier, ont vu leur couvert arboré réduit en raison de la détérioration des conditions environnementales et des pratiques de gestion non durables, dû à la situation critique de changement climatique et de dégradation des sols, et aggravée par l'augmentation de la pression démographique. Cela s'est traduit par un problème de disponibilité des terres qui, conjugué à une faible productivité agricole, entraîne des périodes annuelles de pénurie alimentaire pouvant aller de 5 à 8 mois, selon les régions du pays. Ceci, à son tour, a provoqué un phénomène devenu habituel, tout comme la migration saisonnière des hommes vers d'autres pays de la sous-région pendant la période entre la récolte et la nouvelle semence.

Cette étude prend deux régions agroécologiques du Niger comme modèle pour la conservation et l'amélioration des ressources forestières alimentaires, au sein du système de production dans lequel elles se trouvent. Les produits forestiers non ligneux sont d'une grande importance dans le cadre du régime alimentaire et remplacent même les aliments de base en temps de crise. Les arbres dans les terres marginales et les systèmes agroforestiers ont une grande valeur écologique, économique, médicinale et nutritionnelle pour les populations rurales. Certains de ces produits, tels que les feuilles d'*Adansonia digitata* (baobab) utilisées quotidiennement par les ménages ruraux, sont devenus un secteur prioritaire pour l'économie nigérienne.

La thèse analyse les préférences sociales dans les programmes de conservation et d'amélioration des espèces ligneuses alimentaires présentes dans les systèmes agroforestiers. Le problème (surtout dans les régions arides) est que la gestion traditionnelle ne peut pas

s'adapter aux conditions actuelles découlant du changement climatique et de l'augmentation de la pression humaine. De plus, les changements qui affectent la densité, la qualité et la composition de la couverture arborée ont un impact direct sur les ressources génétiques de l'espèce. De plus, si nous proposions simplement la récupération de la partie forestière du système, sans tenir en compte les besoins agropastoraux, cela aurait tendance à revenir à la situation actuelle. Par conséquent, nous voulons encourager les agriculteurs à participer à la conception et à la mise en œuvre d'un programme durable dans lequel tous les acteurs impliqués peuvent parvenir à un accord: agriculteurs, commerçants, consommateurs, société civile et administrations locales et nationales.

À cette fin, à travers des groupes de discussion et des questionnaires individuels (i) étude 1, les communautés locales ont hiérarchisé les espèces et évalué leur état de conservation actuel, (ii) étude 2, les agriculteurs ont déclaré leur volonté de participation par leur effort de travail iii) étude 3, les consommateurs ont montré une volonté positive de payer une prime pour préserver et améliorer ces ressources naturelles.

Différentes analyses statistiques nous ont permis d'avoir une vue générale sur la perception qu'a la société rurale sur la diminution de la présence d'espèces ligneuses alimentaires. Un système complexe de facteurs communs de menace découle de cette perception, sans fournir une explication univoque pour l'ensemble des espèces étudiées, les principaux facteurs étant la surexploitation, les ravageurs et les maladies, et la sécheresse.

Les méthodes d'économie environnementale, nous ont permis de montrer que les agriculteurs et les consommateurs participeraient à la conservation et à l'amélioration des espèces ligneuses alimentaires. Le scénario préféré par l'agriculteur pour la récupération et l'amélioration du système de production est celui qui envisage la conservation et l'amélioration de l'espèce *A. digitata*, par des plantations en demi-lunes et avec du matériel de reproduction sélectionné. Le 49% des agriculteurs participeraient pour un minimum de 5 ans et 38,75% pour une durée indéterminée. Les raisons pour lesquelles les consommateurs déclarent participer au programme sont dues à la tradition de l'utilisation des produits de baobab, car ceux-ci sont bons pour la santé, parce que la conservation et l'amélioration du baobab est important et à fin d'assurer la disponibilité des feuilles de baobab dans le marché.

Sur la base des résultats des études précédentes et de la connaissance existante sur *A. digitata*, les principales actions, outils et acteurs sont proposés à fin de réaliser un programme de gestion durable et de conservation de l'une des espèces forestières les plus précieuses pour la société du Niger et de l'Afrique en général.

RESUMEN

Esta tesis doctoral tiene como objetivo principal incentivar la participación de la sociedad en su propio desarrollo. Es decir, hacer partícipe principalmente a la población rural, cuyo medio de vida lo encuentra en sistemas agroforestales de baja productividad, en la promoción y mejora de su calidad de vida, y de su seguridad nutricional y alimentaria. Los sistemas agroforestales de la República de Níger (África Occidental), uno de los países más desfavorecidos del mundo, están basados en un estrato arbóreo y arbustivo remanente de los bosques originales, en el cultivo extensivo principalmente de mijo, y en una ganadería también extensiva y trashumante en su mayoría. La región del Sahel, y Níger en concreto, ha visto reducida su cubierta arbórea debido al empeoramiento de las condiciones medioambientales y las prácticas de manejo insostenibles para esta situación crítica de cambio climático y degradación de los suelos, agravadas por el aumento de la presión demográfica. Esto ha derivado en un problema de disponibilidad de tierras, que junto con la baja productividad agrícola, hace que las poblaciones padezcan anualmente periodos de carencia de alimentos que pueden ir de 5 a 8 meses, según las regiones del país. Esto a su vez, ha provocado un fenómeno asumido como habitual, como es la migración estacional de los hombres a otros países de la subregión durante el período comprendido entre la cosecha y la nueva siembra.

Este estudio toma dos regiones agroecológicas de Níger como modelo para la conservación y mejora de los recursos forestales alimenticios, dentro del sistema de producción en el que estos se encuentran. Los productos forestales no maderables tienen una gran importancia como parte de la dieta e incluso sustituyendo al alimento base en épocas de crisis. Los árboles en las tierras marginales y los sistemas agroforestales tienen un gran valor ecológico, económico, medicinal y nutricional para las poblaciones rurales. Algunos de estos productos, como las hojas de *Adansonia digitata* (baobab) utilizadas diariamente en la alimentación de los hogares rurales, se han constituido como sector prioritario para la economía de Níger.

La tesis analiza las preferencias sociales ante los programas de conservación y mejora de especies de leñosas alimenticias presentes en los sistemas agroforestales. El problema

(sobre todo en las regiones áridas) ha sido que la gestión tradicional no puede adaptarse a las condiciones actuales derivadas del cambio climático y del aumento de la presión humana. Además, los cambios que afectan la densidad, la calidad y la composición de la cubierta arbórea, tienen un impacto directo en los recursos genéticos de las especies. Pero, si simplemente propusiéramos la recuperación de la parte arbórea del sistema, sin tener en cuenta las necesidades agropastorales, este tendería a volver a la situación actual. Por lo tanto, queremos incentivar a los agricultores para que participen en el diseño y la implementación de un programa sostenible en el que todos los actores involucrados puedan ponerse de acuerdo: agricultores, comerciantes, consumidores, sociedad civil y las administraciones locales y nacionales.

Para tal fin, mediante grupos de discusión y cuestionarios individuales (i) en el estudio 1, las comunidades locales han priorizado las especies y evaluado su estado de conservación actual, (ii) en el estudio 2, los agricultores han declarado su voluntad de trabajar para realizar programas de conservación y mejora, y (iii) en el estudio 3, los consumidores han mostrado una disposición positiva a pagar para preservar y mejorar estos recursos naturales.

Diferentes análisis estadísticos nos han permitido obtener una visión general sobre la percepción que la sociedad rural tiene de la disminución de la presencia de especies leñosas alimenticias. Un complejo sistema de factores de amenaza comunes surge de esta percepción, sin proporcionar una explicación unívoca para todas las especies investigadas, siendo los principales factores la sobreexplotación, las plagas y enfermedades, y la sequía.

Los métodos de economía ambiental nos han permitido mostrar que los agricultores y consumidores participarían en la conservación y mejora de las especies de árboles alimenticios. El escenario preferido por el agricultor para la recuperación y mejora del sistema de producción es el que contempla la conservación y mejora de la especie *A. digitata*, por plantaciones en medias lunas con material de reproducción seleccionado. Un 49% de los agricultores participaría durante un mínimo de 5 años y un 38.75% por un período indefinido. Las razones de los consumidores declaran para participar en el programa se deben a la tradición de utilizar productos de baobab, porque estos son buenos para la salud, porque la conservación y mejora del baobab es importante y para garantizar la disponibilidad de las hojas de baobab en el mercado.

Con base en los resultados de estudios anteriores y en el conocimiento existente sobre *A. digitata*, en la aplicación se proponen las principales acciones, herramientas y actores para lograr un programa de gestión y conservación sostenible de una de las especies forestales alimenticias más valiosa para la sociedad de Níger, y de África en general.

ESTRUCTURA DE LA TESIS DOCTORAL

La tesis doctoral se estructura en tres estudios y la aplicación práctica de estos. La identificación de los problemas y las soluciones se han ido estudiando a lo largo de la tesis desde una visión más general en el esudio 1 hasta una aplicación práctica, que define los elementos necesarios para que las comunidades locales participen en la conservación y mejora de la especie leñosa alimenticia autóctona y prioritaria por excelencia para la sociedad nigerina, *Adansonia digitata*. A continuación se expone un mapa con los estudios o etapas seguidas en el desarrollo de la tesis (Figura E1).

Figura E1. Esquema de la tesis y de la progresión que siguen los tres estudios y su aplicación.

El estudio 1 se basa en la consideración del conocimiento y las percepciones locales desde una fase inicial del diseño de las actividades de mejora y conservación. A la identificación de las especies leñosas prioritarias, le sigue una evaluación de la percepción de su estado de conservación y de los factores que actúan sobre la conservación de las especies. Los

datos se han obtenido a partir de encuestas dirigidas a grupos de discusión y personas clave, y analizados con distintas herramientas estadísticas. Los resultados de este estudio nos han permitido identificar las cuatro especies prioritarias para diseñar un programa de conservación, dando paso al estudio 2.

Con el fin de proponer actividades participativas de gestión y conservación de acuerdo con las preferencias de las comunidades beneficiarias, en el estudio 2 se realiza un diagnóstico sobre la disposición a participar y la asignación óptima que garantizaría la participación de las comunidades locales en los programas de conservación y mejora de sus sistemas agroforestales. Para ello, se ha diseñado un ejercicio de valoración basado en métodos de elección discreta que permite predecir las preferencias y los valores que otorgan los agricultores a los elementos que constituyen el programa. La herramienta para la toma de datos se basa en encuestas a los agricultores. La especie *A. digitata*, conocida comúnmente como baobab, se muestra como la que mayor valor alimenticio proporciona a los agricultores, por lo que los siguientes estudios se centran en esta especie.

El estudio 3 trata de la participación de los consumidores en los programas de conservación y mejora. Nos centramos en el mercado y en el estudio de las preferencias de los consumidores de productos de baobab. Hemos aplicado el método de valoración contingente para comprobar si los consumidores están dispuestos a pagar un sobreprecio en su cesta de consumo con el fin de cofinanciar el programa de conservación. A los consumidores se les explica la situación actual de los recursos de *A. digitata*, y el efecto que se obtendría tras la aplicación de estos programas en los sistemas agroforestales, garantizando la disponibilidad de los productos de baobab en el mercado.

La aplicación identifica las herramientas para la mejora de la producción y conservación de *A. digitata* en Níger, en la que los agricultores y consumidores serían los actores directos, como representantes de la sociedad nigerina interesada en su propio desarrollo. La identificación de los distintos elementos se ha realizado aplicando los resultados obtenidos en los estudios anteriores y por revisión bibliográfica. Este estudio supone la base para la gestión sostenible, y la conservación y mejora de los recursos de las especies leñosas alimenticias en una de las zonas menos favorecidas del mundo.

Artículo científico derivado de la tesis doctoral, como requisito para su presentación y defensa.

El estudio 1 ha sido publicado en la revista Forest Systems, Q3 en Forestry (JCR 2016).

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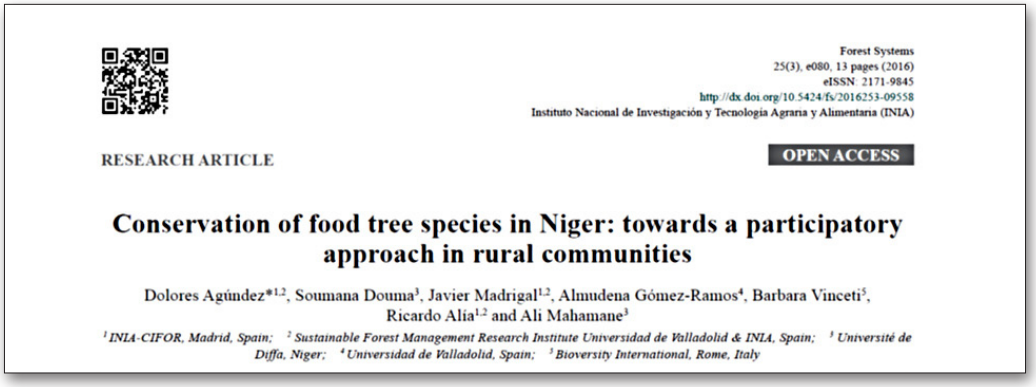

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RESEARCH ARTICLE

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Conservation of food tree species in Niger: towards a participatory approach in rural communities

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INTRODUCTION

This doctoral thesis discusses the promotion of food and nutritional security and the role played by forestry products in the promotion thereof in one of the most disfavored countries of the world, the Republic of Niger. The thesis therefore also discusses the conservation and breeding of woody species, trees, and shrubs of high food value in that country, where promotion efforts are designed for and include the participation of those who are directly involved. It is a study that offers a tool for assuring the conservation of, the availability of, and access to naturally occurring woody species that provide food products, in sufficient quantity and quality for both local communities and the Nigerien society as a whole. The results obtained will make it possible to convey the needs of this society and reinforce the capabilities of the agents who are directly involved in the production and consumption of these products, which must be seen as key elements in the processes of national planning and policy on the environment, agriculture, and food security.

Food and nutritional security

Hunger and malnutrition are the direct results of food insecurity. They restrict vital human functions, they threaten the right to life, and they block opportunities to develop capabilities, thereby preventing human development at a basic level. Approximately 795 million people in the world, more than one out of every nine persons, cannot consume enough food to lead a healthy life. The vast majority, approximately 780 million, live in developing regions. In sub-Saharan Africa, it is calculated that approximately 220 million people suffer from hunger (FAO, IFAD, WFP, 2015), meaning practically one out of every four people.

The Republic of Niger is one of the poorest countries in the world. According to the 2016 Human Development Index (HDI), Niger holds position 187 out of the 188 countries indexed in the world (UNDP, 2016a), despite being the sixth leading country in the group with a gradual positive change in the period between 2000 and 2014 (UNDP, 2016b). Likewise, Niger is the African country with the highest Multidimensional Poverty Index

(MPI): 73.5% of the population of Niger is in a state of severe multidimensional poverty and 5.9% is in a state of near multidimensional poverty.

Food and nutritional security requires that foods be available, that they be accessible, and that they be in sufficient quantity and be of sufficient quality to assure good nutritional results. Adequate nutrition helps people to develop all their potential and take advantage of the opportunities offered by the development process (FAO, IFAD, WFP, 2015), and it allows people to make their own choices and build resilience to face crises. Building resilience, understood as the capacity to overcome critical moments and adapt and/or return to normalcy after experiencing an unusual and unexpected situation, is specific for local conditions. In Niger, both structural poverty and the persistent shortage of food production cause the population to be highly vulnerable to weather and economic disturbances.

The role of forests and forest systems in nutrition

This doctoral thesis focuses on the importance of forest systems in nutrition. It is calculated that, more than 10 millennia after the onset of agriculture, in the majority of regions in the world there are millions of small rural producers who still depend on wild products for their nutrition and subsistence (Wunder et al., 2014). Ickowitz et al. (2014) found a positive relationship between forest cover and diet diversity, which suggests that children in Africa who live in areas with more forest cover have more diverse and nutritional diets. At the same time, it is evident that forests and forest systems play an important role in complementing agricultural production by providing better and more nutritionally balanced diets (Vinceti et al., 2013).

Agroforestry systems and their non-wood forest products (NWFP) are a source of food, such as fruits, fats, oils, leafy vegetables, dried fruit and nuts, and condiments, which are used to complement the basic food crops in local diets (Faye et al., 2011; Kalinganire et al., 2007). Agroforestry is considered to be one of the few solutions that can provide a combination of food security and resilience to climate change and provide one of the best possible solutions for conserving the environment and biodiversity (Mbow et al., 2014). Trees and shrubs in marginal lands or in agroforestry systems have high ecological, economic, and nutritional value for the homes of poor rural communities (Pingali et al., 2014; Thiombiano et al., 2013; Assefa and Abebe, 2011; Larwarnou and Saadou, 2011).

The baobab (*Adansonia digitata*) represents a specific case of the importance of these resources in nutrition, and it is a tree for which over 300 different uses have been

identified in Western Africa and whose leaves and fruits are consumed daily by 90% of the people in semi-arid zones (Buchmann et al., 2010). In rural zones of Burkina Faso, local fruits play a fundamental role in the balance of diets, given the contribution by their content in proteins, fats, sugars, minerals, and mainly vitamins to satisfying nutrient needs (Lamien et al., 2009). These latter authors suggest that many deficiency diseases are avoided by children in Burkina Faso most likely as a result of consuming local fruits as if they were sweets or appetizers. As another example, in Niger the fruits and nuts of *Sclerocarya birrea* are a useful food supplement, not only for children but also for adults (Glew et al., 2004).

In addition to the fact that production from the trees play a direct role in nutrition, there are also normally more resistant to adverse ecological conditions than crops in agricultural production. The trees therefore constitute a safety net at times when the annual production from crops may be lost, as well as in periods of food shortage between two harvests (Blackie et al., 2014). For example, the seed of *Boscia senegalensis* (anza in local language), a wild shrub or small tree, is traditionally used as a staple food in times of food shortage in arid zones of Niger (Kim et al., 1997), and it continues to be associated with famines, considering anza's use as a staple during the crises of 1970 and 2000.

Unfortunately, national and international communities don't give forest systems the merit they deserve. They play a crucial role in achieving global food security by complementing agricultural production systems, especially by providing production and consumption systems that are resilient and accessible to the most vulnerable groups (Blackie et al., 2014; Keller et al., 2006; Shackleton and Shackleton, 2004). Even without this recognition, the foods coming from forests and forest systems will continue to form an essential part of the strategies of rural homes as a food source and as a way to achieve nutritionally balanced diets.

The use of forest species for nutrition in the Republic of Niger

The Republic of Niger is located in West Africa, south of the Sahara Desert, and is one of the countries included in the Sahel region. The Sahel is the region of Africa where the Sahara Desert borders the tropical, sub-Saharan zone (Sudanese region), with both of these regions forming the semi-arid Sudanese-Sahelian zone that goes from East to West Africa, from Senegal to Somalia, with an annual mean precipitation of between 200 and 1000 mm (Figure 1). In this region, human prosperity is closely linked to the resources offered by the vegetation, given that the life strategy of approximately 80%

of the population is based on traditional practices of subsistence farming through agricultural and livestock production (FAO, 2016). The beginning of the rainy season, which has major importance for growing cereals, comes increasingly later, with serious episodes of drought followed by major floods.

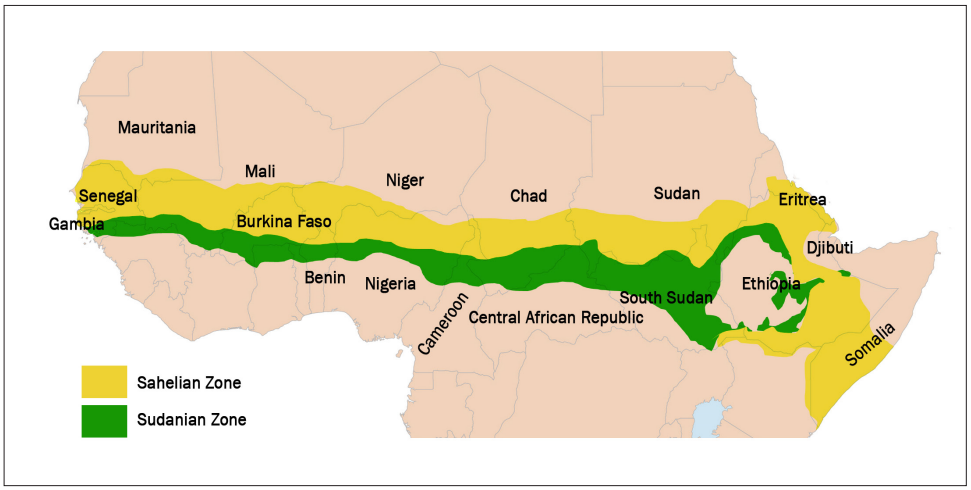


Figure 1. Semi-arid, Sudanese-Sahelian zone (modified from Karlson and Ostwald, 2015).

Agricultural production is generally insufficient to cover the needs of the local populations. A study conducted in Kollo (Tillaberi, Sudanese zone) illustrates this situation, where the majority of homes are involved in agriculture as the main activity. Nevertheless, all the homes are net buyers of food, because they do not produce enough to cover their food needs for the whole year. Some are even forced to sell part of their production as soon as it is harvested (when prices are low) in order to cover other needs, later having to purchase food when the prices have risen. 92.6% of homes state that they suffer from food scarcity at some point during the year (Zakari et al., 2014).

The Sudanese-Sahelian zone of Niger is a good model for studying and proposing management and conservation activities, thereby considering the great nutritional importance of non-wood forest products (NWFP), the environmental changes that are taking place and the high human interaction. Woody food species play an important role in the daily diet of adults and children, and they generate economic benefits for both rural and urban communities (Freiberger et al., 1998; Sena et al., 1998; Cook et al., 2000; Abasse et al., 2007; Bernholt et al., 2009). Many plants commonly regarded as foods in times of shortage are actually used daily in diets as traditional ingredients, even when there isn't s shortage of grain-based foods (Muller and Almedom, 2008). A preliminary study on the use of wild food plants in the peripheral zones of W National Park in Níger

(Dan Guimbo et al., 2012) determined that 12% of the plants there are consumed during the entire year, while the remainder (88%) have high consumption value during the dry season.

The problem is that woody food species are under pressure for several reasons (Larwanou and Saadou, 2005; Abdou, 2013; Dan Guimbo et al., 2012; Douma et al., 2010). The region is subject to the combined effects of climate change and human pressure, which are resulting in insufficient agricultural production, a decrease in forest cover, and an increase in soil degradation, all of which is in detriment to both food security and the development of the human population. The direction of the change and the factors thereof are not entirely clear (uncertainty about the changes caused by man versus those caused by the climate), and they can vary from one place to another. Despite this uncertainty, there is a general perception that degradation of the vegetation is progressively occurring, with a different impact in the Sahelian and Sudanese agroecological zones due to their different environmental conditions, the ethnic composition, migration processes, and greening efforts (Jalloh et al., 2012; Hermann et al., 2005). This degradation process must be corrected, and management and conservation practices must be improved to ensure the continued use and preservation of resources from at-risk woody food species that have vital traits (for example, populations and/or individuals of species that are resistant to drought).

Illustration of the management of agroforestry systems in the Sudanese-Sahelian zone of Niger

The agroforestry systems in Niger, as in other parts of West Africa, are traditional systems in which native woody species are protected and maintained in crop and pasture lands. Farmers follow different stages to reach their current system of cultivation. The land is cleared, while selecting trees according to the farmers' preferences, and those selected trees are subsequently pruned and protected, with the remainder being cut down. Once the production system is established, farmers eliminate any regeneration as it occurs and prune the trees that are kept (FAO, 2017).

Agricultural production systems in Niger are based on a subsistence system of agro-forest-pastoral production, with cereal crops (mainly millet and sorghum) as the basis of production. Traditionally, livestock have been allowed to take advantage of the waste after harvests, by agreement between and in mutual benefit to both the grower and the livestock farmer, given that the fields are then left fertilized after the animals pass

through. More recently, it is common to find growers who also keep a few head of small livestock. Consequently, growers use the millet or sorghum straw from the fields to feed their animals, or they may even harvest the straw for sale. These practices by farmers eventually become a problem for both livestock farmers, who cannot find land to feed their animals, and for growers, whose lands become more degraded every year.

The images shown below represent different aspects and situations of agroforestry systems. In image 1, we can see the general aspects of the millet agroforestry system, where different tree species can be noted. A partially harvested sorghum field can be observed in image 2, with two baobab trees and non-target species. The leaves of the baobab on the left were harvested at the time of the photograph (October 2016), but the baobab tree on the right still has foliage. Image 3 illustrates the passage of migratory cattle in a field of millet where crop remains were left. And finally, image 4 shows a *Balanites aegyptiaca* tree, which a boy has climbed in order to cut and throw down branches. Women and other children on the ground can subsequently harvest the leaves and flowers. *B. aegyptiaca* is a thorny tree, and the pulp from the fruit is used to suck on, with the seed being used for oil.

Image 1. Aspect of an agroforestry system in Bodol (Makalondi, August 2016).

Image 2. Agroforestry system in Safo (Madarounfa, Maradi, October 2016).

Image 3. Migratory cattle in Kouré (Kollo, Tillabéri, April 2015).

Image 4. Women and children collecting leaves and flowers of *B. aegyptiaca* in Kouré (Kollo, Tillabéri, April 2015).

The value of Adansonia digitata (baobab)

The baobab has been and is an emblematic and highly important tree for humans throughout its entire area of distribution in Africa. The baobab constitutes a major source of food, of products for pharmacopeia and veterinary medicine, and of fibers and materials for tools. Plus it also performs important ecological functions that include participation in the nutrient cycle, regulating the climate and run-off, water purification, and soil formation, and it serves as a niche for accommodating high biodiversity (Hellekson, 2009). The baobab also forms a part of the cultural identity and the spirituality of the populations, and its use and harvesting are regulated according to rules that govern the life of the surrounding communities. Therefore, the baobab generates multiple ecosystem services that are associated with the values of direct use, indirect use, and passive use.

The species occurs naturally in semiarid regions of tropical Africa. The approximate area of distribution can be found in Assogbadjo and Loo (2011). Considering various models of climate change (Sanchez et al., 2011), the current distribution of *A. digitata* will be

reduced in the future. Baobab populations need to be managed in order to ensure that their genetic diversity is maintained over the long term, that the resources endure, and that baobab products remain available (Dhillion and Gustad, 2004; Schumann et al., 2010; Venter and Witkowski, 2011).

This is important not only for actual conservation of the species and its genetic resources, but also due to its socioeconomic value. The leaves of the baobab, which have a high content of proteins and minerals, especially magnesium, potassium, calcium, and iron, form a part of the daily diet of the rural populations in many areas of West Africa. Fresh leaves are boiled and consumed as vegetables or in a salad, and dry or ground leaves are used as a thickener for sauces that accompany the staple food. Surplus dried leaves are stored and sold in the market, thereby assuring the availability of this food throughout the year (De Caluwé et al., 2009). Its products are marketed in urban and rural markets, thus constituting a source of income for rural homes (Venter and Witkowski, 2011). Likewise, the production of baobab offers considerable market opportunities not just in Africa. In recent years, there has been growing international interest in the species, with acceptance of the baobab fruit pulp in the EU and USA. For example, in Europe there are over 300 products whose ingredients include some derivative of the baobab, ranging from food products (drinks and beverages, energy bars, sweets, and chocolates) to pharmaceuticals and cosmetics (Gebauer et al., 2016).

The products provided by the baobab, in addition to being common ingredients in the diet, are a source of income derived from trade within rural areas and between these areas and urban areas. For poor urban households, baobab leaves are the basic product for preparing the daily sauce of family meals. In recent times, a practice has been observed in which agricultural land is sold without the right to enjoy the products of the baobab trees that are present on the acquired land. This is due to the great value and economic return offered by baobab products. The management of baobab is conducted mainly for leaf production, and the common practice of leaf collection causes the trees to become mutilated, thereby preventing the production of flowers, fruit, and seeds (Agúndez et al., 2016).

Currently, farmers have realized that traditional management no longer adapts to their needs, due to human pressure on the land, climate change, rule changes regarding land ownership and access to resources, the traditional right to planting trees, etc. For example, in the north of Mali, the rural population has to resort to importing baobab leaves to complement their diet (Leach et al., 2011). Local populations already perceive that the

current status of the baobab is in decline. This decline is attributed to climate change and to different factors of human pressure, such as land clearing, fires, livestock grazing, and actual collection of the leaves and fruit of the baobab, and to pest and diseases (Agúndez et al., 2016). Even in conservation zones such as the W Transborder (Benin, Niger and Burkina Faso) Park there is also a decrease of its presence (Schumann et al., 2012), with a very low density and a predominance of old, large-diameter trees and scarce regeneration in Niger (Douma et al., 2010).

Conservation and participation

African dry territories are among the most threatened and least studied agroforestry systems, and there is an urgent need to support the development of sustainable management and conservation policies (Blackie et al., 2014). The Sahel has experienced dramatic environmental changes during the last four decades, including the droughts during the 1970s and 1980s, the causes and effects of which are still under debate (Herrmann et al., 2005; Hiernaux et al., 2009; Lézine et al., 2011; Mertz et al., 2012; Nutini et al., 2013). Despite a recent trend of increasing rainfall over the last decade, the prevailing view is that a decline in annual rainfall has been the main driver of climate change at the regional level, operating in synergy with other factors, such as population trends, land management strategies, management of local natural resources and public policies (Mbow et al., 2008; Epule et al., 2014). There is a general gap in understanding of land use change in Niger (D'haen et al., 2013) and comprehensive studies are necessary to inform actions improving the resilience of the rural populations and buffering the current negative effects on agroforestry systems (van Vliet et al., 2013).

Changes that affect the density, quality, and composition of the tree cover have a direct impact on the genetic diversity of a species (Dawson et al., 2014). This diversity is related to the adaptability to changes that could occur in the ecological conditions of the environment inhabited by a species, in addition to being related to the potential to improve the production traits of a species. Patterns and levels of genetic diversity are available for only a few native woody food species in the Sudanese zone, such as *Adansonia digitata* (Kyndt et al., 2009) and *Vitellaria paradoxa* (Tom-Dery et al., 2014), but no specific information is included for the Sahelian-Sudanese zone. Generally and in view of a lack of knowledge about the genetic diversity of forest species, precaution is initially suggested. The idea would be to conserve the largest possible quantity of important genetic resources at the local level. This would make it possible to assure

the conservation of woody species that currently have value or that could be a source of values (unknown up to now) and/or of products and services for future generations (Bozzano et al., 2014).

Social participation must be the focal point of any effective activity to conserve natural sources, including forest genetic resources. Local communities should be involved in every aspect: from identifying the problem to discovering the possible solutions, including the planning, organization, and implementation of conservation actions. One of the functions of scientific studies is to verify many of the perceptions of the problems in these communities and moreover collaborate on offering proposals that can be assumed by these communities to solve the problems. A participatory conservation strategy increases both the possibility of real implementation and the probability of success (FAO, FLD, IPGRI, 2004). Thus, in the national parks of Africa, Muhumuza and Balkwill (2013) suggested that conservation approaches should place more emphasis on the human facet of conserving biodiversity and should not be solely focused on purely scientific studies of species and habitats, which abound in literature.

The success of management plans is often based on community-based conservation interventions, including community knowledge and capacity to observe the process and gather key information (Rodríguez-Izquierdo et al., 2010; Waylen et al., 2010). Furthermore, recognizing how and why people value different resources minimizes the conflicts between stakeholders and promotes the social acceptability of management activities (Ives and Kendal, 2014).

In this doctoral thesis, we have sought to study the participation by a society in conserving and improving woody food sources as a way to drive the very development of that society. Conservation, defined as the rational and sustainable management of natural resources, often comes into conflict with human survival and development. Yet from the perspective of the "man-nature" dynamic, it is possible to develop sustainable interactions between human societies and the environment (Mace, 2014). Previous studies that used environmental economy methods have allowed confirming and quantifying the desire of a society to participate in voluntary conservation programs. For example, regarding the conservation of large African mammals, such as the rhinoceros of Namibia (Swanson et al., 2002), English society would agree to making use of the fauna and marketing the products thereof to ensure its conservation. Evidently, English society does not suffer from the conflict that could exist between man and the rhinoceros with respect to its conservation. Switching continents, and therefore switching the conditions for

development, local communities in contact with elephants in the Democratic Republic of the Congo would be willing to participate in conservation of the animal, as long as measures were established to prevent conflict between man and the elephant (Ngouhouo et al., 2016). The creation of protected areas has a relevant impact on poor rural communities that depend on those areas. For communities in the south of the Côte d'Ivoire, the conservation of an area subject to protection has notable passive use values. In some cases, the problem is not that conservation isn't wanted, rather the problem is that the resources for undertaking the pertinent measures are not available, and external financing is needed to complement the market returns from products of the area to be protected (Amin and Koné, 2015).

Gender and ethnicity (e.g. in level of knowledge, preferences and types of use) may affect the management and conservation of natural resources (Koura et al., 2011; Gómez-Ramos et al., 2013). Indigenous knowledge may vary according to gender; for example in the assessment of the importance of an edible tree species, *Blighia sapida*, in Benin (Ekué et al., 2010), in the perception of vegetation changes in semi-arid areas in Niger (Wezel and Haigis, 2000), and in local attitudes towards conservation in northern Benin (Gómez-Ramos et al., 2013). In contrast, gender was not significant in indigenous knowledge of vegetation dynamics in Burkina Faso (Sop and Oldeland, 2011), wild fruit consumption in the Amhara region in Ethiopia (Fentahun and Hager, 2009), or identifying woody vegetation in south Western Niger (Ayantunde et al., 2008).

The participatory approach is a way of incorporating both traditional and scientific knowledge and can result in good outcomes when applied to natural resources conservation management. Participatory approach recognise the existence of different types of knowledge associated with the different stakeholders, and during the analysis phase, both traditional information and scientific knowledge, should be validated (Baia and Luisa, 2016).

The previous literature offers lists of useful wild plants from Niger, including edible species, and the nutritional value of some of them (Freiberger et al., 1998; Cook et al., 2000) but this thesis states the base line of the local perception of the food tree species status in two regions of Niger, to be used in participatory conservation planning. It constitutes the basis for a participatory planning, this is why the approach considered in this study is the Rapid Rural Appraisal Approach (RRA; Blumenthal and Jannink, 2000).

In this case, in Niger, the resources to be conserved have high use value, given that they form a part of not only daily nutrition but also nutrition in times of shortage, mainly

for the rural populations. Moreover, the resources to be protected tend to compete with other resources (agriculture, livestock), with different scales of space and time, thereby creating long-term sustainability problems. Knowing the factors that cause a loss of resources, comparing them with local perceptions (which can differ, depending on questions of age, sex, or ethnicity), and offering management alternatives are the way to minimize the conflicting commitments between different uses and to favor the resilience of agroforestry systems.

The activities proposed in this doctoral thesis are based on conservation through use, or *circa situm* conservation of woody food resources in agroforestry systems. According to Dawson et al. (2013), *circa situm conservation is the preservation of planted and/or remnant trees and wildings in farmland where natural forest or woodland containing the same trees was once found, but where natural vegetation has been lost or modified significantly through agricultural expansion*. In *circa situm* conservation, the farmers are in charge of the sustainable management and conservation of the species they use, with the support of the responsible institutions and society in general.

OBJECTIVES

The main objective of this doctoral thesis is to contribute to the sustainable management of woody food species, through their conservation and breeding, and taking into account the participation of Nigeriens as actors for their own development. The specific objectives included in the studies of this thesis are:

1. Establish the basis for the participation of the society in a program of conservation and breeding of woody food species (studies 1 to 3).

2. Identify the key woody food species and the perception of rural communities about their status of conservation (study 1).

3. Confirm that the perception of the factors that threaten the species is influenced by the food value attributed to them, the change in the occurence of the trees and the lack of regeneration, as well as the agroecological zone, the genus and the socio-cultural group to which the surveyed population belongs (study 1).

4. Estimate farmers' preferences towards different elements of a conservation and breeding program and estimate the effort they would be willing to invest in the implementation of the proposed program (study 2).

5. Describe the market of baobab products and assess the preferences of consumers for co-financing the conservation and breeding program of the species (study 3).

6. Identify the key elements and activities to be considered for the improvement of the production and conservation of *A. digitata* in Niger, and the actors that would participate in the design and implementation of the proposed activities (application).

MATERIAL AND METHODS

TOWARDS A PARTICIPATORY CONSERVATION OF FOOD TREE SPECIES

Study area

Four villages in Southwest Niger were selected, two in each of the main agroecological regions (Sudanian and Sahelian). The Sudanian agroecological region is characterized by an annual 7-month drought period, and a mean annual precipitation of 650 mm, while the Sahelian agroecological region has a 9-month drought period and a mean annual precipitation of 350 mm.

The traditional agrosilvopastoral system in both regions is extensive and highly vulnerable to drought. The start of the rainy season, of vital importance for cereal production, is subject to fluctuations and affected by delays. In both agroecological regions, the diet is largely based on cereals, mainly millet and sorghum, complemented with pulses (cowpea and Bambara groundnut). Consumption of food of animal origin, of fruit and vegetables (rich in micronutrients) remains low, and the consumption of milk, a tradition in an agro-pastoral context, is declining due to the reduction in the number of cattle. The use of wild edible plants (leaves and fruits) is rather a common practice during the dry season. The collection has become systematic after recurrent cases of very severe food shortage (FAO, 2009). Village dwellers are largely dependent not only on agricultural products but also on indigenous woody vegetation for their food security.

In the Sudanian agroecological region the two selected villages, Senokonkodje and Weillagorou, are located within the Total Wildlife Reserve of Tamou. In the Sahelian agroecological region, the two villages selected were Tondikiwindi and Tondibiya (Table 1). The study sites are characterized by the presence of the major ethnic groups that populate the region (i.e., Zarma, Hausa, and Fulani). The inhabitants of Tondikiwindi and Tondibiya were affected by a severe drought during the 1970s, forcing some of them to migrate and settle in the Tamou area. People living in Senokonkodje are refugees from Tondikiwindi; while the inhabitants of Weillagorou are autochthonous settled originally inside the W National Park (WNP) in Niger, however cultivating the lands outside the

Park. They were forced later to leave their settlements when the W Transboundary Biosphere Reserve (Benin, Burkina Faso and Niger) was established in 2002.

Zarma and Hausa ethnic groups are smallholder farmers, practising extensive agriculture to produce millet for household consumption. Integration between agriculture and livestock is very low. Fallow reduction and changes in rainfall, combined with structural adjustment measures, have led them to depend increasingly on seasonal migration and small trading. The Zarma are autochthonous in the study sites, while the Hausa are immigrant from the Southwest of Niger.

Traditionally Fulani are nomads; but after many years of integration with other cultures, and due to adverse environmental conditions leading to a reduction of their herds (cows, sheep, goats and dromedaries), nowadays they largely rely on farming for their livelihood. So they are only partly nomadic, setting up temporary camps, where they exchange dairy products for cereals.

Fieldwork description

The field work at household level was divided in two parts: the focus group discussions and the individual interviews. The overall sample is presented in Table 1.1 and questionnaires in annexes. The local communities of the region suffer annually of food shortage and food crises due to severe drought, thus we were interested on involving the household representatives as the main actors.

Focus group discussion were performed with the participation of all women of the household, women were the main target due to their responsibility for food preparation and with three to ten women by each focus group. The response was unique, representing the behaviour of the household. A questionnaire was used to guide focus group discussions aiming at identifying the edible woody species used, the parts of the plant consumed and the collection sites for each species (i.e. bush, parkland, plantation on agricultural land, or plantation in home garden), as well as the period of availability compared to the shortage period.

Table 1. Location of villages studied, characteristics of the population and sample size by village and type of interview.

Department Municipality	Say Tamou		Ouallam Tondikiwindi	
Village	Senokonkodje	Weillagorou	Tondikiwindi	Tondibiya
Code	Sudanian 1	Sudanian 2	Sahelian 1	Sahelian 2
Location	02°22'33" 12°42'33"	02°44'82" 12°62'30"	02°02'10" 14°18'00"	02°01'40" 14°27'40"
Ethnic group	Zarma	Fulani	Zarma / Hausa	Zarma
Origin	Ouallam	Autochtonous	Autochtonous (Zarma)	Autochtonous
Status of residence	Climatic refugees	Decamped (WNP)	Inmigrant (Haussa)	
N. of Years	20-30		20-30 (Haussa)	
Activity	Agriculture (28)	Agriculture (10) Agropastoralism (6)	Agriculture (18) Agropastoralism (3)	Agriculture (24)
N. of Focus Group (106)	29	16	37	24
N. of Key Informants (89)	28	16	21	24

WNP= W National Park

Questionnaire was addressed to the head of the house, usually a man, considered as key informant. This questionnaire was focused on how the local communities prioritized the edible woody species, how they defined their conservation status, and their perception of the impact of biotic, abiotic factors, management and collection practices on the conservation status of the species. In some cases, the head of the household was a woman, either a widow or a woman leading the household where her husband was temporarily absent working in another region or country. Demographic data were collected for each individual interviewed.

Food value (Fv) was determined by each key informant attributing a ranking to the ten woody species most valued as food. The species list and ranking were generated independently by each informant. For each species, the informant was also asked to indicate his/her perception about the change in occurrence of the species in the area surrounding the village, over the previous 10 years. The parameter was defined as occurrence change (Oc) and a trend was identified by a score from 1 to 4, with 4 indicating a very high decline. A score indicating the status of regeneration (Rg) was also assigned to each of the top ten edible woody species (1=Lack of regeneration; 2= Presence of regeneration).

A total of 12 factors (Figure 2) had been pre-identified in the literature as common pressures, associated with management measures for agroforestry systems, harvesting practices for tree products, and biotic or abiotic factors (Assogbadjo and Loo, 2011; Gouwakinnou et al., 2011; Muok et al., 2011; Sanou and Lamien, 2011; Sop and Oldeland, 2011). Each key informant was asked to give a score from 1 to 4 (with 4 indicating a high effect on the given variable) on the factors driving the conservation status (Oc and Rg) of each species.

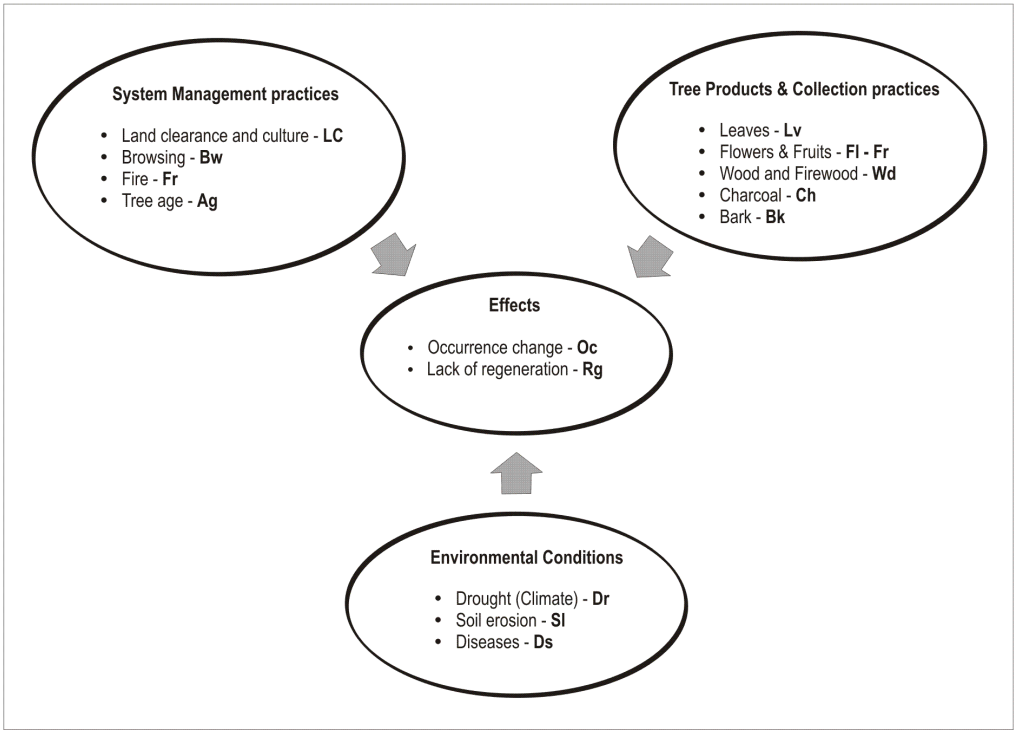


Figure 2. Pressure factors affecting the perception of the conservation status (occurrence change and regeneration).

The fieldwork was carried out from May to October 2011 during the food-shortage period, in French with support from translators for all the local languages, i.e. Zarma, Hausa and Fulani. Specimens of the edible woody species identified during field activities were used during focus group discussion and interviews to ensure correct species identification. To help resolve issues related to wrong attribution of vernacular names, herbarium specimens and photographs were collected, for later identification at the laboratory of Biology Garba Mounkaila (Faculty of Sciences University Abdou Moumouni, Niamey). Some samples were collected from local markets, given the difficulty of finding the species in the field.

Data analysis

Two different approaches were used to process the data generated by the individual interviews: i) the median value for all variables (Fv, Oc and Rg) and pressure factors was calculated. Median values were considered as the most appropriate indicators of respondents' perception averages; exploratory approaches for data analyses using medians and non-parametric statistic methods are considered appropriate to treat the type of data collected in this study (Tukey, 1977). The dataset was not suitable for parametric tests, due to the large number of variables analysed in a relatively small dataset, the significant amount of missing values (absence of responses for some variables), and the strong autocorrelation among variables; ii) Seven pressure factors were included in the analyses and the species prioritized by at least 6 key informants were considered. The relationship between the 7 factors (dependent variables), the food value and the two variables associated with the conservation status of an edible woody species (Oc and Rg; independent variables) were analysed by Partial Least Squares multiple regression models (SIMPLS algorithm).

In order to test for the influence of respondents' gender, ethnicity or status of residence on food value and occurrence change, the three most common species cited in the four villages were subjected to one-way ANOVA using the non-parametric Kruskall-Wallis test. Dependent variables were the food value of an edible woody species (0 to 10 scale) and occurrence change (1 to 4 scale). Regeneration was discarded from this analysis, as this parameter turned out not to have relation with gender, ethnicity or status of residence. Two levels were assigned to gender (male and female), three levels to ethnic group (Zarma, Hausa and Fulani) and four levels to village (one for each village).

FARMERS' PREFERENCES FOR CONSERVATION OF AGROFORESTRY FOOD RESOURCES

The program

In this study, an action program to improve the living conditions of the rural inhabitants of Niger is proposed. The proposed solution goes from sustainable management towards the conservation and breeding of forestry resources, such that existing resources are conserved and the quantity and quality of the system's production is improved. The elements comprised in the program are presented as attributes with different levels of action. The attributes proposed in this study include the following: 1) the species of human

food interest that are deemed to have priority by the local population; 2) actions for increasing tree density; 3) tree density actions reinforced by soil conservation actions; and 4) the quality of the seed to be used in actions aimed at the conservation thereof through use. The purpose is to increase agricultural production and favor the implementation and production of native and naturalized food tree species in the studied regions.

The woody species of this program are the priority species for the local communities, and they are present in all the studied communes (municipalities): *Adansonia digitata*, *Boscia senegalensis, Balanites aegyptiaca*, and *Ziziphus mauritiana*. The selection was made considering the common species cited the most in Agúndez et al. (2016), thereby considering that they represent a different degree of presence and/or interest due to their food products. Moreover, the questionnaire included one question to confirm the selection of these species.

An increased interest in conserving woody species in Niger can be perceived, mainly due to the loss of natural forests. This has been partially caused by human pressure, which requires a considerable area of land for agricultural production (Lawarnou et al., 2012). In the majority of cases (Larwanou and Saadou, 2011), interventions by different cooperation projects have been highly appreciated in terms of restoration efforts on degraded lands, especially regarding erosion control, Farmer Managed Natural Regeneration (FMNR), and tree planting. FMNR is an approach for arable land restoration and reforestation that seeks to reconcile food production, soil conservation, and the protection of biodiversity. It involves helping and protecting regeneration based on the seed bank existing in the soil, on stems regrown from the live stumps of felled trees, and on pruning to achieve straight trunks. The two proposed levels for increasing tree density in the fields are FMNR and planting.

Likewise, previous studies show that in Niger, seedlings tend to burn if water conservation techniques are not applied (WSC, Water Soil Conservation), given that young roots in hardened soil cannot collect enough water to cool the leaves (Wildemeersch et al., 2015). In degraded soils, these techniques are used to capture rain water through collection or to slow the run-off and improve efficiency in water use, therefore reducing evaporation to a minimum and increasing percolation to favor plant growth. Stone bunds improve water retention and filtration into the ground, thereby increasing the quantity of water available for plants and guaranteeing a good harvest. They also provide protection against wind erosion if there is good growth of plant cover. They are limited by the availability of stones in the area. Simultaneously, tassa or zaï is a water collection technique to

improve water retention and prevent the loss of organic fertilizer due to run-off. It has the advantage of allowing crops to be sewn even in periods of low rainfall. It involves preparation of the land in holes covered with mulch and organic fertilizer. This technique has been used successfully to increase the quantity and yield of millet in Niger. Preparing the soil in the form of half-moons is advantageous when rain is scarce and there is a slight slope. They slow run-off and allow collected water to be taken advantage of. They are used to restore degraded soils for vegetable crops, grazing, or forest plantations (Maisharou et al., 2015).

The changes that affect the density, quality, and composition of the tree cover cause a direct impact on the genetic diversity of the species that are present and on the corresponding current or potential value of this diversity. Regarding NWFPs, there is high variability in the desirable traits, such as the size of the fruit, the proportion of pulp, the content of vitamins, and the oil composition, which is an essential prerequisite for breeding and domestication. It also provides an excellent opportunity to develop cultivated varieties of phenotypically superior trees, although a greater understanding of the genetic aspects of production is currently required (Dawson et al., 2014).

The genetic quality of a seed and, in this case, the origin or source where it is collected are going to have an influence, first, on the adaptation of any new plants, and second, on the production and the results expected from using it. There are various types of seeds. By "non-selected" seed, we understand a seed whose origin we are unaware of, and farmers could even have acquired it in the market as a food product, later to be sewn. In the case of *A. digitata*, the pulp is purchased with seeds, but only the pulp is used. There is no certainty about the behavior of the plants obtained from the purchased sees, in terms of adaptation or in terms of production quality or quantity. A "selected" seed is one that is collected from trees identified by their good production, growth, and/or adaptation, normally by an officially recognized provider of seeds, wherefore we can forecast similar behavior. Finally, a "bred" seed comes from production breeding programs, with recommendations and guarantees for subsequent planting under certain ecological conditions.

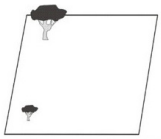
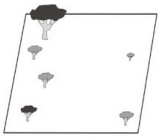
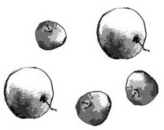
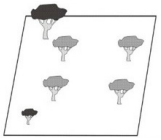
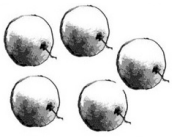
In Africa, different tree breeding and domestication programs are being developed (Ræbild et al., 2011), for example for the production of baobab leaves and fruits (Anjarwalla et al., 2016; Korbo et al., 2013; Jensen et al., 2011) or the production of Sahel apple fruits (*Z. mauritiana*) (Ibrahim et al., 2015; Kalinganire et al., 2007), but we are unaware if there is currently any program for the other two species selected in this study.

In order to be able to evaluate the preferences of the local populations in terms of willingness to make sacrifices for implementing conservation and breeding programs (in this case, non-monetary sacrifices, rather sacrifices in the form of effort), the number of work days that the local population must work in order to succeed with the proposed programs has been included as an attribute (15, 30, 45, or 60 work days per year). Work time has been chosen instead of a monetary measure due to the fact that the majority of the population is subject to a subsistence economy. Posing a monetary attribute, which is normal in economic assessment exercises in countries with greater economic development, would hardly be credible for a population that experiences major periods of food scarcity. Nevertheless, follow-up questions that allow us to transform effort into a monetary cost have been included. Other, previous studies have already demonstrated the suitability of using work time and not monetary units to evaluate the willingness to pay in developing countries (Gibson et al., 2015; Rai and Scarborough, 2012, 2015; Abramson et al., 2011).

In summary, Table 2 presents the attributes and levels that would be comprised in the program to be evaluated. After having selected the attributes and levels, we create an experimental design that allows obtaining the necessary choice cards to obtain the individual preferences for each element of the program.

A pivoting design based on D-efficiency criteria has been conducted using Ngene software. Priors were obtained from a pilot survey to 47 farmers. A total of 12 choice cards were designed with a ranking format, each of which included 4 programs (including *status quo*), and they also provided the possibility that the respondent might not respond (doesn't know, doesn't answer). In each card, the four proposed programs were ranked from 1 to 4, with 1 representing the preferred program and 4 the least-preferred. An example of the ranking cards is shown in Figure 3.

Table 2. Attributes comprised in the program and choice levels.

Species	*Tree density action*	*Water and Soil conservation*	*Seed quality*	*Work force (days/year)*
Adansonia digitata 	*Status quo* 	*Status quo* 	*Status quo (Non selected)* 	 15
Balanites aegyptiaca 	*Farmer Managed Natural Regeneration (FMNR)* 	*Half moon* 	*Selected* 	 30
Boscia senegalensis 	*Plantation* 	*Tassa/Zaï* 	*Breeding* 	 45
Ziziphus mauritiana 		*Stone bunds* 		 60

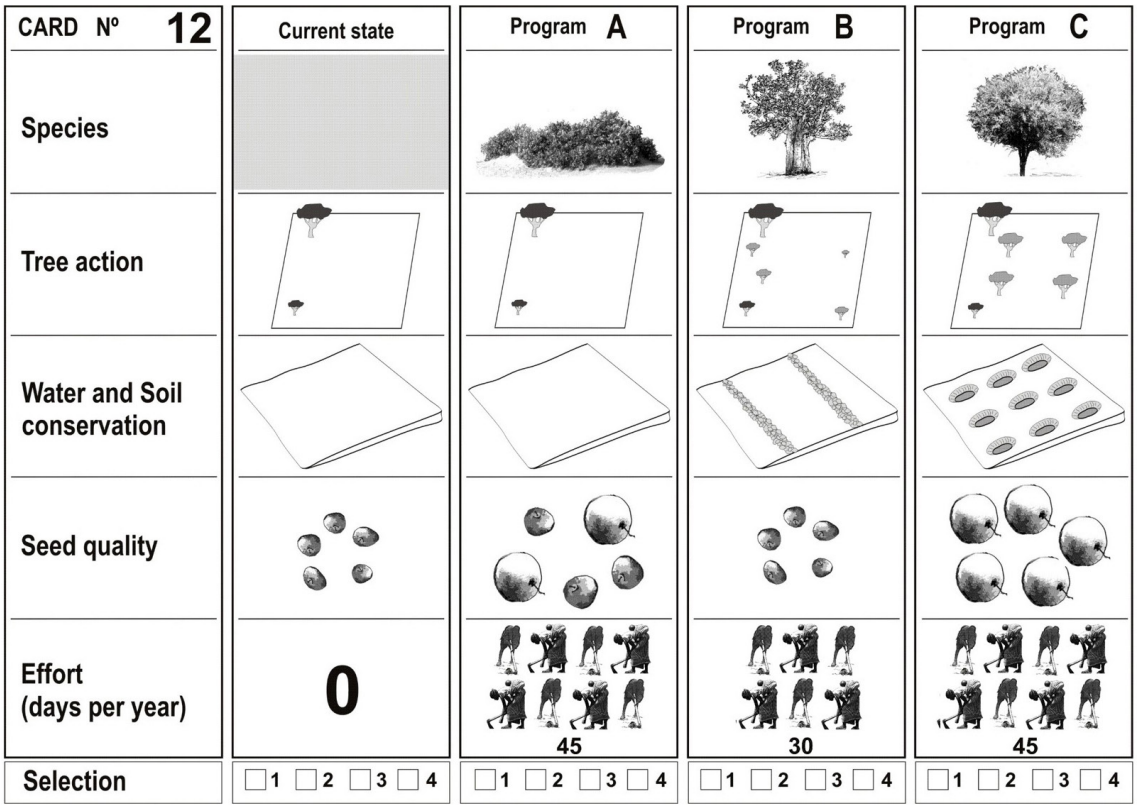


Figure 3. Example of ranking card.

The rankings made by the individuals were analyzed according to the econometric model proposed by Beggs et al. (1981) and the random parameters models popularized by Train (2003). The willingness to work (WTW) or to pay (WTP) was calculated considering that the coding of attributes and levels was in the form of effect codes and not as dummies (Lusk, 2003).

The sample

In order to gain a more in-depth understanding of the local population's preferences for this type of program, we designed an assessment questionnaire targeted at the managers of Niger's lands (farmers who are owners or who have rights of use). The respondents were offered several scenarios related directly to actions to be developed in the territory. The target population included the families of 40 villages, which were selected according to their different ecological characteristics and agroforestry practices, and they represented the agroecological zones where agriculture has the most importance. All the zones are subject to food vulnerability and need to improve the quality of the environment with respect to health, productivity, and yield, and they are highly affected by climate change. Figure 4 shows the locations of the 40 studied villages. A total of 401 surveys were taken of people likely to participate in and make decisions about the proposal of a conservation and breeding program.

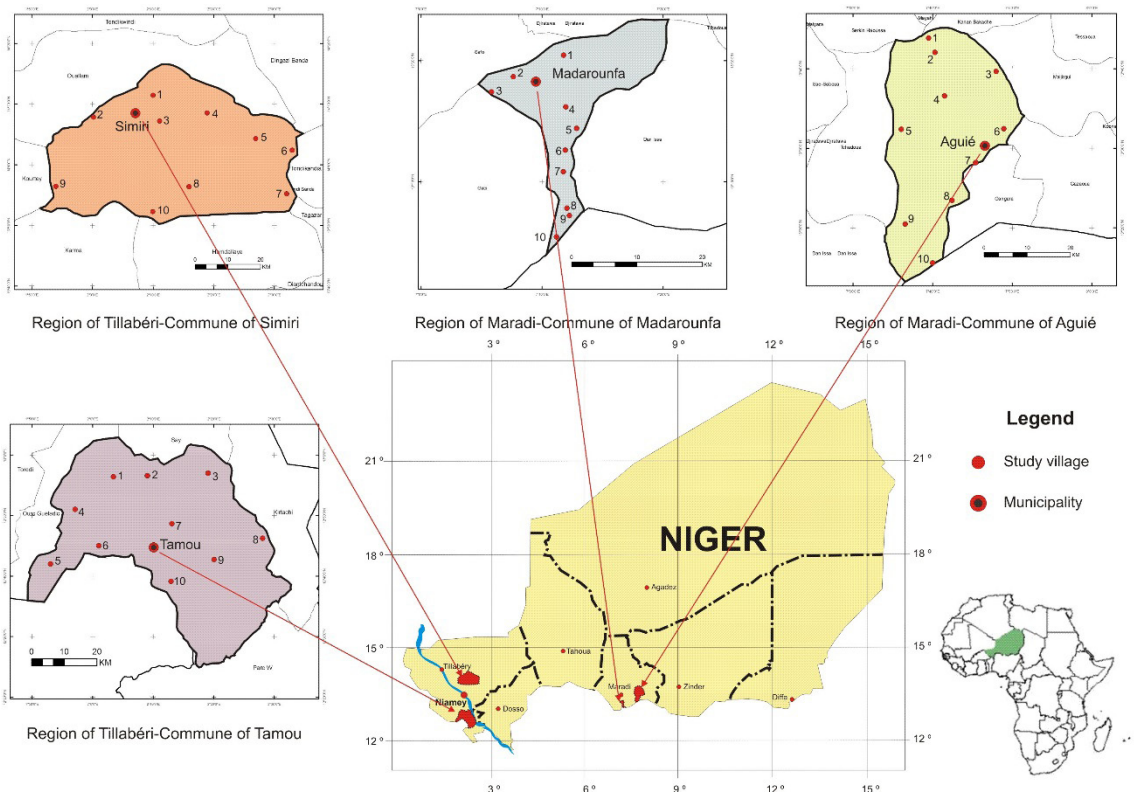


Figure 4. Study area.

ANALYSIS OF CONSUMER PREFERENCES FOR BAOBAB

Description of the study area and of the baobab market in Niger

The area of study includes the markets of two administrative regions (Maradi and Tillabéri), such that the three agroecological areas (described below) in which the trees and shrubs form a part of the production systems are represented. The Sahelian zone (8% of the surface area) has semi-arid conditions, clearly formed by shrubs or woodland, and the agropastoral system predominates. In the Sahel-Sudanese zone (7% of the surface area), the vegetation consists of a savannah of shrubs or trees with highly varied rates of production. This is an area with high agricultural potential, mainly dryland but also irrigated farming. Livestock is also heavily present in the agroforestry systems. Finally, in the Sudanese zone (1% of the territory), the vegetation is composed of one, more or less continuous, herbaceous layer and a woody layer formed by trees and shrubs that can form small tree stands locally.

In a typical market of Niger, the various products are displayed in sacks, piles, or mounds, and consumers choose what they want and pay for or negotiate the price of the selected product. Vendors of similar products are located in the same zone of markets, which are normally open-air, and they are generally located close to or even right next to each other in rural markets. There is no published information available that contains initial data on the market of baobab products in Niger. Nevertheless, our field work and visits to various markets allowed us to simulate the market. Some peculiarities included the fact that the amounts sold and the corresponding prices varied according to the location of the market and the time of year. It should be pointed out that scales are barely used, because operators prefer using local units of measure (LUM) for their transactions. The LUM used the most is the "tia" (cup) for cereals and agricultural products in general.

Image 5 shows some images illustrating markets, baobab products, and measurement containers. For baobab products, a scale is not used in any event, and the type of measurement containers varies according to the product, vendor, and market. The normal practice consists in filling the container and making a mound that overflows, then putting it in a bag and adding two fistfuls, with the second smaller than the first. The most frequently used measure for all products is the "tia" or "half of a tia", which also isn't an official measure. In any event, there is a high variety of LUM, with the smallest being small plastic bags used to hold dry or powdered leaves. And different sizes can be used according to the type of product, especially powder, for both leaves and pulp. There are

different qualities of dry leaves due to the drying process. It is possible to bargain and get a small reduction in the initial price, but prices are more or less fixed in the same season and market. There are also different qualities of pulp, which are distinguished by color and taste, but they are all sold at the same price (so it must be assumed that the measurement container could have a lower capacity for higher qualities).

In Niger, the market for baobab products is in the hands of both men and women. In rural markets, we find that leaves are only sold by women, and in urban markets the sellers of both leaves and pulp are predominantly men. The acquisition of these products by women is not as pronounced as in other countries of the sub-region (such as Benin, for example), and men may purchase the products that women need for cooking. The criterion when taking the surveys was to interview any person (male or female) who might acquire baobab products. The results of the subsequent analysis showed that there were no statistically significant differences by gender with respect to participating in the conservation program.

Image 5. Photos of the baobab products at the market.

Baobab products are consumed in both rural and urban areas, although the interest in and frequency of consumption could vary from one area to another. Therefore, the sample of respondents was distributed between the urban and rural markets of the

regions identified for the study. It was thus possible to check if there were participation differences due to dependence on the product and/or due to the proximity of the production zone in rural areas or due to the possibility of finding replacement products in urban areas. Two urban markets and four rural markets were selected per region. One region is Maradi, with its two urban markets in the city of Maradi, and the other region is Tillabéri, with two urban markets in Niamey (Figure 5).

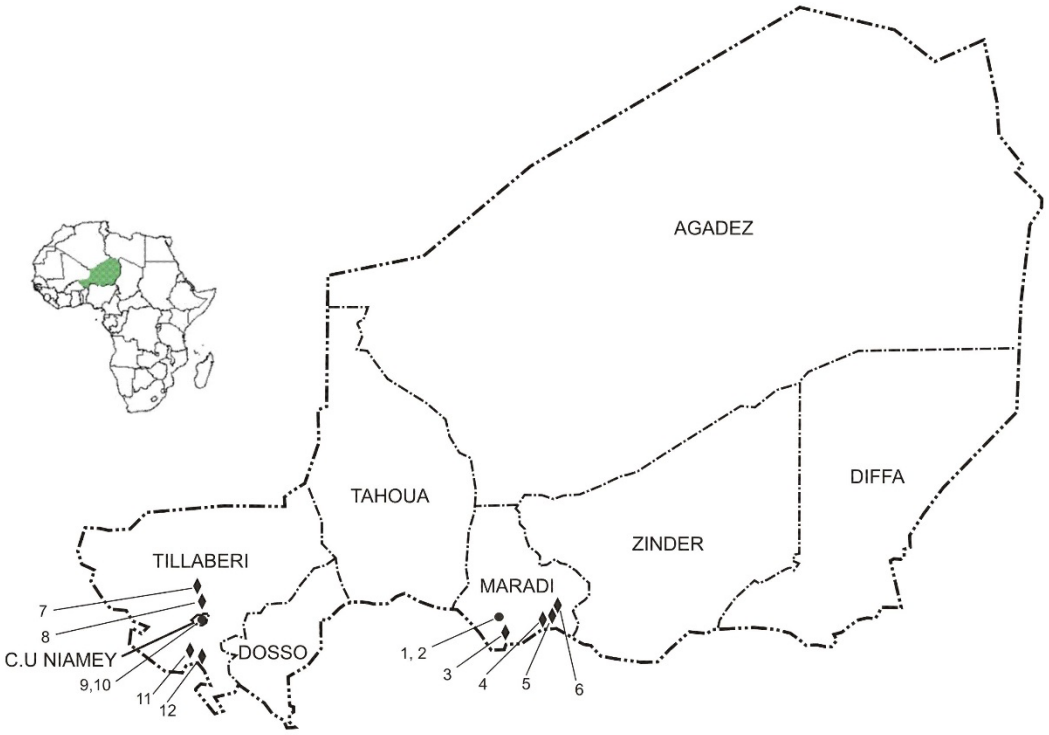


Figure 5. Market locations in two different regions of Niger and number of respondents (n). Urban markets of Maradi: 1-Kadro (50), 2-Kassua Mata (50); rural markets of Maradi: 3-Madarounfa (25), 4-Aguié (25), 5-Gabi (25), 6-Dan Saga (25); rural markets of Tillabéri: 7-Banne (25), 8-Simiri (25), 11-Tamou (53), 12-Allambare (27); urban markets of Niamey: 9-Harobanda (49), 10-Katako (53).

Contingent valuation method

The contingent valuation method (Carson, 2012) is used in this research to assess a conservation program for the baobab's genetic resources. The method is based on the design of a hypothetical market. For this study, we have the problem of a lack of prior information about various aspects that condition the market: imperfect competition, asymmetrical information, a diversity of products derived from baobab resources, a lack of knowledge about the diversity of qualities of the resources, the use of LUM and their wide variety of measures, not knowing their equivalence in grams, etc. We therefore created a design in which the payment vehicle is based on a percentage increase over

the purchase price of the usual product for baobab consumers. The heterogeneity of the consumers in the market is so large that we cannot, a priori, establish a reference price using the usually recommended dichotomous format or a payment card that presents a wide range of prices, wherefore we used an open question format. The survey was conducted of consumers in the markets at the baobab stalls, right after making their purchase. The questionnaire included questions about the baobab products they had just purchased, therefore including all the corresponding products, measures, and prices. Then consumers were asked about which product they normally purchased, the measure, and the usual price, in addition to the reason for purchasing the product. The currency used is the West African CFA Franc (XOF), which has an exchange rate that is pegged to the euro (1 euro = 655.957 XOF).

Prior to the valuation exercise, the regression situation of the resources of *A. digitata* and the consequences of applying a conservation and breeding program were simply and graphically explained (Figure 6). By applying baobab conservation and breeding programs in the agroforestry systems of Niger, the density of the trees and the quantity and quality of the products would tend to increase, thereby guaranteeing the availability of baobab products in the market. The failure to take action in this regard would result in greater degradation of the production system and problems in the availability or supply of the products that are currently being purchased. Consumers were also informed about the economic importance of these programs and about the fact that they could be financed by all the players who are involved, including farmers, consumers, local and state institutions, universities, research institutions, and non-governmental organizations.

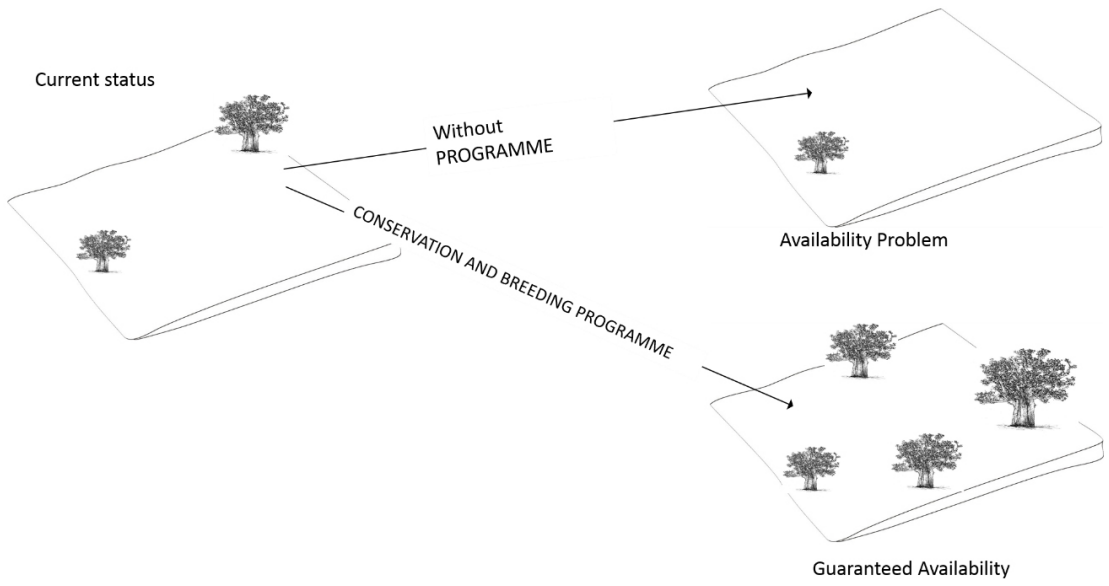


Figure 6. Valuation scenario.

The question they were asked in the valuation exercise was "Would you be willing to pay more for the product you normally purchase and thus participate in the program?" Those who responded negatively were asked to indicate why they wouldn't participate, and the valuation exercise was ended, therefore skipping the remainder of the informative questions. We thus identified the protests to the program (the people who were not willing to participate in a program of this type), and we differentiated them from those who couldn't participate in the program, not because they weren't interested, but because of economic reasons (true zeros).

Those who indicated that they would like to participate in the program were asked "What is the most that you would be willing to pay for the product that you normally purchase?" Before responding, consumers were informed that they must take into account that the amount of money they were going to use to assure the availability of baobab products would not be available for other food expenses or savings. The individual willingness to pay has been calculated as the difference between the maximum price they would pay and the price at which they normally purchase the same product. They were also asked why they would assume the surcharge, since the design of the conservation and breeding strategy not only required knowing the reasons for protest responses but also the reasons that led consumers to assume a willingness to pay for the product.

Finally, we obtained information about the amount of the weekly shopping basket and the expenditure on different baobab products. We also asked if the different baobab products offered in the market have different qualities. The last part of the questionnaire covered information about the surveyed person and their household, the period during which they suffer from a food shortage annually, the activities they are engaged in, and whether or not they are a gatherer of baobab products.

Econometric model

When using an open-ended (OE) willingness-to-pay question, it is common for a relevant proportion of respondents to report zero bids or outlier WTP values (Soliño et al., 2010). In many OE CVM studies, protesters and outliers are excluded from the analysis, but this approach can be problematic, given that the willingness-to-pay equation is estimated based on what may be called a self-selected sample (Álvarez-Farizo et al., 1999). Heckman (1979) recast the problem of sample selection bias as an omitted variable problem and proposed an econometric correction. In order to apply Heckman's method to our data, we let Z_i be a latent variable that determines whether or not a baobab consumer gives a

valid willingness-to-pay response (i.e., a positive WTP or a true zero). This latent variable may be related to a set of explanatory factors as a linear equation in the following form:

$$Z_i = \alpha' W_i + \mu_i \qquad (1)$$

where Wi is a vector of variables thought to influence whether or not an individual bids (WTP ≥ 0); α is a set of unknown parameters to be estimated; and μi is assumed to be normally distributed, with a zero mean and constant variance. Estimates of equation (1) are used to construct the inverse of Mill's ratio:

$$\lambda_j = \phi(-\alpha' W_j) / [1 - \Phi(\alpha' W_j)] \qquad (2)$$

where ø(.) is the standard normal density function (pdf) and $\Phi(.)$ is the standard cumulative density function (cdf). This correction factor (λ_j) for sample selection is then added to the vector of independent variables in the willingness-to-pay equation (equation 3), which is estimated in a second stage by Ordinary Least Squares.

$$WTP_j = \beta' X_j + \gamma \lambda_j + \varepsilon^* \qquad (3)$$

where γ is the covariance between the error terms in the selection equation and the willingness-to-pay equation. Equation (3) should provide an unbiased estimate of β if the selection equation is properly specified.

RESULTS

TOWARDS A PARTICIPATORY CONSERVATION OF FOOD TREE SPECIES

A list of key edible woody species was produced with the information provided by focus group discussions, including characterization of the key species identified, the information of parts of the plant used as food, the habitat or location where the species is found, and the agroecological region where the species was reported.

A total of 23 woody species (trees, shrubs, a palm tree, a vine and a parasitic sub-woody plant) were valued for their contribution to the diet (Table 2). Five of the species were common to the two agroecological regions, 11 specific to the Sudanian agroecological region, and 7 to the Sahelian agroecological region. The main products used as food were fruits (14 species), leaves (6 species), or both (3 species). For *B. aegyptiaca* the flowers were also reported as edible, while *C. nigricans* was mentioned for its rubber (used as a candy). Some products have to be consumed at the time of harvesting (i.e. leaves of *M. crassifolia* and *C. farinosa*), while the leaves and fruits of *A. digitata*, fruits of *B. aegyptiaca*, *B. senegalensis*, *D. microcarpum*, *T. indica* and *Z. mauritiana* and the gum of *C. nigricans* can be stored for consumption all through the year. Most species and products listed were consumed during periods of food shortage, but a few species, while not available during the shortage period (i.e. *C. farinosa*, *D. mespiliformis* and *P. reticulatum*), were reported by key informants. *A. digitata* leaves are part of the diet of every household throughout the year. Edible woody species were sourced mainly in the bush, and in agroforestry systems, with a few products collected from planted trees (i.e. *A. digitata* and *P. biglobosa*, in the Sudanian agroecological region).

The results of the Kruskall-Wallis test for the three most commonly mentioned species (*B. aegyptiaca*, *B. senegalensis* and *Z. mauritiana*) indicate that location of the village, gender and ethnic group influence food value of a species and its occurrence change (Figure 7). Food value (Fv) varies significantly between villages for each of the three species but is not linked to the status of residence of the respondents. Weillagorou (Sudanian agroecological region, autochthonous) and Tondikiwindi (Sahelian agroecological region,

Table 2. Species cited by at least six key informants, agroecological area in which they have been mentioned; part of the plant used as food in times of scarcity, and habitat in which the products are collected. TR: Tree, SH: Shrub, ST: Small Tree, PA: Palm, LI: Liana, PS: Parasite; Lv=Leaves, Fl=Flower, Fr=Fruits; Prep=Prepared, Tr=Transformed; Sudan: Sudanian, Sahel: Sahelian.

						Period of disponibility (Months)													
								Sahelian Shortage Period											
								Sudanian Shortage Period											
Species Code	Scientific name	Family	Life form	Part(s) used as food and	Consumption	Jn	Fv	Mr	Ap	My	Jn	Jl	Au	Sb	Oc	Nv	Dc	Habitat	Agroecological region
Ad	*Adansonia digitata*	*Malvaceae*	TR	Lv	Prep					x	x	x	x	x				Bush / Land / Planted	Sudan
				Fr	Raw	x									x	x	x		
Ba	*Balanites aegyptiaca*	*Zygophyllaceae*	TR	Lv/Fl	Prep			x	x									Bush / Land	Sahel / Sudan
				Fr	Raw	x										x	x		
Bs	*Boscia senegalensis*	*Capparaceae*	SH / ST	Fr	Tr/Prep							x	x	x				Bush	Sahel / Sudan
Cf	*Cadaba farinosa*	*Capparaceae*	SH	Lv	Prep	x											x	Bush	Sahel
Cn	*Combretum nigricans*	*Combretaceae*	TR	Gum	Raw											x	x	Bush / Land	Sudan
Dm	*Detarium microcarpum*	*Caesalpiniaceae*	TR	Fr	Raw	x	x	x	x									Bush	Sudan
Dy	*Dyospiros mespiliformis*	*Ebenaceae*	TR	Fr	Raw	x	x									x	x	Bush / Land	Sudan
Gb	*Grewia bicolor*	*Tiliaceae*	SH / ST	Fr	Raw									x	x			Bush / Land	Sahel
Ht	*Hyphaene thebaica*	*Arecaceae*	PA	Fr	Raw							x	x	x	x	x	x	Bush / Land	Sudan
Lf	*Lannea fruticosa*	*Anacardiaceae*	SH /ST	Fr	Raw		x	x	x	x	x							Bush / Land	Sudan
Lm	*Lannea microcarpa*	*Anacardiaceae*	TR	Fr	Raw		x	x	x	x	x							Bush	Sudan
La	*Leptadenia arborea*	*Asclepiadaceae*	SH	Lv	Prep	x	x	x	x	x	x	x	x	x	x	x	x	Bush	Sahel
Lh	*Leptadenia hastata*	*Asclepiadaceae*	LI	Lv	Prep	x	x	x	x	x	x	x	x	x	x	x	x	Bush	Sahel
Ma	*Maerua angolensis*	*Capparaceae*	TR	Lv	Prep						x	x						Bush	Sahel
Mc	*Maerua crassifolia*	*Capparaceae*	TR	Lv	Prep			x	x	x	x							Bush	Sahel
Pb	*Parkia biglobosa*	*Fabaceae*	TR	Fr	Tr/Prep			x	x	x	x							Bush / Land / Planted	Sudan
Pr	*Piliostigma reticulatum*	*Fabaceae*	SH / ST	Fr	Raw	x	x									x	x	Bush / Land	Sahel / Sudan
Sb	*Sclerocarya birrea*	*Anacardiaceae*	TR	Lv	Prep					x	x	x						Bush / Land	Sahel / Sudan
				Fr	Raw								x	x	x	x			
Ti	*Tamarindus indica*	*Fabaceae*	TR	Fr	Prep	x	x										x	Bush / Land	Sudan
Tg	*Tapinanthus globiferus*	*Loranthaceae*	PS	Lv	Prep	x	x	x	x	x	x	x	x	x	x	x	x	Bush	Sahel
Vp	*Vitellaria paradoxa*	*Sapotaceae*	TR	Fr	Tr/Prep						x	x						Bush / Land	Sudan
Vd	*Vitex doniana*	*Lamiaceae*	TR	Fr	Raw						x	x						Bush / Land	Sudan
Zm	*Ziziphus mauritiana*	*Rhamnaceae*	TR	Fr	Raw	x	x									x	x	Bush / Land	Sahel / Sudan

autochthonous) tend to cluster with regarding the food value of *B. aegyptiaca* and *B. senegalensis*.

Considering occurrence change (Oc), differences were significant between agroecological regions, with a higher perception of Oc in the Sudanian region. The perception of the occurrence change of *B. senegalensis* is significantly different between genders; men's perception of Oc is higher than Oc women's perception.

The food value of *Z. mauritiana* for the Fulani ethnic group was lower and their perception of the occurrence change of *B. senegalensis* and *Z. mauritiana* was higher; both parameters were significantly distinct from the other socio-cultural groups.

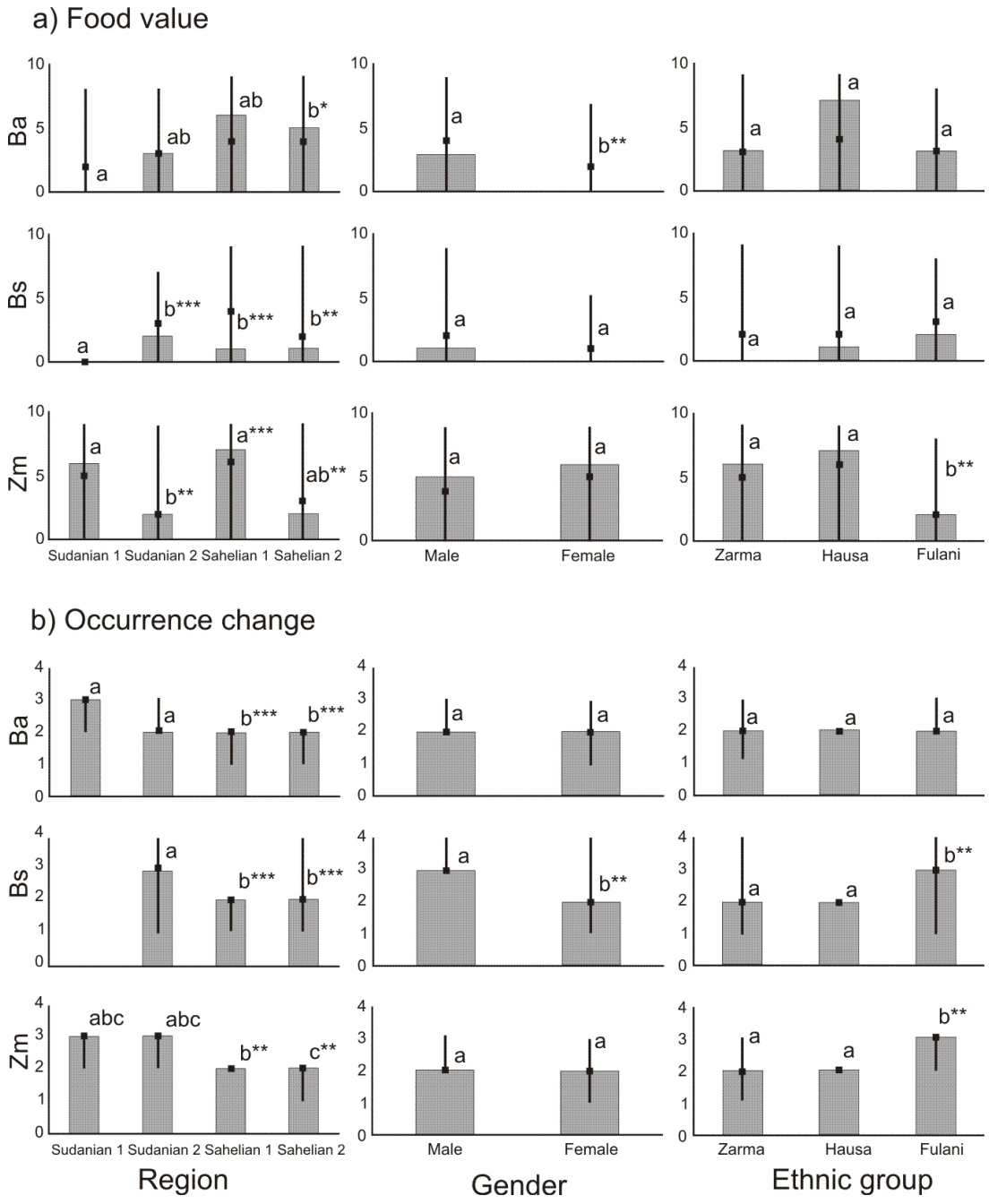


Figure 7. Kruskal-Wallis test for a) Food value and b) Occurrence change of 3 common species: *B. aegyptiaca* (Ba), *B. senegalensis* (Bs) and *Z. mauritiana* (Zm). Different letters show significant differences about the food value/ perception of occurrence change among villages: Senokonkodje (Sudanian 1), Weillagorou (Sudanian 2), Tondikiwindi (Sahelian 1) and Tondibiya (Sahelian 2); gender and ethnic group. Vertical grey bars indicate median, vertical black lines indicate range of responses and black points indicate average value of responses (without response is assumed by zero Food value).

The species providing the highest contribution to the diet were *A. digitata* (Fv=10) in the Sudanian region, followed by *B. senegalensis* (Fv=9) in both regions, *M. crassifolia* (Fv=9) in the Sahelian region, and *T. indica* (Fv=9) in the Sudanian region (Table 3). *V. doniana* is the species identified with the lowest contribution of all the species identified (Fv=3).

Table 3. Median for species food value, occurrence change, regeneration and driven factors.

Species Code	Region Code	N	Fv	Oc	Rg	Factors											
						Lc	Fr	Bw	Wd	Fl-Fr	Lv	Bk	Ch	Ds	Dr	Ag	Sl
Ad	Sd	45	10	2	2	1	1	1	1	1	4	1	1	2	3	1	1
Ba	Sh/Sd	57	7	2	2	1	1	1	3	1	1	1	1	1	1	1	1
Bs	Sh/Sd	43	9	2	**1**	2	1	1	1	**4**	1	1	1	1	3	1	1
Cf	Sh/Sd	17	8	2	**1**	1	1	1	1	1	**4**	1	1	3	**4**	1	2
Cn	Sd	27	7	3	2	2	1	1	2	1	1	1	1	1	1	1	1
Dm	Sd	11	4	3	2	1	1	1	1	1	1	1	1	1	**4**	1	1
Dy	Sd	22	5	3	2	3	1	1	1	1	1	1	1	1	1	1	1
Gb	Sh/Sd	18	6	2	**1**	1	1	1	3	**4**	1	1	3	1	**4**	1	1
Ht	Sd	15	5	3	2	1	1	1	1	1	1	1	1	1	1	1	1
La	Sd	6	5	**4**	**1**	2	1	3	1	**4**	2	1	1	**4**	**4**	1	**4**
Lf	Sd	13	4	3	2	1	1	1	1	1	1	1	1	1	1	1	1
Lh	Sh	8	5	2	1	**4**	1	**4**	1	**4**	**4**	1	1	**4**	**4**	1	**4**
Lm	Sh	30	5	2	2	1	1	1	1	1	1	1	1	1	1	1	1
Ma	Sh	8	5	**4**	**1**	3	1	3	1	**4**	**4**	1	1	**4**	**4**	1	**4**
Mc	Sh	39	9	2	**1**	1	1	3	3	1	**4**	1	1	**4**	**4**	1	1
Pb	Sd	30	6	2	2	2	1	3	1	3	1	1	1	2	3	1	1
Pr	Sh/Sd	24	6	2	2	3	1	1	1	**4**	1	1	1	1	3	1	1
Sb	Sh/Sd	43	5	2	2	1	1	1	**4**	1	1	1	1	1	1	1	1
Tg	Sh	7	6	**4**	**1**	2	1	1	1	**4**	**4**	1	1	**4**	**4**	1	**4**
Ti	Sd	43	9	2	2	1	1	3	1	1	1	1	1	1	3	1	1
Vd	Sd	8	3	3	1	2	1	1	1	1	1	1	1	1	3	1	1
Vp	Sd	27	7	2	2	1	1	1	1	**4**	1	3	1	1	**4**	1	1
Zm	Sh/Sd	64	6	2	2	1	1	2	1	1	1	1	1	1	1	1	1
Vd	Sd	8	3	3	**1**	2	1	1	1	1	1	1	1	1	3	1	1
Vp	Sd	27	7	2	2	1	1	1	1	**4**	1	3	1	1	**4**	1	1
Zm	Sh/Sd	64	6	2	2	1	1	2	1	1	1	1	1	1	1	1	1

Species (see code in table 1.2) cited in Sudanian (Sd) or Sahelian (Sh) region or both (Sd/Sh)

N= Number of respondents citing the species; Fv Food value (10 the most important species); Oc Occurence change 1=More occurrence than 10 years ago to 4=impossible to find the species nowadays; Rg Regeneration 1=Lack of regeneration; 2=presence of regeneration Factors 1=Not threatened by this factor; 4= Very important threat

Lc=Land clearing; Fr=Fire; Bw=Browsing; Wd=Wood or firewood; Fl-Fr=Flowers-Fruits; Lv=Leaves; Bk=Bark; Ch=Charcoal; Ds=Diseases, Pests; Dr=Droughts; Ag=Age; Sl=Soil

For all 23 species examined, reduced occurrence through the ten years preceding the interview (Oc between 2 and 4) was found. Except for *Z. mauritiana* (Oc=2), informants expressed the view that all species were under significant pressure (Oc = 3-4). In addition, lack of regeneration (Rg = 1) was recorded for 9 out of 23 species.

The multiple regression models were significant for 12 species (Table 4). Some factors with species-specific effects on conservation status were identified. For example, land clearing was found to affect only *P. reticulatum* and ageing only *P. biglobosa* and *V. paradoxa*. All other factors revealed a similar influence on many more species (affecting 4 to 6 out of the 12 species). The range of perceived pressure factors affecting each species varied widely across species: 1 out of 7 factors affected *A. digitata* (pest and diseases), *L. microcarpa* (browsing), *T. indica* (browsing) or *Z. mauritiana* (drought), while 5 out of 7 factors affected *P. reticulatum* (land clearance, wood collection and bark harvesting, pest and diseases and drought).

Table 4. Models fit (R^2Y) of Partial Least Squares (PLS) models (SIMPLS algorithm) to correlate main driven factors (dependent variable) with independent variables of main species.

Factors	SIMPLS models	Species											
		Ad	Ba	Bs	Cn	Lm	Mc	Pb	Pr	Sb	Ti	Vp	Zm
Lc	R^2Y	0.07	0.12	0.04	0.05	0.05	0.03	0.09	**0.24**	0.17	0.10	0.01	0.11
Bw	(models fit)	0.15	0.07	0.05	**0.26**	**0.23**	**0.23**	0.12	0.03	0.09	**0.24**	0.13	0.03
Wd		0.03	**0.44**	**0.47**	**0.20**	0.02	**0.26**	0.05	**0.31**	0.01	0.02	0.07	0.16
Bk		0.04	**0.28**	0.07	0.00	0.10	**0.21**	0.00	**0.50**	**0.24**	0.00	**0.52**	0.17
Ds		**0.22**	**0.23**	0.15	0.04	0.07	**0.28**	**0.29**	**0.28**	**0.24**	0.03	0.00	0.10
Dr		0.17	**0.35**	**0.29**	**0.33**	0.09	0.10	0.06	**0.21**	**0.35**	0.17	0.17	**0.32**
Ag		0.01	0.07	0.05	0.00	0.08	0.03	**0.29**	0.06	0.08	0.04	**0.20**	0.00

(food value, occurrence change and regeneration). Best models fit in bold.

Dependent variables: Lc=Land clearing; Bw=Browsing; Wd=Wood or firewood; Bk=Bark; Ds=Diseases, Pests; Dr=Droughts; Ag=Age.

Scaled coefficients and autocorrelation showed a significant relation between food value, the variables associated with conservation status (occurrence change and regeneration) and the degree of threats at species level (Table 5). It is to be noted that food value showed a significant relation with the level of threats in 15 out of the 17 significant cases, corresponding to almost all species analysed (10 out of the 12). The pressure factors with a significant relationship with food value and conservation status variables were browsing (3 species), bark harvesting (3 species), pest and disease occurrence (4 species) and drought (4 species).

Occurrence change was significantly and positively correlated with browsing (*L. microcarpa* and *T. indica*), land clearing (*P. reticulatum*), wood extraction (*B. aegyptiaca*) and pests and

diseases (*A. digitata* and *P. biglobosa*). Regeneration (lack of regeneration) was positively related with wood or firewood harvesting (*C. nigricans*), bark extraction (*P. reticulatum* and *V. paradoxa*), pest and disease occurrence (*P. reticulatum*) and drought (*C. nigricans*).

Table 5. Scaled coefficients and autocorrelation (R^2X) for each PLS model.

Dependent	Independent variables	Scaled coefficients and autocorrelation by species											
		Ad	Ba	Bs	Cn	Lm	Mc	Pb	Pr	Sb	Ti	Vp	Zm
Lc	Fv	-0.16	0.45	0.22	0.09	-0.17	-0.16	0.12	-0.21	0.10	0.11	-0.04	0.21
	Oc	-0.01	-0.36	0.00	0.05	-0.19	0.00	0.16	0.29	0.22	0.26	0.06	-0.23
	Rg	0.23	-0.20	0.10	0.21	-0.01	0.03	-0.22	-0.21	-0.37	0.17	-0.06	0.00
	R^2X	0.30	0.36	0.26	0.35	0.30	0.37	0.34	0.45	0.29	0.31	0.51	0.39
Bw	Fv	0.18	-0.07	-0.06	0.48	0.32	-0.16	-0.11	0.01	0.26	0.40	0.30	0.10
	Oc	0.22	0.20	-0.18	0.03	0.28	0.02	-0.31	0.02	0.04	0.25	-0.12	0.08
	Rg	-0.17	0.15	-0.17	0.12	-0.17	-0.50	-0.03	0.18	-0.16	0.07	-0.19	0.09
	R^2X	0.45	0.36	0.32	0.37	0.40	0.36	0.37	0.34	0.35	0.38	0.32	0.28
Wd	Fv	0.12	0.5	0.14	-0.38	-0.12	0.20	0.06	0.19	0.08	0.08	0.00	0.07
	Oc	-0.03	0.37	-0.30	-0.16	-0.01	-0.39	0.17	-0.37	-0.07	-0.10	0.09	-0.33
	Rg	0.14	-0.20	0.76	0.36	0.08	0.40	-0.12	0.24	0.04	0.13	-0.21	0.21
	R^2X	0.33	0.38	0.29	0.40	0.40	0.25	0.34	0.45	0.42	0.29	0.45	0.33
Bk	Fv	0.05	0.28	0.22	nc	0.15	0.07	nc	0.09	0.27	nc	0.23	0.09
	Oc	-0.18	-0.38	-0.06	nc	0.26	-0.31	nc	-0.42	-0.32	nc	-0.26	-0.31
	Rg	0.03	-0.14	0.29	nc	-0.07	0.41	nc	0.48	0.04	nc	0.47	0.24
	R^2X	0.38	0.38	0.19	nc	0.37	0.30	nc	0.41	0.44	nc	0.52	0.34
Ds	Fv	0.39	0.11	0.39	0.01	-0.09	0.43	0.42	0.08	0.29	0.08	nc	0.02
	Oc	0.20	-0.44	-0.18	0.18	0.21	-0.06	0.24	-0.34	-0.29	0.13	nc	-0.24
	Rg	-0.11	0.09	0.11	-0.09	-0.06	0.40	0.10	0.30	0.08	0.05	nc	0.19
	R^2X	0.40	0.35	0.34	0.36	0.42	0.31	0.39	0.43	0.44	0.34	nc	0.37
Dr	Fv	-0.28	0.29	0.43	0.12	0.16	0.23	-0.05	0.46	0.38	-0.19	0.08	0.23
	Oc	-0.23	-0.47	-0.31	-0.05	-0.14	0.05	0.08	-0.41	-0.32	-0.20	-0.19	-0.47
	Rg	0.10	0.14	0.53	0.55	0.18	0.25	0.22	0.11	-0.05	-0.22	0.27	0.04
	R^2X	0.41	0.36	0.19	0.33	0.41	0.34	0.35	0.40	0.45	0.45	0.51	0.38
Ag	Fv	-0.04	0.11	0.17	nc	0.24	0.14	0.47	-0.19	-0.01	-0.02	0.19	nc
	Oc	-0.05	-0.14	0.02	nc	-0.11	0.10	0.10	-0.19	-0.10	0.05	-0.24	nc
	Rg	0.03	0.22	-0.08	nc	-0.06	0.08	0.19	-0.19	-0.29	-0.10	0.16	nc
	R^2X	0.43	0.30	0.56	nc	0.40	0.35	0.36	0.20	0.30	0.26	0.53	nc

Higher scaled coefficients in bold; nc= no computable. Dependent variables: Lc=Land clearing; Bw=Browsing; Wd=Wood or firewood; Bk=Bark; Ds=Diseases, Pests; Dr=Drought; Ag=Age. Independent variables: Fv=Food value, Oc=Occurrence change; Rg=Regeneration

FARMERS' PREFERENCES FOR CONSERVATION OF AGROFORESTRY FOOD RESOURCES

Description of the surveyed population

The three main ethnic groups that the respondents belong to are the Hausa (51.9%), Zarma (29.9%), and Fulani (17.2%), with the surveyors speaking the Zarma, Hausa, Fulani, Gourmantchema and French languages. The majority of the respondents were men (85.8%), and practically all of them were married (92.3%). Nearly all the respondents were heads of household (77.6%) or female heads of household (11.2%).The 39.7 of the families has at least 15 members (mean of 14.2 members) and a mean of 4 children (up to 7 years old) per family. They were natives (84.3%) and farmers (90.8%) as the primary activity. As the secondary activity, they are cattle breeders (13.2%), traders (20.2%), gardeners (9.2%) or temporally migrants (14.7%). The 95.5% of the respondents stated that annually they suffer from a 4.7 mean month period of scarcity (from March to July). Predominantly, the surveyed population is illiterate (68.17%), and 38.4% of them have studied the Koran. In Niger, Koranic schools represent the traditional institutions of basic education in rural areas. Their functions are not merely limited to reading and memorizing versus of the Koran, rather it also includes broader and more fundamental areas of civic education, community life, and spirituality, and depending on the teacher's knowledge, an educational program could touch upon many other areas of general and Islamic culture.

Regarding property, the 85.8% have the right to cultivate for live at least one parcel of land, with an average surface area of 16.13 hectares per respondent, and the 23.7% with larger parcels of land. The mean distance from the home to the parcel is 1.77 km and a 33.4% walk larger distance to reach the parcel. The main crops are millet, cowpeas, sorghum, sesame seeds, and peanuts.

Species uses, management and perception of threats

All the considered species are present on the land and managed by FNMR being *A. digitata* mostly the only woody plant planted by farmers. The perception by farmers about the growing density of the trees in the land, varies from 49.9% for *Z. mauritiana* to 15.70% for *A. digitata* (Table 6). The main use of these four woody species is human food, although they are also used for animal feed, pharmacopeia, and firewood, veterinary, as insecticide, or in traditional ceremonies (Table 7). The main threats to these trees were identified with some specifics. For example, *B. aegyptiaca* and *Z. mauritiana* are subject to

over-grazing and land clearing, *A. digitata* and *Z. mauritiana* have suffered from insect and diseases and *B. senegalensis* from drought (Table 8).

Table 6. Percentage of citation as priority species, and status of the species in the agroforestry systems, as a %. Land= present on; Managed= planted or FMNR; Planted=planted; Density: density stable or growing.

	Priority sp	Land	Managed	Planted	Density
Adansonia digitata	56,40	48,10	34,90	25,90	15,70
Balanites aegyptiaca	20,70	60,10	31,70	1,70	31,70
Boscia senegalensis	2,00	31,40	19,70	0,00	18,70
Ziziphus mauritiana	5,50	65,30	52,40	2,20	49,90

Table 7. Uses of the species (x) and priority use for each species (+), as a percentage of times cited and by order of priority in ().

	A. digitata		*B. aegyptiaca*		*B. senegalensis*		*Z. mauritiana*	
	X	+	X	+	X	+	X	+
Human food	89.8	70.8 (1)	70.1	67.3 **(1)**	56.4	37.9 **(1)**	79.3	73.1 **(1)**
Cattle feed	17.7	13.5	31.2	26.4 **(3)**	24.7	13.2	56.1	39.7 **(2)**
Wood construction	21.2	0.5	20	19	16.5	7.5	17.7	10.0
Firewood	21.9	2.2	57.9	32.4 **(2)**	17.2	10.5	30.7	16.0
Tools, handicrafts, musical instruments	21.4	1.5	62.3	22.7	19.2	17.2 **(3)**	26.9	8.5
Pharmacopoeia	40.6	23.2 **(2)**	24.4	23.7	9.2	4.0	38.2	22.4 **(3)**
Animal health	42.9	17.2 **(3)**	20.2	16.7	22.4	5.0	19.2	16.2
Products against the enemies of crops	23.2	1.5	30.7	3.7	18.7	18.0 **(2)**	23.7	2.0
Ceremony, tradition	18.7	4.5	22.4	1.2	19.7	1.5	24.4	2.5

Table 8. Perception of the threats of degradation of the species (x) and the main threat (+), as a percentage of times cited and by order of relative importance ().

	A. digitata		*B. aegyptiaca*		*B. senegalensis*		*Z. mauritiana*	
	X	**+**	**X**	**+**	**X**	**+**	**X**	**+**
Land clearing	20.4	6.7	18.7	17.0	35.7	35.4 **(1)**	59.4	50.1 **(1)**
Fires	15.7	1.0	19.2	3.2	17.0	2.7	25.7	3.5
Over-grazing	20.4	3.5	29.4	24.7 **(3)**	15.2	13.2 **(2)**	29.9	28.4 **(2)**
Wood construction over-exploitation	17.2	2.2	42.9	41.1 **(1)**	10.7	9.0	15.2	10.5
Flowers, fruits over-exploitation	15.2	3.7	16.0	7.7	15.0	7.2	14.2	5.5
Leaves over-exploitation	22.7	6.7	17.0	7.5	13.5	7.5	17.7	12.7
Bark over-exploitation	22.4	4.2	15.2	5.0	13.7	3.5	14.2	7.0
Charcoal, firewood over-exploitation	14.7	1.2	29.7	27.2 **(2)**	10.5	8.0	13.2	7.0
Roots over-exploitation	16.5	2.0	14.0	5.2	12.2	6.7	19.5	10.7
Pruning problems	27.7	5.2	23.9	18.0	14.7	4.5	14.0	10.7
Insects and diseases	76.3	64.1 **(1)**	18.5	4.0	18.7	6.0	21.9	20.7 **(3)**
Drought	19.7	6.2	16.5	13.2	20.0	9.7 **(3)**	18.5	11.7
Wind	28.7	7.2 **(2)**	16.2	10.0	17.0	5.2	15.7	6.7
Aged trees	21.4	7.0 **(3)**	12.7	5.7	13.5	3.5	13.7	3.7
Depleted soils, fertilizer influence	14.2	2.7	14.0	4.2	12.0	5.0	11.2	5.7

Contingent ranking results

The contingent ranking allows us to analyze the preferences of the local farmers according to the various attributes and resulting levels of the experimental design. 84.54% of the respondents always prefer one of the offered programs as opposed to leaving the crop fields in their current state (*status quo*).

The preferred conservation scenario or program is clearly the one based on the species *A. digitata*, plantation[1] half moon, and selected seeds (Table 9). The main effects of the program, according to the surveyed population, would be an increase in crop production, soil fertility, avoiding runoff erosion, and an increase in income from tree products.

Table 9. Ranking experiment results.

	Coefficient (Std.Err.)	**Std.Dev. of RPs** (Std.Err.)	**WTW** days/year (Std.Err.)	**95% CI**		**WTP (1)** euros/year
A. digitata	1.094***	0.888***	32.68***	25.56	39.80	96,76
	(0.942)	(0.054)	3.63			
B. aegyptiaca	0.745***	0.521***	22.27***	18.54	26.00	65,94
	(0.055)	(0.060)	(1.90)			
Z. mauritiana	0.589***	0.511***	17.58***	11.59	23.57	52,05
	(0.088)	(0.548)	(3.06)			
Plantation	0.804***	0.433***	24.02***	21.36	26.69	65,20
	(0.045)	(0.356)	(1.36)			
Tassa	0.780***	0.156*	23.29***	18.51	28.07	68,96
	(0.079)	0.082	(2.44)			
Half moon	1.159***	0.327***	34.63***	30.06	39.21	102,53
	(0.078)	(0.076)	(2.33)			
Stone bunds	0.621***	0.443***	18.55***	15.95	21.14	54,92
	(0.044)	(0.046)	(1.32)			
Selection	1.764***	1.002***	52.71***	45.35	60.07	156,06
	(0.101)	(0.050)	(3.75)			
Breeding	1.266***	1.181***	36.62***	31.85	41.40	94,30
	(0.070)	(0.048)	(2.44)			
Effort	0.033***	fixed				
	(0.001)					

*** p<0.01; ** p<0.05; * p<0.10

(1) 1 euro = 0XF 655.957 (fixed exchange rate)

1. The levels FMNR and the current practice were joined due to problems of multicollinearity intra-attribute.

In terms of Willingness to Work (WTW), the quality of the seeds would represent the greatest contribution to payment. The selected seeds are associated with a WTW of 52.71 work days, whereas bred seeds have a WTW value of 36.62 work days. The soil conservation action (half-moon) contributes 34.63 work days, the use of *A. digitata* contributes 32.68 work days, while the action to increase the density of the trees (plantation) contributes 24.02 days. Also, the respondents were asked about the time horizon during which they would maintain their effort, and it is observed that 38.75% of the population would participate in the program for an indefinite period, while 49% would do so for a period of 5 years or more.

Finally, the questionnaire included questions that allowed the possibility of transforming the WTW into monetary terms. Thus, the respondents were asked about the number of hours that an agricultural work day represents in their village and about the corresponding wage that they would receive. The mean agricultural work day represents 5.84 hours, with a remuneration of XOF 1942. Considering these values, the WTW can be transformed into WTP, thereby obtaining an assessment, in monetary terms, of the preferences for the proposed program. This information is illustrated in Table 9.

ANALYSIS OF CONSUMER PREFERENCES FOR BAOBAB

Description of the surveyed population

Of the 432 surveyed people, only 1 person in the urban market of Harobanda refused to participate in the study due to a lack of time. The surveyed population was between 15 and 81 years of age, with a mean of 39 years. 127 were men and 273 were women, mainly belonging to three ethnic groups: 204 were Hausa, 136 were Zarma, and 57 were Fulani.

A significant part of the sample has received no kind of education (137 individuals). For those who have received an education, we can observe the following distribution: Koranic studies (70), literacy (42), primary (101), secondary (56), and higher (13). In Niger, Koranic schools represent the traditional institutions of religious and moral education in rural areas. In this study, it has been considered the lowest level of education, given that people who do not have access to a formal education neither learn to read nor write in Koranic schools.

Of the 432 surveyed people, 350 were married, and 49 were either divorced, widows, or single women. 373 were either the heads or the wives of the heads of the family unit,

and 40 people held no type of decision power in the home (child, worker, sibling, etc.). The size of the families ranged from 1 to 73 members (mean of 10.3 members) and 2.6 children (up to 7 years old) per family. 141 of the respondents lived in polygamous homes. Regarding professional activities, it should be pointed out that men were mainly engaged in agriculture (213) and trade (60), while of the women, 242 were housewives, 52 were farmers, and 123 had other activities. Finally, 92 of the respondents were baobab gatherers (21% of the sample).

Regarding the food shortage period, 62% of the sample stated that they suffered from such a shortage, with a mean of 3.9 months per year, most frequently beginning in the month of April.

All the described variables have been tested to see if they turned out to be explanatory of baobab consumers' willingness to pay. Variables pertaining to age, sex, education level, family size, civil status, profession, or having suffered from periods of food shortage were not found to be statistically significant (at a level of 90%). Table 10 shows a summary of the characteristics of the sample, which are used as eventual explanatory variables in the econometric modeling of consumer behavior.

Description of baobab products

We indexed the different types of baobab products, the quantity purchased (not in grams, rather by type of measure or the container used), and the acquisition prices by product and measure. As we previously mentioned, it is difficult to know the exact quantities and their equivalent prices. In the surveyed markets, up to seven different kinds of measures are used, which are equivalent to seven different quantities of product. The prices between measures of the same product overlap, wherefore from all the responses for all the products, we constructed four categories of unit prices, which are related to the sales measures of the products: (i) small: from 25 to 175 XOF, acquired by 27.8%; (ii) medium: between 200 and 450 XOF, acquired by 38.3%; (iii) large: between 500 and 900 XOF, acquired by 19.7%; and (iv) very large: 1000 XOF and above, acquired by 14.2% of the buyers.

Table 10. Description of variables.

Variable	Description of the variable	Sample %
REG1	Maradi region = 1; Tillabéri-Niamey region = 0	46.30
ETH1	Zarma Ethnic group = 1; Hausa, Fulani, and others = 0	26.43
KORANIC	Koranic education Yes= 1, No = 0	14.33
GATHER	Gatherer of baobab products = 1; Non-gatherer = 0	21.06
HAROB	Harobanda (Niamey) Urban Market = 1; Others = 0	4.46
SIMIRI	Simiri (Tillabéri) Rural Market = 1; Others = 0	5.41
TAMOU	Tamou (Tillabéri) Rural Market = 1; Others = 0	9.24
MKTR	Rural Market = 1; Urban Market = 0	59.03
HEALTH	Health is the reason to buy the usual baobab product = 1; Other reason = 0	30.89
MKETBEV	Usual product is acquired to be marketed or transformed into beverage (only pulp) = 1; Other reason = 0	11.11
PRMEAS	Range of prices for all products by measure: 1 = from 25 to 175 XOF, 2 = from 200 to 400 XOF, 3 = from 500 to 900 XOF, 4 = from 1000 XOF	n.a.
TIA	Tia is the name of a traditional and usual measure in the market. The acquired measure is the tia or bigger = 1; Small measures = 0	45.86
PROCONS	Conservation of baobab resources is the reason for participating in the program = 1; Other reason = 0	25.48
PROHEALT	Health properties of baobab products is the reason for participating in the program = 1; Other reason = 0	6.69
PROTRADI	Traditional use of baobab products is the reason for participating in the program = 1; Other reason = 0	9.24
PROAVAIL	To assure the availability of baobab products at the market is the reason for participating in the program = 1; Other reason = 0	31.85

The amount of the weekly purchase basket in the market is a mean of 5620 XOF. Of the total basket, 23.19% of the products are from the baobab. At the time of the survey, consumers acquired baobab products for a mean value of 695.12 XOF, with a range of between 25 and 10,000 XOF. The lowest price refers to little plastic bags and the highest price refers to sacks. Dry leaves are the product regularly acquired by 41.3% of the surveyed buyers, ground dry leaves by 42%, ground pulp by 11.4%, and pulp with seeds by 5.3%. Pulp can be considered a "luxury" product, and all the respondents who cited two preferred products cited leaves and pulp. In fact, the products coming from the gathering of fruit (pulp and pulp with seeds) mainly come from other countries, due to the fact that the type of management in Niger does not prioritize the production of fruit.

Identification of the protest responses

Figure 8 shows a schematic of the sample selection procedure for estimating the econometric models. Of the 432 surveyed buyers, 227 would participate in the program, and 155 would not participate. Of the total number of people who would participate in the program, extreme values of willingness to pay (outliers) are identified, thereby considering a threshold of 100% with respect to the usual price of the product, and these outliers are not considered in the analysis. To detect the protests, those who responded that they were not willing to pay an additional surcharge above the price they usually pay for the product were asked a series of follow-up questions to identify the true zeros of the protests to elements of the scenario or program. Of these, a total of 105 protests and 50 real zeros were identified. 24.3% of the responses were protests, meaning that they did not want to participate in the program being offered. The reasons why they would not participate in a conservation program of baobab resources are mainly because they think that there won't be any availability problems in the market, they think that the products are always going to be found in another market, and they think that baobab resources can be replaced by other products, or they would prefer paying for other products.

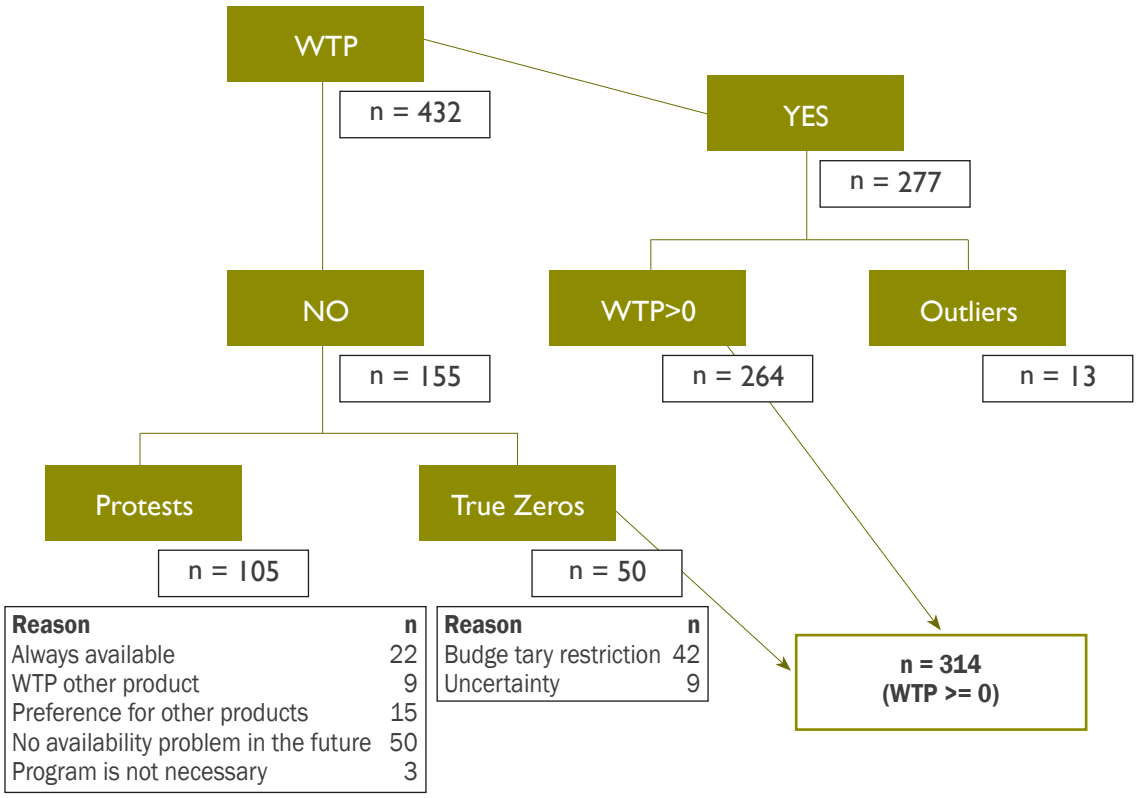


Figure 8. Sample selection procedure.

Table 11 shows the results of the probit model for sample selection, in which the variables that positively explain the probability of being included in the sample are REG1 (Maradi region), MKTR (rural market), PRMEAS (price of the measure), and GATHER (gatherers). Moreover, the MKETBEV variable has a negative influence, meaning that acquiring the product for the transformation thereof into a beverage (pulp) or to resell it (leaves and pulp) is associated with a greater probability of being identified as a protest.

This latter variable could be indicating that the intermediaries of leaves and pulp for resale and that pulp processors for the beverage trade are not concerned about the conservation of baobab resources, given that they can substitute the products of their commercial activity.

Table 11. Probit model for sample selection.

	Coeff.	Std. Err.	t-ratio
Constant	-1.010***	0.243	-4.15
REG1	1.179***	0.182	6.47
MKTR	0.869***	0.175	4.97
PRMEAS	0.404***	0.08	5.04
MKTBEV	-0.737***	0.254	-2.90
GATHER	0.415*	0.219	1.90
Log likelihood function	-175.481		
Restricted log likelihood	-239.577		
Pseudo R^2	0.268		
n	432		

*** p < 0.01;**p < 0.05; *p < 0.10

Note: Dependent variable Z (0: protest; 1: WTP > 0 and true zeros)

Willingness to pay

A mean of 61% of the sample is willing to pay for a conservation and breeding program of baobab resources. The reasons for participating in the program are because of the tradition of using baobab products (PROTRAD), because the products are good for health (PROHEALTH), because the conservation and breeding of baobab is important (PROCONS), and to ensure that it is possible to continue purchasing the usual product (PROAVAIL).

Given the diversity of measures and prices, we transformed WTP into percentage terms (WTP%), given that working in unit terms would lead to problems of scale. The mean WTP% is 24.73% above the acquisition price of the preferred product, and we verified the expected inverse relationship between the WTP% and the price of the measure of the acquired product. Table 12 includes the willingness-to-pay model of baobab products. As it can be seen, there is no sample selection problem, given that the inverse of the Mill ratio is not a statistically significant variable in the model (λ=1.54; Std.Err. 6.284).

Table 12. OLS model.

Variable	Coeff.		Std.Err.	t-ratio
Constant	15.768	***	3.814	4.13
ETH1	8.794	***	3.030	2.90
EDU1	7.566	**	3.497	2.16
HAROB	30.042	***	6.193	4.85
SIMIRI	13.772	**	6.014	2.29
TAMOU	16.567	***	4.524	3.66
TIA	-8.338	***	2.751	-3.03
PRMEAS	-3.375	**	1.421	-2.38
HEALTH	8.634	***	2.873	3.00
PROCONS	14.761	***	3.366	4.38
PROHEALTH	15.08	***	5.219	2.89
PROTRAD	16.627	***	4.846	3.43
PROAVAIL	14.696	***	3.317	4.43
LAMBDA				
R^2 (adjusted) = 26.09%				
n = 314				
Average WTP	24.73%			

*** p < 0.01;**p < 0.05

The average profile of the person who is willing to pay a surcharge on the purchase of the usual product (table 3.3), thereby contributing to the conservation and breeding program of planted baobab, is that of someone who belongs to the Zarma ethnic group (ETH1), who has a Koranic school education level (KORANIC), who is a customer of the Harobanda market (HAROB, urban market of Niamey) or the Simiri or Tamou markets (SIMIRI, TAMOU, rural markets of Tillabéri), and who uses baobab products for health reasons (HEALTH). The larger the measure (TIA) and the greater the price of the measure, the less a consumer is willing to participate in the program (PRMEAS).

No statistically significant differences were found with respect to the influence on the WTP of rural or urban markets, probably due to the importance of baobab products in the nutrition and health of Niger's population as a whole. The markets whose consumers are more willing to pay have special characteristics. The Harobanda market (HAROB) is characterized by the concentration of NWFP sellers, and it could attract a clientele interested in ensuring the availability of those products. TAMOU is in the area of the Tamou Fauna Partial Reserve and the entrance to the W Transborder Park. In this area, the population is highly sensitized to the conservation of resources because of environmental conservation actions and due to the major presence of forestry agents. Moreover, agroforestry practices are applied, including the regeneration and planting of trees, with the practices being passed on from generation to generation. In recent years, due to the drought and the increased pressure from livestock, the preservation of trees in the fields has been seriously threatened, wherefore the population of this area is highly receptive to conservation programs. In SIMIRI, also due to the major droughts in 1972-73, there was a major loss of tree vegetation. From the 1980s up to now, major efforts have been under way by NGOs and various international institutions such as the WFP (World Food Programme) to reverse this situation.

Even though an ethnic group can have an influence on the assessment of NWFP and on the preferences of local communities for the conservation of those products (Heubach et al., 2013), in these areas the predominant ethnic group is the Zarma, wherefore it isn't possible to assure that this variable responds strictly to cultural aspects.

The variables corresponding to the different levels of education (from illiterate to higher education) have not been shown to be significant in the conservation program. The KORANIC variable corresponds to people who have attended Koranic schools and who have no degree of formal education (they are illiterate). KORANIC is a variable that possibly masks other variables of an economic (poverty), cultural (tradition), moral, and religious nature. We verified that being illiterate has no influence on whether or not someone participates in the program.

DISCUSSION

TOWARDS A PARTICIPATORY CONSERVATION OF FOOD TREE SPECIES

Edible woody indigenous resources play a noteworthy role in the diets of rural communities. Three woody species emerged from this study as crucial resources contributing to the diet of local communities: *A. digitata*, *B. senegalensis* and *M. crassifolia*. While *B. senegalensis* had been previously reported as a staple food in periods of scarcity in Niger (Muller and Almedom, 2008; Dan-Gimbo and Barrage, 2012), our study revealed that *M. crassifolia* leaves are also consumed by humans, although they had been reported only as animal forage in other regions of Niger (Dan-Gimbo and Barrage, 2012). *A. digitata* and *M. crassifolia* had previously been highlighted as important famine foods also in the Sahelian region of Burkina Faso (Sop et al., 2012; Thiombiano et al., 2013, 2012), and marketed locally in Northern Nigeria (Harris and Mohammed, 2003). The food value attributed to edible woody species by key informants from the Sudanian villages seems to be consistent with results from research conducted in other sub-Saharan countries, similarly pointing at *A. digitata* as the most important food tree species (Vodouhê et al., 2010; Faye et al., 2011; Dan-Gimbo and Barrage, 2012; Sop et al., 2012; Thiombiano et al., 2013).

The local communities involved in this study valued the woody species differently depending on the agroecological context, as was found in a similar study in northern Benin (Assogbadjo et al., 2010); however the food value obtained in our study does not seem to be linked to the status of residence of the respondents. No similarities in the food value were found between Tondikiwindi and Senekonkodje inhabitants (the latter ones, climatic refugees in the Sudanian agroecological region, former habitants of Tondikiwindi) as we were expecting.

In our study, significant differences were found according to gender: men attributed a greater value to *B. aegyptiaca* than women, and expressed a perception of a more pronounced decline of its occurrence over time. Men also perceived a more pronounced decline in *B. senegalensis* than women, despite this species being quite resilient, broadly distributed and re sprouting. These findings seem to be explained by different gender

roles; men are responsible for clearing land for cultivation and therefore they directly affect the density of edible woody species, such as *B. aegyptiaca* and *B. senegalensis*, even if this practice was not perceived as a pressure factor.

In West Africa, ethnicity has been reported as a factor that influences preferences and resource knowledge with regard to food tree species. Examples of such findings are available for *A. digitata* (De Caluwé et al., 2009), *P. biglobosa* (Koura et al., 2011) and *T. indica* (Fandohan et al., 2011). In our study, the Fulani indicated a slightly lower preference for *Z. mauritiana* and they reported a higher declining occurrence of this species and of *B. senegalensis*. These results can be explained by their semi-nomadic lifestyle and livelihood strategy; they depend less on locally available resources given their mobility; they rely largely on dairy products for their diet, and they have the opportunity to observe vegetation changes on a much wider area, beyond village boundaries.

All informants expressed a general view of all species, except *Z. mauritiana*, being under significant or very strong pressure. These results reveal a certain concern for the conservation of woody resources, similar to participants in research in the neighbouring Pendjari National Park in Benin (Vodouhê et al., 2010). Nevertheless, the model developed in this study did not provide a univocal explanation for the observed conservation status of the edible woody species investigated. The relation between the food value of edible woody species and the perception of pressure factors varies among species. For some species with high food value, such as *A. digitata*, *B. aegyptiaca*, *M. crassifolia*, *P. biglobosa*, *S. birrea* and *P. reticulatum*, the perception of key informants indicate pests and diseases as the main threats. For *B. senegalensis* the main threat factors were drought and wood and firewood harvesting; for *M. crassifolia*, drought, pest and diseases, browsing, wood harvesting and bark exploitation. For *V. paradoxa* the most important threat factor turned out to be ageing of individuals, in line with what was observed in parklands in West Africa by Sanou and Lamien (2011).

In a previous study carried out in Niger and Burkina Faso (Wezel and Haigis, 2000; Wezel and Lykke, 2006), *B. aegyptiaca* resulted as a non-threatened, well-preserved species, included among the drought-resistant species. It is remarkable that in our study, *B. aegyptiaca* was cited as being under threat due to wood harvesting and bark exploitation along with drought and pest and diseases. This result constitutes an alert about the continued increase of resource degradation by natural or biological factors (e.g. extreme climate events) and by human pressure, with a consequent loss of genetic resources. *B. aegyptiaca* is used both for human and animal consumption and regularly

pruned by women farmers for use in dishes and by men farmers to feed livestock during the dry season. This practice puts pressure on the regeneration capacity of the species because young leaves and flowers are harvested all together generally from the adult trees required for the renewal of the species (Abdourhamane et al., 2013).

Based on the perceptions of the people interviewed in our study, almost all key species investigated seem to have undergone a considerable decline in occurrence and a lack of regeneration seems to have affected nearly half of the species examined. Therefore, the availability of the resources in the future is at risk. This perception is in agreement with what has been highlighted in research projects on land use change (USGS, 2013). Rapid population growth and growing demand for food have produced a large expansion of cultivated areas (grown by 42.7% during the period 1975-2000), which has determined a contraction of fallows, bushland and pastures, and increased the pressure on woodlands.

Our study contributes with a general view of the causes of the perceived pressures not being linked to the management practices of the land system but mainly to the collection practices of tree products or to biotic and abiotic factors. Land clearing was not generally cited as a real concern, probably because agriculturalists are obliged to increase arable land at the expense of some food tree species, which they do not perceive as disappearing thanks to their re-sprouting capacity after cutting the main stem. The informants attributed land clearing as a pressure factor of the one species *P. reticulatum*, as it is has been observed by Wezel and Haigis (2000).

According to the perceptions of the local dwellers interviewed (90% agriculturalist), the decline of edible woody species seems mainly attributable to the effects of browsing, reflecting a well-known tension between agriculturalists and pastoralists. However, contrary to expectation, absence of regeneration in species with high food value is associated with an excessive exploitation of wood and bark, worsened by drought, pests and diseases, and not with browsing. In Burkina Faso, when the main causes of changes in the vegetation were identified, drought was the most important factor, followed by deforestation, ageing of the trees and fires (Sop and Oldeland, 2011). In a study in North Benin focused on *S. birrea*, all respondents reported a recent decline (Gouwakinnou et al., 2011). Their views indicated that the responsible factors were both anthropogenic (agriculture, grazing and felling for carving) and natural (decreased soil fertility, natural death and drought).

Our findings provide essential elements on local knowledge for a participatory design of conservation activities of priority edible woody species. To strengthen this basis, the

present findings should be combined with inventories of the vegetation in representative plots, to link perception of dwellers with a direct assessment of the conservation status of key food tree species and the dynamics affecting occurrence and regeneration. Improving species regeneration dynamics knowledge in the context of human and climatic pressure should contribute to the success of adaptive management and conservation of indigenous edible woody species.

FARMERS' PREFERENCES FOR CONSERVATION OF AGROFORESTRY FOOD RESOURCES

The type of agroforestry management that the local population applies depends to a large extent on the forest species of reference. According to the responses from the farmers, the species *A. digitata* is chosen mainly because its products are used for food in the home and can also be sold in markets. Planting actions or actions that favor regeneration are justified by generating an increased number of trees in the field. The soil conservation technique is chosen with the aim of yielding better trees, meaning trees that are more productive and resistant. Finally, the type of seed is identified with better-quality production (selected seed) and greater production (bred seed). In general, the local population selects the superior trees of *A. digitata* based on the quality of the leaves, and in order to be able to provide some care and increase leaf production, they take young trees selected from among those in the crop field to transplant them at their homes (Jensen et al., 2011).

As we can see, conserving, protecting, and managing trees of *A. digitata* in the crop fields has an impact on the economy and well-being of the rural populations of the Sahel. Binam et al. (2015), in a study conducted in Burkina Faso, Mali, Niger, and Senegal, finds an increase of US$72,000 in annual income for 1000 homes that continuously apply FMNR. The income derived from the sale of leaves from one tree of *A. digitata* in Zinder (Niger) can represent between US$27 and US$75 per tree, depending on the location and frequency of markets. Haglund et al. (2011) calculated crop production values, and in the fields where FMNR was practiced, the values were nearly 60% higher than in fields where this practice was not applied. Binam et al. (2015), in four countries of West Africa, found that the yields of crops where FMNR was applied were between 15% and 30% higher than where FMNR was not applied. In general, adopting the practice of FMNR in the Sahel - West Africa could mean an increase of US$300 per home and year in strictly economic terms (Weston et al., 2015).

Moreover, if soil conservation techniques are used, agricultural production increases. One comparative study of WSC techniques in the region of Tillabéri (Niger) clearly showed that these techniques improve the growth of millet crops, regarding both straw and grain yields. The greater grain yield came from using zaï or tassa, which was approximately 2.5 times greater than the yield using the half-moon technique (Wildemeersch et al., 2015b).

In recent years (Moussa et al., 2016), the perception of local communities regarding natural resources has undergone a change in favor of conserving these resources. The Rural Code and other institutional reforms, international and technical support from civil society (NGOs), as well as incentives for planting or conserving trees have caused an impact on communities, thereby allowing them to be the owners of the trees and benefit from their products. The most important crops for human consumption in Niger are sorghum and millet, but currently their production represents 30-50% of the potential. Increasing production using adequate agricultural techniques for conserving the soil and moisture would also mean an increase in food security.

This study has allowed identifying a program that would provide the greatest well-being for the local population. Such a program is highly important for farmers, since it would allow them to simultaneously increase both the production of their crops and the production of a woody food species such as the baobab, in addition to allowing an increase in income from derived products if there were a need and a surplus.

ANALYSIS OF CONSUMER PREFERENCES FOR BAOBAB

This study contributes key elements to the success of a policy for the conservation and improvement of NWFP production, always within the framework of Niger's national policies for the promotion of food and nutritional security and the reduction of poverty. The 3N initiative ("Les Nigériens Nourrissent les Nigériens", Nigeriens feeding Nigeriens) is a political commitment to save the Nigerien population from hunger and to guarantee conditions so that Nigeriens can participate in national production and improve their income. This involves finding appropriate solutions for increasing and diversifying agrosilvopastoral production, the regular supply of rural and urban markets with agri-food products, and improvement of the populations' resilience to climate change, crises, and catastrophes, among other things (Haut Commissariat à l'initiative 3N, 2012).

The strategy and action plan for the promotion of NWFP in Niger (MESU/DD, 2016) highlights, as one of the common problems of NWFP, their lack of consideration as

staples and products of daily use, despite their socioeconomic importance. The leaves and fruits of the baobab constitute one of the priority production lines. Our results show that baobab products represent 23.19% of the purchase basket of weekly food, and 83.3% of the studied population preferably consumes leaves, whether whole dried or ground. The strategy highlights some of the problems cited in this article, such as ageing of the trees and the lack of regeneration due to unsustainable practices caused by anthropogenic pressure and drought conditions.

Some of the opportunities include increased awareness by producers and a strong political will to enhance the value given to NWFP. In recent years, different policies on the environment and on the regeneration of plant cover in Niger (Moussa et al., 2016) have promoted a change in the perception of local communities regarding the natural resources in favor of preserving those resources. The Rural Code and other institutional reforms, international support, and the civil society (NGO), as well as incentives for planting or preserving trees, have also caused an impact in communities, thereby allowing farmers to be owners of the trees, to benefit from their products, and to take an interest in preserving the trees.

In other regions of Africa, it has already been seen how poor rural populations depend on NWFP to a great extent for their subsistence and trade, as well as how the contribution by NWFP to the family economy can range from 22 to 40% (Suleiman et al., 2017; Langat et al., 2016; Vedeld et al., 2007). In Tigray (Ethiopia), the rural population is interested in preserving the forests where frankincense is produced (a NWFP coming from *Boswellia papyrifera*, a species that is in a troubling state of degradation), where there is a willingness to pay of at least $4.86 per person (Tilahun et al., 2015).

Among the direct players in the production-to-marketing chain, the NWFP strategy (MESU/DD, 2016) considers producers, processors, and traders; and as indirect players, it considers those from the public sphere, such as services of the Ministry of Hydraulics and the Environment and development projects (NGOs), which take part as actors for implementing public policies on NWFP.

To the best of our knowledge, this is the first study on participation by consumers in the conservation and improvement of a forest food product. It has been verified that 61% of the surveyed consumers in rural and urban markets are willing to pay a mean of 24.73% above the price that they usually pay for purchased products. There are four reasons for participating in the conservation program: because it is a traditional product, because

it is healthy, to ensure availability in the market, and to conserve baobab resources. The importance of baobab products is therefore reflected by the interest of consumers in conservation and breeding programs of baobab resources.

For years, there has been growing interest in Africa regarding the preferences of consumers with respect to the potential of new food products or in relation to increasing and improving the production of those that already exist in the market. Thus, Adenegan and Fatai (2015) found in Nigeria that consumers are willing to pay a surcharge for organically produced and traceable vegetables to ensure safety in the consumption thereof. Other studies include the preferences of rural and urban consumers in Togo regarding the origin (local or imported) and different types of preferred attributes in relation to the quality of local rice, such as cleanliness, taste, and texture (Fiamohe et al., 2006); consumer preferences in Niger for different types of millet porridge (Ndjeunga and Nelson, 2005); and the preferences of livestock farmers for different selection traits of the Azawak zebu sire breed in Niger (Siddo et al., 2015). They offer useful results for breeders in West Africa.

In our case, the problem is not so much concerned with environmental awareness, or a change towards more sustainable practices, or an increase in the production of healthier and safer foods, rather it concerns the interest that is generated in the conservation and breeding of resources due to the perceived situation of regression in detriment to food production. We propose the market and the predisposition of consumers to pay to be included in the conservation policy of a resource, the baobab, which is so important to nutrition in the society of Niger. Conservation programs are costly, and they are not easily quantifiable due to the fact that they depend on external factors that are difficult to predict (Fady et al., 2016). This study contributes to the conservation strategy in which the consumers of baobab products would participate through a surcharge on the price of the product in the market.

One of the challenges of the NWFP strategy (MESU/DD, 2016) is, through research and development, to provide populations with productive and profitable resources and varieties of NWFP. The potential for breeding with respect to the production of leaves and fruit regarding *A. digitata* has been confirmed. In general, it can be assumed that there is considerable phenotypic variability, verified in the morphological traits, the molecular markers, and the first stages of growth, thereby offering an opportunity for selection, breeding, and domestication strategies of the species and its adaptation to drought. In this regard, progeny-provenance testing of *A. digitata* has begun, which could be the basis

for an off-site breeding program. The knowledge acquired through this testing and other studies of genetic variability and the variation of different breeding characters will allow the design of a domestication strategy of *A. digitata* in Burkina Faso, Mali, and Niger (Jensen et al., 2011). The horticultural production of the baobab, developed by the World Agroforestry Centre (ICRAF) and the national agricultural research centers of the Sahel, is proving to be an alternative for increasing the supply of baobab leaves for rural homes (Bationo et al., 2009), and it could in turn contribute to decreasing pressure on the species in favor of conservation. Regarding conservation of the genetic resources of *A. digitata*, Assogbadjo and Loo (2011) propose a strategy for the species as a whole, with different approaches: *in situ* conservation in natural areas, *ex situ* conservation at seed or gene banks, and *circa situm* conservation in agroforestry systems. *Circa situm* conservation, accompanied by training, awareness-raising, and support for stakeholders, is probably the approach with the greatest possibility of success. We would therefore recommend efforts directed at those population groups that have rejected participation in a conservation program for *A. digitata.*

Culturally, due to tradition, and due to the knowledge that is transmitted from generation to generation, consumers in Niger value the baobab leaves as a healthy ingredient in dishes. This could represent the starting point of a "baobab" brand of the cultural identities of Niger, complemented the 3N policy and the NWFP strategy, thus allowing both the promotion of its products and the conservation of its resources. Jama et al. (2007) include *A. digitata* as the first of the "Big five", thereby referring to the large African mammals for which there are conservation programs at an international scale, and also because of the importance of this food tree in large regions of Africa. Gebauer et al. (2016), in their review of the baobab tree in Sudan and Kenya and with the objective of promoting investment in the conservation of this species, talk about the "wooden elephant". In Madagascar, and even though *A. digitata* is not the only species of the genus, it is, together with the Traveler's tree and the lemur, a banner national species; this allows spreading information about it and making the national and international community aware of its importance and the need for conservation.

Finally, in Niger there is already a market of baobab leaves and baobab pulp, although this latter product is imported from other countries of the sub-region. This market could be improved with respect to assuring production of the appropriate quantity and quality, without major price fluctuations and with knowledge of the quantity and quality that consumers acquire. In Niger, baobab pulp could be considered a luxury item with

greater market potential in urban areas. The certification of sustainable products and the certification of certain landscapes with baobab trees or small woods could have an impact on greater interest in the conservation of baobab resources, above all in urban areas and in the international market. It is therefore advisable to complement the data obtained up to now through a study on the production chain and a market study in order to gain a better understanding of the importance of baobab products in both the household and in towns and cities, at a regional and national scale.

APPLICATION OF THE RESULTS

ACTIONS FOR THE SUSTAINABLE USE AND CONSERVATION OF BAOBAB RESOURCES

Context

The identification and implementation of local strategies is key in the processes of both developing and building the resilience of local communities, especially in poor rural communities (FAO, IFAD, WFP, 2015). Resilience should be understood as the capacity to overcome critical moments and adapt and/or return to normalcy after experiencing an unusual or unexpected situation. Within this context, since the 1970s countries of the sub-Saharan region of the Sahel have experienced severe droughts that have negatively affected agricultural, forestry, and livestock production, subsequently resulting in major human and environmental crises. Food shortages, a decrease in both agricultural productivity and forest cover, increased soil degradation, and increased wind erosion can be attributed to the combined effects of climate change, demographic pressure, and sociopolitical changes (FAO, 2017).

In agricultural production systems, the promotion of human development and resilience necessitates an increase in the adaptation capacity of both farmers and the systems in which they live by using sustainable management approaches, in addition to programs that improve not only production but also the socioeconomic conditions. Other tools proposed by different organizations (FAO, IFAD, WFP, 2015), such as insurance programs and effective early warning systems, are clearly impossible to implement in regions of extreme poverty.

In Niger, the agricultural production systems are the subsistence type, in which agrosilvopastoral production is applied based on cereal crops, mainly millet and sorghum. Traditionally, livestock have been allowed to take advantage of the waste after harvests, by agreement between and in mutual benefit to both the grower and the livestock farmer, given that the fields are then left fertilized after the animals pass through. The trees in these systems have economic, nutritional, foraging, medicinal, and environmental value. In addition to providing wood for cooking, they also provide highly valuable food resources and hold a highly prominent place in the local economy. Moreover, periods of

food shortage force the population to feed themselves based on forest products (leaves and fruits) in order to mitigate the lack of other foods. The pressure on resources results in mutilations to the trees that remain in the system, in addition to a reduction in density, thereby aggravating the availability of the products these trees provide.

As we have highlighted in the previous chapter, the 3N initiative (from the French, "Les Nigériens Nourrissent les Nigeriens", Nigeriens feeding Nigeriens) is a political commitment to save the Nigerien population from hunger and guarantee conditions so that Nigeriens can participate both in national production and in improving their income. The marketing of non-wood forest products (NWFPs) represents 1/3 of the non-agricultural income (Haut Commissariat à l'initiative 3N, 2012), yet despite their socioeconomic importance, one of the common characteristics of NWFPs is that they are not considered a staple food or a product of daily use. Therefore, a strategy and an action plan were recently prepared for the promotion and recovery of NWFPs in Niger (MESU/DD, 2016). The strategy has identified the NWFPs coming from the baobab (*Adansonia digitata*) as one of the eight priority sectors with the greatest production potential. The available knowledge, the level of farmer training, and the prioritization of the actions to be undertaken nevertheless limit the viability of this strategy.

Adansonia digitata in the agroforestry systems of Niger

The baobab (*Adansonia digitata*) is a food tree found in Niger, at the northern part of the tree's distribution limit, where the conditions are the most arid (Figure 9). The density in this zone is very low (1 tree/hectare), with a predominance of old trees. Moreover, tree management favors neither the production of seeds nor natural regeneration (Douma et al., 2010). In addition to this situation, reproduction material of unknown origin is being introduced: seeds acquired in markets, together with pulp coming from other countries of the sub-region.

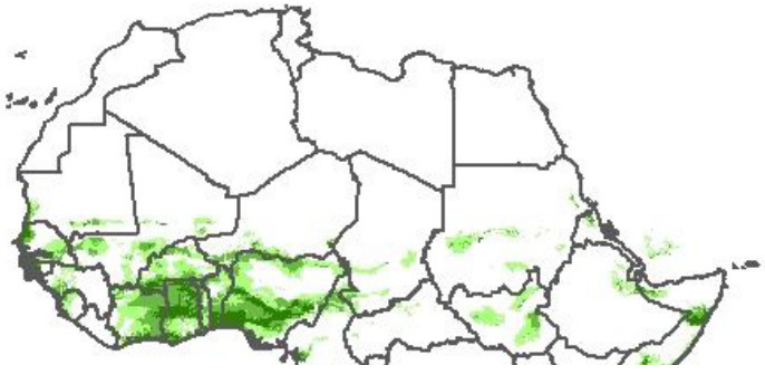


Figure 9. Location of Niger in Africa and current potential distribution of *A. digitata* (modified from Macías Barredo, 2016).

For local communities, the baobab is an essential source of leaves, buds, flowers, fruit, bark, seedlings, and roots. The leaves are used in the daily diet of rural homes in Niger (Agúndez et al., 2016), yet this type of use of the tree is mainly anarchic. Harvesting usually causes mutilations, thus leaving trees exposed to attacks from parasites (Garba, 2000). Due to the importance of the leaves as a staple food for the rural population (and therefore its importance for producers as well) and due to unsustainable practices, there is a high risk of losing resources that are adapted to local conditions. These circumstances result in highly degraded systems, both ecologically and genetically, thereby making it considerably difficult for these systems to last over time.

FRAMEWORK OF ACTION AND IDENTIFICATION OF THE PLAYERS

The geographic framework of action corresponds to three zones where the baobab is present in Niger or where it could be planted using adequate techniques (Figure 10). Table 13 describes the main institutions involved in the management and conservation of natural resources and agricultural production (in the broadest sense of the meaning), together with the missions entrusted to each one.

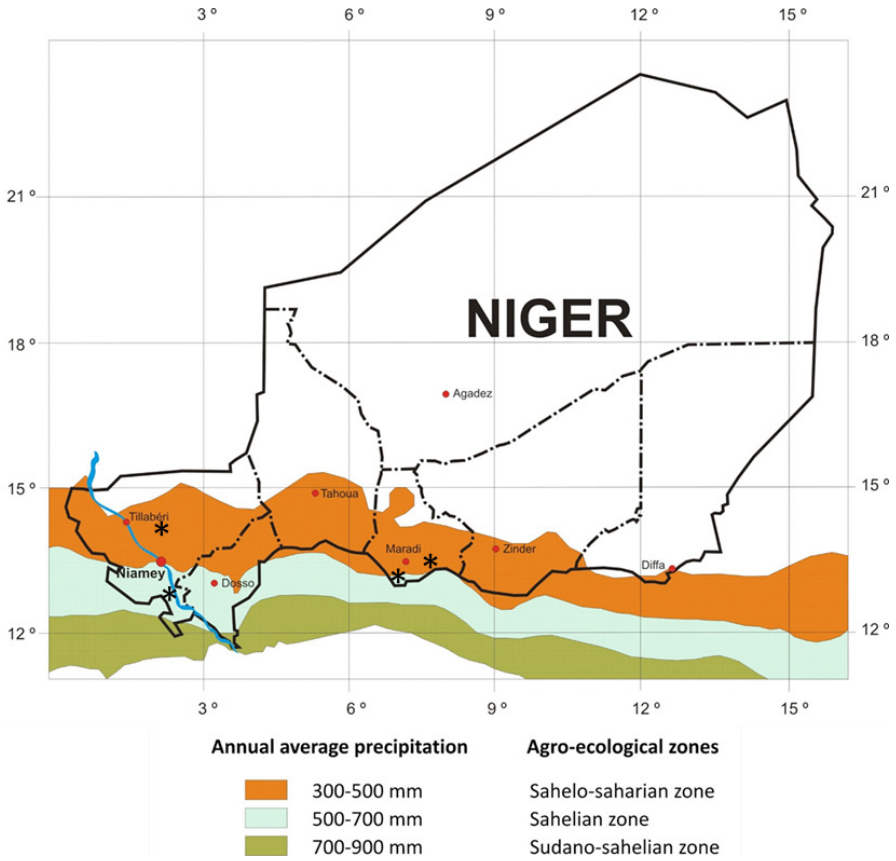


Figure 10. Agroecological zones and distribution of average annual rainfall. * represents the situation of the study areas.

Table 13. Mission of the institutions involved in the management and conservation of natural resources and the promotion of resilience in Niger.

INSTITUTION	MISSION
National Council of the Environment for Sustainable Development (Conseil National de l'Environnement pour un Développement Durable, CNEDD)	Coordinate and supervise all actions related to the environment and sustainable development
Ministry of Hydraulics and the Environment (Ministère de l'Hydraulique et L'Environnement)	Define and implement policies and strategies related to forest resources, wildlife, fishing and beekeeping
Office of the High Commissioner for the Implementation of I3N (Haut-Commissariat à la mise en œuvre de l'I3N)	Coordinate, planning, mobilize funds and actors
Universities and National Institute of Agricultural Research of Niger (INRAN), which are public institutions	Provide scientific, cultural and technical solutions to promote rural development
Civil society organizations (producer organizations, associations, NGOs, etc.)	Promote the management of biodiversity and improve the production and transformation of NTFPs, as well as train producers in general and women's groups

Farmers have rights over the private ownership of the trees, which rights are conferred by the forestry scheme established in 2004 (FAO, 2017). The land owner is the owner of the trees and is the one who has the right to harvest the baobab leaves (Maisharou and Larwanou, 2015). An owner may also transfer their right to use the baobab trees to their wife or wives. Recently, a new practice has been observed: agricultural land is sold without the right to use the products of the baobabs that are present on the land acquired by the new owner. This practice results in dual ownership: ownership of the agricultural land and of certain woody species on the one hand, and ownership of the baobab trees on the other.

Farmers cultivate a mean surface area of 16 ha, and 84.54% of surveyed farmers state that they would not leave their land in its current state. They are available to undertake actions or programs that are targeted at increasing crop yield, improving soil fertility, decreasing water erosion, and increasing income through woody food species. Moreover, the program for the conservation and breeding of baobab resources preferred by farmers includes planting, preparation of the land using Water Soil Conservation (WSC) techniques (called half-moons), and the use of selected seeds. Farmers are also willing to participate through work provided over 143 workdays per year (4.8 months), valued at a mean of €293 per year. Nearly 40% of farmers would participate in the program for a long period exceeding 20 years, while 49% would do it for a period of between 5 and

20 years (Chapter 2). The majority (61%) of consumers of baobab products who were surveyed in rural and urban markets would be willing to pay a mean of 24.73% above the price that they usually pay (Chapter 3).

IDENTIFICATION AND DEVELOPMENT OF ACTIONS

Studies that have been conducted have clearly shown that the perception of the problems and the solutions taken accordingly does not always have a solid scientific-technical basis. This study considers the main role played by farmers in developing the solutions (direct agents). Based on the farmers' preferences and on the existing scientific and technical knowledge (Annex 4), this study identifies a series of actions and tools for the sustainable management and conservation of baobab agrosystems, as well as the effort that farmers would have to invest in the various activities (Table 14). These actions take place along three axes: sustainable management, regeneration of the species, and domestication of the species, for which training and education for the farmers, technicians, and civil society in general would be essential. Each axis of action lists the priority research subjects to be developed by the universities involved and INRAN (Institut National de la Recherche Agronomique du Niger). For the three axes as a whole, other agents are also listed, who would participate together with the farmers on carrying out the activities.

Table 14. Effort to be made by farmers in the different activities

ACTIVITY	Tools	Private effort	Communal effort	Training & supervision
Management	WSC + Plantation	100	.	6
	Sustainable exploitation	.	.	4
Regeneration	Tree selection	4	.	4
	Communal parcels	.	100	.
	Plant production	.	25	.
	FMNR	15	.	4
Domestication	Punctual plantation	1	.	2
	Establishment of orchards	15	.	4

WSC= Water soil conservation techniques; FMNR= Farmer Managed Natural Regeneration

Table 15 lists the various tasks that take place throughout the year in the agrosilvopastoral systems. Moreover, both the proposed actions and the most important aspects of the phenology of the baobab are also shown in the table so that it can be used as the

basis for a more detailed planning of farmers' fields. Actions are focused on the species *A. digitata* as a model, although the calculation of tree density per hectare has been estimated considering other species that mainly provide forage and firewood. Due to the perception differences between men and women regarding the management and conservation of existing resources (Agúndez et al., 2016), it is essential to include the gender aspect in all stages, from the design of the planning to carrying out the activities.

Table 15. Calendar of agricultural and pastoral tasks in relation to the phenology of the baobab and the proposed activities (Modified from Dhillion and Gustad, 2004).

	My	Jn	Jl	Ag	St	Ot	Nv	Dc	Jn	Fb	Mr	Ap
AGRO	Land preparation		Seeding and weeding			Main harvest						
PASTORAL												
BAOBAB Phenology	1st Flushing			2nd Flushing				Falling				
		Flowering										
			Fruiting									
			Germination and regeneration stablishment									
Improvement system programme (100 suppl. work days/ha)	WSC		Nursery	Plantation								
Sustainable Leaves harvesting	Early			Definitive								
Regeneration programme (15 suppl. work days/ha)	Tree selection		Seed production			FMNR						
Domestication (15 suppl. Work/days/ garden)	Gardening										Gardening	

Sustainable management

Actions and tools

- Improvement of the agroforestry system focuses on improving soil fertility, reducing water erosion through WSC techniques, and reducing wind erosion by planting windbreaks. It is therefore necessary to prepare 300 half-moons per hectare for agricultural crops, including the planting of 100 trees in the half-moons.

- The sustainable use of leaves must take place rationally, therefore applying a rotation system to the trees, after having previously selected those that produce good fruit. The idea is to preserve the trunks and branches so that trees can bear fruit and thus favor the regeneration and production of seeds that are adapted to the local conditions. Pruning must be done cleanly to favor healing and prevent disease and plagues.

Identified research subjects

- We must gain more in-depth knowledge about the phenology of the species and about the effects that leaf cultivation practices and pruning intensity have on weakening trees and on the propensity to diseases and plagues.
- The interaction between the use of leaves, fruit, and bark and the relationship between fruit harvesting and regeneration must be studied. This knowledge will allow the preparation good harvesting practices of fruit, branches, and leaves, consequently indicating the frequency, season, and quantities for harvesting.

Regeneration

Actions and tools

- Prior to the selection and subsequent production of seeds and plants, the resources that can produce a viable seed (baobab trees and stands) must be identified and inventoried, nationally, regionally, and locally, in both protected areas and in agroforestry systems.
- Trees that have production traits of interest and that are adapted to the local conditions must be selected. This action requires supplementary work by farmers to define the selection criteria and understand how to apply them, after which 15-25 trees per zone should be selected.
- Communal/regional parcels or orchards for conservation and for selected local seed production must be established. The parcel will have a density of 400 baobab trees per hectare, with a space of 5 x 5 meters each, and the management design will include pruning and clearing when the trees are adults. Farmers will actively participate in the planting, care, and monitoring of the parcel belonging to their community. Preparing the land, putting up fences, and the irrigation and maintenance of these orchards involve considerably more communal work during the first year, subsequently followed by occasional planting, irrigation, and

fence repair work. Planning requires organization between the farmers to cover the various tasks and to monitor the parcel.

- Plant production will be based on seeds coming from the communal orchards. Farmers will participate in installing and maintaining a nursery.
- The density of baobab trees must be increased, due to either planting or farmer managed natural regeneration (FMNR). The tasks of preparing crop land coincide with the germination and installation of young plants and with weeding work. This is the moment when a farmer must decide which plants are going to be protected from livestock pressure, subsequently leaving a density of 100 trees per hectare.

Identified research subjects

- For selecting and producing the seeds and plants of baobab resources, we must have an in-depth knowledge of the genetic diversity of the species, an understanding of the production traits, in the local conditions of Niger.

Domestication

Actions and tools

- Planting of baobab trees in highly frequented locations, such as watering points where women and children collect water daily for domestic use, or in the vicinity of homes: farmers will plant and care for the trees and install protectors.
- A baobab orchard will be grown based on the seed selected for the communal orchards. Until these orchards start to produce, the mix of seeds from selected trees can be used or, in default thereof, seeds originating from an area close to the crop location should be acquired from the National Forestry Seed Center. Orchards should be set up in areas that are close to watering points that are available for irrigation. Farmers will set up the orchard, handle production, and care for the trees.

Identified research subjects

- Identification of populations and individual trees with production breeding traits adapted to the local conditions. Some research studies have already been started in Burkina Faso, Mali, and Niger (Jensen et al., 2011; Maman and Svejgaard, 2010).

Other players involved in carrying out actions

- The local city government and the chief of the town will be in charge of selecting and granting land for a nursery and for the communal parcels or orchards, in addition to being in charge of ensuring that the tasks entrusted to the farmers are carried out according to the participatory planning.
- The technical services of the Ministry of Hydraulics and the Environment and NGDOs will conduct demonstration workshops and will accompany farmers when harvesting the baobab products to ensure that good practices are applied. They will also be involved in protecting the selected trees, in training for nursery production, in subsequent planting, and in supervising the actions that are carried out.
- The Ministry of Hydraulics and the Environment is the inventory manager, always with the participation of the farmers and with the cooperation of the universities involved and INRAN.
- Moreover, both the universities involved and INRAN, in cooperation with the National Forestry Seed Center, will identify the selection zones according to ecological differences and will prepare the documentation pertaining to the selected zones and trees. Together with the farmers and in order to reach a common understanding of the selection criteria, they will also identify the main traits for production and adaptation.
- The universities involved and INRAN play a fundamental role in following up on and studying behavior and growth, both in the nursery and of the planted material. They will also follow up on regeneration through FMNR and on the growth and production of the material used.

FINANCING AND COORDINATION

Participation by the farmers is calculated at a maximum of 118 workdays per hectare/year on lands where improvement of the system is necessary (through WSC), which includes training on good practices regarding the use and selection of trees. In cases in which the FMNR technique is sufficient (instead of WSC), then a total of 27 workdays per hectare/year is calculated. Furthermore, in those cases in which domestication is possible, this would represent an additional 22 workdays per hectare/year. A total of

125 community workdays per year has been estimated, to be distributed among all the participating farmers.

Given that the mean crop surface area is 16 hectares and that the mean willingness to participate is 143 workdays per year, if improvement of the system against erosion has to be carried out, then the farmers' availability would cover 1 hectare/year. Within this context, it would be advisable to seek supplementary labor and financing in order to take actions on an additional 2 hectares/year, as well as carry out improvements within a time frame of no more than 5 years, at 3 hectares/year.

In this regard, we have calculated the effort to be applied by farmers. However, planning and financing would have to consider the contributions to actions made by all the other players involved, including actions such as the preparation, selection, and documentation of good practices, in addition to training and supervision. The supply of work materials with adequate quality is likewise deemed important.

The Office of the High Commissioner for the Implementation of the I3N is responsible for the following: coordination; planning; conducting technical, economic, and financial studies; mobilizing funds; mobilizing public and private players; and mobilizing technical and financial partners. The National Council of the Environment for Sustainable Development (CNEDD in French) has the mission of coordinating and supervising all actions related to the environment and sustainable development.

CONCLUSIONS

1. There is a general perception of a declining occurrence of food tree species and a lack of regeneration, but there is no one clear view among the rural communities involved in this study about the processes influencing this decline. Gender should be considered in the design of conservation activities because there are notable differences between perceptions of women and men.

2. A complex system of common threats emerges. The main ones identified were the pressure of overexploitation, pests and diseases, and drought. Land clearing for agriculture is not considered by the farmers the main driver leading to a decline in occurrence of edible woody species.

3. Special attention in monitoring the status of natural resources should be paid to species such as *A. digitata* and *B. senegalensis*, with critical role in the diet, and *M. crassifolia*, used for human consumption in extreme situations.

4. The preferred conservation scenario by the farmers or program is clearly the one based on the species *A. digitata*, chosen mainly because its products are used for food in the home and can also be sold in markets.

5. It is essential for farmers to ensure the sustainability of the agroforestry system and to increase agricultural production, and the yield and production of the system would be improved by increasing the number of trees of *A. digitata* with selected material. 87.75 % of the farmers would like to improve their production system and invest sustainable effort for five months per year and for a minimum of 5 years, or even indefinitely.

6. The importance of baobab products, mainly the leaves, has been confirmed by its contribution to the weekly shopping basket. They represent 23.19% of the purchase basket of weekly food, and 83.3% of the studied population preferably consumes leaves, whether whole dried or ground.

7. It has been verified that 61% of the surveyed consumers in rural and urban markets are willing to pay a mean of 24.73% above the price that they usually pay for purchased products to finance a conservation program. There are four reasons for participating in the conservation program: it is a traditional product, it is healthy, it is necessary to ensure availability in the market, and it is necessary to conserve baobab resources.

8. The main actions and tools to achieve the sustainable management and conservation of *A. digitata* have been identified in three main axes: sustainable management, regeneration and domestication, as well as the main agents involved (farmers) and other institutional agents and organizations from the civil society.

9. The proposed actions are the necessary framework to promote the inclusion of valuable woody food species in the design and implementation of specific programs and projects, dealing with the improvement, sustainable management and resources conservation for rural development.

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ANNEXES

QUESTIONNAIRE 1: Focus group

Questionnaire N°:
Region:
Commune/Village:
Geographical Coordinates:
Socio-cultural group:
Language:
Autochthonous
Immigrants
Number of years leaving in that village (for immigrants):
Nº of Young women: Nº of Old women:
Shortage period: learn before starting the questionnaire, if this year the situation is normal related with the shortage period or there have been extraordinary events that exacerbate or ameliorate the situation (ceremonies, good, fair or poor harvest, humanitarian aid...)

Table 1. Dishes and ingredients consumed at the village at the shortage period (use as many pages as necessary)

Dish name:	
Ingredients of the staple food	Ingredients of the sauce

Table 2. Part of the tree used, way of consumption, where they are obtained. Lv, Leaves; Fl, Flowers; Fr, Fruits; Bk, Bark; Rt, Root; Wd, in the wild (bush); Ld, in the land or home garden (preserved but not planted) ; Pl, planted ; Mk, market ; St, stocked ; Aid: humanitarian aid.

Species	Part used					Consumption			Obtained in					
	Lv	Fl	Fr	Bk	Rt	Rw	Ck	Pr	Wd	Ld	Pl	Mk	St	Aid

Table 3. Tree products consumed in the past by you or your ancestors and which are no longer consumed. Lv, Leaves; Fl, Flowers; Fr, Fruits; Bk, Bark; Rt, Root; Hab, habit lost ; Prep, difficult to prepare; Rare, difficult to be found.

Species	Part used					Why they are no longer used for food?			Still available?		When did people stop consuming them? Number of years
	LV	Fl	Fr	Bk	Rt	Hab	Prep	Rare	Yes	No	

QUESTIONNAIRE 2: Key Respondents

Questionnaire N°:

Agro-ecological Region:

Region/ Department:

Commune/Village:

Geographical Coordinates:

Key respondent name:

Socio-cultural group:

Language:

Autochthonous

Immigrant

Number of years leaving in that village (for immigrants):

Main activity:

Table 0. List of species mentioned in the documents 1 completed with others cited by the key informant. Use the number to identify the species in the table of threats.

Species name from Documents 1 and 2	N°		N°

Table 1. Perception of the food tree and shrub species conservation status.

Condition/Nº Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
I. Threats Key informants will rate each potential threat for each priority species in each village using scores: 1 = not important, 2 = somewhat important, 3 = very important, 4= not known															
Land clearance															
Fire															
Grazing (Branch or regeneration damage)															
Timber harvest															
Leaves harvest															
Fruit harvest															
Flowers harvest															
Root harvest															
Bark harvest															
Charcoal production															
Pests, disease															
Drought															
Age of trees															
Soil quality (poor soils, fertilizer influence)															
Other															
II. Ease of locating compared with 10 years ago 0= easier (Please, fill in comments the cause of that fact) 1=about the same, 2= harder; 3=not possible															
Ease of locating															
III. Presence of regeneration (Y or N)															
IV. Conservation practices (Y or N)															

QUESTIONNAIRE «Social preferences in the design of improvement and conservation programs of food tree species (FTS) in Niger»

Form number .....

Surname and name of the surveyor:

.....

Date ...../...../.....

Start time of the survey

.....

Region:

Maradi..... 1
Tillabéri 2

Department:

Aguié..... 1
Madarounfa..... 2
Say..... 3
Ouallam..... 4

Commune:

Aguié..... 1
Madarounfa..... 2
Tamou..... 3
Simiri..... 4

Village:.....

Language in which the survey is taken:

Zarma..... 1
Hausa..... 2
Peul..... 3
Tamasheq..... 4
Gourmantché..... 5
Kanouri..... 6
Arabe..... 7
Toubou..... 8
Boudouma..... 9
French..... 10
Other.....

Translator:

No..... 1
Yes..... 2

I. Information about the respondent, their household and resources

Surname and name.....

Q1 Sex:

Male..... 1
Female..... 2

Q2 Age:..... years

Q3 Origin:

autochthonous..... 1
inmigrant..... 2

Q4 Civil status:

Married..... 1
Divorced..... 2
Widower/Widow..... 3
Single..... 4

Q5 Ethnic group:

Zarma..... 1
Hausa..... 2
Fulani..... 3
Touareg..... 4
Gourmantché..... 5
Kanouri..... 6
Arabe..... 7
Toubou..... 8
Boudouma..... 9
Bella..... 10
Other.....

Q6 Way of life:

Nomad..... 1
Sedentary..... 2
Transhumant..... 3

Q7 Level of education:

Primary..... 1
Secondary..... 2
Higher..... 3
Koranic studies..... 4
Literacy..... 5
None..... 6
Others.....

Q8 Activity:

	Main	Additional
Agricultural farmer.....	1	1
Cattle farmer.....	2	2
Agropastoralist.....	3	3
Housewife.....	4	4
Shopkeeper.....	5	5
Civil servant.....	6	6
Artisan.....	7	7
Beekeeper.....	8	8
Fisherman.....	9	9
Vegetable grower.....	10	10
Moto-taxi driver.....	11	11
Teacher.....	12	12
Tour guide.....	13	13
Butcher.....	14	14
Carpenter.....	15	15
Unemployed.....	16	16
Seasonal migrant.....	17	17
Long-term migrant.....	18	18
Others.....	.....	.....

Q9 Role in the household:

Head..... 1
Wife of head..... 2
Child..... 3
Adopted..... 4
Worker at the home..... 5
Other.....

Q10 Number of members in the household:

Elderly (over 50 years):.....
Adults (21 to 50 years):.....
Youths (8 to20 ans):.....
Children (0 to 7 ans):.....

Q11 Number of working people in the household:

Men:.....
Women:.....

Q12 Does your home suffer from a period of food shortage?

No..... 1
Yes..... 2

Indicate all the shortage months

J	F	M	A	M	Jn	Jl	A	S	O	N	D

Information about the property

Q13 Do you cultivate the property?

No..... 1 (If not, go to Q16)
Yes.....2

Q14 What is the status of the property ownership and the characteristics of the fields, cite the plots in order of productivity

Plot	Status	Surface (ha)	Distance to home (Kms)	Type of soil
1				
2				
3				
4				

Table Q14 Codes to fill in Q14

Status:	Type of soil:
Heritage..... 1	Sand.....1
Rented..... 2	Dune..... 2
Loan..... 3	Glacis..... 3
Pledge..... 4	Glacis-silted..... 4
Don..... 5	Sandy-silty glacis..... 5
Purchase..... 6	Sandy clay..... 6
Collective field..... 7	Ferruginous..... 7
Other..... 8	Other.....

Q15 Crops in the property

Cultures	**No**	**Yes**	**Others** (indicate)
Peanut	1	2	.....
Squash	1	2	.....
Fonio	1	2	.....
Okra	1	2	.....
Corn	1	2	.....
Cassava	1	2	.....
Millet	1	2	.....
Moringa	1	2	.....
Cowpea	1	2	
Onion	1	2	
Sorrel	1	2	
Sweet potato	1	2	
Chilli pepper	1	2	
Rice	1	2	
Sesame	1	2	
Sorghum	1	2	
Souchet	1	2	
Voandzou	1	2	

Q16 The 4 most important NATURAL woody species according to you in order of priority, the mode of access and if they are present on your property

	Sp	1	2	3	4	Access		Property	
						Free	Private	Yes	No
1	Ad	○	○	○	○	○	○	○	○
2	Ba	○	○	○	○	○	○	○	○
3	Bs	○	○	○	○	○	○	○	○
4	Cn	○	○	○	○	○	○	○	○
5	Di	○	○	○	○	○	○	○	○
6	Ht	○	○	○	○	○	○	○	○
7	Lm	○	○	○	○	○	○	○	○
8	Mc	○	○	○	○	○	○	○	○
9	Pb	○	○	○	○	○	○	○	○
10	Pr	○	○	○	○	○	○	○	○
11	Sb	○	○	○	○	○	○	○	○
12	Ti	○	○	○	○	○	○	○	○
13	Vd	○	○	○	○	○	○	○	○
14	Vp	○	○	○	○	○	○	○	○
15	Zm	○	○	○	○	○	○	○	○
16	Zs-ch	○	○	○	○	○	○	○	○
Other		○	○	○	○	○	○	○	○

If other, write down here the scientific and the local name

II. Information about the production of 4 FTS proposed by the program

Q17 FTS on the field. If not, go to Q21

Field	N°	Type of regeneration			Conservation status			Presence of regeneration	
		Wild	FMNR	Planted	↙	↔	↗	No	Yes
Ad	1	1	2	3	1	2	3	1	2
Ba	1	1	2	3	1	2	3	1	2
Bs	1	1	2	3	1	2	3	1	2
Zm	1	1	2	3	1	2	3	1	2

↙ Regression ; ↔ Stable ; ↗ Increase

Q 18 Uses of food species products

		Adansonia		***Balanites***		***Boscia***		***Ziziphus***	
		x	**+**	**x**	**+**	**x**	**+**	**x**	**+**
1	Human food	□	○	□	○	□	○	□	○
2	Animal feeding	□	○	□	○	□	○	□	○
3	Timber	□	○	□	○	□	○	□	○
4	Charcoal, firewood	□	○	□	○	□	○	□	○
5	Tools, inst. music, crafts	□	○	□	○	□	○	□	○
6	Pharmacopeia	□	○	□	○	□	○	□	○
7	Veterinary	□	○	□	○	□	○	□	○
8	Against pest and diseases	□	○	□	○	□	○	□	○
9	Ceremonies, tradition	□	○	□	○	□	○	□	○

Q19 Perception of threats

		Ad		Ba		Bs		Zm	
		x	+	x	+	x	+	x	+
1	Land clearance	□	○	□	○	□	○	□	○
2	Fire	□	○	□	○	□	○	□	○
3	Over-Grazing (Branch or regeneration damage)	□	○	□	○	□	○	□	○
4	Timber Over-Exploitation	□	○	□	○	□	○	□	○
5	Flowers, fruits over-exploitation	□	○	□	○	□	○	□	○
6	Leaves over-exploitation	□	○	□	○	□	○	□	○
7	Bark Over-exploitation	□	○	□	○	□	○	□	○
8	Firewood, charcoal over-exploitation	□	○	□	○	□	○	□	○
9	Roots over-exploitation	□	○	□	○	□	○	□	○
10	Bad pruning	□	○	□	○	□	○	□	○
11	Insects and diseases	□	○	□	○	□	○	□	○
12	Drougth	□	○	□	○	□	○	□	○
13	Wind	□	○	□	○	□	○	□	○
14	Rodents and other animals	□	○	□	○	□	○	□	○
15	Old trees	□	○	□	○	□	○	□	○
16	Depleted soil, excess of fertilizer or manure	□	○	□	○	□	○	□	○

III. Effects of the Conservation and Improvement Program

[Show the explanatory cards to understand the different levels of the program] 12 cards will be shown, with 4 possible program options are offered on each, including the option of not participating in a conservation and improvement program (current state). Please, carefully observe all the elements and pay attention to the effort you must invest: YOU WILL NOT DISPOSE OF THIS EFFORT FOR OTHER ACTIVITIES. Remember that you can always choose the current status that does not imply any additional effort from you and your family.

Q20 Please choose the best (1) and the worst (4) alternatives; Of the remaining two, the best (2). The one that remains is the 3rd. NK / NA Does not know, does not answer [Show the choice cards]

Card	Current state				Progr. A				Progr. B				Progr. C				NK NA
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
1	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
2	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
3	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
4	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
5	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
6	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
7	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
8	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
9	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
10	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
11	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
12	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○

Q21 If you have never chosen A, B or C: Why do you have always chosen the "current state alternative"??

I don't have the capacity to work on the program..... 1
There are others who must make the effort..... 2
My family is small..... 3
I don't understand the programs..... 4
I have other priorities..... 5
Other (indicate).....

Q22 Have you considered ALL the elements of the program?

Yes..... 2
No..... 1 If not, indicate the ones you have never considered (fill in the following table)

	No	Yes
Species	1	2
Actions	1	2
Soil/Water conservation	1	2
Seeds	1	2
Work Effort	1	2

Q23 The effects that the program will cause according to your perception (mark X effects, choose the most important +)

		x	+
1	Avoid runoff erosion	□	○
2	Decreases agricultural productivity	□	○
3	Increases forage production	□	○
4	Promotes soil fertility	□	○
5	Increases crop production	□	○
6	Resources used in the tradition	□	○
7	Promotes habitat for hunting	□	○
8	Decrease forage production	□	○
9	Promotes the availability of water in the soil	□	○
10	Increases income from trees	□	○
11	Reduces wind and high temperatures	□	○
12	Promotes traditional diets	□	○

Q24 Please, choose the options that would make up your favorite program [Choice card]

Species	***Adansonia***	***Balanites***	***Boscia***	***Ziziphus***
	1	2	3	4
Actions	None	FNMR	Plantation	
	1	2	3	
Soil/Water	None	Tassa	Half-moon	Stones
	1	2	3	4
Seeds	None	Selected	Bred	
	1	2	3	

Q25 If you were offered the program with your favourite options, you would be willing to invest in it,

a maximum of days / year (indicate).....

a Surface of

0.25 ha..... 1
0.5 ha..... 2
1 ha..... 3
1-2 ha..... 4
2-3 ha..... 5
>3 ha..... 6

For:

1 year..... 1
5 year..... 2
10 year..... 3
20 year..... 4
Long-term..... 5

Q26 Indicate the number of hours included in a typical working day and the salary per individual/day in agricultural working in your town

No. hours / day (indicate).....

FCFA per day (indicate).....

Your opinion on the benefits of choosing:

Q27 your favorite FTS

		x	+
1	Less competition with crops	□	○
2	Adapted species	□	○
3	Products for sale at the market	□	○
4	Consumer products in the household	□	○
5	Easy to maintain	□	○
6	Species not protected by law	□	○
7	None	□	○

Other (indicate).....

Q28 your favorite action on the tree occurence

		x	+
1	Easy to maintain	□	○
2	More trees on the field	□	○
3	Less competition with crops	□	○
4	Promotes land appropriation	□	○
5	Avoid erosion	□	○
6	None	□	○

Other (indicate).....

Q29 your favorite action on the soil

		x	+
1	Less effort	□	○
2	Increases the water reserve	□	○
3	No action is necessary	□	○
4	Avoid erosion	□	○
5	Durability	□	○
6	None	□	○

Other (indicate).....

Q30 your favorite seed quality

		x	+
1	Highest quality products	□	○
2	Higher performing trees	□	○
3	Highest production	□	○
4	More consistent production	□	○
5	Less effort	□	○
6	Early production	□	○
7	None	□	○

Other (indicate).....

End time of the survey

.....

THANK YOU VERY MUCH !

EXPLANATORY CARDS

Boscia senegalensis

The 4 Food Tree Species

- Woody species that we eat fruits or leaves, even flowers
- Consumed during the lean season (food deficit from the beginning of the rainy season until the new harvest).
- Maybe these species are not among the priority species, but are common to different regions
- These species may turn on priority species at some point in the area.

Adansonia digitata

Balanites aegyptiaca

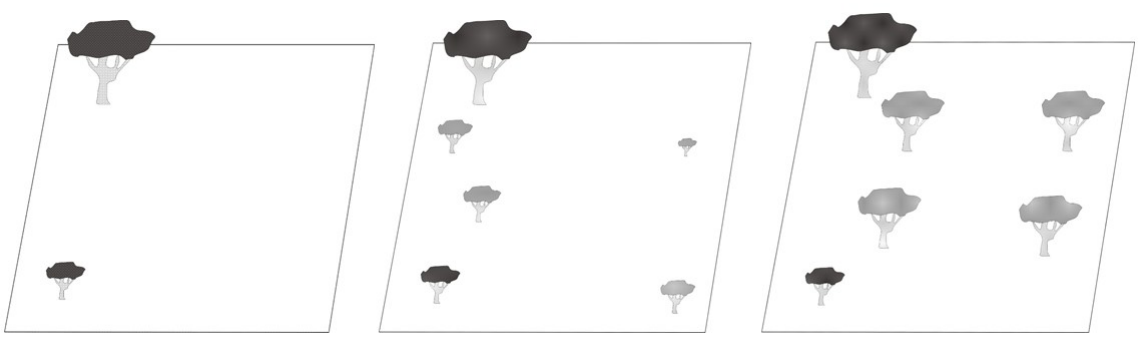
Ziziphus mauritiana

Management and increasing tree density actions

Current status
The land remains as it is now without doing anything more, we let the system evolve or regress without intervening on the density of trees

FMNR
The practice of farmer managed natural regeneration to increase the number of food trees according to the seedbank in the soil

Plantation
Planting to increase the number of trees according to the productivity of the field



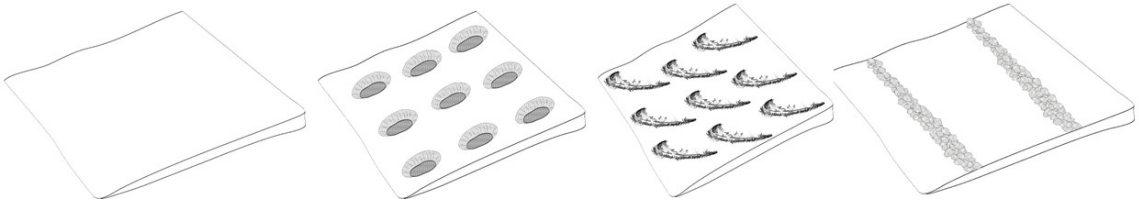
Soil Conservation (against erosion)

Current status
The land remains as it is now

Tassa
Recovery of encrusted soils, holes filled with organic matter to collect runoff and let them infiltrate

Half-moon
Semi-circle, contour, staggered, to collect and conserve runoff

Stone bunds
Stones of different shapes and weights, made in level curves, to reduce runoff and soil erosion.



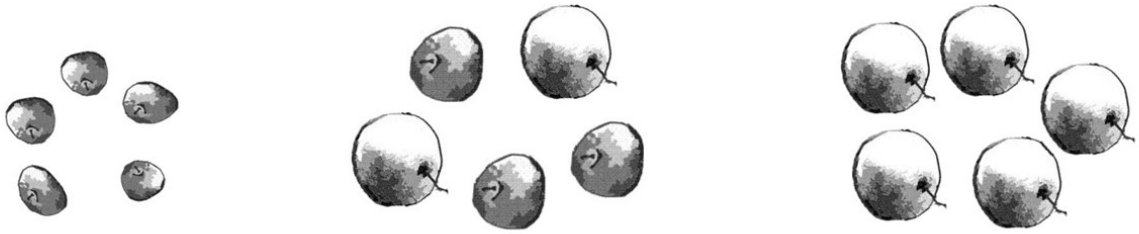
Seed quality

to be used in demonstrative plots and for the installation of seed orchards in communal, university or state parcels

Non selected
Seeds harvested from trees without taking into account their behavior or production characters

Selected
Seeds harvested from trees with good quality and quantity production and behavior characters

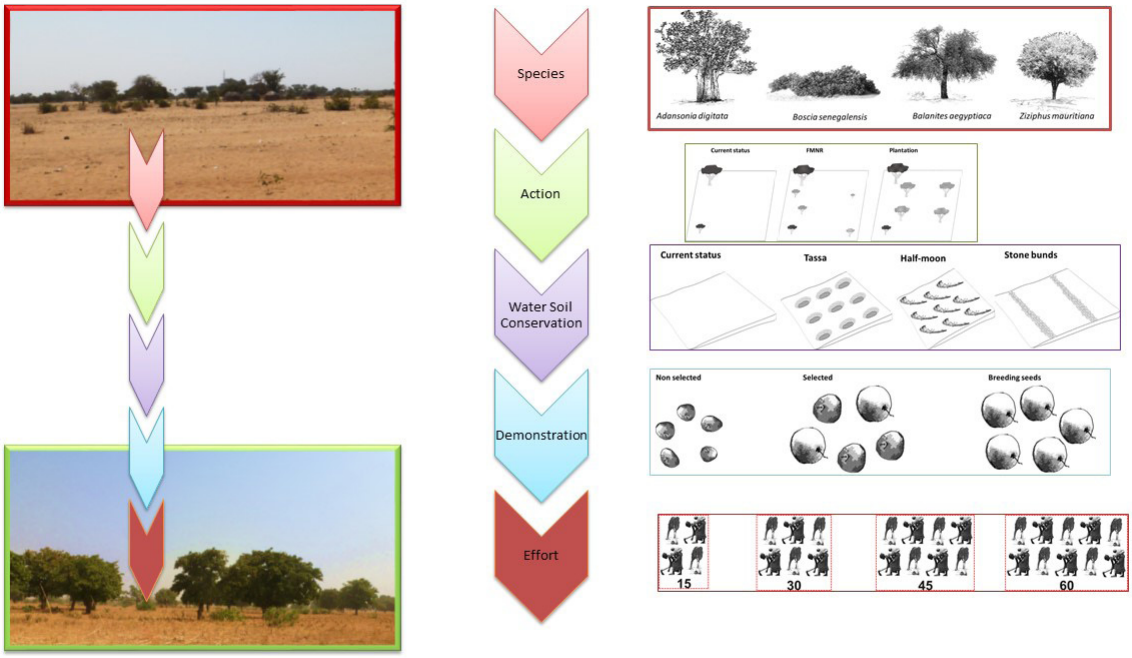
Breeding seeds
Seeds harvested from improvement programs



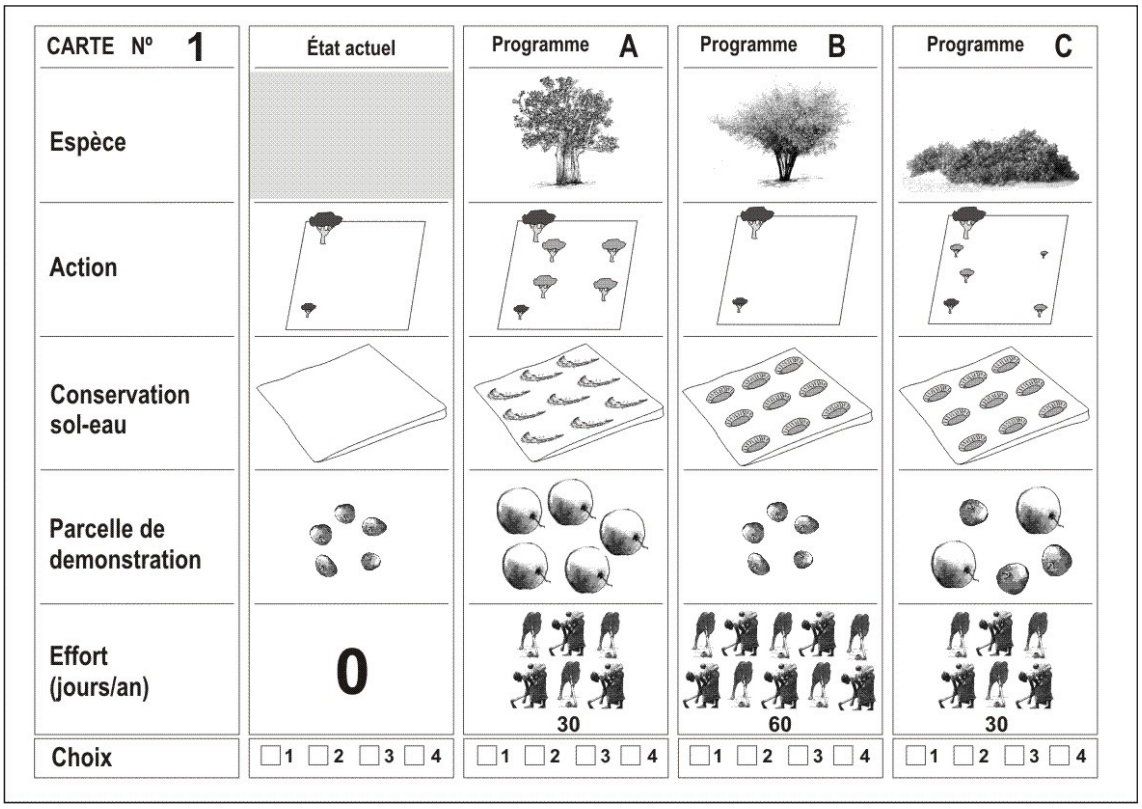
Work Effort

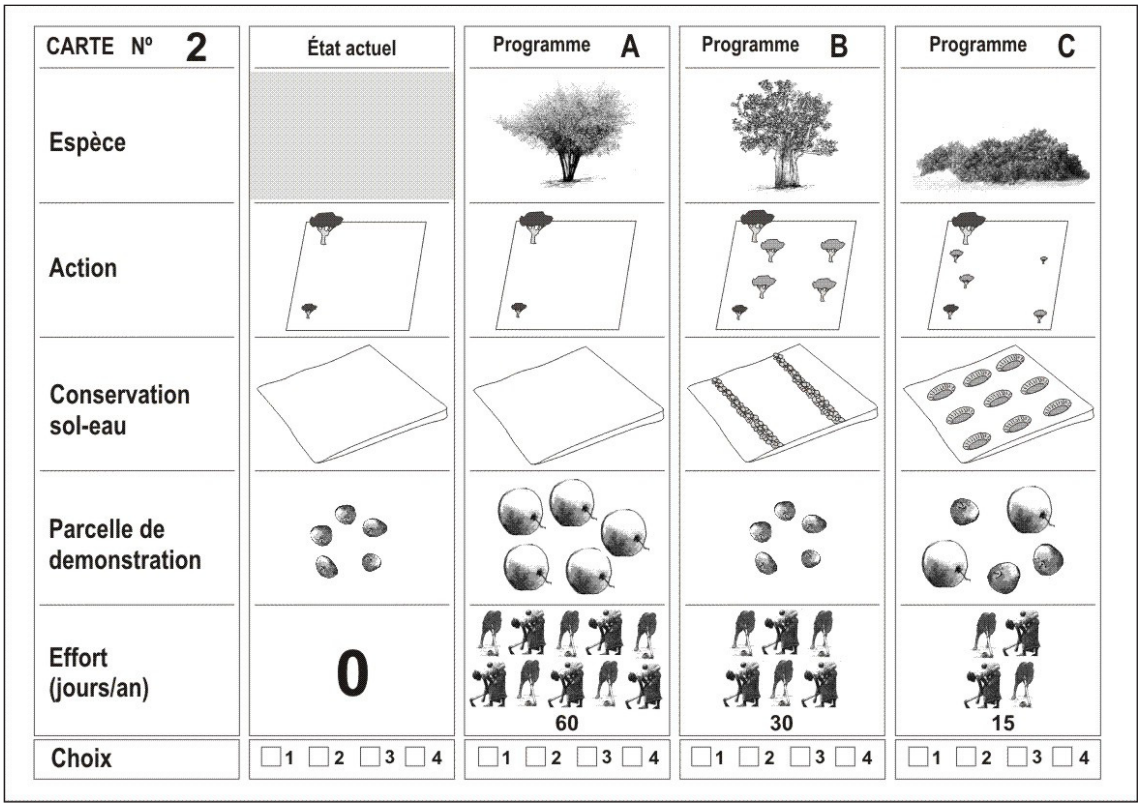
We calculated the effort in working days per year. This work is considered voluntary and it is to be shared with other actors interested in the production and conservation of trees, such as the consumers who will buy the food tree products at the market, NGOs and others, and public institutions (University, INRAN, Seed Centers, Town Hall ...).

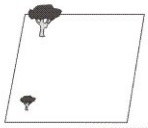
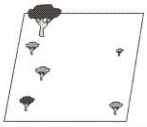
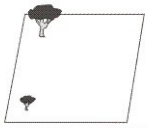
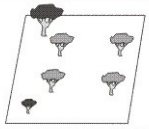
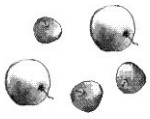
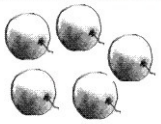
Warning! YOU WILL NOT DISPOSE OF THIS EFFORT FOR OTHER ACTIVITIES

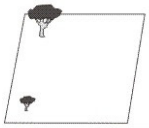
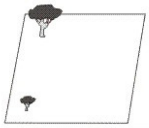
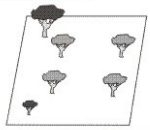
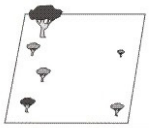
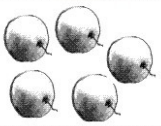
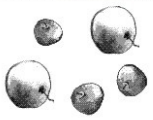


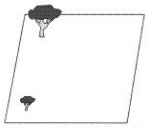
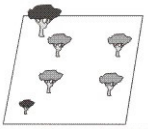
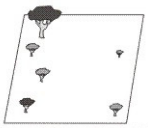
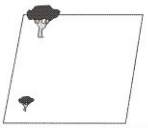
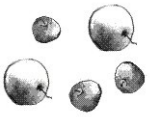
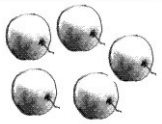
CHOICE EXPERIMENT CARDS

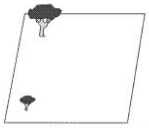
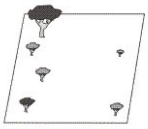
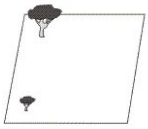
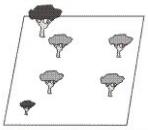
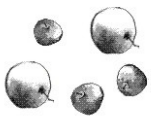
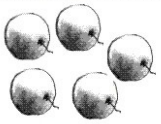


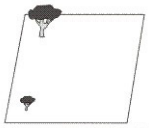
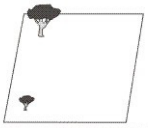
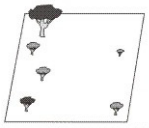
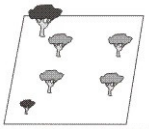
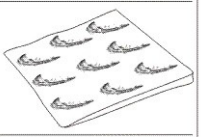
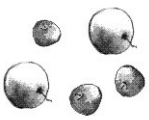
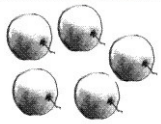


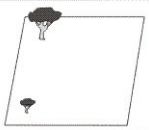
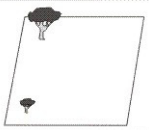
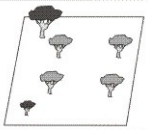
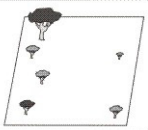
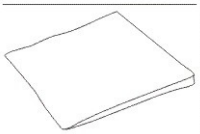
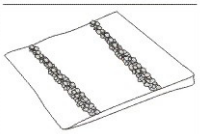
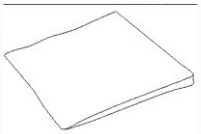
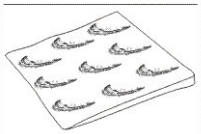
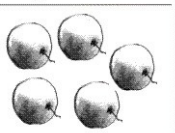
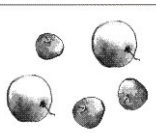
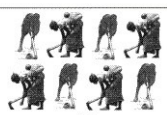
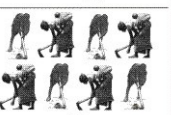
CARTE Nº 3	État actuel	Programme A	Programme B	Programme C
Espèce				
Action				
Conservation sol-eau				
Parcelle de demonstration				
Effort (jours/an)	0	 15	 60	 30
Choix	☐1 ☐2 ☐3 ☐4	☐1 ☐2 ☐3 ☐4	☐1 ☐2 ☐3 ☐4	☐1 ☐2 ☐3 ☐4

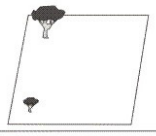
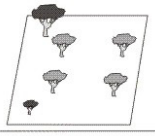
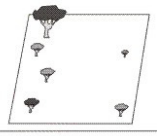
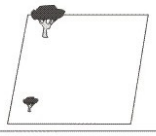
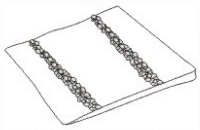
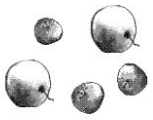
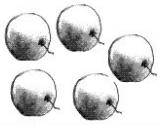
CARTE Nº 4	État actuel	Programme A	Programme B	Programme C
Espèce				
Action				
Conservation sol-eau				
Parcelle de demonstration				
Effort (jours/an)	0	 45	 45	 15
Choix	☐1 ☐2 ☐3 ☐4	☐1 ☐2 ☐3 ☐4	☐1 ☐2 ☐3 ☐4	☐1 ☐2 ☐3 ☐4

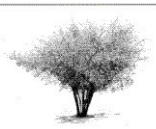
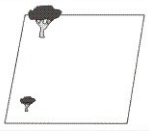
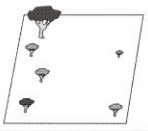
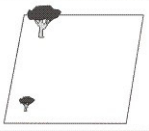
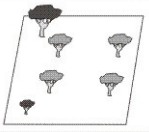
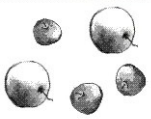
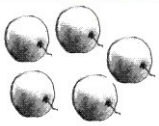
CARTE N° 5	État actuel	Programme A	Programme B	Programme C
Espèce				
Action				
Conservation sol-eau				
Parcelle de demonstration				
Effort (jours/an)	0	 60	 30	 45
Choix	☐1 ☐2 ☐3 ☐4	☐1 ☐2 ☐3 ☐4	☐1 ☐2 ☐3 ☐4	☐1 ☐2 ☐3 ☐4

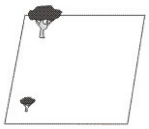
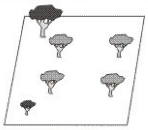
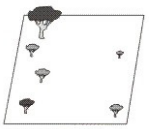
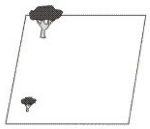
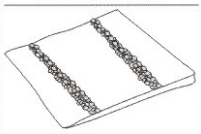
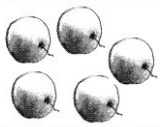
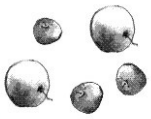
CARTE N° 6	État actuel	Programme A	Programme B	Programme C
Espèce				
Action				
Conservation sol-eau				
Parcelle de demonstration				
Effort (jours/an)	0	 15	 60	 30
Choix	☐1 ☐2 ☐3 ☐4	☐1 ☐2 ☐3 ☐4	☐1 ☐2 ☐3 ☐4	☐1 ☐2 ☐3 ☐4

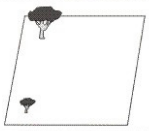
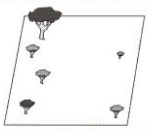
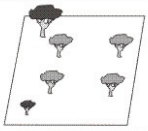
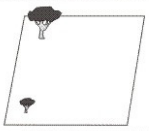
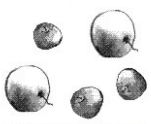
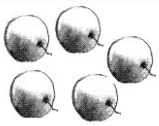
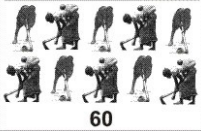
CARTE Nº 7	État actuel	Programme A	Programme B	Programme C
Espèce				
Action				
Conservation sol-eau				
Parcelle de demonstration				
Effort (jours/an)	0	 60	 15	 45
Choix	☐1 ☐2 ☐3 ☐4	☐1 ☐2 ☐3 ☐4	☐1 ☐2 ☐3 ☐4	☐1 ☐2 ☐3 ☐4

CARTE Nº 8	État actuel	Programme A	Programme B	Programme C
Espèce				
Action				
Conservation sol-eau				
Parcelle de demonstration				
Effort (jours/an)	0	 45	 45	 15
Choix	☐1 ☐2 ☐3 ☐4	☐1 ☐2 ☐3 ☐4	☐1 ☐2 ☐3 ☐4	☐1 ☐2 ☐3 ☐4

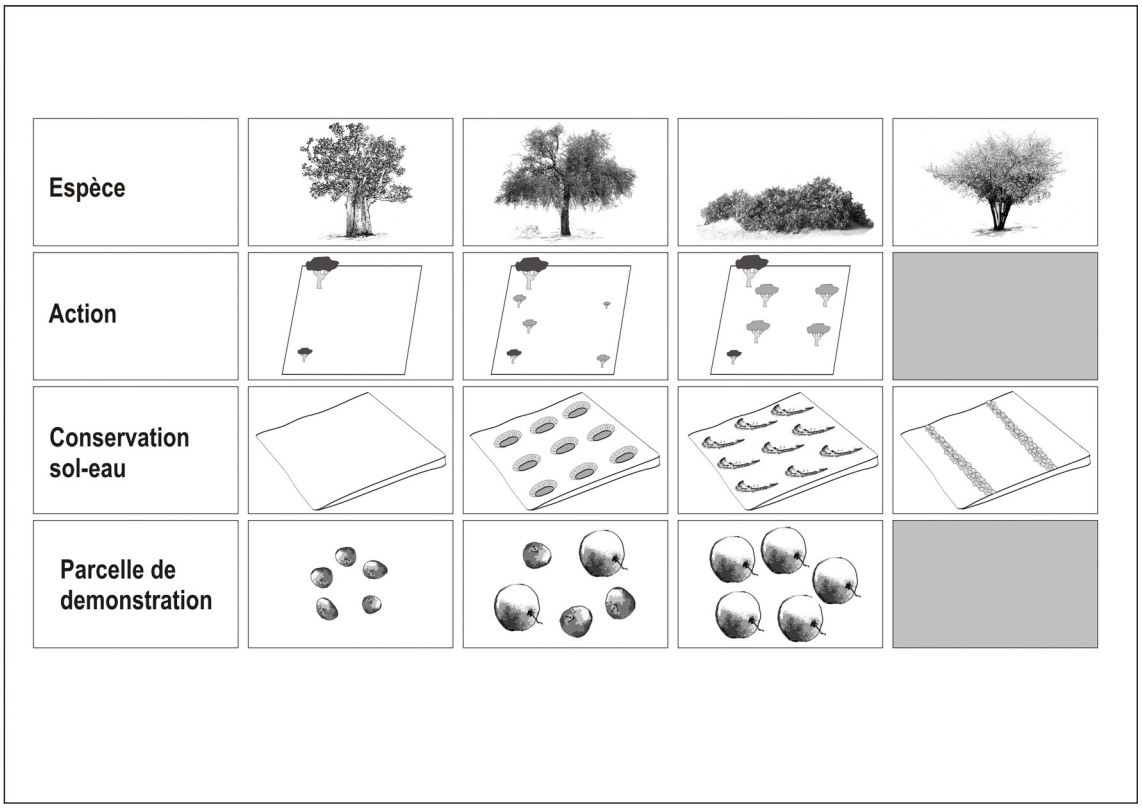
CARTE Nº 9	État actuel	Programme A	Programme B	Programme C
Espèce				
Action				
Conservation sol-eau				
Parcelle de demonstration				
Effort (jours/an)	0	 45	 15	 60
Choix	☐1 ☐2 ☐3 ☐4	☐1 ☐2 ☐3 ☐4	☐1 ☐2 ☐3 ☐4	☐1 ☐2 ☐3 ☐4

CARTE Nº 10	État actuel	Programme A	Programme B	Programme C
Espèce				
Action				
Conservation sol-eau				
Parcelle de demonstration				
Effort (jours/an)	0	 15	 45	 60
Choix	☐1 ☐2 ☐3 ☐4	☐1 ☐2 ☐3 ☐4	☐1 ☐2 ☐3 ☐4	☐1 ☐2 ☐3 ☐4

CARTE N° 11	État actuel	Programme A	Programme B	Programme C
Espèce				
Action				
Conservation sol-eau				
Parcelle de demonstration				
Effort (jours/an)	0	 30	 15	 45
Choix	☐1 ☐2 ☐3 ☐4	☐1 ☐2 ☐3 ☐4	☐1 ☐2 ☐3 ☐4	☐1 ☐2 ☐3 ☐4

CARTE N° 12	État actuel	Programme A	Programme B	Programme C
Espèce				
Action				
Conservation sol-eau				
Parcelle de demonstration				
Effort (jours/an)	0	 30	 30	 60
Choix	☐1 ☐2 ☐3 ☐4	☐1 ☐2 ☐3 ☐4	☐1 ☐2 ☐3 ☐4	☐1 ☐2 ☐3 ☐4

CONTIGENT VALUATION CARD



ANNEX STUDY 3

Questionnaire: "Analysis of consumer preferences in the design of improvement and conservation programs of food tree species (FTS) in Niger"

Questionnaire targeted at consumers (men and women) who have just purchased one or several baobab products

Form number..... Date...../...../..... Start time of the survey.....
Surname and name of the surveyor:.....
Market:.....

Language in which the survey is taken:

Zarma..... 1	Hausa..... 2	Fulani..... 3
Tamasheq..... 4	Gourmantchéma..... 5	Kanouri..... 6
Arabic.....7	Toubou..... 8	Boudouma..... 9
French..... 10	Other (indicate)	

I. Identification of the person who is purchasing

Sex: Female..... 1 Male..... 2

Surname and name:.....

Q1 Age:..... years

Q2 How many kilometers have you travelled to reach the market?

Distance:..... km

II. Information about the baobab products that the respondent is purchasing

Q3 Purchased product

	Number of measures purchased			Price		
	Large	Medium	Small	Large	Medium	Small
Green leaves						
Dry leaves						
Ground leaves						
Whole fruits						
Pulp with seeds						
Powdered pulp						
Seeds						
Other (indicate)						

Q4 Which product do you purchase most often (usual product), and which measure do you usually use, and at what price, for purchases at this station?

Product:.....

Measure:.....

Price:.....

Q5 At the market, do you always find the usual product you have just bought?

No..... 1 Yes..... 2

Q6 When do you buy the usual product you have just bought? Indicate the months

J	F	M	A	M	J	J	A	S	O	N	D
□	□	□	□	□	□	□	□	□	□	□	□

Q7 What is the reason for buying the usual product you just bought?

	x	+
I prefer others for the same use, but they are not available in this period of the year	□	○
Good flavor	□	○
Good for health	□	○
I usually cook with it	□	○
Cheaper than others for the same use	□	○
Other(indicate)	□	○

Q8 There is a risk that the baobab product that you usually purchase may not be available in the market. To ensure its availability in the market, a conservation and improvement program for production of the product must be established. This program is costly and would be financed by various institutions (government, universities, NGOs, etc.).

Would you be willing to pay a little bit more for this product and thus participate in the program? Before responding, you must keep in mind that you will not have that money available for other food expenses or for savings.

□ No → Q8.1 What is the reason for not paying a surcharge? (Fill in and go to Q10)

	x	+
I'm always going to find it, even though it may be in another market	□	○
I prefer to pay the surcharge for other products	□	○
I am unable to pay a surcharge	□	○
I prefer buying another product	□	○
I don't believe that there's a product availability problem	□	○
The conservation and improvement program isn't necessary	□	○
I would pay, but I don't know how much	□	○

□ Yes → Q9.1 What is the maximum amount you would be willing to pay for the baobab product you usually purchase?

.....XOF

	x	+
Conservation and improvement of the baobab is important	□	○
Good flavor	□	○
Good for health	□	○
I usually cook with it	□	○
I want to ensure that I'll be able to continue buying this product	□	○
Cheaper than others for the same use	□	○
I prefer others for the same use, but they are not available in this period of the year	□	○

Q10 What is the total weekly expenditure at the market for preparing meals?

.....XOF per week

Q11 What is the expenditure on baobab products in a week

	Expenditure XOF
Green leaves	
Dry leaves	
Ground leaves	
Whole fruits	
Pulp with seeds	
Powdered pulp	
Seeds	

Q12 Do you find different types of quality of baobab products in the market?

Product	No	Yes	Product	No	Yes
Green leaves	1	2	Pulp with seeds	1	2
Dry leaves	1	2	Powdered pulp	1	2
Ground leaves	1	2	Seeds	1	2
Whole fruits	1	2	Others	1	2

III. Information about the respondent and their home

Q13 Their ethnic group:

Zarma..... 1 Kanouri..... 6

Hausa..... 2 Arabic..... 7

Fulani..... 3 Toubou..... 8

Touareg..... 4 Boudouma..... 9

Gourmantché..... 5 Bella..... 10

Other (indicate).....

Q14 Their level of education (one level only):

Primary..... 1

Secondary..... 2

Higher..... 3

Koranic studies..... 4

Literacy..... 5

None..... 6

Others (indicate).....

Q15 Civil status:

Married..... 1

Divorced..... 2

Widower/Widow..... 3

Single..... 4

Q16 Relationship with the head of household:

Head..... 1

Wife of head..... 2

Child..... 3

Adopted..... 4

Worker at the home..... 5

Others (indicate).....

Q17 Number of dependents of the head of household:

Elderly (over 50 years): .....

Adults (21 to 50 years): .....

Youths (8 to 20 years): .....

Children (0 to 7 years): .....

Q18 Number of co-wives in the home:

.....

Q19 Does your home suffer from a period of food shortage?

No..... 1 Yes..... 2

Indicate all the shortage months

J	F	M	A	M	J	J	A	S	O	N	D
□	□	□	□	□	□	□	□	□	□	□	□

Q20 & Q21. Main activities in the household

	Q20 Male	Q21 Female
Agricultural farmer.....	1	1
Cattle farmer.....	2	2
Agro-pastoralist.....	3	3
Housewife.....	4	4
Shopkeeper.....	5	5
Civil servant.....	6	6
Artisan.....	7	7
Beekeeper.....	8	8
Fisherman.....	9	9
Vegetable grower.....	10	10
Moto-taxi driver.....	11	11
Teacher.....	12	12
Tour guide.....	13	13
Butcher.....	14	14
Carpenter.....	15	15
Unemployed.....	16	16
Seasonal migrant.....	17	17
Long-term migrant.....	18	18
Others (indicate).....	.....	.....

Q22 Do you harvest baobab products?

Product	No	Yes	Product	No	Yes
Green leaves	1	2	Pulp with seeds	1	2
Dry leaves	1	2	Powdered pulp	1	2
Ground leaves	1	2	Seeds	1	2
Whole fruits	1	2	Others	1	2

End time of the survey

.....

THANK YOU VERY MUCH !

«Conservation and use of genetic resources of *A. digitata* in agroforestry systems: A review»

Pictures from Madarounfa (Niger, D. Agúndez)

Element for a strategy on conservation and use of genetic resources of *A. digitata* in agroforestry systems. D. Agúndez agundez@inia.es, R. Alia alia@inia.es INIA-CIFOR/iuFOR

Objectives of this document

- an approach to value social preferences on conservation genetic resources within a master dealing with agroforestry
- the integration of genetics, ecological and management information for design management and conservation strategies
- the approach is based in different study cases

Case study in Conservation Forest Genetics. This case study is based in the ones developed by D. Boshier, M. Bozzano, J. Loo (eds). Bioversity International. Training material available in the web (english and French)
http://forest-genetic-resources-training-guide.bioversityinternational.org/

Why *A. digitata*?

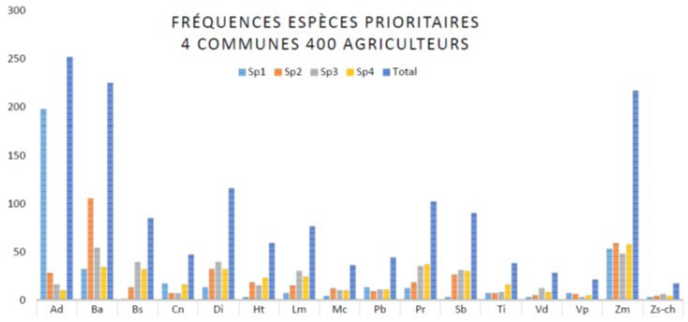
Leach et al. 2011, Mali

Pictures: D. Agúndez, Niger

Schumann et al. 2012, Burkina Faso

A. digitata: a paradigmatic species in Agroforestry systems

Highly appreciated by local communities



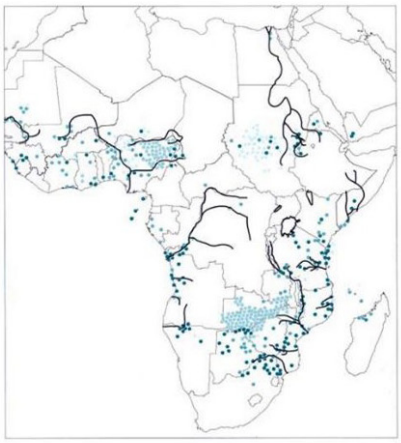
Different uses depending on the community

A. digitata	%
Human food	92.9
Cattle feed	4.8
Pharmacopoeia	2.4

Source: ACGVELA (AECID 2014/ACDE/003520)
« Acceso, Conservación, Gestión y Valorización de Especies Leñosas Alimenticias en Níger»

Distribution of A. digitata in Africa

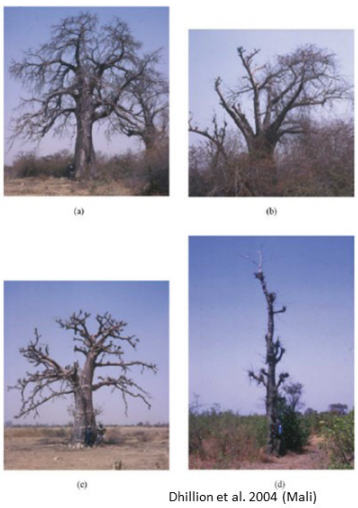
Picture: Fayari (Niger, D. Agúndez)



Link to Potential Distribution https://josemaciasbarredo.neocities.org

A. digitata: Lack of sustainable management/restoration practices

Pictures from Kankani, Torodi, Aguié, Madarounfa (Niger, D. Agúndez)

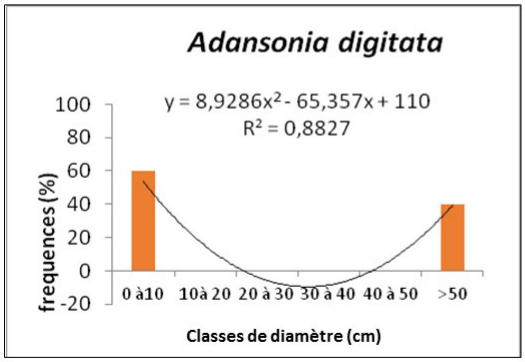


Dhillion et al. 2004 (Mali)

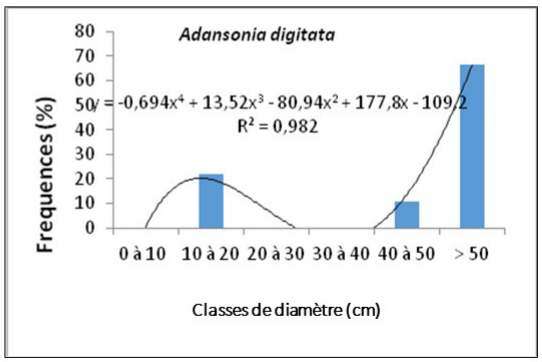
The demography of the populations are biased: collapse of populations in the near future?

ZONE SOUDANIENNE : Structure démographique

Zone protégée



Zone déclassée



Douma et al. 2011 (Tamou, Niger)

Pictures from Maradi (Niger, D. Agúndez)

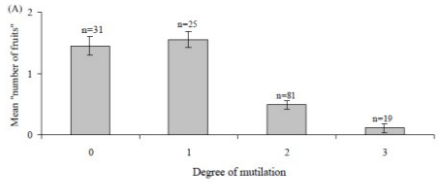
Pictures from Madarounfa (Niger, D. Agúndez)

How human are using the species. Type of local practices, products, collection and final use.

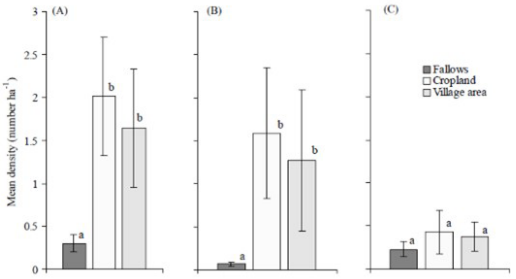
Activity / phenological event	Seasonal diagram (Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec)	n	Harvesting tools (% response of total)
Germination		38	
Flowering		38	
Leaves			
- presence		40	Sickle (96), *dolé* (81), hand(18)
- harvesting		37	
- consumption		39	
Fruits			*Dolé* (100), wind (44), stick (13), hand (6)
- presence		38	
- harvesting		37	
- consumption		38	
Bark			*Daba* (93), axe (21)
- collection		31	

Dhillion et al. 2004 (Mali)

Density and Production of fruits depending of type of system



Mean "number of fruits" (±S.E) for mature tres (dbh>100 cm) according to the degree of mutiliation, where category 0, no fruits, category 1 with 1-9 fruits, category 2 with al least 10 fruits



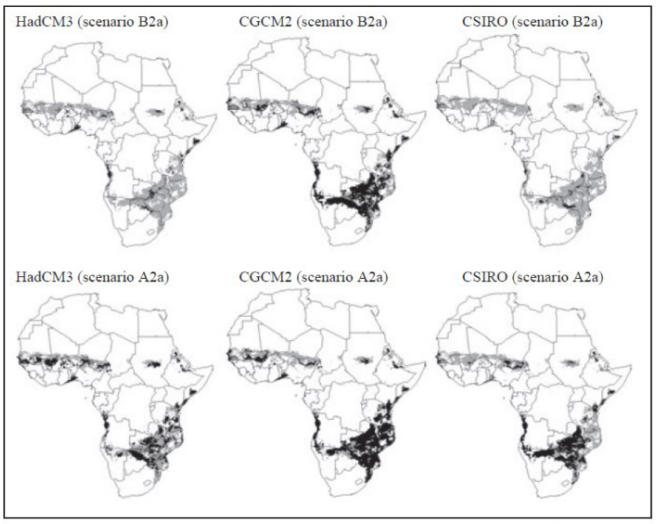
Mean density (±S.E) of the (A) total, (B) recruit and (C) mature populations in fallows (n=15), cropland (n=3), and village areas (n=3). For each population different letters above bars denote significant differences (Tukey's test)

Dhillion et al. 2004 (Mali)

Different threats identified by the local communities / scientist

	% of respondents
Land clearing	0,00
Fires	0,00
Over-grazing	0,00
Wood construction over-exploitation	2,60
Flowers, fruits over-exploitation	33,30
Leaves over-exploitation	10,30
Bark over-exploitation	15,40
Charcoal, firewood over-exploitation	5,10
Roots over-exploitation	10,30
Insects and diseases	7,70
Drought	5,10
Wind	7,70
Aged trees	0,00
Depleted soils, fertilizer influence	2,60

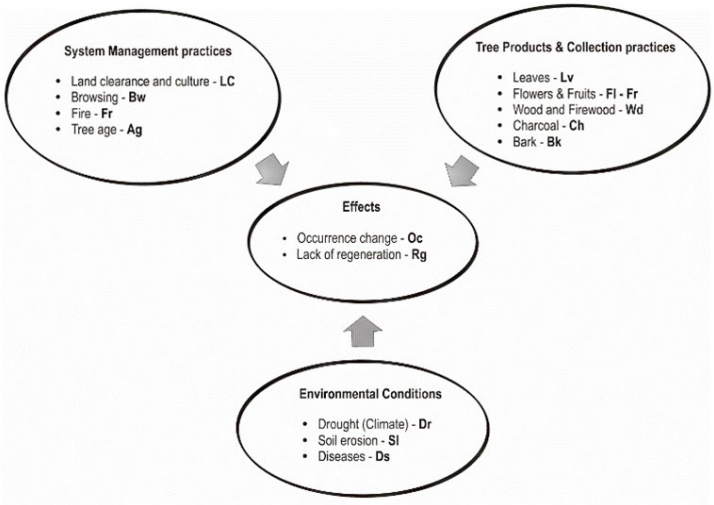
Agúndez et al. 2017 (under review, Niger)



Current potential distribution
Future potential distribution

Cuni Sanchez et al. (2010a)

Relationships among sustainability, use and different drivers influencing the processes



Agúndez et al. 2016 (Niger)

Why bother about genetic diversity?

- adaptation to changing environments
- direct use of genetic resources
- viability of populations in short term
  - seed production
  - inbreeding depression

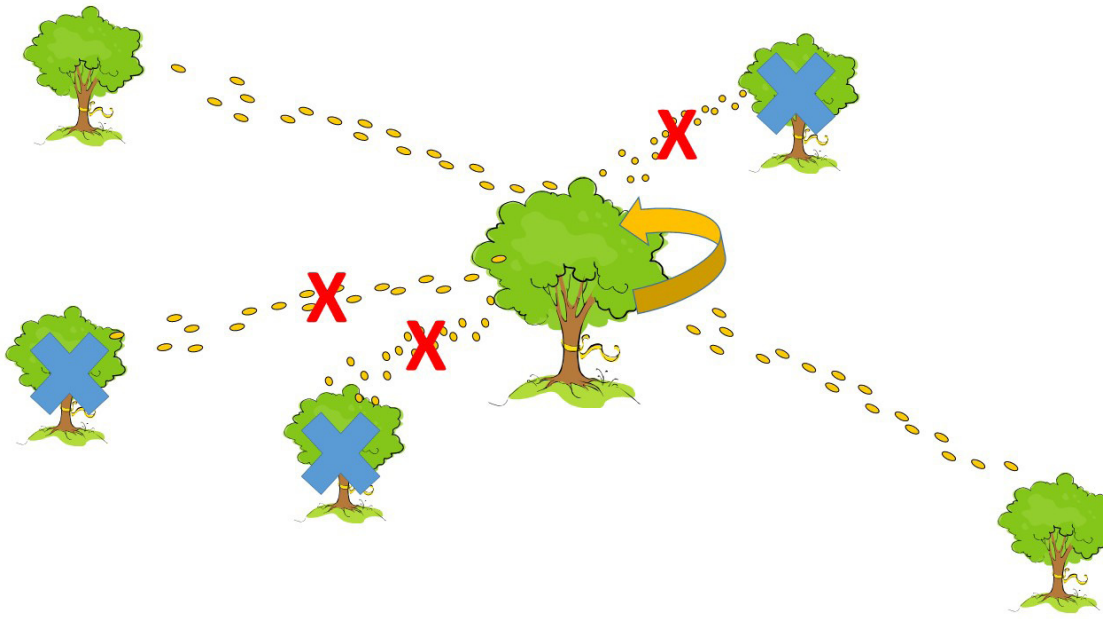
Theory

• ***direct impacts***	***genetic processes***
• decrease pop. size	*genetic drift*
• increase spatial isolation	
• decrease densities	
• change local environment	

Bottleneck → genetic drift

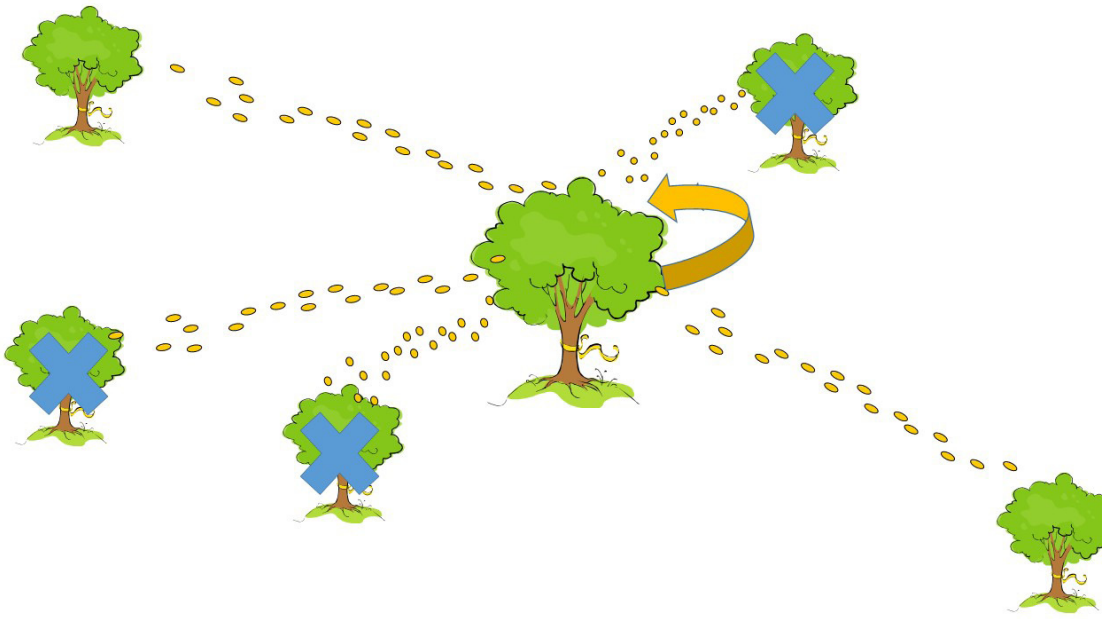
Theory

• ***direct impacts***	***genetic processes***
• decrease pop. size	*genetic drift*
• increase spatial isolation	*gene flow*
• decrease densities	
• change local environment	



Theory

• ***direct impacts***	***genetic processes***
• decrease pop. size	*genetic drift*
• increase spatial isolation	*gene flow*
• decrease densities	*mating - inbreeding*
• change local environment	



Theory

• ***direct impacts***	***genetic processes***
• decrease pop. size	*genetic drift*
• increase spatial isolation	*gene flow*
• decrease densities	*mating – inbreeding*
• change local environment	*selection*

Plantations as a local managing practice?

	Wild	FMNR	Planted
Adansonia digitata	**5.4**	**29.7**	**64.9**
Balanites aegyptiaca	23.1	74.4	2.6
Boscia senegalensis	63.3	36.7	0.0
Ziziphus mauritiana	32.4	67.6	0.0

Agúndez et al. 2017 (under review, Niger)

Table 2
People's adherence to practices of protection/cultivation of the baobab tree and association of practices to land use categories

Practice	Adherence, affirmative response (%)	n^a	Association (percentage of respondents) with land use				n^b
			Fallows >10 years old	Fallows ≤10 years old	Cropland (*kungoforos*)	Cropland (*soforos*)	
Protection of natural germinations	49	89	50	32	80	89	38
Sowing	10	89	0	11	33	56	9
Transplantation	60	89	2	0	21	96	52

Dhillion et al. 2004 (Mali)

… But usually lacking proper knowledge on germplasm management

Growing A. digitata

https://www.youtube.com/watch?v=jYrIyHnkpOk

For leaf production in gardens

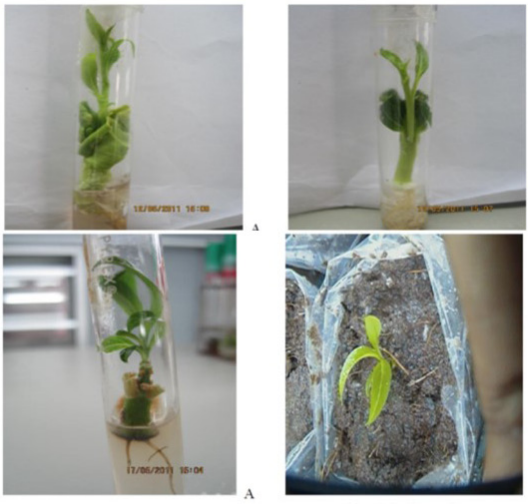
Bationo et al, 2009 (Burkina Faso)

For plantations

https://www.inecoba.com/kit-enseignant/comment-reussir-la-germination-de-graines-de-baobab.html

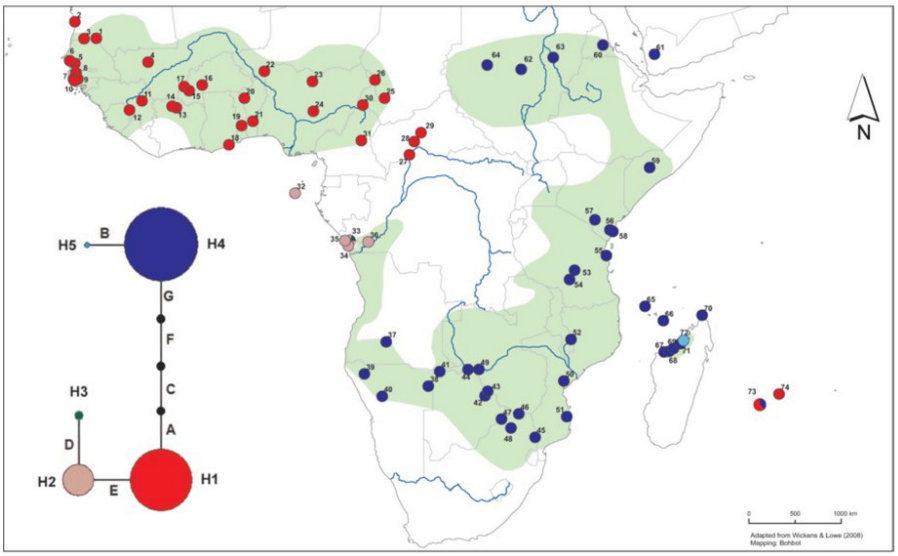
A. digitata propagation

Anjarwalla et al. - 2016



Fasola & Okerenkporo - 2012

Different maternal (neutral) lineages have been identified in *A. digitata*



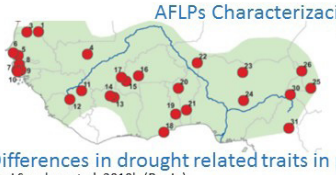
Pock Tsy, et al. 2009. Molecular Ecology, 18(8), 1707–1715.

A. digitata provenance trials (ICRISAT, Niger)

Pictures: D. Agúndez, Niger

Genetic diversity of *A. digitata* populations

AFLPs Characterizacion of populations
Assogbadjo et al. 2009



Differences in drought related traits in provenance tests
Cuni Sanchez et al. 2010b (Benin)

TABLE 1. Genetic diversity within 11 baobab populations.

Country	Pop	*N*	d_{max} (m)	H_e	SD	P_p (%)
Benin	P1	29	26817	0.30	0.01	94.1
	P2	26	25008	0.30	0.01	94.5
	P3	23	30387	0.31	0.01	93.7
Ghana	P4	28	46511	0.32	0.01	94.1
	P5	16	8000	0.35	0.01	94.5
	P6	15	50000	0.29	0.01	95.3
Senegal	P7	19	5630	0.22	0.01	41.7
	P8	26	4876	0.27	0.01	95.3
Burkina Faso	P9	22	1084	0.32	0.01	94.0
	P10	26	2430	0.32	0.01	96.1
	P11	21	6894	0.28	0.01	94.5

Table 3 Leaf morphological and stomatal characteristics of *Adansonia digitata* from eight study sites ($n = 100$)

Agro-climatic zone	Study sites	ML length (cm)	Pedicel length (cm)	No. leaflets	ML thickness (mm)	SLW (mg/cm^2)	No. stomata per mm^2
Sudanian	Karimama	8.54 ± 1.62 a	8.10 ± 2.50 a	5.62 ± 0.90 b	0.28 ± 0.04 a	8.14 ± 1.85 a	128.26 ± 18.39 c
	Sanpeto	7.42 ± 1.45 c	6.12 ± 1.89 b	4.12 ± 0.97 c	0.22 ± 0.03 c	5.89 ± 1.41 c	124.08 ± 24.95 bc
	Porga	6.26 ± 1.26 b	4.56 ± 1.42 c	3.71 ± 0.89 d	0.24 ± 0.04 b	7.89 ± 1.58 a	146.08 ± 29.71 f
	Boukombé	7.11 ± 1.64 c	5.68 ± 1.93 b	4.67 ± 0.84 a	0.29 ± 0.04 a	9.81 ± 1.22 d	101.09 ± 16.46 e
Sudano-Guinean	Bassila	8.19 ± 1.90 a	6.09 ± 2.46 b	4.60 ± 0.88 a	0.25 ± 0.03 b	5.81 ± 1.43 c	75.45 ± 16.29 d
	Dassa	6.07 ± 1.44 b	5.93 ± 2.16 b	4.28 ± 1.02 c	0.26 ± 0.04 b	6.79 ± 1.67 b	119.21 ± 17.16 bc
Guinean	Sèhouè	8.71 ± 1.63 a	7.28 ± 1.84 a	5.39 ± 1.10 b	0.28 ± 0.04 a	8.03 ± 2.10 a	114.85 ± 17.60 b
	Comé	8.88 ± 1.29 a	7.53 ± 2.35 a	4.74 ± 1.26 a	0.28 ± 0.05 a	8.26 ± 2.20 a	90.26 ± 16.52 a

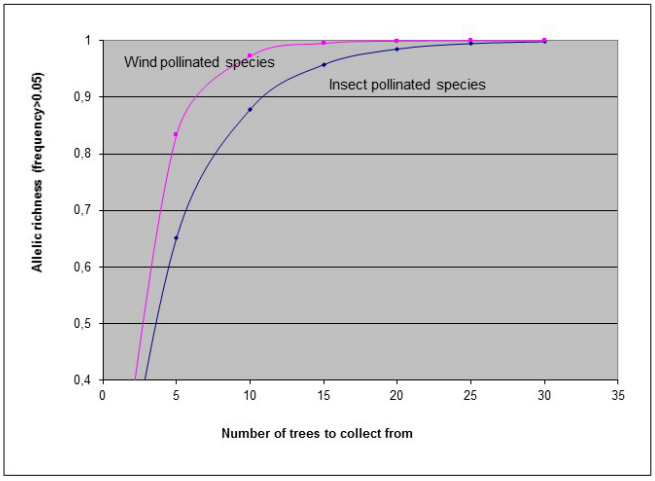
Means followed by the same letter within a column are not significantly different at $P < 0.01$ (Games-Howell test)
ML medial leaflet, *SLW* specific leaf weight

How big is "big enough"?

50/500 rule (Franklin 1980)

- 50 - ↓ inbreeding depression to acceptable level
- 500 - sufficient for new variation from mutation to replace that lost by genetic drift
- refers to effective population size (N_e) rather than survey numbers (N) – so may need many more!
- in trees N_e smaller than N due to: overlapping generations, dioecy, asynchronous flowering, fecundity differences between individuals

How many trees to collect from?



Main points for discussion

- the main actors influencing the conservation of the ressources? (i.e. forest service, gender issues)
- the main effects of current management in the conservation of the ressources? (i.e. topics without enough knowledge and how to solve it, interaction between Ecology and social issues and Genetics)
- the genetic diversity of trees for seed collection in nursery stablishement (i.e. origin of the material, number of trees to be collected, main characteristics of the trees)

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Breeding for high production of lea *digitata* L) in an irrigated hedge sys

Adama Korbo · Erik D. Kjær · Haby Sanou · Anders Ræbild · Jan S. Jensen · Jon K. Hansen

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Using a deterministic population model to evaluat and the effects of fruit harvesting and livestock on *digitata* L.) populations in five land-use types

Sarah M. Venter*, Ed. T.F. Witkowski

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Opportunities for domesticating the African baobab (*Adansonia digitata* L.): multi-trait fruit selection

David J. Simbo · Sebastiaan De Smedt · Nina Van den Bilcke · Bruno De Meulenaer · John Van Camp · Veronique Uytterhoeven · Filip Tack · Roeland Samson

Bioversity International
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Descriptors for

Baobab

(*Adansonia digitata* L.)