Title: Domesticating and conserving indigenous trees species: an ecosystem based approach for adaptation to climate change in sub-Sahara Africa

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Short title: Indigenous trees species and adaptation to climate change

Abstract

The current food production systems in Africa geared towards alleviating poverty and eliminating hunger, in accordance with Millennium Development Goal number one, are faced with many challenges. These challenges include among others: i) the need to sustainably feed people and improve their livelihoods while conserving native ecosystems ii) loss of local capacities and know-how to sustainably manage local resources due to decades of implementation of an agriculture mainly based on exotic plants; iii) the choice of plant species that will best suit specific environmental conditions under climate change. In the present communication, some potential solutions are addressed. To date, there is agreement that domestication of indigenous plant species for the diversification of subsistence agriculture could play a big role in the achievement of the Millennium Development Goals. These species can be conserved and used to halt and reverse the increasing degradation of ecosystems while providing economic opportunities, particularly in African countries. Integration of these indigenous species into formal production systems could help establish an ecosystem based development path in African countries. To ensure the sustainability of such a new development pathway, it is important to guarantee availability of sufficient scientific information to guide decision making especially within the context of climate change and socioeconomic vulnerability. In addition, policy makers will need scientific information on market incentives and other policy instruments that can facilitate both conservation and development goals considering the MDGs. Moreover, paradigm shift in the development concept, education and capacity building will also be needed.

Key words: Prioritization, Indigenous species, Socio-economic importance, resistance to climate aggressiveness

Titre: Domestiquer et conserver les espèces végétales autochtones: une approche d'adaptation aux changements climatiques en Afrique Subsaharienne, basée sur les écosystèmes

Résumé

En Afrique, les systèmes de productions alimentaires actuels visant à réduire la pauvreté et éliminer la faim, conformément aux Objectifs du Millénaire pour le développement, sont confrontés à de nombreux défis. Aux nombre de ces défis on peut citer entre autres: i) la nécessité de nourrir durablement les populations et améliorer leurs revenus tout en protégeant les écosystèmes locaux ii) la perte des capacités locales et des savoir-faire pour gérer durablement les ressources autochtones, due à des décennies de pratique d'une agriculture basée sur des plantes exotiques; iii) le choix des espèces végétales capables de s'adapter le mieux aux conditions environnementales résultant des changements climatiques;. Dans la présente communication, nous abordons quelques approches de solutions. Aujourd'hui, il est admis que la domestication des espèces végétales autochtones pour la diversification de l'agriculture de subsistance pourrait jouer un grand rôle dans l'atteinte des Objectifs du Millénaire. Ces espèces peuvent être conservées et utilisées pour arrêter et inverser la dégradation croissante des écosystèmes tout en offrant des opportunités de développement économiques, en particulier dans les pays africains. Leur intégration dans les systèmes formels de production pourrait aider les pays africains à établir une voie de développement fondée sur la conservation des écosystèmes. Pour assurer la pérennité de cette nouvelle voie de développement, il est important de garantir la disponibilité d'informations scientifiques suffisantes pour guider la prise de décision, en particulier, dans le contexte des changements climatiques et de la vulnérabilité socio-économique. Aussi, les décideurs ont besoin d'informations scientifiques sur les indicateurs du marché et d'autres instruments de politique qui peuvent faciliter la conservation et la réalisation des Objectifs du Millénaire. En outre, un changement de paradigme dans le concept du développement, de l'éducation et du renforcement des capacités sera également nécessaire.

Mots clés: Priorisation, Espèces autochtones, Importance socio-économique, résistance à l'agressivité du climat

Introduction

The current food production systems in Africa geared towards alleviating poverty and eliminating hunger, in accordance with Millennium Development Goal number one, are faced with many challenges. These challenges include among others: i) the need to sustainably feed people and improve their livelihoods while conserving native ecosystems ii) loss of local capacities and know-how to sustainably manage local resources due to decades of implementation of an agriculture mainly based on exotic plants (Auteur, personal observation). At the same time, the current system is unprecedentedly affecting native ecosystems. Land clearing to make room for agriculture and slash-and-burn agriculture are major drivers of deforestation in Africa (FAO 2011). Another major deforestation driver is, exploitation of indigenous timber species in the absence of sufficient sylvicultural knowledge for reforestation using these indigenous species. According to FAO report on state of world's forests, reduction of forest land cover in Africa is estimated at 3.5 million hectares per year (FAO 2011). With the global warming, not only that the abovementioned concerns are expected to be exacerbated, but also, an additional challenge is expected to rise: iii) the choice of plant species that will best suit specific environmental conditions under climate change.

A great number of approaches are being developed to improve the capacity of socio-economic and biological systems to withstand climate change, including ecosystem based adaptation (EBA) (Doswald and Osti 2011). Ecosystem Based Adaptation also known as Ecosystem Based Adaptation Approaches to climate change is a relatively new concept. Fundamentally, it refers to the use of locally available natural resources by people to withstand climate change impacts (Munang *et al.* 2013). These approaches aim at using local biodiversity and ecosystem services as part of an overall adaptation strategy to help people adapt to the adverse effects of climate change (Convention on Biological Diversity 2009).

To date, there is agreement that domestication of Indigenous Agroforestry Tree species for the diversification of subsistence agriculture could play a big role in the achievement of the Millennium Development Goals (Leakey *et al.* 2007). In the same way, these species can be used to halt and reverse the increasing degradation of ecosystems while also providing economic and job opportunities, particularly in African countries (Zomer *et al.* 2009; Garrity *et al.* 2010). Indeed, any attempt to find sustainable solutions to the problems of inappropriate food production system should take into account locally known, available and used natural resources (Chadare 2010). Bayala *et al.* (2014) have more recently argued that, Indigenous Agroforestry Tree species can help buffer the sociocultural and economic impacts of climate change. For instance, the potential local market demand in Cameroon for the bush mango nuts (*Irvingia gabonensis*) has been estimated at 80.000 tons per year (Ndoye *et al.* 1999). As such their commercialization has generated US$ 94,000 to local Cameroonians sellers in 1996 (Ndoye *et al.* 1999). More recently, two Arabic gum species (*Acacia Senegal* and *A. seyal*) have contributed to local incomes in Nigeria for US$ 600,000 (Njohama 2008). Besides their potential to sustainably improve livelihoods, some indigenous species have strong ability for native environment stabilization and ecological restoration. For example, in dry-lands of Western Africa (i.e., Mauritania, Senegal, Niger, Mali, Burkina Faso, Benin, Ghana, etc.), potential candidate species for ecological restoration include: the gum arabic tree, (*Acacia Senegal*), the red acacia (*Acacia seyal*), the desert date (*Balanites aegyptiaca*), the date palm (*Phoenix dactylifera*), the Jujube tree (*Ziziphus mauritiana*), the shea tree (*Vitellaria paradoxa*), the baobab (*Adansonia digitata*), the tamarind tree (*Tamarindus indica*), the marula tree

(*Sclerocarya birrea*), amongst others. As such, integration of these indigenous species into formal production systems could help establish an ecosystem based development path in African countries. Since indigenous species are likely to have the genetic basis that is required to adapt to climate change, such approach could further enable establishment of climate change resilient and/or tolerant development paths. In short, use and conservation of the abovementioned species fit well within the EBA approach. In the following lines some prerequisite and challenges to their optimal use and conservation, and suggestions to facilitate their promotion are further addressed.

Conserving indigenous agroforestry tree species under EBA

Planning for sustainable use and conservation programs for Indigenous Agroforestry Tree species require certain policy considerations. Information and attention to knowledge gaps on the following theme are required: (i) priority keystone species, (ii) effect of current harvesting pressure and critical thresholds on the dynamics of socio-culturally and commercially important species, (iii) level and pattern of genetic diversity, (iv) threat and vulnerability status, (v) sylviculture, (vi) existing and potential value-chains and their contributions to local economies. Up to date, scientific interest in indigenous edible plants and their timber counter parts has yielded outstanding data covering much of the concerns above (e.g. Akinnifesi *et al.* 2008). Yet, these data need to be synthesized and made available to managers in countries that need to take policy measures that are holistic and reconcile conservation and development. Moreover, despite the huge literature available on these species very few studies have adequately addressed the climate change dimension in terms of vulnerability and adaptation strategies and interventions. It is projected that 20 % to 30 % of plant and animal species will be at increased risk of extinction if increases in global average temperature exceed 1.5°C to 2.5°C in Africa (IPCC 2007; Busby *et al.* 2010). At the same time 25 % to 42 % of plant species are projected to be at risk of extinction by 2085, sequel to loss of 81 % to 97 % of their habitats (IPCC 2007). The questions that have not been on the policy forefront are: i) how does climate change affect Indigenous Agroforestry Trees species distribution, and, ii) what are the socioeconomic ramifications for resource dependent communities?

Presently scientific evidence suggests that some key agroforestry species have been introduced into dry Sudano-Sahelian areas during high-rainfall periods in the climate cycles back to 1,000 - 3,000 BP (e.g., the Shea tree) (Maranz 2009). However, native trees may adapt to varying climate cycles that span millennia. This suggests that climatic factors such as rainfall decline and temperature rise may either displace or favor these tree species distributions and thus limit or enhance livelihoods.

Besides, selection of preferred varieties in the domestication processes for specific species often drives genetic erosion through lost of genetic diversity (Ofori *et al.* 2014). If there are no effective conservation strategies in place that ensure the perpetuation of wild relatives, this may lead to ecological and socioeconomic negative effects. Protected areas are known to play an important role in the conservation of the genetic diversity of such species. But, because climate change is expected to induce spatial dynamic of species distribution or geographic shifts in their suitable habitats (Hannah 2008), how will these static bio-reserve networks guarantee the conservation of the genetic diversity of these species under climate change? According to Scott (2005), never before has there been an ecological stressor that raised questions about the adequacy of nature reserve systems to protect and conserve representative samples of species. Therefore, under an EBA approach, some further questions need to be addressed to enable informed decision-making: Which indigenous species could be sustainably conserved and/or promoted in specific areas under changing climate? What spatial rearrangement of reserve systems will be needed to ensure climate change resilient/resistant conservation of representative samples?

Toward a framework for species prioritization

Under EBA, species prioritization is important to ensure climate change resilient/resistant species are being given greater importance. To this end, it is relevant to design an objective framework. Here we propose a list of criteria to be taken into account in a decision framework adapted from Brehm *et al.* (2010) :

(i) *Native status*: Native edible species will be given greater consideration.

(ii) *Economic value*: Species that better contribute to local economies will be given higher priority.

(iii) *Ethnobotanical value*: This will be assessed through local knowledge on the uses of a species and coupling qualitative and quantitative methods in ethnobotany. Priority will be given to the species having a high importance value for local communities.

(iv) *Climate change adaptation / drought tolerance value*: Priority will be given to the species that can tolerate desert conditions (temperature rise/ or high evapo-transpiration) if the trend is towards a decrease in the rainfall.

(v) *Soil stabilization value*: Priority will be given to the species having high capacities for stabilization of soil structure.

(vi) *Global distribution value*: Priority increases with the more restricted distribution, so national or regional restricted species or endemics will be given higher priority than species with larger distribution

(vii) *National distribution value*: National distribution will be considered here as an indicator of rarity. A species occurring in a few geographic regions at country level, will be considered rarer than a species occurring throughout the country.

(viii) *In situ* and *ex situ conservation status value*: Before a taxon can be given high priority for sustainable use and conservation, current conservation activities relating to it should be reviewed. If sufficient genetic diversity is already being conserved *in situ* and/or *ex situ*, additional conservation efforts may not be justified, and resources should focus on those species that are not being conserved.

(ix) *Legislation value*: A species under any kind of legislation requires conservation attention because national governments are responsible for protecting them.

(x) *Threat assessment value*: The IUCN Red List threat status is probably the most used criterion for determining conservation priority. Endangered species received greater attention than those that are not under threat.

Four different methods combining the ten criteria above may be developed as described in Brehm *et al.* (2010): point scoring procedure (PSP), point scoring procedure with weighting (PSPW), compound ranking system (CRS) and binomial ranking system (BRS).

In the PSP, a series of scores for multiple criteria will be assigned to each species, with the highest number always indicating highest priority. The overall score for each species will be obtained by summing scores for each criterion. A species having higher overall score better deserves integration into formal production systems and greater conservation concerns. The PSPW is very similar to the PSP with the difference that to each criterion a particular weight is given. The CRS uses individual criteria ranking positions (not scores as in PSP), which are then combined in order to obtain a compound rank for each of the species and for each of the major criteria. The BRS is based on a series of Yes/No questions, with a ''Yes'' answer always having higher priority than a ''No'' answer. Then, the top 50 species will be short -listed for each prioritization method. The number of times each top 50 species occurred in the different sub lists will be noted and used to further short list 20 species. The 20 priority species will be those mostly prioritized across methods. Figure 1 summarizes the prioritization framework.

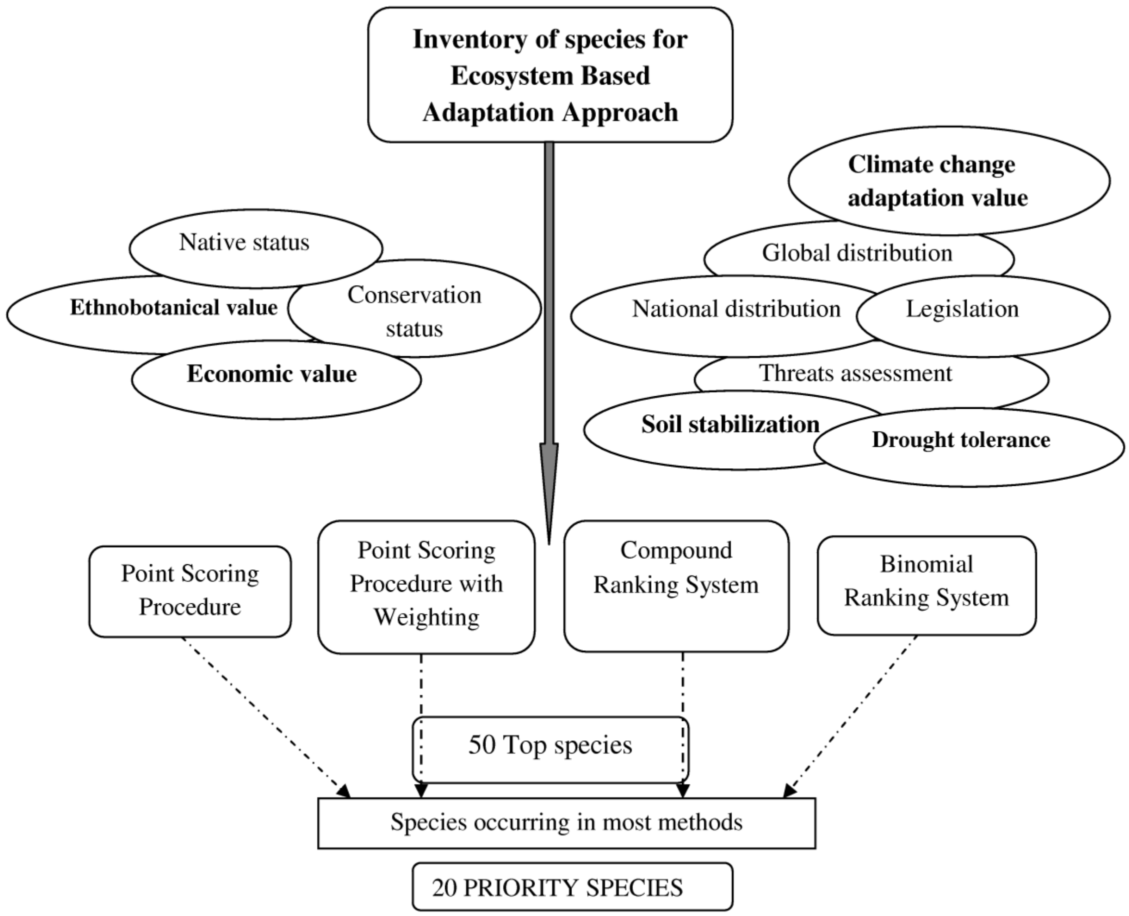

Figure 1. A methodological framework for species prioritization (adapted from Brehm.*et al.* 2010)

Conclusion

Indigenous Agroforestry Tree species in developing countries could play a key role in implementation of an EBA approach. To this end, these plants species need be integrated into formal production systems. To ensure the sustainability of such a system, it is important to guarantee that there is sufficient scientific information to guide decision making especially within the context of climate change and socioeconomic vulnerability. In addition, policy makers will need scientific information on market incentives and other policy instruments that facilitate both conservation and development. Moreover, paradigm shift in the conceptualization of "development", education and capacity building will also be required.

Key information to make available includes:

i. Recommended tree species (species which produce useful products and which deliver ecosystem benefits should be favored);
ii. The suitable environments/climatic regions/soil types for cultivation and conservation; This will be possible by screening all candidate species using Climate change multi-scenarios to identify top climate resilient/tolerant species (i.e., Multi-Scenario analysis of the impact of climate change on the geographic range of suitable habitats for prioritized species, using up-to-date emission);
iii. Technical details for planting (suitable methods for propagation, appropriate tree densities and optimal spatial structure, costs of nursery establishment and training requirements);
iv. The time required for tree establishment and return of tree benefits to local communities;
v. Country-specific business models based on various tree products (including cash flow analyses from time zero to year 4 or 5; and, description of the value chain and the estimated size of the market).

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