Assisted Natural Regeneration in slash-and-burn agriculture: Results in the Democratic Republic of the Congo

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Photo 1.
A large part of the human impact on natural tropical forests in Central Africa is linked to shifting cultivation (a) and the extraction of fuelwood which often is associated with it (b).
Photo R. Peltier.

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RÉSUMÉ

RÉGÉNÉRATION NATURELLE ASSISTÉE ADAPTÉE À L'AGRICULTURE SUR BRÛLIS : RÉSULTATS EN RÉPUBLIQUE DÉMOCRATIQUE DU CONGO

La majorité des impacts anthropiques sur les forêts tropicales naturelles en Afrique centrale est liée à l'agriculture itinérante et à l'extraction du bois de feu en zone périurbaine. Cela est en particulier le cas autour de Kinshasa, en République démocratique du Congo (RDC). C'est pourquoi, en 2010, la Régénération naturelle assistée (RNA) a été adaptée et testée par le Projet Makala dans le bassin d'approvisionnement en bois de feu de cette ville, pour améliorer les systèmes de culture sur abattis-brûlis et contribuer à l'enrichissement des jachères forestières. Avant la défriche, des arbres utiles sont sélectionnés pour être protégés. Puis, pendant la période de culture, la germination et la multiplication par rejets de souche et drageons des espèces forestières locales préexistantes sont favorisées par des pratiques de sarclages sélectifs, d'éclaircies et d'élagages. Le suivi de ces tests montre une faible survie des vieux arbres conservés lors du défrichement pour les cultures, en raison de la difficulté de contrôle des feux lors du brûlis, ce qui limite l'applicabilité de cette technique à la périphérie des parcelles, sous forme d'enrichissement progressif de haies bocagères. Par contre, à l'intérieur des parcelles, les rejets de souche exploités et les drageons des espèces forestières naturelles, protégés par RNA au moment des sarclages, ont montré une croissance rapide qui permet, à faible coût, d'installer rapidement une jachère ligneuse. En 2014, trois ans et demi après le brûlis, ces jachères ont une biodiversité et une biomasse supérieures à celles des jachères non gérées par RNA. Une meilleure productivité en charbon et en produit agricole ainsi qu'une réduction de la savanisation des espaces forestiers sont espérées. Cependant, l'acceptation sociale, qui est un facteur critique pour la diffusion d'une telle innovation à grande échelle, reste à étudier, en relation avec l'évolution possible des droits fonciers traditionnels et modernes.

Mots-clés : régénération naturelle assistée, agroforesterie, jachères améliorées, charbon de bois, bois-énergie, amélioration des systèmes agraires sur brûlis, République démocratique du Congo.

ABSTRACT

ASSISTED NATURAL REGENERATION IN SLASH-AND-BURN AGRICULTURE: RESULTS IN THE DEMOCRATIC REPUBLIC OF THE CONGO

Human impacts on natural tropical forests in Central Africa are to a large extent linked to shifting cultivation and fuelwood extraction in peri-urban areas. This is especially true around the city of Kinshasa in the Democratic Republic of the Congo (DRC), which is why research was conducted in 2010 by the Makala Project in the city's fuelwood supply basin. The aims were to adapt and test Assisted Natural Regeneration (ANR), improve slash-and-burn crop systems and contribute to the enrichment of forest fallows. Prior to slashing and burning, useful trees were selected for protection. Then, during cropping, the germination and multiplication of stump shoots and root suckers from existing local forest species were promoted by selective weeding, thinning, and pruning. Monitoring of the test areas found low survival rates for old trees conserved before the land was slashed and burned, due to the difficulty of controlling the fires. This means that the technique can only be used for the edges of plots, by gradually enriching hedgerows. In contrast, stumps shoots and root suckers from natural forest species protected by ANR during agricultural weeding grew rapidly inside the plots, thus rapidly establishing woody fallows without the need for costly inputs or heavy labour. In 2014, three and a half years after slashing and burning, biodiversity and biomass in these fallows is greater than in non-ANR fallows. Better charcoal and crop productivity and a slower rate of forest transition into savannah are expected. However, social acceptance, a critical factor in the large-scale dissemination of this innovation, must be investigated in the light of potential developments in traditional and modern land tenure rights.

Keywords: assisted natural regeneration, agroforestry, improved fallows, charcoal, fuelwood, improved slash-and-burn farming systems, Democratic Republic of the Congo.

RESUMEN

REGENERACIÓN NATURAL ASISTIDA ADAPTADA A LA AGRICULTURA DE TALA Y QUEMA: RESULTADOS EN LA REPÚBLICA DEMOCRÁTICA DEL CONGO

Los impactos antrópicos en los bosques tropicales naturales de África Central están en gran medida vinculados a la agricultura itinerante y a la extracción de leña en áreas periurbanas. En particular, este es el caso en torno a Kinshasa, en la República Democrática del Congo (RDC). Por ello, en 2010, el proyecto Makala adaptó y experimentó la Regeneración Natural Asistida (RNA) en el área de suministro de leña de dicha ciudad. El objetivo era mejorar los sistemas de cultivo de tala y quema y contribuir al enriquecimiento de los barbechos forestales. Antes de la roza, se seleccionan algunos árboles útiles para protegerlos. Luego, durante el período de cultivos, se favorecen la germinación y multiplicación por brotes de cepa y de raíz de las especies locales preexistentes mediante escardas selectivas, raleos y podas. El seguimiento de estos experimentos mostró bajas tasas de supervivencia de los viejos árboles que se protegieron de la roza previa a los cultivos. Esto se debe a la dificultad de controlar los fuegos durante la quema y restringe la aplicación de esta técnica a los linderos de las parcelas, en forma de enriquecimiento progresivo de setos vivos. Sin embargo, en el interior de las parcelas, los brotes de cepas aprovechados y los brotes de raíz de especies forestales naturales, protegidos por RNA durante la escarda, mostraron un rápido crecimiento que permite, con bajo costo, establecer rápidamente un barbecho leñoso. En 2014, tres años y medio después de la quema, estos barbechos tienen una biodiversidad y una biomasa superiores a la de los barbechos sin manejo por RNA. Gracias a esto se espera una mayor producción de carbón y productos agrícolas, a la vez que una reducción de la sabanización de espacios forestales. No obstante, queda por estudiar la aceptación social, un factor crítico para difundir esta innovación a gran escala, en relación con la posible evolución de los derechos tradicionales y modernos sobre la tierra.

Palabras clave: regeneración natural asistida, agroforestería, barbechos mejorados, carbón de leña, leña, mejoramiento de sistemas de cultivo de tala y quema, República Democrática del Congo.

Background and research question

A colossal city with an enormous demand for wood and disappearing periurban forests

Human impacts on natural tropical forests in Central Africa are to a large extent linked to shifting cultivation and fuelwood extraction in periurban areas (Megevand, 2014). This is especially true around Kinshasa.

Population estimates for Kinshasa, the capital of the Democratic Republic of the Congo (DRC), vary between 8 and 10 million inhabitants, 90% of whom rely largely on charcoal for cooking. The conglomeration's annual needs were assessed at 4.8 million cubic meters of wood equivalent, in the form of logs or charcoal, with a value of 143 million US dollars (Schure *et al.*, 2011; Schure, 2014). The city is surrounded by wooded savannah interspersed with gallery forests which are becoming degraded. Slash-and-burn agriculture, practiced most often in secondary forests, covers the bulk of demand for food, especially cassava and maize, and charcoal (Peltier *et al.*, 2013) (photos 1). As the population grows, pressure on natural forests is increasing and leading to reductions in the length of fallow periods required to restore soil fertility (Floret and Pontanier, 2000). As a result, the biodiversity and biomass of fallows are steadily diminishing, soils are being leached, and invasive herbaceous plants and shrubs, such as *Chromolaena odorata*, *Pteridium aquilinum* and *Imperata cylindrica,* are beginning to replace forests. Savannah fires, which occur several times a year, are now able to penetrate into the most degraded fields bordering the savannah, which may lead to the savannization of the environment and a reduction in the arable land traditionally cultivated by slash-and-burn agriculture (photo 2). Fewer and fewer crops are being produced after each fallow, and products traditionally harvested in forests and on forest fallows (game, edible leaves and shoots, medicinal plants, honey, edible caterpillars and mushrooms, fibres, etc.) are becoming increasingly rare and expensive (Nsimundele *et al.*, 2010). For example, on the land around Kinduala, a village located 120 km outside Kinshasa in the province of Bas-Congo, above-ground ligneous biomass stocks decreased by 75% between 1995 and 2012 (Boulogne *et al.*, 2013). On a 140,000 ha area located around Mampu, on the Bateke Plateau, Peroches (2012) demonstrated that despite the afforestation of 8,000 ha, the average wood volume dropped from 7.1 m^3/ha in 1984 to 4.6 m^3/ha in 2012, and the charcoal production potential decreased from 0.8 t/ha in 1984 to 0.5 t/ha in 2012. The planting of *Acacia auriculiformis* on the savannah helped increase the wood volume devoted to energy production in the 1990s. However, deforestation in valleys on the Bateke Plateau has resulted in a biomass loss of nearly 50% over the last decade (Boulogne *et al.*, 2013).

Note: Part of the results discussed in this article (measurements taken in 2013) already have been presented in the form of a poster at the New Delhi World Congress on Agroforestry (Peltier *et al.,* 2014a) and in a technical extension manual (Peltier *et al.,* 2014b). However, the results of the 2014 measurements, discussed here, have never been published.

Photo 2.
A farmer from Lufimi valley, which cuts across the Bateke Plateau, points to the last slivers of gallery forests that he is preparing to clear. Savannah is visible higher on the plateau, between the two, there is a former crop field that was overrun by fire and on which forest fallows have little chance of becoming re-established without human intervention.
Photo R. Peltier.

Replacement or enrichment of forest fallows, a question which has long concerned agronomists

Since the first half of the 20th century, many agronomists, foresters and agroforesters have recognized the role of forest fallows in restoring tropical soil fertility, especially in Congo (Humblet, 1944; Renier, 1946). While deploring the damage caused by burning, they have tested different techniques to identify a sustainable replacement for slash-and-burn agriculture (Pollini, 2009). However, to date, the alternative crop management sequences proposed (alley cropping, Ramial Chipped Wood, Biochar, etc.) have not been adopted widely by farming populations, which still rely heavily on slash-and-burn practices.

With regard to enriching tree fallows, actions undertaken in the DRC and other African countries have demonstrated the value of planting fallows with leguminous trees since the 1990s. However, these practices have been implemented little if at all by local populations (Peltier and Balle Pity, 1993; Peltier *et al.*, 2010), mainly due to a lack of social acceptance. In the DRC, 8,000 ha of *Acacia auriculiformis* were planted on the sandy soil of the Bateke Plateau between 1987 and 1993 by the HVA company, and later taken over by the Mampu Project (Bisiaux *et al.*, 2009). This plantation is divided into plots covering 25 hectares; each plot is managed by a farm family following an agroforestry model inspired by traditional slash-and-burn cultivation. The European funded Makala Project allowed this village-based *Acacia auriculiformis* plantation type to be extended to savannah and highly degraded forest areas. These activities have contributed to disseminating the technique and to adapting the system to small scale plantations in the DRC and the Republic of the Congo (Bisiaux *et al.*, 2013). However, when the environment is not too degraded, leading farmers to believe that a natural reconstitution of tree vegetation remains possible, they prefer not to resort to afforestation, which is costly in terms of time and inputs. Many farmers are nevertheless conscious of the fact that the resulting forest will not be productive in terms of wood or non-timber forest products (NTFP). They also are aware that there is a high risk of colonization by invasive plants which, being more easily combustible, could lead to the savannization of the area. When surveys were conducted to establish Simple Management Plans (SMP) of village territories, some farmers expressed an interest in improving low-cost slash-and-burn techniques (Dubiez *et al.*, 2013). The idea therefore emerged to test the method known as "Assisted Natural Regeneration" (ANR) in degraded forested areas. This technique was designed and has been successfully used in certain arid regions of the Sahel, in particular Niger (Pye-Smith, 2013). The protection of sprouts and root suckers in crop fields allowed the reforestation of alluvial valleys with *Faidherbia albida* (Montagne, 1996) and lateritic plateaus with *Combretaceae* (Larwanou *et al.*, 2006). ANR also has been tested widely in Southeast Asia to restore degraded forests invaded by *Imperata cylindrica* (Shono *et al.,* 2007). The Makala Project was determined to use as the starting point the slash-and-burn system in its currently practiced form to design with farmers a sustainable system that could be productive and easily reproduced, and therefore adopted.

Research was conducted to address four questions: Could ANR be accepted by farmers under the ecological and social conditions of the DRC? How farmers would adapt this technique to their environment, capacities and needs (number of trees preserved before and after burning, choice of species, density, etc.)? Was it possible to prove that this technique accelerates canopy closure and increases fuelwood productivity of the fallow? Which challenges and opportunities are necessary to unfurl ANR to a large-scale development in the DRC and in the sub-region?

Methods

The first ANR tests in humid tropical Africa

Starting in 2010, ANR was tested in the last patches of gallery forest on the Bateke Plateau, 150km northeast of Kinshasa, with about thirty volunteer farmers from four villages. Participants were given supervisory support but no monetary compensation. This experiment then was continued up to 2014 in other villages on the Bateke Plateau and in the Kisangani region (figure 1).

Prior to any intervention, semi-structured socio-economic surveys were conducted in the four villages selected to determine whether the farmers were interested in testing the method, and to choose the tree species that they wished to develop. This step made it possible to identify the most motivated individuals with whom the project could work.

At the end of this joint protocol construction stage, the ANR method was adapted from traditional techniques.

Stage one: existing trees on the fallows are selected to be conserved during cultivation

Farmers clear the undergrowth to open up the space before cutting down trees. During this preliminary activity, the first ANR stage is implemented to assess the wood potential and designate which species were to be conserved. This choice is based upon the diverse potential products that species can supply (fuelwood, edible caterpillars, fruit, timber, medicinal plants, etc.) and/or on their soil fertilizing role. Farmers assess each species' abundance, its potential to be associated with crops, and the difficulties that might complicate the preservation of a tree during felling and slash burning. Based on this analysis, they select the trees to conserve, trying to obtain the best possible distribution over the plot. In order for the woodcutters to be able to identify and conserve the selected trees, farmers mark their trunks with a ring of white paint (photos 3). In general, farmers conserve at least one individual of each useful species and limit canopy coverage to avoid excessive shade over the crops. The trees without marks are then cut down, trying in the process to limit damage to the trees to be conserved. The felled trunks are sawn to make charcoal or, more rarely, timber. A 2 m radius around the base of conserved trees is cleared of branches before the slash burning, which takes place once two to three rains have fallen to better control the fire. Once the charcoal is made and exported, the plot is sown with short-cycle crops (maize, peanut, etc.), then cassava cuttings are planted. Three months later, the first crops are harvested and the first selection of young tree regrowth is made.

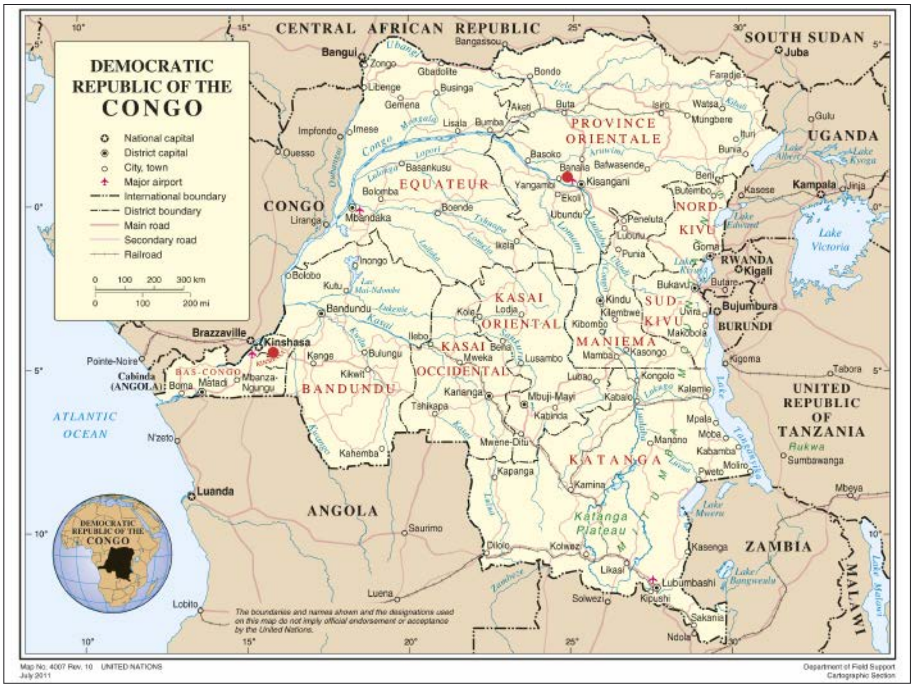

Figure 1.
The regions of Kinshasa and Kisangani where the Makala Project tested Assisted Natural Regeneration.

Photo 3.
On an approximately 10-year old tree fallow, a farmer paints a white ring around the trunk of a tree he wishes to conserve (a). Woodcutters have slashed the trees that were not selected, sawn the wood, burned the coarse woody debris and finally made an earth-mound kiln (b).
Photo R. Peltier.

Photo 4.
Once the charcoal is produced and exported, the plot is sown with maize, then planted with cassava cuttings. Before weeding the crop, the farmer uses a painted picket to designate the young Wenge seedling that he wishes to protect.
Photo R. Peltier.

Photo 5.
After the cassava is harvested, the conserved and/or spontaneous ligneous plants are left to grow over a 6 to 12 year fallow period. The farmer uses this fallow to gather diverse forest products, apiculture, and catching small game. For example, this trapper has conserved a tree whose seeds attract pigeons.
Photo R. Peltier.

Stage two: selection of seedlings, sprouts, and root suckers which have grown since the felling, fire, and start of cultivation.

Before the crops are weeded for the first time, farmers select the young tree regrowth (seedlings, stump sprouts or root suckers) that they wish to keep and designate them with painted pickets (photo 4). When weeding, all of the young trees that are not so designated are eliminated along with the weeds. If there is a clump of offshoots, farmers choose one by thinning. Cassava are then harvested progressively for about two years, during which time the farmers first take a few tubers from certain stems as a function of their needs before definitively uprooting the plants. These periodic harvests often are accompanied by new weeding operations; when so doing, farmers might again thin the selected shoots, prune low branches getting in the way of the crops, and potentially select new trees to conserve. After the final cassava harvest, the conserved and/or spontaneous ligneous plants grow over the following 6 to 12 years fallow period. Farmers use the fallow land to gather diverse products (edible caterpillars, medicinal plants, honey, etc.) (photo 5). Each farmer applies the technique described with minor modifications depending on his or her circumstances and preferences.

Setting up the ANR monitoring system

Before any trees were cut, farmers were interviewed on their preferences regarding the conservation of various species based on their uses and abundance. The survey followed the Qualitative Surveys Applied to Natural Resource Management method (Sibelet *et al.*, 2013).

Seven, 17 and 23 months after the initial slash-and-burn, inventories of the large trees that had been selected for conservation prior to this operation were conducted on 31 plots in four villages, noting the state of their health (Marquant, 2011; Gigaud, 2012; Peroches, 2012).

In parallel, monitoring of the seedlings, sprouts, and root suckers conserved during weeding operations was begun on 13 permanent plots set up on farmer fields where ANR had been implemented. These plots were positioned using a GPS-receiver (Garmin 60Cx). Five control plots with soil conditions, pre-existing vegetation, and cropping systems as similar as possible to the monitored ANR plots were set up in locations agreed to by the farmers managing the plots. ANR was not practiced on these control plots.

On all of these plots, the species, height, and circumference (taken at a height of 0.30 m for trees shorter than 2.5 m and at 1.30 m for trees taller than 2.5 m) of the young conserved trees were noted 7, 17, 23, 31 and then 43 months after the initial slash-and-burn. When the third round of these monitoring measurements was taken, cassava had been harvested definitively on two thirds of the plots monitored. When the fourth round of measurements was taken, all of the fields had been harvested and one of the permanent plots had been cleared in the absence of the person managing the plot. The surface area of the ANR plots was calculated, as was the number of trees/ha which survived the fire and were conserved during weeding, the growth of different species, etc.

The floral diversity and the structure of the stands also were studied using the Shannon and Weaver (1949) diversity indices, noted as “H’”, and the Pielou (1966) evenness index, noted as “E”.

In addition, the 13 villagers whose plots were monitored between 2010 and 2012 were interviewed again by Makala Project staff during the third monitoring campaign at the end of the cassava harvest (2012). This survey aimed to gain an understanding of how farmers perceived the ANR technique and the degree to which it had been appropriated by other farmers in the area.

Results of the assessment of the first ANR tests

Tree conservation before clearing

The farmers expressed an interest in numerous species based on their uses (table 1), but were particularly interested in six of these species, which together represented 64% of the trees conserved (Peltier *et al.*, 2013). They selected for conservation an average of 66 young trees/ha, of which the large majority had a diameter at breast height (DBH) of between 5 and 25 cm (figure 2). Only 9% of the trees survived the slash-and-burn operation, with the exception of trees on the edges of plots where the survival rate reached 75%. However, on one level plot where the farmer had respected the protocol (clearing at the base of the tree, waiting for the first rains to fall before setting the fire), 55% of the trees survived, which shows that it is possible to conserve trees on a plot when slash-and-burn is practiced cautiously.

Conservation of stump sprouts, root suckers, and seedlings during weeding

Among the young trees selected by farmers while weeding their crops, coppice shoots (trees that already had been cut at least once) initially grew faster than stump sprouts (trees cut for the first time), while the growth of seedlings and root suckers was slower. However, after three and a half years, this difference was proportionally less important (figure 3), the mortality rate of trees (all species) produced by stump sprouts was 32% while that of coppice shoots was 29%; the seedlings and root suckers selected for conservation had the highest mortality rate at 60% (figure 4).

If all of the conserved trees are considered together without distinction regarding their origin, a relatively rapid growth in height and diameter is seen (figures 5 and 6). Over a 10 month period, from May 2011 to March 2012, height growth of young trees, all origins together, was on average about one metre, and diameter growth at 30 cm above the ground was 1.09 cm. Between March and September 2012, these values were respectively 0.38 m and 0.66 cm. Between September 2012 and May 2013, height growth was 0.77 m, while diameter growth 30 cm above the ground was 1.05 cm. In May 2014, three and a half years after burning, all species had an average height of 4.20 m and an average diameter at 30 cm above ground of 5.62 cm.

Table I.
List of the main species conserved by farmers by ANR and their declared uses.

Name	Kitéké Name	Family	Uses
Albizia adianthifolia	Koako	*Mimosaceae*	Charcoal making - Fuelwood
Hymenocardia ulmoides	Mushanu	*Hymenocardiaceae*	Fuelwood - Charcoal making - Consumption of young leaves and shoots
Markhamia tomentosa	Muntso	*Bignoniaceae*	Charcoal making
Millettia laurentii	Itoo	*Fabaceae*	Timber - Charcoal making - Gathering caterpillars - Pharmacopoeia
Oncoba welwitschii	Mubama	*Flacourtiaceae*	Gathering caterpillars - Fuel wood - Fruit consumption - Honey - Charcoal making - Pharmacopoeia
Pentaclethra eetveldeana	Isili	*Mimosaceae*	Charcoal making - Gathering caterpillars - Honey

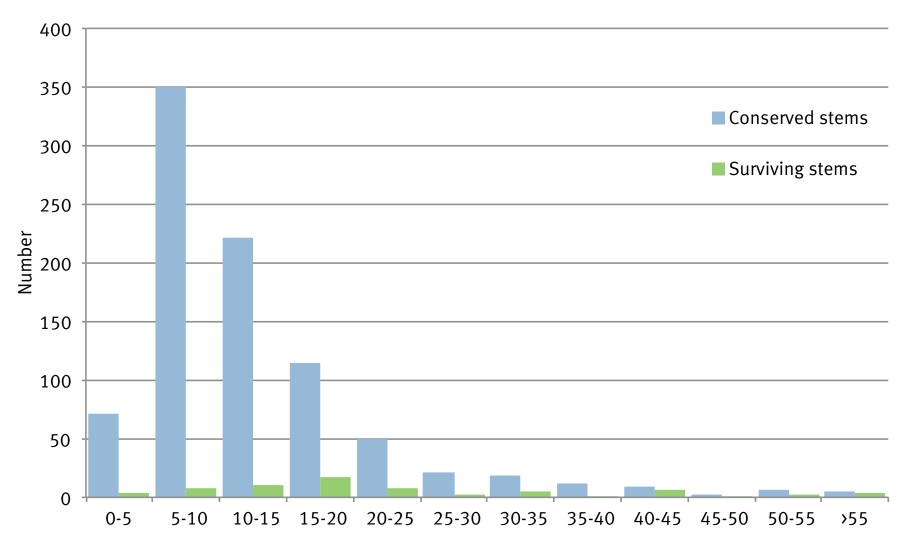

Figure 2.
Distribution of the number of stems conserved and which survived burning by diameter at breath height (DBH) class on 31 plots (11.4 ha in total) in four villages on the Bateke Plateau (Nsuni, Imbu, Yolo and Kaméléon).

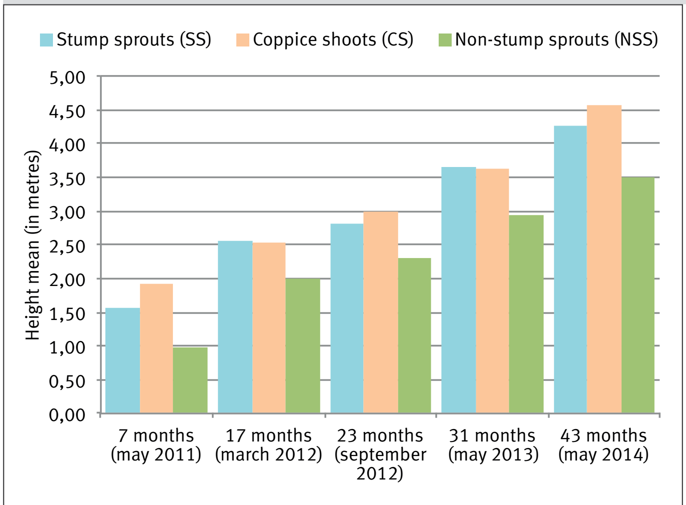

Figure 3.
Mean height of stump sprouts (SS), coppice shoots (CS) and non-stump sprouts (NSS) of all of the conserved species, according to the number of days after the burning of the crop field, on the 13 measurement plots (0.2 ha in total) of three villages on the Bateke Plateau (Nsuni, Imbu and Kameleon).

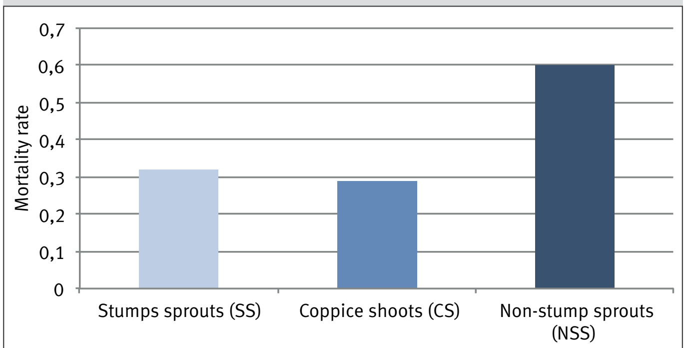

Figure 4.
Mortality rate of stump sprouts (SS), coppice shoots (CS) and non-stump sprouts (NSS) of all of the conserved species, after 43 months.

Seven months after the slash-and-burn, of the young trees selected for protection during weeding, an average of 1,290/ha (± 325) were still alive. Five species: *Markhamia tomentosa, Hymenocardia ulmoides, Oncoba welwitschii, Pentaclethra eetveldeana* and *Millettia laurentii*, represented 82.6% of the total. Ten months later, 1,103/ha (± 448) young trees still survived, enough to reconstitute a closed forest cover in a few years (photo 6).

Despite six undetermined individuals, the Shannon (H'=2.39, H'max=3.46) and Pielou (E=0.69) indexes show that at the time of the second monitoring campaign, a few of the conserved species dominated the rest; *Markhamia tomentosa* accounted for nearly 50% of the total number.

In less than two years, *Markhamia tomentosa* and *Oncoba welwitschii* have already flowered and born fruit, and the seeds produced will accelerate canopy closure (photo 7).

When the definitive cassava harvest took place, new sprouts were measured. At 23 months, an average of 3141 stems/ha (±2119) were counted; at 31 months, the figure was 3872 stems/ha (±1800). Differences in harvest dates between farmers explain the important variability between the plots monitored. The abandonment of plots favoured the appearance of pioneer species such as *Chaetocarpus africanus* and *Sapium cornutum*, which were the most present species alongside *Markhamia tomentosa* and *Hymenocardia ulmoides*. The stand was thus more diversified than during the preceding monitoring campaign (E = 0.81).

At 31 months, the density of trees with a height over 2.5 m and a DBH greater than 3 cm was 202 young trees/ha on the ensemble of control plots, and 628 young trees/ha on the ensemble of ANR plots. This value of 638 young trees/ha already represents 70% of the number of large stems found on a young fallow (≤ 6 years) and 28% on an old fallow (› 6 years). At 43 months, the density of trees with a height over 2.5 m and a DBH greater than 3 cm was 429 young trees/ha on the ensemble of control plots, and 648 young trees/ha on the ensemble of ANR plots (figure 7). The comparison between the last two years of measurements shows that the tree density increased rapidly on the control plots, once they were no longer cultivated with crops, while it remained almost constant on the ANR plots. Likewise, by calculating the wood volume on the permanently monitored plots (with or without ANR), and comparing this figure to that of different types of plant formations inventoried on the Bateke Plateau by Peroches (2012), one may note that after three and a half years of cropping, ANR plots have a wood volume reaching 48% of that of a young fallow (27% for control plots) (figure 8) and a stem density approaching 70%.

The results of these five monitoring campaigns show that ANR engenders a net gain in wood productivity which is now perceived by the farmers themselves (photos 8).

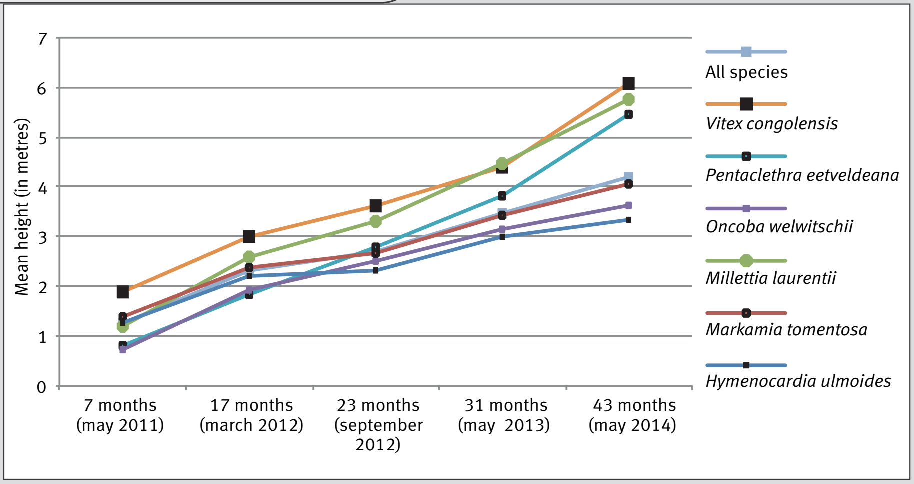

Figure 5.
Mean height (in metres) of young Assisted Natural Regeneration (ANR) trees, by species and as a function of time (in months) after burning.

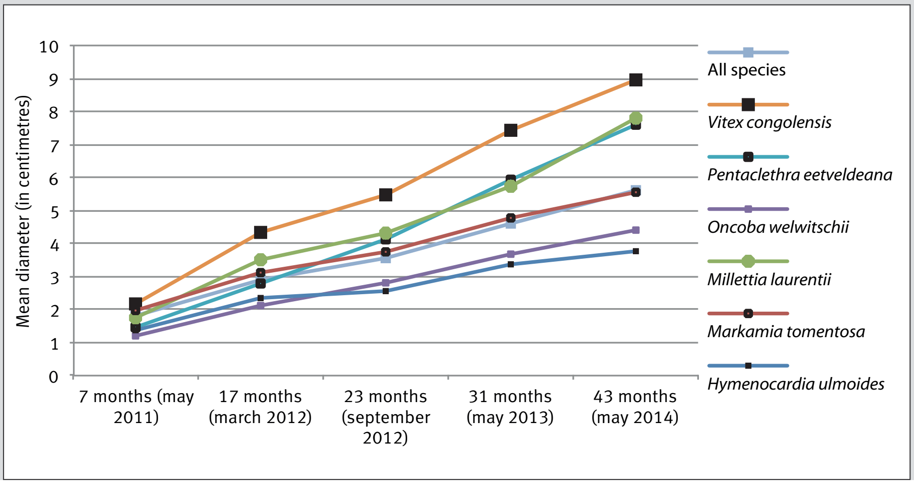

Figure 6.
Mean diameter (in centimetres) of Assisted Natural Regeneration (ANR) trees measured 30 cm above the ground, by species and as a function of time (in months) after burning.

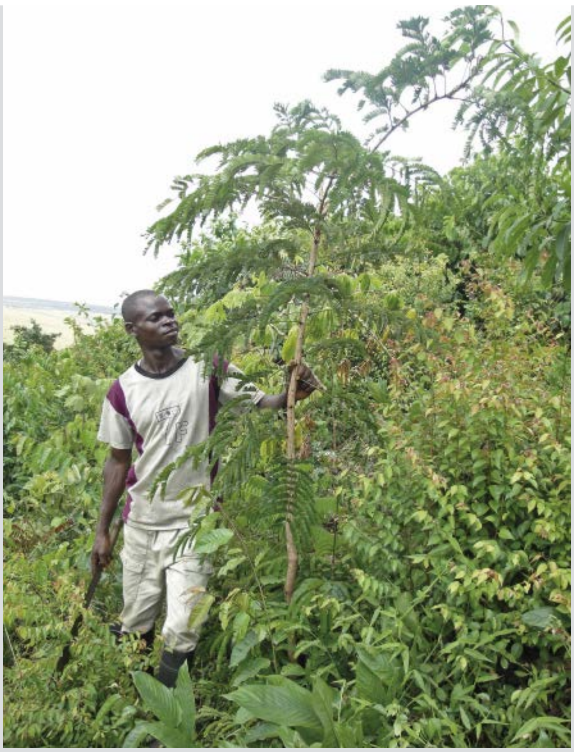

Photo 6.
An ANR protected *Pentaclethra eetveldeana* less than two years old in the Imbu area (Bateke Plateau), Guy Mbama's field.
Photo R. Peltier.

Photo 7.
At 23 months, the ANR protected *Oncoba welwitschii* have already flowered and will bear fruit before the final cassava harvest: these seeds will contribute to the afforestation of the future fallow.
Photo R. Peltier.

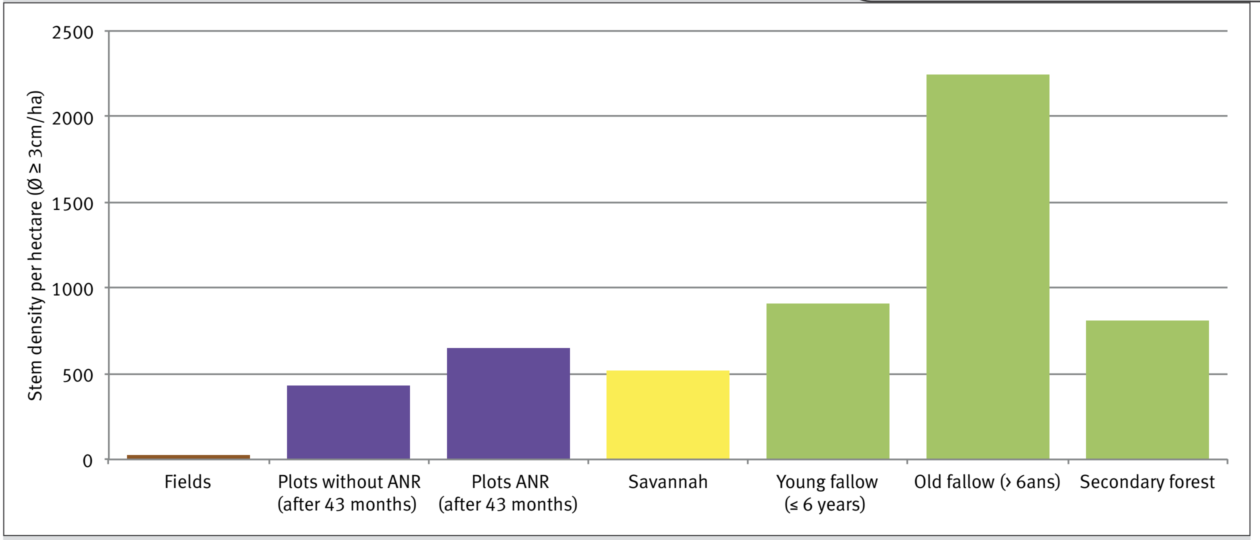

Figure 7.
Stem density per hectare (DBH ≥ 3cm) (diameter at breath height, DBH) on control (without ANR) and on Assisted Natural Regeneration (ANR) plots, 43 months after conservation of young trees and on the different types of plant formations inventoried on the Bateke Plateau.

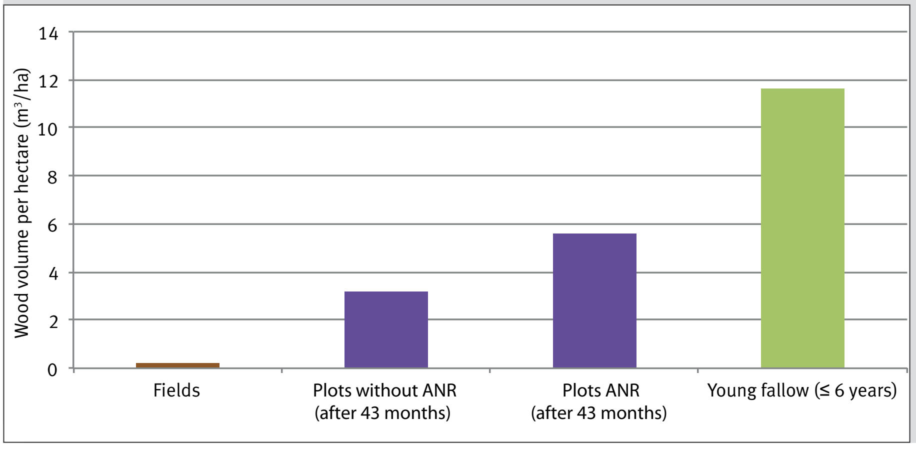

Figure 8.
Wood volume per hectare represented by stems with a DBH ≥ 3 cm on control (without ANR) and ANR plots 43 months after conservation of young trees and on recently cleared fields and young fallows (6 years) inventoried on the Bateke Plateau.

Results of the assessment of the social acceptance of the ANR innovation

The villagers surveyed two years after the implementation of ANR on their plots were aware of the degradation of their lands. They thought that ANR could be a way to control the savannization of the environment. The large scale development of this innovation in farming communities will depend on its social acceptance, which is connected to the benefits generated, the additional workload involved, and the resources employed for the dissemination of the technique.

The selection of existing trees to be conserved prior to clearing the fallow with slash-and-burn was not adopted by farmers

The low survival rate of conserved trees during slash-and-burn, the extra work involved in clearing around these trees, and the loss of a part of their charcoal production, does not entice farmers to adopt this component of the ANR technique.

The conservation of stump sprouts, root suckers, and seedlings during weeding was adopted

Some farmers expressed reservations about this practice in the early stages of the ANR process because they feared that the young trees would compete with the maize and cassava crops. However, the survey conducted when the cassava was harvested showed that all of the farmers had changed their opinion and they did not think that they had suffered any crop production losses. This is a necessary condition for the dissemination of the ANR technique. In 2014, the technique has been tested and is well appreciated by nearly 150 farmers.

The challenge of land tenure security

The most problematic factor at present seems to be the absence of land tenure security. Farmers hesitate to make long term plans for a plot when they cannot be sure that they will have the right to return to cut the wood and prepare the plot for cultivation again (Peroches, 2012). In practice, a fallow is reattributed to the person who worked the land

Photo 8.
In June 2014, the view of a plot in Imbu village where Assisted Natural Regeneration (ANR) was practiced in October 2010. After three and a half years, certain trees, such as the *Pentaclethra eetveldeana*, already have gained an impressive diameter and wood volume (a). The forest cover is almost closed and the *Chromolaena odorata* are tending to disappear (b).
Photo R. Peltier.

before, but this is never entirely sure. The village head may suddenly decide to take over the land or award it to someone else (Vermeulen *et al.*, 2011), which limits land tenure security of improved fallows.

The perception of wood scarcity and the support of traditional chiefs, catalysts behind farmers' interest

The final surveys first of all revealed that interest in ANR was highest on village territories where charcoal production had dropped significantly following forest degradation. This proves that despite farmers' awareness of the degradation of their territory, the move to take action, both on an individual and collective scale, remains difficult as long as farmer incomes are unaffected.

The second point of importance regards the involvement of traditional authorities. In effect, the traditional chiefs who were determined to conserve their territory's forests (photo 9) volunteered to test ANR on their fields. It was in their villages that ANR was disseminated and followed best.

Discussion and conclusion

Acceptance of ANR by Congolese farmers

The first tests to adapt ANR in the DRC show that the technique can be used by slash-and-burn farmers in the ecological and social conditions of the DRC without upsetting their habitual routines, payments, or the use of supplementary material, as also was found in the Sahel in the 1990s (Smektala *et al.*, 2005).

Adaptation of the technique

The conservation of trees before burning largely produced poor results. The extra work involved in selecting and protecting trees before burning a plot is a factor limiting the spread of this technique. The volume of standing wood which cannot be transformed into charcoal and the ensuing loss of income also are factors hindering the acceptance of this method. However, informed, meticulous and motivated farmers capable of respecting low impact burning techniques nevertheless would be able to conserve fire-resistant trees inside their plots (for example, *Elaeis guineensis* and *Vitex congolensis*) or other more sensitive species in hedges at least 5 m wide on the edges of their plots. The surveys effectively demonstrated that the conservation of these trees prior to clearing and burning plays a "psychological" role in collective and family efforts to move from an unmanaged fallow to a managed fallow. By selecting trees to conserve, plot managers clearly affirm to their neighbours, workers (wood cutters, charcoal makers, etc.) and families (spouses and children), who will be sowing, cutting and weeding the plots, that they intend to manage the plots over the long term and enrich them with trees. There thus is a real initial step of "domestication" of some of the wild trees which until then had been exploited unchecked. This is in line with the results of Peltier and Balle Pity (1993) in Ivory Coast, French Guiana and Indonesia. Once this step has been taken, it is easier to proceed further with the ANR process.

Some farmers, on their own initiative, enriched ANR plots by planting fruit trees and trees supporting edible caterpillars. In fact, each farmer makes his own choices regarding which species to maintain or reintroduce depending on his capabilities and needs. This confirms the observations made in Madagascar by Rives *et al.* (2013), which showed the gap between a project favouring only the production of fuelwood and farmers more interested in multipurpose trees.

Canopy closure and fuelwood productivity improvement

Thirty-one months after a plot is cleared by slash-and-burn, the protection of young trees (sprouts, seedlings, and root suckers) when the area is weeded enables the number of young trees over 2.5 m tall with a DBH greater than 3 cm to be multiplied by three (638 young trees / ha) compared to a non-ANR plot (202 young trees / ha). Forest cover thus will close more rapidly on ANR plots than on non-ANR plots. This cover also should slow down the development of species liable to spread fire during the dry season, such as *Pteridium aquilinum*, *Chromolaena odorata* and *Imperata cylindrica*, and thus

Photo 9.
The involvement of village chiefs and a collective awareness of the increasing scarcity of wood are the factors driving farmers to commit themselves to a collective and family shift from unmanaged fallow to Assisted Natural Regeneration (ANR) managed fallow.
Photo R. Peltier.

limit the risk of the "savannization" of the landscape. However, informal observations on ANR plots that have been affected by fire before canopy closure show that the majority of protected trees disappear after one or two passages of fire. This confirms the absolute necessity of setting up firewalls on the borderline between savannas and forest fallows to avoid the spread of the savanna and forest loss.

The forest fallows densified by ANR are expected to allow soil fertility to be restored more rapidly, produce greater quantities of fuelwood thanks to increased wood volume, and contribute to supplying numerous non-timber forest products (edible caterpillars, medicinal plants, edible leaves and shoots). Although some results concerning the improvement of soil fertility have been known for a long time (Humblet, 1944), some hypotheses should be quantified during the next slash-and-burn and crop planting cycle to improve knowledge related to the development of the ANR technique in farming areas.

Opportunities and challenges of large-scale development of the ANR

While the majority of farmers who participated in the first ANR tests said they were convinced of the usefulness of the method to reconstitute forest fallows, all of them would not have applied it without the supervision of the Makala Project. The conservation of standing trees diminishes the volume of wood used to produce charcoal, causing financial loss. This is the leading reason that farmers do not use ANR. Two other, community-level factors behind a failure to adopt the technique are weak support from traditional authorities and uncertainty over the land tenure security of fallows cleared by farmers. The transition from slash-and-burn agriculture to ANR modifies management practices. Future gains could be threatened by traditional authorities, the landholders. The cultivation of crops on forest fallows is generally done by the same person who clears the plot but there is no guarantee of this. The rights of farmers practicing ANR should be reinforced by securing their access to the fallows that they clear and develop.

Despite these limiting factors, the technique has been tested and already is well appreciated by nearly 150 farmers due to its low labour costs, limited negative impact on crops, and their hope to control invasive species. The hoped for legalization of Simple Management Plans in the first half of 2014 by the Ministry for the Environment, Nature Conservation and Tourism in the DRC should contribute to the conservation of farmer's rights over areas that they develop, including through ANR. This confirms the findings of Galabuzi *et al.* (2014), in Uganda, on the importance of securing access to forest products for farmers before engaging them in a process of forest restoration.

Given the results presented in this article, it would be interesting to circulate this information and disseminate the method on a large scale over the years to come. Research activities also must be continued to enhance the knowledge needed to justify the use of ANR in the reconstitution of degraded natural forest areas.

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Photo 10.
Many thanks to the farmers who chose to trust us and dedicate their time, labour, and land to participate in this collective research effort.
Photo R. Peltier.

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