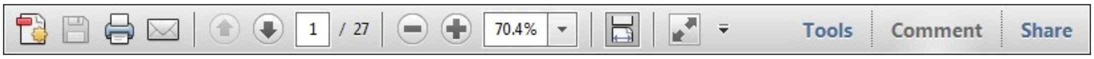
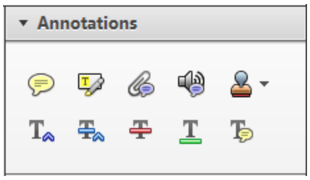
USING e-ANNOTATION TOOLS FOR ELECTRONIC PROOF CORRECTION

WILEY

Once you have Acrobat Reader open on your computer, click on the Comment tab at the right of the toolbar:



This will open up a panel down the right side of the document. The majority of tools you will use for annotating your proof will be in the Annotations section, pictured opposite. We've picked out some of these tools below:

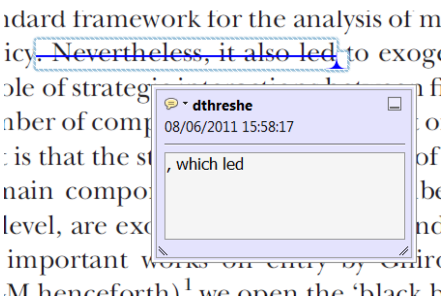


1. Replace (Ins) Tool – for replacing text.

Strikes a line through text and opens up a text box where replacement text can be entered.

How to use it

- Highlight a word or sentence.
- Click on the Replace (Ins) icon in the Annotations section.
- Type the replacement text into the blue box that appears.

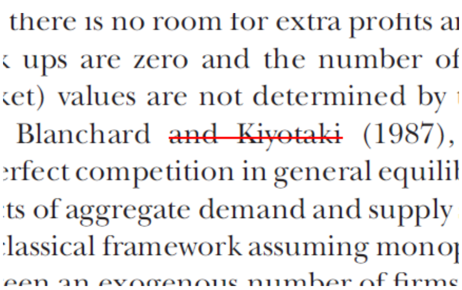


2. Strikethrough (Del) Tool – for deleting text.

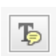
Strikes a red line through text that is to be deleted.

How to use it

- Highlight a word or sentence.
- Click on the Strikethrough (Del) icon in the Annotations section.



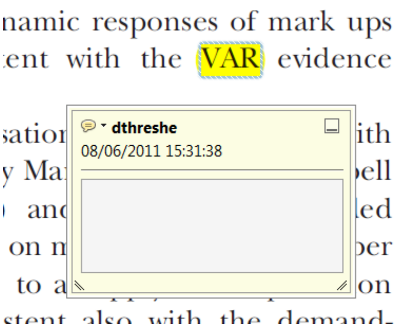
3. Add note to text Tool – for highlighting a section to be changed to bold or italic.



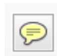
Highlights text in yellow and opens up a text box where comments can be entered.

How to use it

- Highlight the relevant section of text.
- Click on the Add note to text icon in the Annotations section.
- Type instruction on what should be changed regarding the text into the yellow box that appears.



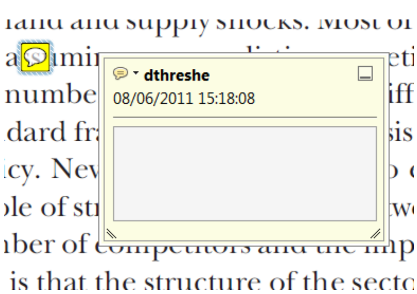
4. Add sticky note Tool – for making notes at specific points in the text.



Marks a point in the proof where a comment needs to be highlighted.

How to use it

- Click on the Add sticky note icon in the Annotations section.
- Click at the point in the proof where the comment should be inserted.
- Type the comment into the yellow box that appears.

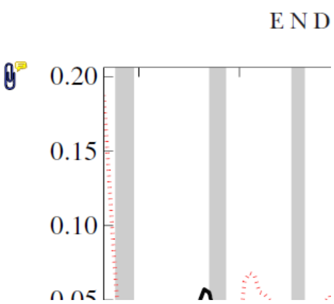


5. Attach File Tool – for inserting large amounts of text or replacement figures.

Inserts an icon linking to the attached file in the appropriate place in the text.

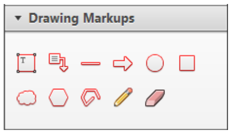
How to use it

- Click on the Attach File icon in the Annotations section.
- Click on the proof to where you'd like the attached file to be linked.
- Select the file to be attached from your computer or network.
- Select the colour and type of icon that will appear in the proof. Click OK.



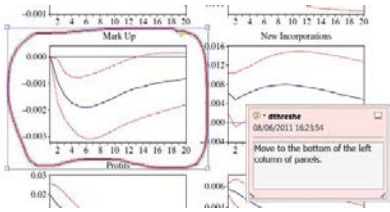
6. Drawing Markups Tools – for drawing shapes, lines and freeform annotations on proofs and commenting on these marks.

Allows shapes, lines and freeform annotations to be drawn on proofs and for comment to be made on these marks.



How to use it

- Click on one of the shapes in the Drawing Markups section.
- Click on the proof at the relevant point and draw the selected shape with the cursor.
- To add a comment to the drawn shape, move the cursor over the shape until an arrowhead appears.
- Double click on the shape and type any text in the red box that appears.



Scaling up farmer-managed natural regeneration in Africa to restore degraded landscapes

Chris Reij[1,3], and Dennis Garrity[1,2]

[1] World Resources Institute, Washington, DC, USA

[2] World Agroforestry Center, Nairobi, Kenya

ABSTRACT

We present examples of large-scale farmer-managed natural regeneration of woody species in Africa to create new agroforestry systems. We also analyze two cases in Ethiopia of large-scale natural regeneration. The available evidence shows that the average costs per hectare of promoting on-farm natural regeneration are low as soon as farmers are familiar with this practice and begin to spontaneously adopt it. Based on these cases, current ambitious forest restoration targets can be achieved, but this goal requires a shift from tree planting to assisted natural regeneration. We propose a scaling-up strategy for natural regeneration based on experience gained mainly in the West African Sahel.

Key words: Africa; agroforestry systems; assisted natural regeneration; Burkina Faso; Ethiopia; Malawi; Mali; Niger; on-farm natural regeneration; scaling-up strategy; Senegal.

CE: Shanthi M | PE: Krishnaveni A | Dispatch: 26.9.16 | No. of pages: 10 | WILEY | 12390 Manuscript No. | BTP Journal Code

Agroforestry is defined as the deliberate integration of trees and shrubs into farming systems. They may be planted, or farmers may deliberately protect and manage them through the regeneration of roots and seeds that are already present in the soil, known as farmer-managed natural regeneration (FMNR). These agroforestry practices lead to more complex, more productive, and more drought-resilient farming systems. Assisted natural regeneration (ANR) also involves protecting and managing natural regeneration, but its key objective is to restore natural vegetation on degraded forest and grazing land (Chazdon & Guariguata 2016). Here, we examine several examples of farmer-managed natural regeneration of woody species to create new agroforestry parklands in Niger, Mali, and Senegal, and we document some examples of assisted natural regeneration in Ethiopia. We emphasize the large-scale transformation of degraded agricultural landscapes in Niger since the middle of the 1980s and watersheds in Ethiopia more recently.

Since 2004, several examples of large-scale creation of new agroforestry parklands have emerged in the West African Sahel. Farmers in many parts of Africa (*e.g.*, Niger, Burkina Faso, Mali, Senegal, Ethiopia, and Malawi) protect and manage the natural regeneration of woody species on-farm to create new agroforestry parklands, but in some cases they also promote natural regeneration off-farm to create new second growth forests (for instance the Humbo forest in southern Ethiopia). If farmers are building new agroforestry systems at scale, some questions need to be addressed. For instance, what triggered them to do so? How have they done it? What was the role of external agents? What did it cost? What steps needed to be taken to foster a further scaling-up of existing agroforestry systems and to accelerate the process?

The latter is a key question, as the need to increase the number of trees on farms as well as off-farm is important in a context of accelerated climate change and ambitious pledges to restore degraded forestland. For instance, the Global Partnership on Forest Landscape Restoration is supporting the achievement of the Bonn Challenge, which has a target to restore 150 million ha of degraded forestland by 2020. The New York Forest Declaration (September, 2014) formulated and called for achieving a target of 350 million ha under restoration by 2030. Also, the Africa Union launched the African Forest Landscape Restoration Initiative (AFR100) in December 2015 to restore 100 m ha of degraded land across the continent by 2030.

Here, we examine some examples where farmers have created new agroforestry parklands at scale, and by doing so contributed to these ambitious international goals for forest and landscape restoration, including enhancement of livelihoods (Adams *et al.* 2016).

NIGER

Since the middle of the 1980s smallholder millet-growing farmers in densely populated parts of Southern Niger (rainfall 400–600 mm/yr) have been protecting and managing trees and shrubs that regenerate spontaneously on their farmland (Larwanou *et al.* 2006). Whereas they had 2 or 3 trees per hectare in the 1980s, they now have 20, 40, 60 trees per hectare or more. Until 2004, the scale at which farmers had been protecting and managing natural regeneration on-farm was not known. Studies had been done in the region that had looked at long-term trends, but those studies limited themselves to a selected sample of villages

Received 15 February 2016; revision accepted 3 September 2016.
[3]Corresponding author; e-mail: CReij@wri.org

(Mortimore *et al.* 2001). One of the findings was that farmers now had more on-farm trees. But no one had made an effort to fully assess the geographic scale of this phenomenon.

During a field visit in June 2004, participants observed the density and age of the trees, as well as the scale of the on-farm trees, and they launched a process of documenting the scale of re-greening. Using remote sensing in combination with ground-truthing, the scale at which farmers had built new agroforestry systems was mapped, and the extent was estimated in 2009 to be 5 million ha (12.5 million acres) (Reij *et al.* 2009).

What triggered farmers to protect and manage on-farm natural regeneration? A rapid assessment undertaken in the Zinder Region in 2006 provided some answers to this question (Larwanou *et al.* 2006). Farmers were motivated by the combination of an environmental, economic, and political crisis in the 1980s. High population densities (100+ per km²) in this semi-arid region had led to 'wall-to-wall' agriculture, and an almost complete destruction of natural forests. Crop yields in the 1980s were low (400–500 kg/ha) and they were declining. Also, because of the high population densities it was impossible for many families to expand the extent of their cultivated land. Low crop yields led to structural food deficits. Many men left the villages during the dry season to find employment in Nigeria. The scarcity of natural vegetation meant that women had to walk increasingly long distances to collect firewood. On average they spent 2.5 h/d to collect and transport firewood.

Until the mid-1980s, Niger had a strong and respected president, but his death in 1986 led to a succession of weak (military) governments, and the prices for Niger's key export product (uranium) also declined. The state was increasingly unable to support rural development. One of the impacts was that the presence of the forestry service at village level decreased, which contributed to a change in perception regarding the ownership of trees. Before the crisis, the trees were perceived to belong to the State, but farmers now began claiming ownership of the trees on their farms (Fig. 1). 3

The only low-cost solution to the environmental and energy crises faced by farmers was to increase on-farm tree densities through the protection and management of natural woody regeneration. Impoverished smallholder farmers did not have to buy inputs at the market in order to develop these agroforestry systems, but they did have to organize themselves to protect and manage the trees, particularly from free-grazing livestock. Agroforestry was a traditional practice in the Zinder Region that farmers could fall back on. Historically, it was a culturally sanctioned practice. Early in the 20th century, regulations decreed that a farmer who cut a *Faidherbia albida* (Fabaceae), a native nitrogen-fixing tree, would be punished by cutting off the hand that he had used to cut the tree.

Figure 2 shows a high-density young agroforestry parkland dominated by *Faidherbia albida*. Piles of millet stalks in- between the trees indicate that the picture was taken shortly after the harvest. *Faidherbia albida* exhibits reverse phenology, which means that the trees lose their leaves during the rainy season. Early in the dry season they refoliate again.

The narrative about what triggered farmers in the adjacent Maradi Region to protect and manage on-farm trees is similar to the one for Zinder, but there was one difference. External intervention played a catalytic role in the Maradi Region, whereas this is less evident in Zinder. Tony Rinaudo, an Australian missionary/forester, worked in this region during the mid-1980s. He began his career by planting trees which, according to him, failed miserably. As was the case in so many other dry areas, most planted trees died in the first or second

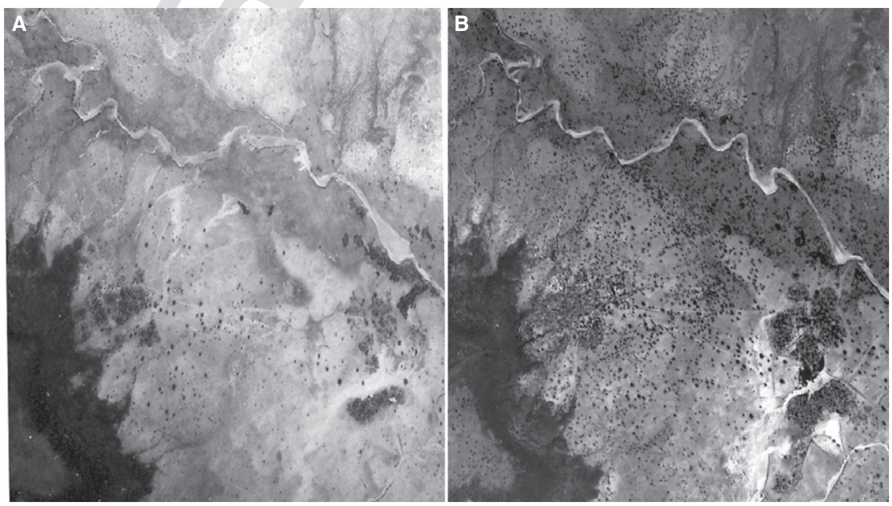


FIGURE 1. On-farm trees in the village of Galma (Central Niger) in 1975 (*left*) and 2003 (*right*). (A) The village of Galma (Central Niger) in 1975. The black dots are mature trees. (B) On the right shows the same village in 2003. The number of trees is much higher in 2003. They are scattered randomly in the fields, which indicates that they are not planted, but have emerged because farmers protected and managed natural regeneration of woody species (Source: Reij *et al.* 2009).

FIGURE 2. A dense and diverse new agroforestry parkland in Niger's Zinder Region.

year. One day he realized that the bare fields contained sprouts from the root systems of trees that had been repeatedly cut and these root systems were still alive. Many farmers must also have been aware of this as they cleaned their fields, before the arrival of the rains, of the sprouts of the young bushy sprouts that had emerged during the past year from the underground rootstocks.

During colonial times, the agricultural services exhorted 'modern farmers' to grow a single crop in monoculture on fields in which all trees were removed. This extension influence persisted for decades. During the drought and famine years of 1984 and 1985, Tony Rinaudo's Service in Mission NGO offered food aid to farmers in 100 villages if they protected the bushes and trees that were regenerating spontaneously on their farmlands. Thousands of farmers seized this opportunity to receive grain. In 1986, rainfall was normal and food aid was no longer provided. About 75 percent of the farmers cut their trees and bushes once again, but the others continued to protect and manage them. Those who had cut them soon regretted it, as the impacts of the trees soon became clear. Those who had cut their trees had to restart the process of clearing the bushy sprouts from the land all over again. The story about the re-greening in the Maradi Region began to spread, and projects operating in other parts of Niger began organizing visits for staff members and for farmers to learn from this experience (Tougiani *et al.* 2008).

The case of the village of Dan Saga illustrates how farmers began to protect natural regeneration on their farms. Some farmers in this village, located about 100 km from Maradi, had returned too late from labor migration in Nigeria to be able to clear their fields for planting millet, so they directly planted their crops without land preparation. At harvest time, it was observed that these farmers had better yields than those who had cleared their fields. The same situation occurred the next year, inducing them all to begin protecting naturally regenerated trees on their farms.

WHICH SPECIES REGENERATE NATURALLY?

The particular tree species that regenerate on farm fields depends largely on the local species having an underground root system and on the composition of a tree seed bank in the topsoil. A limited number of species currently dominate the new agroforestry parkland in south-central Niger (Maradi-Zinder). They include:

Faidherbia albida, a nitrogen-fixing acacia species that stimulates an increase in crop yields in the vicinity of the trees (Fig. 2). It also produces significant quantities of fodder and fuel wood. In the Southern part of the Zinder Region, the new parkland is dominated by this species. Because the average farm size is small, and farmers lack the means to buy inorganic fertilizers, farmers favor this species, which is often grown at a high density (>100 trees per hectare of cropland). It sheds its foliage at the beginning of the rains, and it is dormant during the rainy season, which minimized competition with crops for light.

Adansonia digitata, or baobab, produces leaves and fruit with high nutritional value. The regeneration of baobab dominates in parts of Zinder's Mirriah district.

Piliostigma reticulatum produces pods, which are used as a source of livestock feed.

Combretum glutinosum produces high-quality firewood as well as a high leaf volume which builds soil organic matter.

Guiera senegalensis is a very common species that is used as firewood, and at the end of the dry season its leaves are used as fodder.

The diversity of species in this semi-arid environment tends to be limited. Farmers protect and manage those tree species that they find useful. Cases are known where farmers have increased the diversity of species over the years by re-introducing ones that had disappeared.

IMPACTS OF AGROFORESTRY ON HOUSEHOLD FOOD SECURITY

Reij *et al.* (2009) conservatively estimated that the 5 million ha of new agroforestry parklands had increased average grain yields by 100 kg/ha. They postulated that the yield increases are higher in areas dominated by *Faidherbia albida*, but they may be lower elsewhere. Natural regeneration of trees by farmers was calculated to contribute an estimated annual increase in grain production of 500,000 tons, enough grain to feed 2,500,000 people. Not all smallholder farmers practice agroforestry. In the Southern part of the Zinder Region, the agroforestry parklands are fairly contiguous, but in the Maradi Region one can find villages with and without agroforestry that are adjacent to each other. This difference seems to be due to internal conflicts in some villages that have prevented them from engaging effectively in the protection and management of natural regeneration, which requires community efforts and organization, particularly in grazing management.

Agroforestry also contributes in other ways to household food security. Some tree species produce fodder. This allows

COLOR

FIGURE 3. Goats in Niger eating tree fodder during the dry season.

smallholder farmers to keep more livestock. In Niger, livestock now depends 6 mo/yr on tree fodder. Having more livestock means that farmers have more 'cash on the hoof', which they can sell in drought years. During drought-years farmers sometimes literally survive on trees. They can cut some of their trees and sell the wood in the market for firewood or construction wood to generate cash, which allows them to buy cereals.

The emergence of the agroforestry parklands has increased fodder availability and stimulated smallholder farmers to better control livestock grazing. Tethered goats eat the leaves of *Prosopis africana* (Fig. 3). The sale of leaves and fruit is an important source of income for women. One mature baobab (*Adansonia digitata*) can generate an annual income of 34–75 US$/ha (Yamba & Sambo 2012). This amount of revenue allows a family to purchase 70–175 kg of grain on the market.

AGROFORESTRY AND DROUGHT RESILIENCE

During drought years, the trees provide different sources of income that farmers need to survive. Yamba and Sambo (2012) surveyed in two districts (Kantché and Mirriah) in the Zinder Region, each with high population densities and high on-farm tree densities. Niger's estimated food deficit in 2011/2012 was 600,000 tons. Surprisingly, the Kantché district with 350,000 people had produced a grain surplus of almost 14,000 tons in 2011, a major drought year. The district had produced significant grain surpluses since 2007.

THE COST OF BUILDING NEW AGROFORESTRY SYSTEMS THROUGH THE PROTECTION OF NATURAL REGENERATION

Part of the 5 million ha is the result of project intervention, but most of the adoption is the result of farmers spontaneously applying the practice because they have observed the benefits and find it convenient to take it up without requiring external support.

Donor- and government-supported projects funded several kinds of activities. One key activity was the organization of farmer-to-farmer study visits. Assisting farmers (men and women) who do not yet use the practice to visit with those who have gained experience with it was one of the most effective ways of stimulating the accelerated spread of the practice widely.

Detailed data on the investment costs in support of the adoption of FMNR in Niger are not available, but it is safe to say that all projects in Niger which have supported FMNR, altogether have invested significantly less than $100 million since 1985, and these projects included components on many other aspects besides FMNR. Thus, actual expenditure on the scaling-up of FMNR has been well below $20 per hectare of adoption.

The annual recurrent labor costs per hectare to manage the FMNR are also quite low (Place & Binam 2013). The project of the 5
International Fund for Agricultural Development recently calculated the project costs of about 90,000 ha of farmer-managed natural regeneration in the Maradi Region during a period of 3 yr, amounting to 9000 CFA/ha, which is US$14/ha at current exchange levels (1$ = 607 CFA) (Personal comm. Mr. Guéro Chaïbou). A main reason for the low average costs per hectare is the speed and the scale of adoption of this practice by local farmers.

Famer-managed natural regeneration does not require the effort to acquire germplasm or to propagate seeds or cuttings and nurture them into seedlings. In some cases, the costs of regenerating the trees is essentially zero—new trees emerge from the soil without need for nurturing or protection. However, they need to be pruned periodically, thus establishment and maintenance costs may be required.

The more common establishment costs include protection of desired trees, mainly either in the form of micro-protection of individual trees, or protection of larger areas mainly using simple barriers around individual trees, or fences on field boundaries; and removal of trees not desired by the farmer. This protection is practiced by all farmers to some degree. Maintenance costs may include weeding (primarily done for trees emerging from seed but not needed for those emerging from coppices and roots); pruning and management of the canopy size and shape (this is one of the more demanding labor needs for FMNR when the trees are more mature); and the harvesting of products, an obvious cost of FMNR or all tree-growing practices that must be considered simultaneously along with the benefits.

Three considerations apply to calculating actual costs incurred by farmers: (1) how common are these activities; (2) how much time or material is spent when they are undertaken; and (3) what are the unit costs in terms of time or materials. In our investment analyses we use the data from Abdoulaye and
Ibro (2006) on establishment costs of FMNR (24 d/ha) and 6
ICRAF expert opinion on maintenance costs (3 d/ha). Although the scaling up of FMNR in the Sahel has been labeled as farmer-driven with little external support, a number of programs are now investing in accelerating the scaling-up of FMNR. These programs are spending resources on enhancing farmer awareness

of the benefits of FMNR, building farmer tree management skills, organizing landscape management of grazing and fire, developing tree product markets, and identifying workable solutions to forest code regulations. It is too early to evaluate which of these costs are necessary and to what degree. This evaluation could be a topic of a future study since the programs will have good information on the expenditures made.

Most externalities associated with FMNR are positive. However, trees require water, and as such, there is always the concern that they may use water resources at rates that compromise human, animal, or crop uses. There is poor information on this especially at the landscape scale. Are there alternatives to FMNR? Trees can be grown off-farm, but then the *in situ* effects of trees on agricultural soils and crops will be foregone. The increased rural population, coupled with dwindling woodland, also suggests that woodland management is not an alternative to FMNR, but [7] rather it is a highly complementary activity (Shumba *et al.* 2010; [8] Mayaux *et al.* 2004).

IMPACTS ON HOUSEHOLD INCOME

The income from the sale of firewood alone in Niger has an estimated average annual value of US$ 127–154 per household. The sale of non-timber products, such as fruit alone, can return an average of US$ 237 per year or an additional value of US$ 0.66 [9] per day per household (Place & Binam 2013, quoted by Francis & Weston 2015).

The three main pathways of private benefits are through direct human consumption and/or sale of tree products, indirect benefits on crop production and increased benefits through livestock production. In terms of direct consumption benefits from trees, the major products are foods (fruits, nuts, oils, and leaves) and wood (construction and fuelwood). A recent study in the Sahel (Place & Binam 2013) found that all households harvested tree products for their consumption, and in many locations, the [10] quantity and value was high. Table 1 shows that the average harvested value per household ranged from a low of about US$ 110 in Senegal to about US$ 250 in Niger. Malian households also extensively harvested tree products, and Burkina Faso was in between the two extremes. We use these averages (on a per hectare basis) in the economic model below.

TABLE 1. *Value of harvested and marketed tree products in four Sahelian countries.*

Country	Value of harvested tree products per household (USD) Mean	Value of marketed tree products per household (USD) Mean	% of revenue from trees to total household income Mean
Burkina Faso	181	64	23.8
Mali	254	73	10.1
Niger	267	12	10.0
Senegal	119	37	7.4

Source: Place and Binam (2013).

Few harvested products were sold by households for income—the highest being about 35 percent in Burkina Faso and the lowest being about 4 percent in Niger. Burkina Faso households benefit from the presence of a wide distribution of *Vitellaria paradoxa* (shea), which has a large global market. Harvested value varies 3- to 4-fold among sites within each of the countries. These data are consistent with data collected from Niger (Yamba & Sambo 2012), where the average harvested value varied between US$ 28 and US$ 213 in 5 Nigerian villages. Thus, the ratio of values of marketed to harvested tree products varies across country and are below 0.4 in all cases. As a result, the contribution of tree-based revenue to total household revenue is generally modest, at or below 10 percent. Burkina Faso is the exception where shea is very important as an income source.

Crop yield improvement is another major benefit pathway of trees. It is important to note that in the Sahelian countries, chemical fertilizer use is low both in percentage of farmers (25% to 30%) and in amounts applied. Manure is a much more common input (55% to 80% of farmers). Trees are found everywhere, but the density and age profile of those with known beneficial effects on soils (*i.e.*, fertilizer trees) varies across sites. Both are important, as the older trees have the most significant effect on yields. In Niger, the mean number of mature fertilizer trees per hectare was 32, while in Mali and Burkina Faso it was about 5. After controlling for other effects (rainfall, soil type, seed density, area, manure, fertilizer), the mature fertilizer trees alone explained 15–30% of cereal yields in Niger, Mali and Burkina Faso (no effect was found in Senegal). Furthermore, there is a positive correlation between the presence of mature fertilizer trees and the amounts of manure and fertilizer applied (between +0.15 and +0.4). That is, farmers tend to apply more manure and fertilizer on fields with a higher density of trees. Considering only the direct effect (of 20% contribution), this amounts to about 60 kg of millet per hectare in Niger, 120 kg of millet per hectare in Mali and 150 kg per hectare of sorghum in Burkina Faso.

In Malawi a study of maize yields under *Faidherbia* (mainly regenerated) was conducted in 2010 (Glenn 2011). Controlling [11] for other crop inputs, she found an increase in 12–14 percent of maize yields in the fields with *Faidherbia* compared to fields without *Faidherbia* that averaged 1350 kg/ha. The optimal number of trees per hectare to maximize yields was calculated to be 40, while the average density among the sampled farmers was only about 10. Haglund *et al.* (2011) undertook a study of more than [12] 400 farmers in Niger, comparing those who practice FMNR against those who don't. Their figures suggest that the gross value of crop production for farms practicing natural regeneration was US$ 138, compared to US$ 88 for those that do not practice natural regeneration.

ENVIRONMENTAL BENEFITS

Among the key environmental benefits from FMNR, three are partly internal and are captured to some extent by the landholder and were included in the investment analysis. (1) Soil conservation—much of the soil conservation benefits are captured privately within the farm. However, because trees are long-lived, the benefits are likely to be claimed by both the current land user and at least one other generation to follow. Positive externalities may accrue on land outside the farm due to reduced downslope runoff intensity and erosion. (2) Shade and micro climate—this is purely *in situ* in nature, with the main gain being lower air and soil temperatures that buffer the crops from heat and moisture stress. Tree shade can significantly reduce temperature, radiation, and soil evaporation of the near surface atmosphere leading to higher soil moisture with a major [13] impact on crop performance (Ludwig *et al.* 2013; Lott *et al.* [14] 2009). (3) Micro-level water effects—trees can have both positive and negative effects on water availability for other plants. On the positive side, shade effects temperature and evaporation rates in a positive way and trees can also bring water from sub-surface levels up into the topsoil (*i.e.*, hydraulic lift) where [15] other crops can use it (Balaya *et al.* 2012). On the other hand, trees can also compete for water with other plants. (4) Biodiversity—FMNR is a major source of tree biodiversity on the landscape and as such will have some knock-on effect of biodiversity for other fauna such as birds and insects by increasing the range of microhabitats available to them. (5) Carbon sequestration—studies have shown that trees from FMNR sequester carbon at the rate of about 50 percent of wood biomass aboveground. What is also important in the drylands is the carbon sequestered belowground, in the often deep and vast root systems of the trees, and in terms of soil carbon via organic matter deposition and thus creating a more favorable environment for soil microorganisms. (6) Shocks and Coping Capacity—How do the different benefits generated by FMNR contribute to (i) reducing exposure to environmental shocks, (ii) reducing the sensitivity to shocks, and/or (iii) improving household and community coping capacity? At the scale of a household, FMNR cannot significantly reduce the exposure to shocks such as climate change and weather variability, pest incidence, winds, and price changes. But at the level of a concerted effort by communities, FMNR may reduce the velocity of winds through vegetative cover, and the spread of pests and diseases due to the enhancement of the habitats for pest predators and parasites.

Famer-managed natural regeneration can reduce sensitivity to shocks in the following ways: increased air temperatures can be reduced for plants and soils under the canopy of trees; the effect of low rainfall can be reduced under the tree canopy due to reduced evaporation; and by improving the soil physical, biological, and chemical status, crops can better withstand climate change and variability. In terms of coping strategies, FMNR usually leads to the emergence of a variety of tree species, which can provide alternative subsistence foods and income opportunities. Good examples include: fodder shrubs which produce feeds during the dry season, fruit trees that produce harvests at different times of the year and wood products that may be sold for income anytime during the year.

EMPOWERMENT OF VILLAGE COMMUNITIES

Individual farmers can protect and manage trees, but it is more effective if village communities organize themselves to do so and develop by-laws for managing the trees. This is what was done by the IFAD-funded project in the Maradi Region that supported the building of village institutions. Men and women farmers, but also representatives of the herders, are members of the management committees. The committees also hold meetings with surrounding villages (inter-village organization) to foster cooperation in tree protection. They have developed rules and set fines for the illegal cutting of trees and these rules are enforced. The village of Dan Saga receives many national and international visitors, who come to learn from their experience. The villagers feel empowered by this attention to their technical and institutional innovations. Figure 4 shows a meeting in the village of Dan Saga (Maradi Region) of the village committee responsible for enforcing the bylaws regarding trees in the village.

THE RE-GREENING DEBATE

Average rainfall in the Sahel has increased since the mid-1990s. Does this increase in rainfall explain the emergence of agroforestry parklands? Is it the major cause for the large-scale farmer-managed natural regeneration in Southern Niger? An increase in rainfall has had a positive impact on natural regeneration, and on the growth of woody species. But the process of re-greening had already begun in the mid-1980s during the calamitous drought years. If rainfall were the sole determining factor for natural regeneration, then on-farm tree densities in northern Nigeria should be higher than those in southern Niger, since they have similar population densities, similar soils and the same ethnic population. Northern Nigeria has more rainfall, but

FIGURE 4. Meeting of a village tree management committee in Dan Saga (Niger).

has much lower on-farm tree densities than southern Niger. The conclusion that can be drawn is that rainfall facilitates the regeneration of woody species, but human management is a critical determining factor in realizing the success of FMNR on such a wide scale in Niger.

According to Van Noordwijk *et al.* (2015) new evidence is emerging on credible mechanisms for forest and tree effects on rainfall. If this is the case, the large-scale development of new agroforestry parklands in Southern Niger may have had some impact on rainfall, particularly in areas downwind of the parklands; but the rainfall data for this region have not yet been fully analyzed in this context.

AGROFORESTRY AND CARBON SEQUESTRATION IN NIGER

The carbon sequestration potential of the parklands is one of the gaps in current knowledge that needs to addressed urgently. On a number of sites, the number, height, and diameter of trees were measured in 2008. Repeated measurements in the same sites would give a better idea of the dynamics of the agroforestry parklands creation, the tree growth rates, and their carbon accumulation rates. Assuming that an average of 6 tons of carbon/hectare were sequestered by the trees (excluding soil carbon), this would mean a total accumulation of 30 million tons of carbon over the 5 million hectares parklands that have been mapped.

NEW AGROFORESTRY PARKLANDS ON MALI'S SENO PLAINS

Events since 1994 on Mali's Seno Plains, illustrate the importance of forestry legislation in facilitating farmer managed natural regeneration (FMNR). In 1991, a popular uprising toppled Mali's president. During that period, many forest agents were expelled from the villages and some were even killed. They had managed to make themselves very unpopular, for instance, by starting bushfires and later accusing the villagers of doing so. As starting bushfires was against the law, the forest agents were subsequently able to impose unjustified fines on the farmers. In 1994 a new forest law was adopted that specifically mentioned on-farm trees and the farmers' rights to their trees on condition that the land was not left fallow for more than 10 yr. This policy encourages farmers to reduce the number of years they leave their land fallow and to protect on-farm trees. Due to high and growing population densities on the Seno Plains, most farmers need to cultivate their land permanently.

A radio station in the small town of Bankass on the Seno Plains, which was funded by an NGO (SahelEco), decided to broadcast the contents and implications of the new law because villagers are usually not informed about the contents of laws relevant to them. The reaction of villagers was: 'Does this mean we can refuse access to those who cut our trees with a permit from the forestry service?' The answer was 'Yes', and it was broadcast by the local radio station. From that day forward farmers refused

FIGURE 5. New agroforestry parkland on Mali's Seno Plains.

to allow access to woodcutters and they began protecting their on-farm trees. Young, dense and diverse agroforestry parkland began to develop on Mali's Seno Plains (Fig. 5).

It took until 2011 before the scale of the new agroforestry systems on the Seno Plains was revealed. Local staff membersestimated the scale to be on the order of 16,000 hectares. Gray Tappan of the US Geological Survey's EROS Data Center in South Dakota used high-resolution satellite images to estimate that the area under medium and high-density agroforestry was almost 500,000 ha. Until 2011, no one had imagined the scale of the farmer-managed natural regeneration that was taking place. Field visits revealed that 90 percent of the trees are less than 20 yr old.

FARMER-MANAGED NATURAL REGENERATION IN SENEGAL

In 2008, World Vision Senegal began an FMNR project in the Kaffrine area. This Beysatol Project flew farmers and extension agents from the Kaffrine area to Niger where they visited FMNR in the Maradi Region. Farmers were also taken to visit the extensive FMNR-generated parklands that had been sustained for generations by the Serere people in west-central Senegal, occupying about 150,000 hectares. From 2008 to March 2015 the Kaffrine farmers have protected and managed their natural regeneration on 64,000 ha. The average on-farm tree densities increased from 4 to 37 trees/ha (http://fmnrhub.com.au/projects/senegal-beylene-sen-tol/). This example from Senegal shows how rapid results can be achieved through farmer study visits.

ASSISTED NATURAL REGENERATION IN ETHIOPIA

We describe two cases in Ethiopia where land users protect and manage natural regeneration off-farm to create new forests. Both cases indicate significant potential for upscaling. The first is the exclosure system, which is already used on several hundred thousand hectares in the Tigray region and in the Northern part of the Amhara region. In the exclosure model, very degraded forestland that was mainly used for grazing and firewood collection is closed for any use, except for the collection of fodder through a cut-and-carry system. The objective is to allow the natural regeneration of woody species. This Assisted Natural Regeneration leads to new natural forests rather than to agroforestry systems. The number of tree species that regenerate naturally on very degraded land is quite limited. *Acacia etbaica* is a dominant species. Natural regeneration in this region is usually a slow process because of high altitude (2000+ m asl), lower temperatures, low rainfall (about 600 mm), poor soils, and lack of management of trees and bushes. One of the weaknesses is that the new woody vegetation is protected, but not sustainably managed and exploited through thinning and pruning by the communities. Government has now recognized that active management of the regenerating forests is critical in order to evolve a structure and species composition that will provide sustained benefits to the communities.

To accelerate natural regeneration, simple water harvesting techniques were introduced, *e.g.*, half moons, and fast growing species like *Grevillea robusta* are planted. More than one million ha of very degraded land in the Tigray Region has been restored using a mix of techniques, including exclosures. As a result, northern Ethiopia is now greener than it has ever been during the last 145 yr (Nyssen *et al.* 2014).

The Humbo Community-Based Natural Regeneration Project is Ethiopia's first biocarbon project funded under the Clean Development Mechanism. The natural forest of the Humbo mountain range, about 360 km south of the capital Addis Ababa, was completely degraded in 2007. World Vision Ethiopia supported seven villages to organize themselves to protect and manage natural regeneration on this mountain range and within 7 yr a new dense forest emerged on 2700 ha. After 3 yr the impact of natural regeneration was already clearly visible. Due to high rainfall and the presence of root systems, natural regeneration quickly produced a dense forest cover (Fig. 6).

Over the initial 10 yr the project expects US$ 726,000 in [16] carbon revenues (Brown *et al.* 2011). The project, however, generates multiple benefits, which include fodder for livestock. Also, from the second year onward, pruning tree regrowth from the project site met local domestic firewood needs (Rinaudo 2008). According to Tony Rinaudo, who re-visited Humbo in March 2016, the project has also had a significant impact on food security. He stated: 'In the context of the worst drought in 30 yr, we visited one of the seven Humbo cooperatives and it had 30 tons of grain in storage. This is doubly significant in that prior to the start of the project in 2006, Humbo had received food aid every year to one degree or other since 1984. In 2013, 7 yr after the project commencement, the cooperatives sold 106.7 tons of grain to the World Food Program'.

FIGURE 6. The Humbo mountains in July 2014. Due to high rainfall and the presence of root systems, natural regeneration quickly produced a dense forest cover.

RECOGNIZING AND TRACKING THE SCALE AND SUCCESS OF NATURAL REGENERATION BY FARMERS

Case studies from Niger and Mali show that even large-scale FMNR can fly under the radar. The scale at which farmers had protected and managed natural regeneration was revealed only recently. Why is it that outsiders have not observed it? Is it because the farmers initiated these activities themselves, and no project signboard was put next to it? Is it not likely that more successes remain to be uncovered?

There is growing political support for forest and landscape restoration. The World Resources Institute, German Development Cooperation and the African Union are now jointly engaging a number of countries in Africa to restore 100 million ha of degraded forest landscapes by 2030 through the African Forest Landscapes Initiative (AFR100). Such a level of ambition can only be achieved if on-farm and off-farm natural regeneration, led by farmers and their communities, will be an important component. The Second Africa Drylands Week held in Chad in August 2014, organized by the African Union in collaboration with numerous development partners, went even further. They recommended and proposed that by 2025 every farmer and every village in the drylands of Africa practice FMNR to restore degraded natural vegetation by 2025.

How can the scaling up of natural regeneration be achieved? The World Resources Institute recently published a report about how to scale up re-greening successes (Reij & Winterbottom 2015). This report builds on and distills the experiences observed in the West African Sahel with the scaling-up of Farmer-Managed Natural Regeneration. The scaling strategy has six steps and designated activities under each of the steps.

Step 1: Identify and analyze natural regeneration successes.—There are many smaller and bigger re-greening successes in Africa's drylands. As the examples from Niger and Mali show, natural regeneration by farmers is often overlooked. Each country should make an effort to identify its successes, because these can be used as sources of inspiration and as training grounds for farmers who do not yet protect and manage natural regeneration. It is interesting to note that natural regeneration occurs not only in the Sahel, but also under higher rainfall conditions. The example of Humbo in Ethiopia shows the speed at which natural regeneration has occurred in an area with higher rainfall.

Step 2: Build a grassroots movement for promoting natural regeneration.—In several countries donor-funded projects are already promoting natural regeneration, or other forms of participatory natural resource management. But they are not always working together. The challenge is to get them around the table to create synergies and political leverage in discussions with government about enabling policies and legislation.

Farmer-to-farmer study visits are a very effective way of scaling-up natural regeneration. In some regions, farmers (men and women) have gained so much experience with it that they have become the experts who train other farmers. If it is true that practice precedes policy, then it is important to inform government about the successes and about the existing dynamics that can accelerate the process on-the-ground.

Step 3: Address policy and legal issues and improve enabling conditions for natural regeneration.—Working only at the grassroots level is not sufficient to accelerate scaling up and out. The role of national governments is to create forestry legislation and agricultural development policies that induce land users to invest in trees. Current forest legislation tends to show some weaknesses. One of these is that they often do not recognize the farmers' rights to own, manage and harvest the trees that are established on their land. For instance, in most Sahelian countries, farmers are allowed to exploit and also cut the trees that they have planted, but if they have protected and managed natural regeneration they need a permit from the forestry service in order to manage or to prune or harvest the trees. A major weakness that needs to be addressed is that Ministries of Environment tend to be interested in natural forests and in planting trees, but not in the protection and management of natural regeneration; whereas Ministries of Agriculture usually concentrate their extension efforts on annual crops. However, as soon as funding for agroforestry projects becomes available, turf fights often emerge between the Ministries. The Ministries of Environment then claim that agroforestry is about trees, which is their domain, while the Ministries of Agriculture, which have much stronger extension services, and usually have a much greater capacity to implement such projects, claim that it is all about trees in farming systems. The solution is the development of intersectoral platforms that combine the strengths of both Ministries in the accelerated scaling-up of on-farm natural regeneration as well as tree planting for developing new agroforestry systems.

Step 4: Develop and implement a communication strategy.—It is possible to reach out to tens of millions of smallholders by using rural and regional radio stations to spread the messages about re-greening, and by linking mobile phones with radio and ICT to make the web more accessible to rural people. The process can be enhanced by inviting national and international journalists to visit re-greening successes. However, at this moment most re-greening projects don't have a communication strategy, or if they have one, it is seriously underfunded. The challenge is to inform all land users in a country about what has been achieved and about what they and their communities can do to participate. Land users themselves should be at the heart of regreening communication strategies.

Step 5: Develop or strengthen agroforestry value chains.—This is where the private sector has a major role to play. It can support the development of value chains around cashew, mango, drumstick (*Moringa oleifera*), shea (*Vitellaria paradoxa*), baobab (*Adansonia digitata*) fruit, and other agroforestry products. This will put more cash into the pockets of smallholder farmers and induce them to culture more trees on their farms.

Step 6: Design research activities to fill gaps in knowledge about natural regeneration.—We know enough to move into accelerated action, but at the same time it is important to fill some important gaps in our knowledge. For instance, too little is known, about the impact of on-farm and off-farm trees on surface and ground water hydrology, or about their impact on rainfall, on carbon sequestration in biomass and in soils, and on nutrition and food security.

~~CONCLUDING REMARKS~~

Currently, there are efforts under way to upscale on-farm natural regeneration as well as tree planting to develop new agroforestry systems in 17 countries in Africa and several countries in Asia. But an accelerated effort is needed to expand the reach of these systems to transform the farms of tens of millions of the poorest smallholder farmers. Therefore, a global partnership known as The Partnership to Create an EverGreen Agriculture (Garrity *et al.* 2010: ICRAF 2012; evergreenagriculture.net) has been launched to support governments, farmers' organizations, the NGO community and civil society to achieve a massive scaling-up movement to integrate trees into cropland.

The Partnership is supporting the information needs, capacity building, and knowledge generation required to assist in this effort. Many international and regional organizations have endorsed this work, are supporting it and embedding it into their programming. We are therefore beginning to glimpse a future of more environmentally sound and productive farming systems where much of our annual food crop production occurs by incorporating trees into cropping systems.

The accelerated scaling-up of existing natural regeneration successes is a pragmatic way forward. It will help achieve the ambitious restoration targets, which cannot be achieved with the business-as-usual approach limited to tree planting projects. Unless the conditions are created in which land users are willing to invest their scarce resources in the protection and management of on-farm or off-farm trees, the battle against climate change, ecosystem degradation and famine and malnutrition can't be won.

There is a lot of talk about the need to scale up best practices in sustainable land management, but projects rarely plan a scaling-up strategy. They may have a budget for farmer study visits, but not one for radio programs, which reach many farm households. Most steps proposed for scaling up require only modest funding, but they all require patience, persistence, creativity and local champions. It should be emphasized here that natural regeneration is less costly than tree planting and produces impacts more quickly. In times of financial scarcity these are strong arguments for putting a much bigger emphasis on natural regeneration than is the case at present.

LITERATURE CITED

Adams, C., S. Rodrigues, M. Calmon, and C. Kumar. 2016. Impacts of large-scale forest restoration on socioeconomic status and local livelihoods: What we know and do not know. Biotropica 48: ????–??????.

Brown, D. R., P. Dettmann, T. Rinaudo, H. Tefera, and A. Tofu. 2011. Poverty alleviation and environmental restoration using the Clean Development Mechanism: A case stdy from Humbo, Ethiopia. *In* Environmental Management vol. 48: 322–333. http://fmnrhub.com.au/.

Chazdon, R. L., and M. R. Guariguata. 2016. Natural regeneration as a tool for large-scale forest restoration in the tropics: Prospects and challenges. Biotropica 48: ????–?????.

Francis, R., and P. Weston. 2015. The social, environmental and economic benefits of Farmer Managed Natural Regeneration (FMNR). World Vision Australia, Melbourne.

Garrity, D., F. Akinnifesi, O. Ajayi, G. W. Sileshi, J. G. Mowo, A. Kalinganire, M. Larwanou, and J. Bayala. 2010. Evergreen Agriculture: A robust approach to sustainable food security in Africa. Food Security. 2(3): 197–214.

ICRAF. 2012. Creating an EverGreen agriculture in Africa. World Agroforestry Centre, Nairobi, Kenya, 4 p.

Larwanou, M., M. Abdoulaye, and C. Reij. 2006. Impacts de la régénération naturelle assistée dans la Région de Zinder (Niger): Une première exploration d'un phénomène spectaculaire. International Resources Group for the U.S. Agency for International Development, Washington DC.

Mortimore, M., M. Tiffen, B. Yamba, and J. Nelson. 2001. Synthesis of long-term change in Maradi Department 1960–2000. Drylands Research Working Paper 39. Crewkerne, U.K.

Nyssen, J., A. Frankl, M. Haile, H. Hurni, K. Descheemaeker, D. Crummey, A. Ritler, B. Portner, B. Nievergelt, J. Moeyersons, N. Munro, J. Deckers, P. Billi, and J. Poesen. 2014. Environmental conditions and human drivers for changes to North Ethiopian mountain landscapes over 145 years. The Science of the Total Environment 2014: 164–179.

Place, F., and J. Binam. 2013. Economic impacts of Farmer-Managed Natural Regeneration in the Sahel. End-of-Project Technical Report for Free University Amsterdam and IFAD; World Agroforestry Center, Nairobi, Kenya (mimeo).

Reij, C., G. Tappan, and M. Smale. 2009. Agroenvironmental transformation in the Sahel. IFPRI Discussion Paper, Washington 00914.

Reij, C., and R. Winterbottom. 2015. Scaling up regreening: six steps to success. A practical approach to forest and landscape restoration. Washington, WRI report. https://www.wri.org/sites/default/files/scaling-regreening-six-steps-success.pdf.

Rinaudo, T. 2008. Trip report and recommendations. World Vision Australia, Melbourne.

Tougiani, A., C. Guéro, and T. Rinaudo. 2008. Community mobilization for improved livelihoods through tree crop management in Niger. Geoforum 74: 377–389.

Van Noordwijk, M., S. Bruijnzeel, D. Ellison, C. Morris, D. Sands, V. Gutierrez, J. Cohen, C. A. Sullivan, B. Verbist, D. Murdiyarso, D. Gaveau, and B. Muys. 2015. Ecological infrastructure investment in trees for sustainable development. ASB Policy Brief 47. Nairobi: ASB Partnership for the Tropical Forest Margins.

Yamba, B., and M. N. Sambo. 2012. La régénération naturelle assistée et la sécurité alimentaire des méages de 5 terroirs villageois des départements de Kantché et Mirriah (region de Zinder, Niger). Report for the International Fund for Agricultural Development. Etude FIDA 1246-VU University Amsterdam.

Author Query Form

Journal: BTP

Article: 12390

Dear Author,

During the copy-editing of your paper, the following queries arose. Please respond to these by marking up your proofs with the necessary changes/additions. Please write your answers on the query sheet if there is insufficient space on the page proofs. Please write clearly and follow the conventions shown on the attached corrections sheet. If returning the proof by fax do not write too close to the paper's edge. Please remember that illegible mark-ups may delay publication.

Many thanks for your assistance.

Query reference	Query	Remarks
1	**AUTHOR: Please confirm that given names (red) and surnames/family names (green) have been identified correctly.**	
2	**AUTHOR: As per journal style a maximum of 8 keywords only allowed. Please check and amend accordingly.**	
3	**AUTHOR: Figure 1 was not cited in the text. An attempt has been made to insert the figure into a relevant point in the text – please check that this is OK. If not, please provide clear guidance on where it should be cited in the text.**	
4	**AUTHOR: Tougiani, Guéro and Rinaudo, 2009 has been changed to Tougiani *et al.* 2008 so that this citation matches the Reference List. Please confirm that this is correct.**	
5	**AUTHOR: Place & Garrity, 2015 has been changed to Place & Binam 2013 so that this citation matches the Reference List. Please confirm that this is correct.**	
6	**AUTHOR: Abdoulaye and Ibro (2006) has not been included in the Reference List, please supply full publication details.**	
7	**AUTHOR: Shumba *et al.* 2010 has not been included in the Reference List, please supply full publication details.**	
8	**AUTHOR: Mayaux *et al.* 2004 has not been included in the Reference List, please supply full publication details.**	
9	**AUTHOR: Place & Binam, 2012 has been changed to Place & Binam 2013 so that this citation matches the Reference List. Please confirm that this is correct.**	
10	**AUTHOR: 'Table 3.1-1' has been changed as Table 1. Please check and confirm.**	
11	**AUTHOR: Glenn 2011 has not been included in the Reference List, please supply full publication details.**	
12	**AUTHOR: Haglund *et al.* (2011) has not been included in the Reference List, please supply full publication details.**	
13	**AUTHOR: Ludwig *et al.* 2013 has not been included in the Reference List, please supply full publication details.**	

14	**AUTHOR: Lott *et al.* 2009 has not been included in the Reference List, please supply full publication details.**	
15	**AUTHOR: Balaya *et al.* 2012 has not been included in the Reference List, please supply full publication details.**	
16	**AUTHOR: Brown *et al.* 2009 has been changed to Brown *et al.* 2011 so that this citation matches the Reference List. Please confirm that this is correct.**	
17	**AUTHOR: Please provide the page range for reference Adams et al. (2016).**	
18	**AUTHOR: Please provide the page range for reference Chazdon and Guariguata (2016).**	