World Agroforestry Centre
TRANSFORMING LIVES AND LANDSCAPES

07

Policybrief

Trees on farms: Tackling the triple challenge of mitigation, adaptation and food security

Photo © M. Mäkelä

Trees help fight climate change by storing carbon. They buffer against weather-related production losses, enhancing resilience against climate impacts. And trees on farms provide additional income and diversity of food sources through tree-based products.

Key Points

- Trees on farms sequester carbon and contribute to mitigating climate change.
- Trees on farms enhance resilience to climate variability.
- Tree-based agricultural systems improve food security and livelihoods.

Policy recommendations

- Increased adoption of agroforestry should be supported through finance for agricultural development and adaptation as well as mitigation.
- Payments for environmental services – including carbon finance – should be geared towards increasing the extent of trees on farms
- More support is needed to increase the contribution of tree-based crops to smallholder incomes, thus diversifying income sources and increasing food security in the face of climate change.

Background

Human induced change of ecosystems over the past 50 years has resulted in an unprecedented and largely irreversible loss of biodiversity. If these trends continue, the ability of ecosystems to provide basic needs for food, water, timber, fibre and fuel will diminish. Reversing the trends requires significant changes in policies, institutions and practices (1).

Agriculture, forestry and livestock management are strong contributors to climate change, currently accounting for approximately 20% of greenhouse gas emissions (2) .

An estimated increase in population to approximately 9 billion people by 2050 will require at least a 50% increase in food production. Most of both will take place in developing countries. Climate change will lead to higher average temperatures, more severe weather extremes and altered precipitation patterns, adding additional pressure to agricultural systems, food production and food prices (2, 3).

Climate change threatens progress already made towards achieving the Millennium Development Goals (4) and in providing sustainable livelihoods to millions of smallholders.

Agriculture of the future must meet the triple challenge of: raising food production per unit area; reducing the vulnerability of agricultural systems to climate change; and reducing greenhouse gas emissions from agriculture. Agriculture with trees is ideally placed to tackle all three challenges.

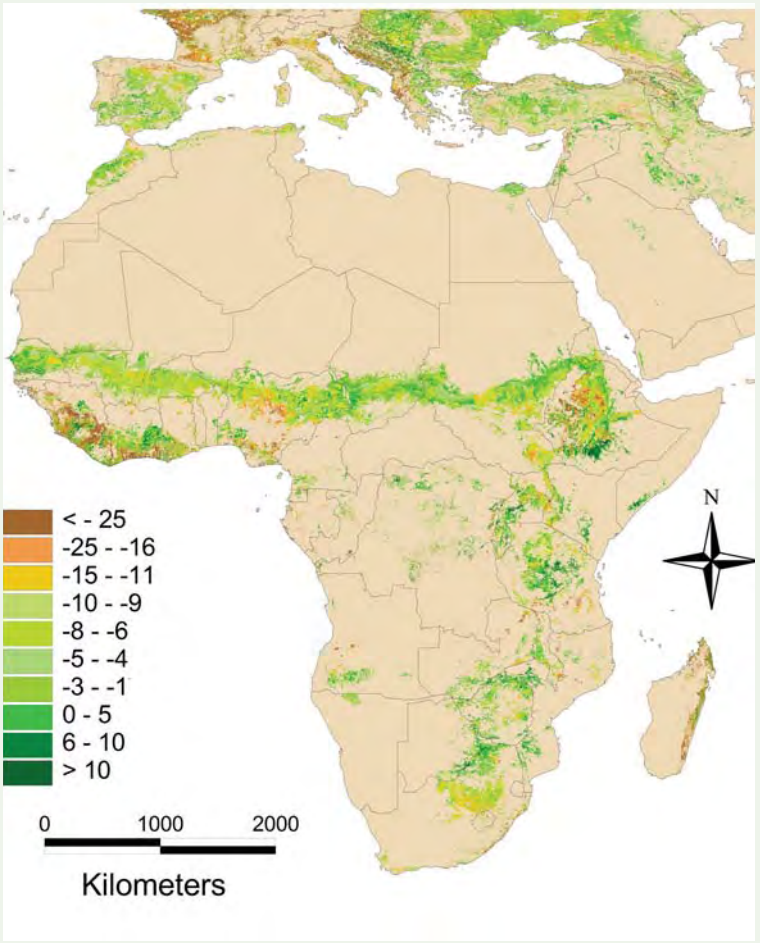

Figure 1 The difference between actual and potential tree cover in Africa. In most of the Sahel, tree cover is below the (low) potential. In the west African coastal lowland, central Ethiopia and the east coast of Madagascar, tree deficit is high despite high agroforestry potential. Further research is needed to estimate the amount of carbon that may be stored in agroforestry systems and to add climatic impacts to this map. Source: Zomer et al., 2009.

Global extent and geographical patterns of trees on farms

Trees and other woody perennials are a common feature on farms and rangelands, and are found in a wide range of traditional and newly introduced land use systems. Well-known agroforestry systems include tree gardens, alley cropping and slash-and-burn agriculture. A recent study to quantify the extent of trees in agricultural landscapes analyzed the global extent of agricultural land with at least 10% tree cover (5). The study shows:

- Trees occur on 46% of all agricultural lands and affect the lives of 30% of the rural population worldwide. This represents over 1 billion hectares of land and 558 million people. Trees on farms are particularly prevalent in Southeast Asia, Central America and South America, where over 80% of the total agricultural area has greater than 10% tree cover.
- While tree cover generally increases with humidity, there are many exceptions to this rule. High tree cover is often found in more arid zones, and low tree cover found in more humid zones. This suggests that tree density can be increased, even in more arid zones.
- Most tree cover patterns cannot be fully explained by aridity, population density or region. This points towards the importance of other factors such as tenure, market access or other policies and institutions affecting incentives for tree planting and management.

Agroforestry and the future for agriculture

1. Trees on farms sequester carbon and contribute to mitigating climate change.

Carbon sequestered by trees and stored in aboveground biomass and soil contributes to reducing greenhouse gas concentrations in the atmosphere. Estimates of the carbon sequestration potential of agroforestry systems vary greatly, from under 100 Mt CO2e per year by 2030 (6) to over 2000 Mt CO2e per year over a 30 year period (7). Regardless of the exact amount, agroforestry systems tend to sequester much greater quantities of carbon than agricultural systems without trees (8).

Analysis of the spatial distribution of existing agroforestry systems (5; see Box 1) shows a wide potential for increasing tree cover on agricultural lands and rangelands. The need for early action to avoid dangerous levels of climate change requires that effective and affordable mitigation options, such as agroforestry, are widely deployed as soon as possible.

Research in Indonesia suggests that the opportunity cost of increasing tree cover on agricultural lands is generally below USD5 (9) which offers an efficient and cost effective way of mitigating climate change.

In Africa, one of the key drivers of deforestation and landscape degradation is the demand for cheap energy. Firewood and charcoal account for between 61% and 86% of primary energy demand (10). Although a farmer may only require 0.25ha of improved fallow to sustainably maintain their household's primary energy demand (11), a lack of incentives to reforest or maintaining existing forests and woodlands means that this energy demand contributes to climate change. Payments for environmental services which are geared towards increasing tree cover on agricultural lands could enhance the sustainability of current energy provision, reduce landscape degradation and deforestation, and mitigate climate change.

What is required to include agroforestry in payments for environmental services?

Innovative methods for measurement, reporting and verification: A balance must be achieved between the accuracy and cost of measurement, reporting and verification (MRV) methods for terrestrial carbon sequestration. Further research is required to develop low-cost but acceptably accurate methods. Options might include the use of aerial or satellite imagery and methods based on modelling and activity-based monitoring. The GEF funded Carbon Benefits Project is working to provide a fast but reliable estimate of expected carbon stocks in complex agro-ecosystems.

Better rules for Afforestation/Reforestation Clean Development Mechanism (CDM) projects: While there is an agroforestry methodology under the CDM, no projects have yet been registered. Current afforestation/reforestation activities under the CDM require project developers to be financially well-off, technically well prepared, and institutionally well governed. In order for smallholders to engage successfully innovations are needed to support aggregation of smallholders' carbon assets and bundling of projects at local and regional levels.

A whole landscape approach to accounting (known as AFOLU – agriculture, forestry and other land uses): Current division into separately accountable forest components leads to problems with forest definition, emission leakage to other locations and sectors, and problems with permanence and additionality. The whole landscape approach requires baseline setting, which is influenced by data availability and political interests, but effectively avoids the problems mentioned above.

Photo © World Agroforestry photo archive

Photo © World Agroforestry photo archive

With maize being the most widely cropped staple in Africa, the potential for adopting *Faidherbia albida* agroforestry systems is tremendous.

2. Trees on farms enhance resilience to climate variability.

Trees on farms help adaptation to climate change by reducing vulnerability to climate impacts . The ability of agroforestry to generate more income and hence raise the adaptive capacity of smallholders is described in more detail in the section on food security.

Trees on farms can diminish the effects of weather extremes such as droughts or heavy rain. For example, a combination of napier grass and leguminous shrubs in contour hedgerows reduced erosion by up to 70% on slopes above 10% inclination without affecting maize yield in central Kenya (12). Research has found that the tree components of agroforestry systems stabilize the soil against landslides and raise infiltration rates (13). This limits surface flow during the rainy season and increases groundwater release during the dry season. With rainfall intensities expected to rise with climate change (2) this feature of agroforestry systems to prevent landscape degradation will become more important in the future.

At the other extreme, agroforestry has been shown to redistribute water in the soil profile, providing annual crops with greater water availability (14). This may help to explain why in Zambia maize yields of improved fallow agroforestry systems were, on average, nearly two times as high as for a pure maize control (15). Using appropriate agroforestry species can also provide fodder and shade for livestock, protect soils against irradiation during the dry season, and provide organic fertilizers for annual crops during the rainy season (16; see Box 2). Whilst important today, these factors are set to become even more important in the future.

Adaptation and increased food security with *Faidherbia albida*

Faidherbia albida, an indigenous acacia-like tree, is proving to be a successful agroforestry tree for Africa. It is widespread throughout the continent, thriving on a range of soils and occurring in ecosystems from, deserts to wet tropical climates (17). The tree has not been shown to turn invasive and does not compete with other species. Faidherbia is a fertilizer tree which captures atmospheric nitrogen and makes it available to plants through the soil.

What makes Faidherbia so special is its 'reversed leaf phenology' meaning it is dormant and sheds its leaves during the early rainy season and its leaves only regrow when the dry season begins. This feature makes it compatible with food crops because it does not compete with them for light, nutrients and water.

The nutritive leaves can be used as fodder or as mulch. Farmers have frequently reported significant crop yield increases for maize, sorghum, millet, cotton and groundnut when grown in proximity to Faidherbia. Faidherbia can report 6% to more than 100% yield increases based on a review of published literature (17).

Like many other agroforestry species, Faidherbia tends to increase carbon stocks both above-ground and in the soil (8) and improves soil water retention and nutrient status.

Faidherbia trees are currently only found on less than 2% of Africa's maize area and less than 13% of the area grown with sorghum and millet. With maize being the most widely cropped staple in Africa, the potential for adopting this agroforestry species is tremendous. Further research is needed to better explore the benefits Faidherbia can provide: its crop productivity benefits over time and space in different agro-ecosystems; potential for market products such as medicine and charcoal; understanding of constraints and trade-offs to planting and maintaining the trees; and possibilities for, and challenges to, engaging with carbon markets.

Photo © World Agroforestry photo archive

Shade coffee agroforestry systems create carbon storage benefits, while providing good income to local farmers.

3. Tree-based agricultural systems improve food security and livelihoods

Diversification of food and livestock production is a key strategy used by climate-vulnerable farmers and herders to increase food security. By integrating trees in their farms and rangelands, farmers reduce their dependency on a single staple crop or sufficient grass for their animals. For example , if a drought destroys the annual crop, trees will still provide fruits, fodder, firewood, timber and other products that often achieve high commercial value. A study of 1000 farmers from 15 districts in Kenya found that tree fruits contributed 18% of crop revenue, and tea and coffee contributed an additional 29% of revenue (18). A study in Zimbabwe concluded that indigenous fruits provided higher returns to labour than annual crop production (19). A study from Nepal on the impact of agroforestry on soil fertility and farm income showed that agroforestry intervention nearly doubled farm income per hectare from USD800-1580 (20).

Higher soil organic matter and available nutrients in tree-based agro-ecosystems can also increase yields in smallholder farming systems. This is of particular importance where access to mineral fertilizers is restricted by high costs or limited availability (16). Soils high in organic matter are generally able to hold more water, thereby improving the availability of water for annual crops. This is despite the fact that trees require additional water. Since trees and annual crops draw most of their water from different layers of the soil, there is rarely direct competition between the two (14). A recent meta-analysis of studies into the effect of agroforestry on maize yields in Africa found that the mean increase in agroforestry systems was between 1.3 and 1.6 tons per hectare per year (21).

Policy recommendations

Increased adoption of agroforestry should be supported through finance for agricultural development and adaptation as well as mitigation.

Considering the multiple benefits of trees on farms, agroforestry practices are still not sufficiently widespread, and where agroforestry is practiced, poor management often leads to undersupply of these benefits. Research and training is required to match high value agroforestry species with the right agro-ecological zones and agricultural practices.

Payments for environmental services –including carbon finance - should be geared towards increasing the extent of trees on farms

While trees on farms will rarely be planted for their carbon value alone, up-front financial provisions could reduce some of the barriers to introducing trees into agricultural systems. Payments would cover labour and costs of planting and nurturing trees before longer-term benefits from fruits, fodder, timber and fuel are realised.

More support is needed to increase the contribution of tree-based crops to smallholder incomes, thus diversifying income sources and increasing food security in the face of climate change.

Diversification of income sources is one of the most successful ways to raise the capacity of smallholders to adapt to extremes of weather. It can also lead to higher incomes and livelihood improvements. Support for smallholder tree-based diversification requires attention to germplasm, management practices which enhance productivity, market linkages and supportive policies that are culturally appropriate. Managing the transition to a more sustainable development pathway in the face of climate change requires a holistic framework that addresses these multiple constraints.

Photo © G. Cerbu

References

1. Millennium Ecosystem Assessment (2005) Ecosystems and Human Well-being: Synthesis. Island Press, Washington DC.
2. IPCC (2007) Summary for Policymakers. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M, Miller, H.L. (eds.). Cambridge University Press, Cambridge, UK.
3. Nelson GC, Rosegrant MW, Koo J, et al. (2009) Climate Change: Impact on Agriculture and Costs of Adaptation. International Food Policy Research Institute, Washington DC.
4. United Nations (2009) The Millennium Development Goals Report 2009. United Nations Department of Economic and Social Affairs.
5. Zomer RJ, Trabucco A, Coe R, Place F (2009) Trees on Farm: Analysis of Global Extent and Geographical Patterns of Agroforestry. ICRAF Working Paper No 89. World Agroforestry Centre, Nairobi, Kenya.
6. Smith P, Martin D, Cai Z, et al. (2007) Agriculture. In: Metz B, Davidson OR, Bosch, RP, Dave R, Meyer LA (eds.), Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report on the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK.
7. Verchot LV, van Noordwijk M, Kandji S, et al. (2007) Climate change: linking adaptation and mitigation through agroforestry. *Mitigation and Adaptation Strategies for Global Change* 12, 901-918.
8. Makumba W, Akinnifesi FK, Janssen B, Oenema O (2007) Long-term impact of a gliricidia-maize intercropping system on carbon sequestration in southern Malawi. *Agriculture, Ecosystems and Environment* 118, 237-243.
9. Swallow B, van Noordwijk M, Dewi S, et al. (2007) Opportunities for Avoided Deforestation with Sustainable Benefits. ASB Partnership for the Tropical Forest Margins, Nairobi, Kenya.
10. Amous S (1999). The Role of Wood Energy in Africa. WETT Regional Study, Food and Agriculture Organization, Rome.
11. Jama BA, Mutegi JK, Njui AN (2008) Potential of improved fallows to increase household and regional fuelwood supply: evidence from western Kenya. *Agroforestry Systems* 73, 155-166.
12. Mutegi JK, Mugendi DN, Verchot LV, Kung'u JB (2008) Combining napier grass with leguminous shrubs in contour hedgerows controls soil erosion without competing with crops. *Agroforestry Systems*, DOI 10.1007/s10457-008-9152-3
13. Ma X, Xu JC, Luo Y, Aggrawal SP, Li JT (2009) Response of hydrological processes to land-cover and climate changes in Kejie watershed, south-west China. Hydrological Processes. Online. DOI: 10.1002/hyp.7233
14. Bayala J, Heng LK, van Noordwijk M, Quedraogo SJ (2008) Hydraulic redistribution study in two native tree species of agroforestry parklands of West African dry savanna. *Acta Ocologica* 34, 370-378.
15. Kandji ST, Verchot LV, Mackensen J, et al. (2006) Opportunities for linking climate change adaptation and mitigation through agroforestry systems. In: Garrity D, Okono A, Grayson M, Parrott S (eds.), World Agroforestry into the Future. World Agroforestry Centre, Nairobi.
16. World Agroforestry Centre (2009) Creating an Evergreen Agriculture in Africa. World Agroforestry Centre, Nairobi.
17. Barnes RD, Fagg CW (2003) *Faidherbia albida*. Monograph and Annotated Bibliography. Tropical Forestry Papers No 41, Oxford Forestry Institute, Oxford, UK.
18. Place, F., and J. Wanjiku. 2006. High Value Tree and Crop Enterprises in Kenya: How Meso and Micro Factors Affect Adoption and Revenues. Paper presented at the International Association of Agricultural Economists Conference, Gold Coast, Australia, August 2006.
19. Mithoefer D, Waibel H (2003).Income and labour productivity of collection and use of indigenous fruit tree products in Zimbabwe. *Agroforestry Systems* 59, 295–305
20. Neupane RP, Thapa GB (2001) Impact of Agroforestry Intervention on Soil Fertility and Farm Income under the Subsistence Farming System of the Middle hills, Nepal. *Agriculture, Ecosystems and Environment* 84, 157–167
21. Sileshi, G.; Akinnifesi, F.K.; Ajayi, O.C.; Place, F. 2008. Meta-analysis of maize yield response to woody and herbaceous legumes in the sub-Saharan Africa. *Plant and Soil* 307, 1-19.

Correct citation:

Neufeldt H, Wilkes A, Zomer RJ, Xu J, Nang'ole E, Munster C, Place F. 2009. Trees on farms: Tackling the triple challenges of mitigation, adaptation and food security. *World Agroforestry Centre Policy Brief 07.* World Agroforestry Centre, Nairobi, Kenya.

Contacts

World Agroforestry Centre
TRANSFORMING LIVES AND LANDSCAPES

United Nations Avenue, Gigiri • PO Box 30677 • Nairobi, 00100 • Kenya
Telephone: +254 20 7224000 or via USA +1 650 833 6645
Fax: +254 20 7224001 or via USA +1 650 833 6646
Email: ICRAF@cgiar.org • www.worldagroforestry.org