Taking Tree Based Ecosystem Approaches to Scale

Evidence of drivers and impacts on food security, climate change resilience and carbon sequestration

Louise Willemen
Abigail Hart | Christine Negra
Celia Harvey | Lars Laestadius
Bastiaan Louman | Frank Place
Robert Winterbottom
Sara J. Scherr

PROFOR

EcoAgriculture Discussion Paper No. 11

ECOAGRICULTURE DISCUSSION PAPER SERIES

The Ecoagriculture Discussion Paper Series is an initiative of EcoAgriculture Partners, a nonprofit organization dedicated to supporting innovators from the agriculture, conservation, and rural development sectors to strengthen and scale up their ecoagriculture management approaches. EcoAgriculture Partners aims to increase understanding and knowledge of ecoagriculture, facilitate collaboration and improve practices among innovators and practitioners, and mobilize strategic institutional change. Ecoagriculture is an integrated approach to landscape management that seeks simultaneously to enhance human livelihoods and well-being, improve agricultural production, and conserve biodiversity and ecosystem health.

The Ecoagriculture Discussion Paper series presents results of research and policy analysis on important aspects of ecoagriculture theory and practice. The series seeks to stimulate dialogue among specialists and practitioners in agriculture, conservation, and rural development.

For inquiries about publishing a paper in the Ecoagriculture Discussion Paper Series, please email info@ecoagriculture.org.

Download a free copy of this paper at www.ecoagriculture.org

EcoAgriculture Partners
1100 17th St. NW Suite 600
Washington, DC 20036
USA
Telephone: +001 202 393 5315

Cover image: Fodder trees support livestock in a mixed-used farming system in Nepal. Courtesy of Sajal Sthapit/EcoAgriculture Partners.

This paper should be cited as:
Willemen, Louise, Hart, A., Negra, C., Harvey, C., Laestadius, L., Louman, B., Place, F., Winterbottom, R., Scherr, S., 2013. Taking Tree-based Ecosystem Approaches to Scale: Evidence of drivers and impacts on food security, climate change resilience and carbon sequestration. *Ecoagriculture Discussion Paper No. 11*. Washington, DC: EcoAgriculture Partners.

ACKNOWLEDGEMENTS

In addition to the project partners, development of this review report was supported by many other individuals. Demelash Alem, Eyleen Angulo, Doug Brown, Eugene Fifer, David Lindenmayer, Elias de Melo, Enrique Murgueitio, Tony Rinaudo, Eduardo Somarriba, Lorena Soto Pinto, and Tor-Gunnar Vagen who assisted with identification of relevant source documents, and report design and production was completed by Louis Wertz. A World Bank expert team provided review comments to an earlier draft of this report. Expert feedback was obtained during a workshop hosted by the World Bank in September 2013 that brought together individuals representing CIRAD, GEF, IFPRI, USAID, the World Bank, and the World Bank Institute.

This report was prepared as part of a larger initiative on Taking to Scale Tree Based Ecosystem Approaches (http://www.profor.info/node/2123) led by Diji Chandrasekharan Behr (Natural Resource Economist, AES). The larger project aims to develop and test in multiple countries a framework on scaling up management practices on productive lands that include trees and deliver increased food security, resilience to climate change, and carbon sequestration. The Taking to Scale initiative is done under the general guidance of Peter Dewees (Forest Advisor, Agriculture and Environmental Services, AES), Mark Cackler (Sector Manager, AES), and Juergen Voegele, Sector Director, AES).

The team is thankful for the financial support provided for this work by PROFOR and the Bank Netherlands Partnership Program (BNPP). A multi-donor partnership housed at the World Bank, PROFOR finances forest-related analysis and processes that support the following goals: improving people's livelihoods through better management of forests and trees; enhancing forest law enforcement and governance; financing sustainable forest management; and coordinating forest policy across sectors. In 2012, PROFOR's donors included the European Union, Finland, Germany, Italy, Japan, the Netherlands, Switzerland, the United Kingdom, and the World Bank. Learn more at www.profor.info

EcoAgriculture Partners Project Team:

L. Willemen, A. Hart, C. Negra, S. Scherr

Project Partners:

C. Harvey (Conservation International), L. Laestadius (WRI), B. Louman (CATIE), F. Place (ICRAF), R. Winterbottom (WRI)

TABLE OF CONTENTS

ANNEXES

LIST OF TABLES

LIST OF BOXES

LIST OF PHOTOGRAPHS

EXECUTIVE SUMMARY

Objectives

Tree-Based Ecosystem Approaches (TBEAs) include a variety of land and forestry management systems and practices that combine trees with agricultural production, in pursuit of sustained or increased productivity, enhanced ecosystem services supply, and a stronger adaptive capacity for land managers. Significant potential benefits for economic development, poverty reduction and climate resilience have inspired growing interest and investment in TBEAs by national governments and their development partners who are eager to understand where and how TBEA benefits can be realized at scale.

Anchored in a targeted review of peer-reviewed and gray literature, this report systematically captures available evidence and examines TBEAs that are practiced at scale (i.e., adopted by a large number of land managers within a large area) or are in the process of scaling up, with emphasis on: (1) the impact of these TBEAs on food security, climate change resilience, and carbon sequestration, and (2) the drivers that explain the implementation and maintenance of TBEAs.

Methods

Three approaches were used to identify documents: (1) a Web of Knowledge search for peer-reviewed scientific papers; (2) an internet search for grey literature; (3) a search for unpublished documents through project partners and key contacts. After applying selection criteria to 242 identified documents, the literature review included 93 documents that describe 111 different sites (ranging in size from communities to multi-country regions) where TBEAs are in some stage of scaling up. While no cut-off dates were applied in the document search, over 50% of the reviewed documents were produced after 2010. Findings reflect the available evidence in peer-reviewed and gray literature, but they likely do not represent the full range of TBEAs as they are actually practiced in different regions around the world, and should be interpreted accordingly.

Findings

TBEAs and sites. Forty different TBEA practices were reported across the 111 TBEA sites resulting from our literature review, including trees in croplands (17), trees in grasslands (7), forest-based systems (8), complex multi-strata agroforestry (4), and homegardens (4). The 111 TBEA sites were found in 53 different countries (more than half in Africa) and 10 countries encompassed 70 of the reported TBEA sites. Sites were most commonly located in the humid, semi-arid, and tropical zones and the main agricultural activity was subsistence farming (4 sites had commercial cash crop farming and 12 sites had commercial livestock production). Information on the extent of a TBEA practice was provided for only 35 sites, while more qualitative descriptions (i.e., widespread, common, rare) were given for 36 sites. TBEA sites with the greatest reported extent include examples of natural regeneration (5 million hectares), trees on sloping lands/afforestation (9 million hectares), parkland agroforestry (5 million hectares), rubber agroforestry (nearly 3 million hectares), silvopastoralism (500 thousand hectares), silviculture (nearly 500 thousand hectares), and community-based forestry management (nearly 500 thousand hectares). TBEAs practiced on over 500 thousand hectares were reported in Niger, China, Burkina Faso, Tanzania, Zambia, and Uruguay.

Impacts of TBEA implementation. Drawing on a very large variety of indicators, documents provided assessments of TBEA impacts on food security (42 sites; measured with 5 different indicators), climate change resilience (12 sites; 7 different indicators), and carbon sequestration (25 sites; 4 different indicators). We also collected information on the impact of TBEAs on income (68 sites; 7 different indicators). All of these reported one or more positive impacts. Negative impacts on income and carbon sequestration were reported for only 6 of 111 sites including unequal benefit sharing for smallholders; reduced production or carbon sequestration coupled with increased income or food security; and displacement of important land uses or economic activities. The reviewed documents assessed TBEA impacts using diverse methods including surveys or interviews, field measurements, literature review, scientific experts, and various models. Common methods for assessing impact varied by impact type and size of the study area.

TBEA adoption 'at scale.' Weak contextual information in the literature regarding TBEA adoption prevented characterization of TBEAs as 'at scale.' Eleven different quantitative indicators of TBEA adoption are reported for 53 TBEA sites. (For only 11 of these sites was adoption quantified as a percentage of a target group and therefore comparable across sites.) A qualitative description of the level of adoption was provided for 45 TBEA sites. The TBEAs that were most frequently described as implemented at scale were: i) natural regeneration practices, all in Africa (6), ii) fertilizer trees, all in Africa (5), iii) silvopastoral practices in Latin-America and Europe (4), and iv) homegardens, all reported in Asia (4). TBEAs were described as historically present (over 100 years) at 21 sites and recently scaled up (<10 years) at 19 sites.

Drivers and mechanisms of TBEA implementation. To explore whether there are characteristic scaling up pathways associated with specific types of TBEAs, the literature review gathered information about drivers and mechanisms for TBEA implementation or maintenance. The most commonly reported drivers were the need for soil quality improvement, income, and subsistence production of food and fodder. At least one driver was reported for 92% of TBEA sites; 68% had multiple drivers suggesting that TBEAs support multiple functions. Information provided about drivers was determined through interviews, surveys or local knowledge for only 37 of the 111 sites; otherwise information was obtained by the authors through literature or common understanding of the area. One or more mechanisms for TBEA implementation or maintenance were described for 83 of 111 sites including 48 sites where interventions by international NGOs were reported as the main mechanism. Local (individual or collaborative) implementation mechanisms were often reported to be driven by the need to improve soil quality, income generation, and household nutrition.

Recommendations

Recent years have seen a scaling up in investment and support programs for TBEAs, which has not been matched by development of analytical methods and frameworks to understand the role of TBEAs in transformation of land use systems or the effectiveness of different strategies for accelerating adoption. Many of the reviewed documents provide valuable insights about scaling up of TBEAs in particular cases, however the body of available literature provides weak guidance for large-scale investment and policy planning. Some specific limitations include: i) weak reporting of farm size, socio-economic conditions, adoption level, and scaling up; ii) inconsistent methods for assessing impacts and drivers; iii) available literature may be biased toward particular geographies, farming systems, TBEA types, impacts or institutional mechanisms; and iv) insufficient evidence about inter-relationships among TBEAs, configurations of tree species, implementation at landscape-scale, or impacts on ecosystem services.

We recommend five specific areas of action for additional assessment activities:

1. Development of a shared conceptual framework and assessment strategy for TBEAs to inform cross-site comparative analysis;
2. Spatial analyses to determine the actual geographic distribution of TBEAs around the world and in individual countries;
3. Comprehensive case studies of TBEA practices, scaling up processes, and dynamics at landscape scale;
4. Organization of action research across landscapes where different TBEA interventions are being implemented to better understand how socio-ecological conditions, external interventions, and local institutions (and their interactions) influence TBEA implementation at scale; and
5. More in-depth analysis of existing literature, through qualitative assessment of scaling up processes and dynamics; expansion of literature review to include studies of ecosystem services and biodiversity impacts; inclusion of studies produced in other languages; and meta-analysis of the comparative quantitative evidence in existing studies.

1. THE OPPORTUNITIES AND CHALLENGES OF SCALING UP TREE-BASED ECOSYSTEM APPROACHES FOR FOOD-SECURE, CLIMATE-SMART LANDSCAPES

Tree-Based Ecosystem Approaches

The term Tree-Based Ecosystem Approaches (TBEAs) refers, in this study, to a variety of land and forestry management systems and practices that combine trees with agricultural production in pursuit of sustained or increased productivity, enhanced ecosystem services supply, and a stronger adaptive capacity for land managers. There are many different types of TBEAs such as farmer-managed natural regeneration (FMNR), conservation agriculture with trees, forest and waterway restoration, shade trees and other perennials in pastures, homegardens, farm woodlots, windbreaks, live fences, and forest fragment conservation (see Annex 1).

In many cases, TBEAs offer farmers and forest managers greater flexibility by incorporating conventional fruit trees and commercial tree crops into agricultural and forested landscapes. For instance, high-value indigenous species that were traditionally harvested in the wild, such as Allanblackia and Prunus africana in West and Central Africa, have been domesticated to support sustainable production to meet local and international demands for forest products. In other cases, farmers have included stands of commercial tree crops or woody perennials in homegardens as is the case with bamboo in the Barak Valley of India or traditional agroforestry systems such as the gum-arabic agroforestry system in Sudan to diversify income and protect against market fluctuations.

TBEAs have been credited with helping to achieve food security, resilience to climate change, carbon sequestration, and ecological protection and restoration (Rapidel et al., 2011). Anchored in a targeted analysis of peer-reviewed and gray literature, this report systematically captures available evidence and examines TBEAs that are practiced at scale or are in the process of scaling up, specifically: (1) the impact of these TBEAs on food security, climate change resilience, and carbon sequestration[1], and (2) the policy, institutional, biophysical, economic, and social parameters that drive and enable the implementation and maintenance of TBEAs.

For the purpose of this study, the project team and partners developed an operational definition of TBEAs to be considered in the literature review that includes agro-forestry practices (woody perennials in agricultural systems) and forestry systems that are actively managed for multiple objectives such as food, timber and non-timber forest production, climate change adaptation and mitigation, and the supply of other ecosystem services (i.e., the full range of benefits people can obtain from ecosystems including water flow regulation, nutrient cycling and pollination). Tree-based systems were only included as TBEAs if they embodied an in situ ecosystem approach (i.e. managed to support the delivery of multiple objectives and ecosystem services). Examples of systems that were not considered TBEAs include monoculture tree

1 While implementation of TBEAs may contribute to net reduction of greenhouse gas emissions in other ways (e.g., by reducing deforestation and degradation of nearby forests or by providing biomass energy to replace fossil fuel use), this study restricted its focus to carbon sequestration and storage.

crops, plantations, and forest actively managed solely for timber production except where these types of tree-based systems were reported to be elements of a multi-objective management strategy at the landscape scale in which farmers or communities also protect or grow a range of other tree species (e.g., where rubber agroforestry is practiced or where communal land management includes monoculture tree production).

Growing Experience, Interest, and Investment

Trees and forests, mixed with annual crops and livestock, were historically important land uses throughout the tropics and sub-tropics (Nair, 1989). However, in the 20th century, the Green Revolution in agriculture and modern land use models of specialization promoted segregation of trees and crops in the landscape, with trees excluded from areas deemed important for agricultural production. Investments in a narrow range of annual crops, particularly staple grains grown in commercial monocultures, increasingly displaced highly biodiverse and tree-dependent systems that supplied food, fiber, medicine, and other products. High-value tree fruits and nuts were commercially promoted in specialized orchards. Forests were claimed by national and state governments and dedicated to a narrow range of species used for timber production or watershed management. The protected area movement that accelerated in the 1970s reinforced the designation of forested areas as a conservation-focused land use (Richards, 1983; Wolman & Fournier, 1987).

The approach of excluding trees from agricultural systems espoused by development agencies and ministries began to shift in the 1970s with the re-evaluation of the role of trees on farms and the recognition of the economic, social, and environmental benefits of tree production and vegetation cover (Nair, 1989). The importance of trees on farms in smallholder farmers' strategies for subsistence and agricultural intensification were more widely recognized (Arnold & Dewees, 1993). The challenge of producing woodfuel, building materials, and other products for rapidly growing populations and economies, in the context of rapid deforestation, has led to greater emphasis on promoting trees on farms and community-managed forestry. The World Agroforestry Centre (ICRAF) was established in 1978 to develop a more rigorous scientific foundation for such systems. The benefits of 'multi-purpose trees' that serve a variety of functions for local people and trade have been explored and beneficial intercrops of trees and crops have been identified and developed. Tree germplasm became available not only for a few widely grown commercial tree species, but for many domestic and exotic species and indigenous species began to receive attention for selection, improvement, and market development (Lundgren, 1987). The widespread retention of traditional TBEAs in indigenous and many rural community land use systems was also increasingly recognized as a benefit for livelihood security, nutrition, and resilience as well as for agrobiodiversity conservation (Thompson et al., 2007).

Meanwhile, greater environmental awareness drew attention to the ecological value of retaining trees and other perennial land cover, for watershed health, conservation of biodiversity, and, more recently, climate change mitigation and adaptation (Wood et al., 2000). Afforestation, forest landscape restoration, and agroforestry were identified as solutions to a variety of land and resource issues. By the 1990s, various types of agroforestry such as fertilizer trees or food- and feed-producing trees were seen by many as attractive components for agricultural development and local food security to substitute for purchased inputs, restore soil structure, provide raw materials for processing, and diversify diets. Landscape approaches linking diverse land uses to achieve a range of products and ecosystem services drew heavily on tree-based ecosystem approaches and interventions (McNeely & Scherr, 2008; IUCN, 2008). Research and improved scientific methods enabled more systematic assessment of land use fragmentation, landscape ecology, and deforestation/afforestation dynamics at beyond-farm scale.

Commercial and household-level demands for tree products are on the rise (Place et al., 2011). TBEAs are anticipated to play an important role in addressing global issues such as achieving the Millennium Development Goals (for food security and poverty alleviation), the Aichi Targets (biodiversity and ecosystem services supply), and climate change adaptation and mitigation strategies (Nair & Garrity, 2012). The Global Partnership on Forest Landscape Restoration has estimated that more than 2 billion hectares of cleared and degraded lands have the potential to be restored to forest or agroforestry cover (Minnemeyer et al., 2011).

Inspired by the significant social, ecological and economic benefits, there is currently a growing interest and investment in TBEAs among national governments and their partners such as international institutions (e.g., the World Bank, the UN agencies), development agencies, agricultural and conservation organizations (e.g., Global Environment Facility), and private investors. These institutions are eager to understand where and how TBEA benefits can be realized at scale and provide even greater social, ecological, and economic benefits (Dewees et al., 2011).

Current Extent of Global and Regional Land Use under TBEAs

Limited information is available on the current extent of global and regional land use under TBEAs and how this has changed over time. While 1.4 billion hectares are classified as annual cropland, these may include an extensive presence of trees and shrubs intercropped or in linear features, although such features are not included as distinct land use types in official statistics (FAOSTAT, 2013). FAOSTAT reports over 119 million hectares in commercial tree crops globally, principally oil crops, coffee, cocoa, rubber, tea, fruits, and nuts. But only a small fraction of all of the tree species grown in farms and communities in the rural tropics are identified in these statistics. In Kenya, for example, data analyzed by ICRAF suggest that fruit trees are planted by about 90% of famers in the humid to sub-humid zones, though only a fraction of these are included in national statistics (Frank Place, personal communication, August 29, 2013).

Remote sensing studies have begun to document the widespread presence of trees and forests in and around farmlands and communities (i.e., outside forests). One of the earliest attempts at empirical assessment of woody biomass in farming communities was in western Kenya (Bradley, 1988) and demonstrated the diversity of tree cover and wood product supplies. The first global study by FAO and ICRAF of 'trees outside forests' found that 46% of total agricultural land has at least 10% tree cover (de Foresta et al., 2013). ICRAF's work using remote sensing to document tree cover has found that more than 1 billion hectares of agricultural land are under agroforestry with over10% tree cover (Zomer et al., 2009). This compares with estimated global forest cover of more than 4 billion hectares (FAOSTAT, 2013). Much of this is probably under long-standing local systems, but most global and regional studies do not provide the time series data required to document change in tree cover over time, to differentiate trees that are intentionally planted or protected from those that are not, or to differentiate specific TBEAs.

Scaling up TBEAs: Challenges and Key Questions for Development Actors and Investors

Choices made by individuals and communities about land use practices are influenced by a complex mix of factors. Decisions to grow more trees or to grow them in different ways and places may be motivated by changes in the local resource base (e.g., need for improved supply of ecosystem services or diversification of diet), financial incentives (e.g., market demand, payments for ecosystem services, available credit or grants), policy and legal frameworks (e.g., land and tree tenure, regulations, policy strategies), and cultural norms (e.g., preferences, traditions, expertise).

Despite considerable interest among international donors, agencies, practitioners, and researchers, as yet there is no widely agreed-upon analytical framework for describing scaling up of sustainable practices in rural landscapes. Scaling up can be seen as a process rather than an endpoint. For example, the International Fund for Agricultural Development defines scaling up as "expanding, replicating, adapting, and sustaining successful policies, programs, or projects in geographic space and over time to reach a greater number of rural poor" (Linn et al., 2010). At the recent conference on *Harnessing Ecosystem based Approaches for Food Security and Adaptation to climate change In Africa*[2], participants articulated that there was "no single approach to up-scaling" and highlighted the need to define what scaling up means (IISD, 2013).

The primary emphasis of this study was to investigate TBEAs that are practiced at scale. This focus on widely adopted TBEA practices is justified both to emphasize practices that could have a significant impact on economic development, poverty reduction, and climate resilience, and also because many of the ecosystem benefits of the practices are only realized if practiced at scale. When decisions to adopt new TBEAs or sustain traditional TBEAs are taken by a large number of land managers within a region, these practices can be considered to be at scale. Therefore, scaling up does not only refer to TBEA implementation in terms of its spatial extent, but also if a TBEA is considered a common practice in an area (or in other words, a TBEA that is being used by many land managers or communities). This definition does not require that the TBEA be practiced over a large spatial extent, nor does it expect that the TBEA has become common practice only in recent years. Recognizing that documents under review were likely to be inconsistent in the information they provided, this literature review includes TBEAs described in reviewed documents that are in various stages of scaling up.

Given the absence of commonly used quantitative measures to assess scaling up of TBEAs (e.g., percentage of land area or population engaged in TBEA implementation), the project team did not set quantitative thresholds for 'common practice' (e.g., percentage of communities or households in a landscape), rather they recorded any relevant quantitative information provided in individual documents (for further details, see Annex 2).

Development agencies and investors are interested to know whether there are characteristic scaling up pathways associated with specific types of TBEAs (such as farmer-to-farmer spread

2 http://www.foodsec.aaknet.org/

of Farmer-Managed Natural Regeneration, FMNR, or collective action on tree-growing for watershed protection) as well as whether scaling up processes are context-specific or embedded in larger development processes. For example, scaling up of TBEAs will, in part, depend upon institutional characteristics:

- TBEA practices that are relatively simple, have near-term benefits, and require little institutional support beyond the community may be spread through farmer-to-farmer (or community-to-community) interactions;
- Where traditional tree-growing practices are already known by farmers or communities, they may be resumed, if previously discontinued, or expanded in response to new economic, social or ecological incentives;
- Adoption of practices that involve new tree species or new management techniques (e.g., propagation or harvesting methods) or local cooperation (e.g., nursery establishment or seed-sharing) may be facilitated through advisory services delivered by NGOs, extension services, or companies;
- TBEAs that require significant coordination among actors (e.g., riparian re-vegetation across multiple farms within a landscape), mobilization of group labor (e.g., community rainwater harvesting), or local governance action (e.g., free grazing control, access to tree or forest resources) may be facilitated by NGOs, governments or farmer organizations.

It is also critical to understand the enabling conditions necessary for TBEAs to be implemented at scale. These may include well-established rights to trees and land, local agreements to control land use, or access to credit or advisory services, among other policy reforms which can shift incentives in favor of TBEA implementation. The prices of tree products and inputs relative to crops and purchased inputs as well as availability of local knowledge, capacity, and technical support may also be important factors in scaling up of TBEAs.

Researchers made significant efforts to address these questions in the early 1990s, following the first generation of institutional efforts to promote trees on farms in developing countries. Arnold and Dewees (1993) identified how farmers' incorporation of trees reflected broader patterns of agricultural intensification with trees carefully selected for particular uses and for synergies with crop and livestock production. ICRAF assessed data being collected from 108 agroforestry extension projects around the world to evaluate evidence for farmer adoption and impact and to assess the value of methodologies being applied (Scherr & Muller, 1990; Scherr & Muller, 1991). Five different agroforestry extension approaches were being used (media-based, commodity-based, training-and-visit, farming systems, and community-based), but methodological weaknesses limited conclusions about impacts (Scherr, 1993). Interpreting the adoption process for agroforestry was more complicated than for annual crop technologies, as the initial establishment of new species or systems was more appropriately considered to be a testing and observation phase.

Comparative farm-level field studies of 21 agroforestry extension projects in eight Central America and Caribbean countries, using a common methodology, were able to draw more robust conclusions. Many of the agroforestry systems were profitable at real discount rates of 20 percent or higher. The most successful extension systems offered a broad basket of species and systems from which farmers could choose. Technical assistance had a major positive effect;

subsidized inputs much less. Scarcity of wood products was a key factor in adoption of non-traditional agroforestry. Incremental adoption was much less risky for low-income smallholders and food security issues were more critical. Improved institutions for tree product marketing were a high priority. Social and environmental data were too weak to draw many conclusions (Current, Lutz & Scherr, 1995a; Current, Lutz & Scherr, 1995b). A small number of in-depth historical case studies tracked a more complex set of pathways for changing tree management on farms, mainly reflecting resource pressures, market incentives, and institutional development (e.g., Dewees, 1989; Scherr, 1992). Overall, however, a large review of socio-economic research in agroforestry and survey of experts concluded that the most important gap in knowledge was about adoption behavior and the second most important the lack of economic and modeling tools (Mercer & Miller, 1998).

This report focuses on literature documenting experience in adoption and continued practice of agroforestry and other TBEAs since the late 1990s, with an emphasis on TBEAs present at scale or scaling up. While all the 21 projects in the Central American study cited above together reached only just over 50,000 households and emphasized newly introduced practices and species, many of the systems documented since then are being practiced across hundreds of thousands or millions of hectares, and include traditional practices that have been adapted as farming systems have evolved.

Objectives of the Study

This report reviews technical and socio-ecological knowledge about TBEAs around the world to inform the design of programs and investments that seek to scale up proven TBEAs. Through a targeted literature review, this report aims to address four key questions and challenges development actors and investors are currently facing:

1. What types of TBEAs (practices, tree species) are land managers actually adopting and why? What TBEAs are being implemented at scale or are expanding in scale?
2. What impacts have different types of TBEAs had on food security, climate change resilience and mitigation, and income? Under what conditions?
3. What are the drivers and facilitating factors for scaling up TBEAs?
4. How are TBEAs contributing to multi-objective landscape-scale management strategies?

By synthesizing what has been reported in the literature about TBEAs in the process of scaling up in specific sites around the world, this report lays the groundwork for analysis in subsequent phases of work. The study compares TBEA implementation across landscapes and outlines the range of indicators that have been used to document impacts.

2. METHODS

The project team conducted a targeted review of published, peer-reviewed, and informal literature and project documents that described TBEAs in different stages of being scaled up (see Annex 2 for more detailed description of study methods).

Literature Search

Three approaches were used to identify documents to be considered for the literature review (note that no 'cut-off' dates were applied):

1. Peer-reviewed scientific literature. A Web of Knowledge search was conducted with a predetermined set of key terms designed to capture a broad range of agroforestry and multi-objective forestry practices (see Annex 1) combined with "food security" OR ("climate change" AND ("resilience" OR "adaptation")) OR "carbon stock" OR "carbon sequestration") in either their title, abstract or key words, resulting in 498 papers. To ensure the papers included management practices, we added the search criteria "decision making" OR "driver" OR "benefit" OR "scal* up" OR "impact" OR "adoption" which left us with a set of papers that would most likely be relevant for our study.
2. Internet search for grey literature. A similar search for publications was conducted using Google Scholar, university libraries, websites of project partners, and other relevant institutions.
3. Network-based search for unpublished documents. Project partners provided direct access to unpublished reports and made connections to key contacts, which were solicited for relevant unpublished reports (e.g., project reports and evaluations).

Based on initial scans, documents were included in the review if they described:

1. A specific site where a TBEA is practiced by land managers (i.e., not just in a research center) and at least one type of impact of TBEA implementation.
2. Tree-based systems that embodied an in situ ecosystem approach (i.e., managed to support the delivery of multiple objectives and ecosystem services);
3. TBEAs that are practiced at scale or are in the process of scaling up (operationally defined as commonly practiced in an area, i.e., used by many land managers or communities).

Literature Review

Analysis of information gathered in the literature review template was focused on the following major topics (see Annex 3 for a full list of information gathered through document review):

- The characteristics of TBEAs including their biophysical and social context;
- The geographic extent and level of TBEA adoption;
- The contributions of TBEAs to food security, climate change resilience, carbon sequestration, and income;
- Drivers of implementation and maintenance of TBEAs; and
- Examination and description of methods used in reviewed document to ascertain the robustness of the evidence and suitability of studies.

In implementing the literature review, the project team strove to discover all relevant sources of information while recognizing that multiple advisors had indicated that the information base was likely to be patchy.

3. DESCRIPTION OF TBEA SITES AND PRACTICES

Outcome of Literature Search

The number of papers that resulting from the original Web of Knowledge search for our listed TBEAs was 13,335, and indeed the total number of search results for agroforestry adoption was 1203. We thus restricted the search to papers that included one of the agroforestry and multi-objective forestry practices listed in Annex 1 along with the other key terms identified in Section 2 which left us with a set of papers that would most likely be relevant for our study.

After reviewing the 242 documents that were identified through the three literature search methods, 93 documents were determined to be relevant for this study based on the inclusion criteria (see Section 2). Application of these criteria resulted in exclusion of 149 documents from further review.[3] The 93 documents included in the review describe 111 different sites, ranging in size from communities to watersheds to countries to multi-country regions, (see Annex 4), as 8 documents report on multiple TBEA sites. The 93 reviewed documents:

- Include 70 peer-reviewed journal articles, 6 unpublished reports, 6 published reports, 3 masters theses, 2 PhD theses, 2 conference proceedings, 3 book chapters, and 1 technical note;
- Are generally recently written, with over 50% (56) of the documents produced after 2010 (note that no date limits were applied in any of the three literature search methods);
- Are all in English except for one French and one Spanish publication;
- Are produced by a variety of different organizations; in most cases the first author was affiliated with an academic institute (47 documents) or an NGO (39); first authors of 6 documents were affiliated with a governmental organization and 2 with bi-lateral donors.

The goal of this focused literature review was to understand the body of existing peer-reviewed and grey literature that report drivers and mechanisms for scaling up TBEAs, as well as provide measured impacts specifically on food security, carbon sequestration, climate change resilience and income generation. The motivation for conducting such a focused review was to inform the design of supportive programs and investments based on documented impacts and drivers for scaling up in specific contexts and TBEAs. Given the variety of entry points for analysis on TBEA, there are likely many other studies that would inform these issues, but these would require additional specialized literature searches.

3 Documents were excluded for the following reasons: i) 71 documents did not describe a TBEA; ii) 28 documents did not describe TBEAs at a specific site (e.g., an overview of TBEA types); iii) 16 documents described TBEAs that were clearly not in the process of scaling up (i.e., study plots in research centers); iv) 8 documents did not describe any TBEA impacts or drivers for scaling up (i.e., solely TBEA technical descriptions); v) 7 documents addressed only the potential for TBEA implementation rather than actual evidence from implementation (i.e., scenario studies); and vi) 6 documents described impacts that were not under investigation in this literature review (e.g., biodiversity benefits were not a component of this literature review).

This report presents information about 111 sites that has been extracted from the 93 documents that met criteria for inclusion. Findings reflect the available evidence in peer-reviewed and gray literature, but they likely do not represent the full range of TBEAs as they are actually practiced in different regions around the world, and should be interpreted accordingly. (See discussion in Section 6 of types of possible bias in the available literature.)

TBEA Sites

The 111 sites included in our review described locations in 53 countries where TBEAs are being practiced, with particularly strong representation of African areas (56 sites) followed by Asia (26), Latin-America (22), Australia/Oceania (3), Europe (2), and US/Canada (2). Of the 111 TBEA sites, 70 are located in 10 countries (Table 1). Most of the documents describing TBEAs in Malawi, Cameroon, and Zambia were produced by ICRAF and USAID. Most TBEA sites are located in the humid, semi-arid and tropical zones.

The majority of documents describe TBEA sites and impacts on a sub-national administrative level (region, province, or district such as Chiapas, Mexico) or in a specific landscape as reported by the authors (e.g., the Silica plateau in Slovakia) (Table 2). Of the 16 larger scale sites (country or multi-country regions such as multiple Sahel countries), 14 are located in sub-Saharan Africa. These different spatial levels indicate strong variation in the extent of study areas.

Table 1. Number of sites and types of TBEA practices described in reviewed documents for the 14 countries where 70 of 111 TBEA sites are located.

Country	No. of Sites	TBEA practices
Zambia	9	Conservation agriculture with tree, evergreen agriculture, fertilizer trees, improved fallows, fodder banks
Cameroon	8	Fertilizer trees, forest garden, improved fallows, participatory tree domestication
Malawi	8	Fertilizer trees, improved fallows, intercropping, fodder banks
Niger	7	Natural regeneration, parkland agroforestry
Indonesia	6	Hutan Kamasyarakatan (social forestry), social forestry, multi-strata agroforestry, natural regeneration, rubber agroforestry
Philippines	5	Agrosilviculture, hedgerows, silviculture
India	4	Hedgerows, homegarden, homegarden with bamboo
Costa Rica	4	Banana/coffee agroforestry, trees in farmland, coffee agroforestry, agrosilvopastoralism
Mexico	4	Coffee agroforestry, community-based forestry management, Taungya agroforestry, silvopastoralism
Argentina	3	Silvopastoralism
Kenya	3	Coffee agroforestry, fodder banks, improved fallows
Ethiopia	3	Fertilizer trees, natural regeneration, wood lots
Brazil	3	Coffee agroforestry, silvopastoralism
Mali	3	Live fencing, parkland agroforestry, silviculture

Table 2. Spatial level of the described TBEA sites.	
Study site level	**Number of sites**
Community/town	2
Multiple communities	9
Landscape	20
Watershed	7
Sub-national administrative unit	57
Country	10
Multiple country region	6
Total	**111**

Site Descriptions

Farm size is an important indicator of the socio-economic status of an area. Information on farm size was provided for half of documented TBEA sites. For the 46 sites that report it, the median reported farm size is quite small, ranging from less than a hectare to five hectares. A few exceptions were reported with farms over 100 hectares (large extensive livestock farms, commercial banana production).

Subsistence farming (arable, livestock or mixed) was the main agricultural activity described for the TBEA sites included in the literature review (Table 3). In only four of the documented sites was commercial cash crop farming the main agricultural activity; 12 sites had commercial livestock production. Note that nearly half of the publications included in this review were written by NGOs and donors focusing on poverty alleviation.

Table 3. Typers of farming systems at TBEA sites.	
Farming system type	**No. of sites per system**
Crop	
Cash	4
Mixed cash & subsistence	9
Subsistence	6
Not reported	5
Livestock	
Subsistence	1
Not reported	12
Horticulture	
Mixed cash & subsistence	1
Not reported	1
Crop & livestock	
Mixed cash & subsistence	9
Subsistence	22
Not reported	7

Table 3 continued. Types of farming systems at TBEA sites.	
Farming system type	**No. of sites per system**
Crop, livestock & horticulture	
Subsistence	1
Not reported	1
Forestry & crop	
Mixed cash & subsistence	1
Forestry & horticulture	
Not reported	1
Farming system not reported	
Subsistence	8
Not reported	22
Total	**111**

Information about specific socio-economic conditions is absent for three-quarters of the documented TBEA sites. Of the 26 sites that provide relevant information, 15 describe TBEA implementation occurring in an area where a large percentage of the population lives below the poverty line, for example the Humbo region in Ethiopia (Box 1).

Box 1. Rapid impacts through farmer-managed natural regeneration in Humbo, Ethiopia (Brown et al., 2011)

The Humbo Community-based Natural Regeneration Project began in 2006 with the aim of rehabilitating the Humbo region's severely degraded lands and preventing further soil erosion, flooding, and biodiversity loss. The Australian and Ethiopian units of World Vision identified forestry-based carbon sequestration as a potential means to stimulate community development while engaging in environmental restoration. Before the project began, more than 85% of Humbo's population of nearly 50,000 people were living in poverty. Many factors including a lack of forest user rights, unsupportive policies, and increasing demands on land for agriculture and firewood were exacerbating deforestation. Through the project, farmers have been able to gain income from temporary certified emissions reduction credits under the Clean Development Mechanism by implementing farmer-managed natural regeneration (FMNR) practices on more than 2,700 hectares of degraded forestland.

Beyond training farmers in FMNR practices, the Humbo Community-based Natural Regeneration Project targeted activities toward the drivers of deforestation by helping to establish user rights to forested areas and supporting the formation of community cooperatives. Within three years, project activities had helped to transform the Humbo area. Communities were able to harvest fodder and firewood within a year of project initiation and wild fruits and other non-timber forest products within three years. By 2009, a variety of regenerated native trees were 2-5 meters in height and other areas where natural regeneration was not feasible have been replanted with high tree survival rates. It is expected that the project will generate more than US$700,000 in carbon offset credit revenue from the 165,000 tCO_2 sequestered during a ten year period. More rigorous monitoring is currently underway to more rigorously document the impact of FMNR, but already local residents report significant decreases in erosion and flooding on their land.

TBEA Practices

Even though a mix of TBEAs are often practiced in an area, the majority of documents report on only one TBEA type per site with only 9 sites reporting two different TBEA practices and 11 sites reporting three different TBEA practices (see Annex 5). Forty different TBEA practices were reported across the 111 TBEA sites in the literature review. We grouped these practices in five general categories: trees in croplands (17 different TBEAs), trees in grasslands (7 different TBEAs), forest-based systems (8 different TBEAs), complex multi-strata agroforestry (4 different TBEAs, see also Box 2), and homegardens (4 different TBEAs) (Table 4). In total, 220 unique tree or woody species or genera were described in the 93 reviewed documents (see Annex 7). Most variation in TBEA practices was found when trees were combined with crop production, often maize, sorghum, or millet.

Table 4. 40 different TBEAs identified in the literature review, grouped into five general categories.

TBEA category	TBEA practices identified
Trees in croplands	Agroforestry, Allanblackia, boundary planting, conservation agriculture with trees, evergreen agriculture, fertilizer trees, fodder banks, fuelwood production on farmland, gum-arabic agroforestry, hedgerows, improved fallows, live fencing, natural regeneration, Quesungual agroforestry, silvopastoralism, Taungya agroforestry, trees in farmland
Trees in grasslands	Agrosilvopastoralism, fodder banks, hedgerows, Ngitili, parkland agroforestry, shelterbelts, silvopastoralism
Forest-based systems	Afforestation/reforestation, agrosilviculture, community-based forestry management, Hutan Kamasyarakatan (social forestry), participatory tree domestication, silviculture, trees on sloping lands, afforestation
Complex multi-strata agroforestry	Banana/coffee agroforestry, coffee agroforestry, multi-strata agroforestry, rubber agroforestry
Homegardens	Forest garden, homegarden, homegarden with bamboo, smallholder fruit production

4. ADOPTION AND SCALING OF TBEAS

TBEA Extent

Information about the extent of TBEAs in hectares is not commonly provided with quantification of TBEA extent reported for only 33 of the 111 TBEA sites. Reported TBEAs cover a wide range of areal extents (Table 5). Several documents describe TBEAs that cover several millions of hectares over multiple sites including natural regeneration and parkland agroforestry in Niger, trees on sloping lands including afforestation in China, and rubber agroforestry in Indonesia. Instead of reporting the extent in hectares, some documents report on extent in qualitative terms: 22 site descriptions reported the extent of a TBEA as "widespread" (including silvopastoralism, natural regeneration, and coffee agroforestry), 9 as "common" (including fertilizer trees and gum-arabic agroforestry), and 5 as "rare" (including improved fallow and Taungya agroforestry). Note that qualitative descriptions are not comparable across different sites.

A mixed coffee agroforestry system in El Plan, Masaguara, August, 2013. Photo courtesy of Trees for the Future.

Box 2. Multiple uses of traditional coffee agroforestry support economic resilience of smallholder farmers in Guatemala and Kenya (Schmitt-Harsh et al., 2012 and Sibelet et al., 2012)

In the Atitlán region of Guatemala, smallholder coffee agroforestry exists within a mosaic of agriculture, tropical dry forest, and pasture. Although the area under coffee agroforestry is relatively small, approximately 500 ha across the landscape, these multi-strata forests provide many services to farmers including income from coffee, erosion control, and production of timber and other non-timber forest products. Despite recent pressures to convert coffee agroforests to sun coffee, such as increased presence of leaf rust and economic incentives favoring coffee monocultures, farmers in Atitlán continue growing coffee in complex poly-cultures. There is currently no widespread policy incentive encouraging the maintenance of shade trees for the benefit of carbon sequestration. In facilitation of such incentives, an understanding of the capacity of coffee agroforests to store carbon is developed. Recently, a number of studies have documented the importance of carbon storage in coffee agroforests with average above and below ground stocks of more than 120 MgC per ha.

Similarly, members of coffee cooperatives in the Mt. Kenya region of western Kenya have maintained coffee agroforests despite significant changes in the international coffee market and economic incentives to abandon coffee farming. While the market value of coffee remains low, the practice of coffee agroforestry, and associated membership in a cooperative, generates a range of benefits to farmers including improved food security, access to cash income, and employment through the cooperative, as well as access to inputs and schools for their children. As a result, coffee farmers in the region were found to be more resilient to the dynamics of the international coffee market than many of their counterparts around the world.

Table 5. Areal extent reported for 33 sites, where reported.		
TBEA practice	**Location site**	**Extent (ha)**
Afforestation/reforestation	Vietnam	24
Agroforestry	Burkina Faso	250,000
	Mozambique	20,000
Agrosilviculture	Nepal	116,000
Coffee agroforestry	Brazil	19
Community-based forestry management	Tanzania	464,474
Conservation agriculture with trees	Zambia	300,000
Evergreen agriculture	Zambia	240,000
Fertilizer trees	Zambia	13,300
Hedgerows	Philippines	1,820
Hutan Kamasyarakatan, social forestry	Indonesia	50,644
Mosaic landscape with trees	Slovakia	1,500
Natural regeneration	Australia	490,000
	Burkina Faso	250,000
	Ethiopia	2,728
	Indonesia	13
	Niger	4,800,000
		5,000,000
	Niger, Burkina Faso, Mali, Senegal	5,000,000
	Senegal	9,124
Ngitili	Tanzania	377,756
Parkland agroforestry	Niger	5,000,000
Quesungual agroforestry	Honduras	7,000
Rubber agroforestry	Indonesia	2,800,000
Shelterbelts	New Zealand	119
Silviculture	Thailand	480,000
Silvopastoralism	Argentina	20,000
		68,500
	Colombia	2,000
	Nicaragua	588
	Uruguay	500,000
Trees on sloping lands, afforestation	China	5,000,000
		9,000,000

TBEA Adoption

Eleven different quantitative indicators of TBEA adoption level are reported across 53 TBEA sites (Table 6). Quantitative estimates of TBEA adoption were absent for 58 sites. For 24 of these 58 sites, a qualitative description of the adoption level was provided; TBEAs at 29 sites are described as commonly practiced, primarily fertilizer trees and natural regeneration.

Table 6. Number of sites for which different indicators of TBEA adoption were reported.	
Indicator of TBEA adoption	**Number of sites**
% beneficiaries	1
% farmers	8
% population	1
% villages	1
# farmers/households	29
# increase farms	1
# nurseries	3
# people	5
# selected farms	2
# trees	1
# villages	1
not reported	58
Total	**111**

There are 11 sites for which adoption levels were reported as a percentage of a target group (i.e., beneficiaries, farmers, population, villages), for 9 different TBEA types (Table 7). If estimates of percent adoption were available for a greater number of sites, this would enable cross-site comparison of adoption of specific TBEA types.

Table 7. Reported adoption levels of TBEAs at 11 sites measured, in percentages.			
TBEA practice or system	**Unit**	**% level adoption**	**Within**
Homegarden	% farmers	100	Cam My landscape, Vietnam
Fertilizer trees	% targeted farmers	92	Malawi
Coffee agroforestry	% farmers	78	Karatina, Kangema and Emba regions, Kenya
Agroforestry	% farmers	75	Communities surrounding Gorongosa National Park, Mozambique
Social forestry (Hutan Kamasyarakatan)	% villages	72	Sumberjaya watershed , Indonesia
Improved fallow	% farmers	67	Eastern-Zambia
Afforestation/reforestation Clean Development Mechanism	% farmers	47	Community in the Cao Phong District, Vietnam
	% farmers	28	Kabale region, Uganda
Natural regeneration	% farmers	26	Maradi region, Niger
Hedgerows based on natural vegetative strips (NVS)	% farmers	22	Claveria, Lantapan region, Philippines
	% population	21	Zambia

Box 3. Examples of TBEA Adoption at Scale in Malawi and Kenya

Fertilizer trees in Malawi have a high reported adoption level at 92% of targeted farmers (Table 7). Reported drivers for adoption include improvement in household nutrition, reduced access to fertilizer, low cost of implementation, and cultural familiarity / traditional practice with some fertilizer tree species. Tree planting commenced in 2007 and facilitation by the international NGO the World Agroforestry Centre was described as a key mechanism (Center for Independent Evaluations, 2011)

In the three regions around Mt Kenya, 78% of coffee farmers were reported to be practicing coffee or multi-strata TBEAs through diversification with edible tree species These TBEAs have been practiced traditionally, but were re-introduced after the collapse of coffee prices a decade ago. Identified drivers include the need for risk diversification, improved household nutrition, and improved soil quality. Adoption was catalyzed by national policy changes (i.e., reversal of colonial agricultural policies to facilitate larger land holding by African families) and individual decision-making. These TBEAs were reported to have positive impacts on income and food security and no negative impacts were reported. The establishment of cooperatives was named as a success factor (see Box 2).

Relying on explicit descriptions of TBEA adoption and extent found in the reviewed documents, and based on document authors' specific wording, we considered 45 of the 111 sites to be fully at scale. The TBEAs most frequently reported as practiced at scale were: i) natural regeneration practices, all in Africa (6), ii) fertilizer trees, all in Africa (5), iii) silvopastoral practices in Latin-America and Europe (4), and iv) homegardens, all reported in Asia (4). For 41 sites, TBEAs were not considered to be fully scaled up and for 25 sites the assessment of whether the TBEA was practiced at scale could not be made based on the reported information. Of the 45 sites where TBEAs were determined to be practiced at scale, 21 sites had TBEAs that were described as historically present (over 100 years) such as agrosilvopastoralism in Latin America. For another 19 sites, TBEAs were reported to have scaled up recently (<10 years); 7 of these TBEAs were natural regeneration and planting of fertilizer tree practices (4 and 3 respectively) in African sites.

We were not able to evaluate the level of scaling up based on reported TBEA extent because the extent of TBEA implementation needs to be considered relative to the total studied area, which was only reported for only a few sites (e.g., does 120 ha indicate a widespread uptake in an area?) It was also often unclear how much land could potentially support implementation of a given TBEA.

Drivers and Mechanisms of TBEA Implementation and Maintenance

This review examined the underlying causes and processes that drive land managers, institutions, and governments to implement and maintain TBEAs as well as the mechanisms that support implementation (e.g., national legislation or incentive programs). The majority of documents reviewed (92%) report one or more drivers and multiple drivers were identified for 68% of TBEA sites (Box 3 and Box 4). These drivers ranged from new market or income generating opportunities available by implementing a TBEA to traditional practices that play important roles in the lives of the people in the site. The most commonly reported drivers for TBEA implementation or maintenance were: i) soil degradation/quality issues, ii) desire to increase income, and iii) the need to produce food and fodder for subsistence (Table 8). Seven drivers – improving soil quality, income generation, food and fiber supply, household nutrition, nature conservation and adoption to climate change – are reported as sole reasons for TBEA implementation. Other drivers such as shade provision and incentives were only reported when there was an additional reason for TBEA implementation (Table 8).

Table 8. Frequency of reporting of different drivers for implementation or maintenance of TBEAs (Note: the second column does not equal 111 as up to three drivers were reported per site; also not all reviewed documents reported on TBEA drivers).

Driver	**No. of sites for which this driver is reported**	**No. of times this driver is reported in combination with other drivers**
Improve or maintain soil quality	47	38
Respond to a market opportunity, or income generation	47	40
Meet demand for food, fodder, fuel, and other ecosystem services	31	27
Improve household nutrition	15	14
Avoid or decrease input costs or labor	10	10
Increase yield	9	9
Preserve environment or biodiversity	9	7
Risk avoidance or diversification	1	1
Traditional practice	7	5
Policies and incentives	6	6
Adaptation to climate change	5	4
Increased knowledge and technology	5	5
Reduced fertilizer access	5	5
Climate change mitigation	1	1
Provide shade and shelter	7	7

In many cases, reported drivers also point to the role of TBEAs in supporting multiple functions. For instance, the integration of trees into conservation agriculture systems in Zambia was reported to be driven simultaneously by reduced access to fertilizer, increasing land degradation, and rising input costs. In Argentina, silvopastoralism was recently scaled up to cover more than 40,000 hectares in the departments of Misiones and Corrientes, driven by risk avoidance, new market opportunities and increasing demand for shade for cattle. Although farmers across the landscape report similar drivers, this TBEA was described as adapted to meet different ecological and market niches.

Most of the information reported in reviewed documents regarding drivers for TBEAs was obtained by the authors through literature or their common understanding of the area. In 37 sites, the drivers were identified through interviews or surveys conducted by the study authors or based on local knowledge. The majority of reviewed documents described one or more

Box 4. The evolution of TBEAs in Dhanusha, Nepal (Dhakal et al. 2012)

Dhanusha district is part of the terai (low land) region of Nepal. A century ago, this region, now recognized for its importance to agricultural production, was sparsely populated and completely covered in forests. In the mid-1900s, pressure from the region's growing population and agricultural subsidies drove the clearing of large areas of forest for production of basic grains. Shortly after, the introduction of new agricultural technologies including fertilizer and irrigation allowed for further agricultural development. However, the same technologies also allowed farmers to diversify production from staple crops, to intercrop cash crops with staples, and to set aside land for livestock production. More recently, roads and infrastructure allowed farmers access new markets for a wide variety of agricultural products including many tree crops. To take advantage of these new market opportunities, farmers further diversified their production systems. Now, a range of TBEAs are practices in the region including forestry-based production systems and silvopastoral and crop-based agroforestry systems.

Although the spread of TBEAs has occurred mainly through farmer-to-farmer extension, institutions and national programs, such as the Terai Private Forest Development Association and the Saganarth Forestry Development Project, have played key roles in supporting farmers to implement TBEAs, especially during the 1980s and 1990s. At the same time, national policies have been at cross purposes with TBEA implementation, for example, agricultural crops are exempt from taxation while tree crops remain subject to taxation. However, market drivers are currently providing a strong enough incentive for producers to continue practicing a variety of TBEAs in the district.

Rice terraces with trees in an integrated hillside farming system in Nepal. Photo courtesy of Sajal Sthapit, EcoAgriculture Partners.

mechanisms for TBEA implementation (83 of 111 sites). Interventions of international NGOs were most often reported as the main mechanism for TBEA implementation (Table 9, see also Box 5).

Table 9. Number of sites for which different mechanisms for TBEA adoption were reported (see Section 5 for discussion of potential bias in available literature). Multiple mechanisms drove implementation in several sites.

Mechanism	**No. of TBEA sites**
International NGO	48
National policy	14
Individual decision	13
National extension	11
Research site	12
Local stakeholder collaboration	11
Private sector promotion	4
Charismatic leaders	2
Bilateral door	1
External payment schemes	3
Farmer-to-farmer training	2
Traditional practice	2
Local policies	1
International policy	1
Not reported	28

Rubber and cassava intercropping in Cambodia. Photo courtesy of Neil Palmer/CIAT.

While Table 9 reports very few cases where private sector promotion was an important direct institutional mechanism, almost certainly private market institutions were instrumental in cases where commercialization was a driver. Income generation is one of the main driving factors for TBEA implementation or maintenance; in many cases this refers to selling produce on the local market (e.g. see Box 4).

Similarly to the 83 sites for which a mechanism was described, for the 48 sites where international NGOs were reported as a primary institutional mechanism, the most common drivers were related to soil quality, income, and fodder and food demand (Table 10). Local (individual or collaborative) implementation mechanisms were often reported as driven by the need to improve soil quality, income generation, and household nutrition.

Drivers of TBEA adoption (large scale uptake of a practice) were reported for 6 of the 19 sites for which TBEAs were reported to have scaled up recently (<10 years) (Table 11). These drivers typically reflect processes that occur over a larger area, not just on a single farm.

Table 10. Number of sites for which different drivers of TBEA adoption were reported, for the 48 sites where international NGOs were reported as a primary mechanism for TBEA implementation.	
Driver for implementation	**No. of sites where driver was present**
Improve or maintain soil quality	29
Market or income generating opportunity	17
Meet fodder demand	9
Meet food demand	6
Avoiding input costs	4
Conserve environment or biodiversity	4
Improve household nutrition	4
Increase yield	4
Meet fuel wood demand	4
Increased knowledge and technology	2
Meet forest products & ecosystem services demand	2
Policies and incentives	2
Reduced fertilizer access	1
Reduced risk of forest fire	1

Table 11. Reported reasons for adoption of TBEAs that were recently (<10 years) taken to scale.
Fodder banks
Higher education level, greater degree of commercialization of dairy enterprise, improved perception of Calliandra, receipt of extension services, participation in on-farm trials (multi-country region including Kenya, Uganda, Tanzania, Rwanda)
Homegardens
Need for access to food in post-conflict times (Sri Lanka)
Natural regeneration
Improved access to markets, economic and other benefits, availability of a viable production technology that is available and known to farmers, access to sufficient areas of land with security of tenure, control risks, such as fire, pests and theft. (Ethiopia)
Appropriate soil type, market access, higher levels of education, greater income, larger stock of assets (Niger)
Participatory tree domestication
Economic incentives, extension focus on people not on forest (Pakistan)
Trees on sloping lands, afforestation
Access to sufficient fertile land apart from land to be converted to forest, households cultivating marginal lands (compensation better than production), households without children or extra labor, lack of livestock/animal husbandry (serious drawbacks to converting land needed for fodder) (China)

5. IMPACTS OF TBEA IMPLEMENTATION

This section of the review assesses available information regarding impacts associated with TBEAs on food security, climate change resilience, carbon sequestration, and income. Where available, information is presented on impacts related to income and also negative impacts and success or limiting factors. This section also evaluates the robustness of evidence (methods and measurements) gathered from the reviewed documents with attention to the methods used for determining TBEA impacts.

Positive and Negative Impacts

Of all documents that reported on impacts, all reported positive contributions of TBEAs on one or more evaluation criteria. Mixed positive and negative impacts of a TBEA on income and carbon sequestration were reported for only 6 sites. These included unequal benefit sharing for smallholders; negative impacts (e.g., production, carbon sequestration) coupled with positive impacts (e.g., income or food security); and displacement of important land uses or economic activities (with potential for reduced income or deforestation). Only one study reported a negative impact of a silvopastoral system on income.

Figure 4. Conservation agriculture with Faidherbia albida. Photo courtesy of Charlie Pye-Smith/ICRAF

Box 6. TBEAs impacting food security, income and carbon sequestration in the Sahel (Reij et al. 2009, Brown et al., 2011)

Natural regeneration and parkland agroforestry in Niger and Humbo, Ethiopia (Box 1) were the only TBEAs for which positive impacts were reported for at least three elements: food security, carbon sequestration, and income. In Niger, natural regeneration was reported to have increased annual cereal production by more than 500,000 tons and annual household income by approximately US$200 as well as sequestering between 100-200 Mt CO2-equivalent across the country. In Ethiopia, farmer-managed natural regeneration practices were found to have positive impacts on fruit production, while sequestering more than 165 Mt CO2 in the first decade, which is expected to generate more than US$700,000 in carbon payments to farmers.

Indicators of TBEA Impacts

In the reviewed documents, a very large variety of indicators were used to report on the impacts of TBEAs, making a quantitative comparison between studies challenging. Impacts of TBEA implementation were reported for 68 sites using seven different types of income indicators, for 42 sites using five different types of food security indicators, for 25 sites using four different types of carbon sequestration indicators, and for 12 sites using seven different types of climate resilience indicators (Table 12).

Table 12. Number of sites for which impact was reported and types of impact indicators used, for each major category of TBEA impact.

Category of input	No. of sites	Types of impact indicators used
Income	68	Estimated cash or non-cash income, value of assets, net profit, payment schemes, reduced production costs, reduced risks, income distribution
Food security	42	Production or yield, dietary consumption and diversity, food deficit, level of self-sufficiency, access to resources
Carbon sequestration	25	Above and below ground biomass, carbon stocks over a given area, emissions or sequestration rates, change in soil erosion
Climate change resilience	12	Flexible and diverse food production/ availability, water availability and retention, climatological variation, land cover/ biomass, GHG flux, pest infestation, crop-water productivity

Methods for Assessing Impacts

The reviewed documents assessed impacts of TBEA implementation using diverse methods: i) interviews / surveys / participatory appraisals (PRA) with stakeholders, ii) on-site field measurements, iii) review of literature, iv) interpretations and assessment by scientists, and v) modeling of impact based on biophysical, economic or statistical models. For example, to evaluate the impact of participatory forest management in two Angai villages in Tanzania, Mustalahti et al. (2012) used a variety of methods for gathering local knowledge including key informant interviews and participatory rural appraisal methods including focus group discussions, transect walks, and ranking and scenario exercises. Haglund et al. (2011) conducted structured surveys with program participants and non-participants to measure the impact of farmer-managed natural regeneration on food security and income.

For 44 of the 62 assessments of food security impacts of TBEA implementation, interviews, surveys, or participatory appraisals were used (Table 13, note that studies commonly reported on multiple indicators and assessment methods). Most food security impact assessment indicators (15 out of 62) directly related to yield increases. Positive impacts on food security were reported for 49 of 62 assessments. The choice of impact assessment method and related indicators typically depended on the size of the studied area. For example, all of the documents that reported use of interviews described implementation of TBEAs at landscape and sub-national level; these documents assessed TBEA impacts using specific food security indicators (access, self-sufficiency). Documents that described implementation of TBEAs at national-scale relied on agricultural production statistics to assess TBEA impact on food security. This difference in level of detail of impact assessment and study area was also observed for impact assessment of climate change resilience, carbon sequestration, and income.

*Table 13. Number of **food security** impact assessments, by category of measurement method, and then by indicator, with the reported direction of impact.*

	Direction of measured impact			
Measurement method and impact indicators	**Positive**	**Neutral**	**Unclear**	**Total**
Field measurements	**4**		**2**	**6**
Production efficiency	1			1
Dietary consumption & diversity	1			1
Food deficit			1	1
Production/ yield increase	2		1	3
Interviews/surveys/PRA	**33**	**10**	**1**	**44**
Coping strategy index	1			1
Farmer perception	1			1
Income	1			1
Indicator not reported	2			2
Relative importance value crop	1			1
Access to resources	2			2
Self-sufficiency	3		1	4
Dietary consumption & diversity	8	4		12
Food deficit	5	2		7
Production/ yield increase	9	4		13
Literature	**5**			**5**
Production/ yield increase	5			5
Scientific expert knowledge	**1**			**1**
Production/ yield increase	1			1
Means of measure not reported	**6**			**6**
Self-sufficiency	1			1
Dietary consumption & diversity	1			1
Production/ yield increase	4			4
Total	**49**	**10**	**3**	**62**

For 12 of the 24 assessments for climate change resilience impacts of TBEA implementation, labor-intensive field measurements were used (Table 14). All sites with impact assessments were those that reported on a sub-national level. Climate change resilience impact indicators were quite diverse: ten different types of indicators were reported; seven of the 24 impact assessments directly related to food production/availability and six directly related to water. All studies that reported on climate change resilience described a positive TBEA impact.

*Table 14. Number of **climate change resilience** impact assessments, by category of measurement method, and then by indicator, with the reported direction of impact.*			
	Direction of measured impact		
Means of measure and specific indicators	**Positive**	**Not reported**	**Total**
Field measurements	**12**		**12**
Crop-water productivity	1		1
GHG flux	1		1
Humidity	1		1
Pest infestation	1		1
Solar incidence	1		1
Water availability	4		4
Flexible and diverse food production/ availability	1		1
Temperature variation	2		2
Interviews/surveys/PRA	**1**		**1**
Flexible and diverse food production/ availability	1		1
Scientific expert knowledge	**4**		**4**
Not reported	1		1
Flexible and diverse food production/ availability	1		1
Biomass/ land cover	2		2
Means of measure not reported	**6**	**1**	**7**
Income	1		1
Water retention	1		1
Wind velocity	1		1
Flexible and diverse food production/ availability	2	1	3
Temperature variation	1		1
Total	**23**	**1**	**24**

Fourteen of the 30 assessments of carbon sequestration impacts of TBEA implementation were based on field measurements of biomass/carbon (Table 15). Focus was on carbon stocks rather than on sequestration: most carbon sequestration impact indicators (16 out of 30) specifically assessed amount of carbon stored per hectare; an additional three assessed other measures of carbon stocks. Biomass was measured 6 out of 30 times. Positive impacts on carbon sequestration were reported for 27 of the 30 assessed indicators (Box 7).

*Table 15. Number of **carbon sequestration** impact assessments, by category of measurement method, and then by indicator, with the reported direction of impact.*					
	Direction of measured impact				
Means of measure and specific indicators	**Positive**	**Both positive and negative**	**Unclear**	**Not reported**	**Total**
Field measurements	**13**			**1**	**14**
Tons C/ha/yr				1	1
Biomass	3				3
Mg C/ha or ton C/ha	8				8

*Table 15 continued. Number of **carbon sequestration** impact assessments, by category of measurement method, and then by indicator, with the reported direction of impact.*					
	Direction of measured impact				
Means of measure and specific indicators	**Positive**	**Both positive and negative**	**Unclear**	**Not reported**	**Total**
Soil carbon	1				1
TOC g/kg	1				1
Process modeling	**2**		**1**		**3**
Mg C/ha or ton C/ha	1		1		2
Tons AGB/ha	1				1
Scientific expert knowledge	**5**				**5**
Biomass	2				2
Mg C/ha or ton C/ha	1				1
Indicator not reported	2				2
Means of measure not reported	**7**	**1**			**8**
Carbon stocks	1				1
Methane sequestration	1				1
Mg C/ha or ton C/ha	4	1			5
Reduced soil erosion	1				1
Total	**27**	**1**	**1**	**1**	**30**

For 65 of the 107 assessments of income impacts of TBEA implementation interviews, surveys or participatory appraisals were used (Table 16). Income impact indicators were quite diverse: twenty-one different types of indicators were reported. Impact assessment was most frequently described simply as income (37 times) or as net profit; the next most common indicators related to yield and payment schemes. Positive impacts on income were reported for 90 of 107 assessments, while negative impacts were reported at 8 (in combination with reported positive impacts at all but one of these sites).

Figure 5. Non-timber forest products, in this case pine sap in Halimun Salak, Java, Indonesia are important features of some types of TBEAs. Photo courtesy of CIFOR.

Box 7. Comparing carbon sequestration potential of three TBEAs in the Sahel (Takimoto et al., 2008)

In the Sahel, a variety of TBEAs have potential to increase carbon sequestration and improve income generation through carbon markets. Takimoto et al. (2008) studied the economic benefits and risks for producers in the Ségou region of Mali who might access carbon markets by generating newly sequestered carbon through implementation of improved agroforestry practices, specifically live fences and fodder banks. These two systems were compared with traditional parkland agroforestry, a system which is currently storing large amounts of carbon, but is ineligible for carbon offset credits since the carbon has already been sequestered (i.e., does not meet "additionality" requirements).

Live fences and fodder banks were both introduced by the World Agroforestry Centre to help combat severe land degradation. Live fencing includes the planting of trees, often fast-growing species with multiple uses, around fields, orchards, or other pieces of land. Fodder banks generally are small blocks of land (50 meters x 50 meters) planted with native or introduced species particularly suited for animal fodder. In contrast to these introduced systems, parkland agroforestry systems with Faidherbia albida and Vitellaria paradoxa are used traditionally by farmers in the region.

Carbon biomass estimation was based on field samples and species-specific allometric equations. Although the traditional parkland agroforestry system has a higher carbon stock compared to the two improved agroforestry systems, fodder banks and live fences, the improved systems were able to sequester additional carbon. In all cases, soil carbon accounted for a large portion of the systems' total carbon stock. Unfortunately, soil carbon is not yet eligible for payments under the Clean Development Mechanism. Therefore, despite the importance of live fences and fodder banks to sustainable land management in the Sahel, these practices are unlikely, at this time, to be rewarded under carbon markets.

*Table 16. Number of **income** impact assessments, by category of measurement method, and then by indicator, with the reported direction of impact.*

	Direction of measured impact					
Means of measure and specific indicators	**Both positive and negative**	**Positive**	**Neutral**	**Negative**	**Unclear**	**Total**
Economic model	**2**	**1**				**3**
Net present value	1					1
Net profit	1					1
Payment scheme		1				1
Field measurements		**6**				**6**
Livestock stocking rates		1				1
Net profit		1				1
Sales		1				1
Yield		2				2
Payment scheme		1				1

*Table 16 continued. Number of **income** impact assessments, by category of measurement method, and then by indicator, with the reported direction of impact.*						
	Direction of measured impact					
Means of measure and specific indicators	**Both positive and negative**	**Positive**	**Neutral**	**Negative**	**Unclear**	**Total**
Interviews/surveys/PRA	**4**	**56**	**2**		**3**	**65**
Estimated cost		1				1
Government payments	1					1
Harvested fuelwood value		1				1
Income	1	23	1		1	26
IRR		1				1
Net present value		3				3
Net profit	1	9				10
Not reported		3				3
NTFP value		1				1
Perceived financial benefit			1			1
Return to labor		2				2
Sales		3				3
Savings					1	1
Tree density		1				1
Value per household		4				4
Yield	1	4				5
Payment scheme					1	1
Market assessment		**4**				**4**
Income		3				3
Payment scheme		1				1
Process modeling		**1**			**3**	**4**
Income					1	1
Net present value		1				1
Payment scheme					2	2
Scientific expert knowledge		**7**				**7**
Income		1				1
NTFP value		1				1
Sales		2				2
Tree value per year		1				1
Yield		2				2
Means of measure not reported	**1**	**15**		**1**	**1**	**18**
Income		4		1	1	6
Income distribution throughout the year		1				1

*Table 16 continued. Number of **income** impact assessments, by category of measurement method, and then by indicator, with the reported direction of impact.*						
	Direction of measured impact					
Means of measure and specific indicators	**Both positive and negative**	**Positive**	**Neutral**	**Negative**	**Unclear**	**Total**
Income distribution throughout the year		1				1
Increased land value		1				1
Net profit		5				5
not reported	1					1
Percent yield increase		1				1
Reduced labor requirement		1				1
Reduced risk		1				1
Payment scheme		1				1
Total	**7**	**90**	**2**	**1**	**7**	**107**

6. CONCLUDING OBSERVATIONS FROM THE LITERATURE REVIEW

Limitations of a Literature Review Approach

We acknowledge a number of limitations in restricting our assessment to a review of existing peer-reviewed and gray literature rather than applying more in-depth approaches to synthesize and align different types of data such as key informant interviews and additional spatial analysis. Importantly, the prevalence and diversity of different TBEAs in practice is unlikely to be proportionately represented in the literature. Similarly, the set of existing studies should be compared with spatial analysis, expert review, and other methods to understand how these studies align with TBEAs as they are actually practiced in different regions. Our search for literature was restricted to studies reporting on the impact of TBEAs on food security, climate change resilience, and carbon sequestration. While these subjects are currently high on the scientific and political agenda, they may not have been top priorities for TBEA studies conducted more than a few years ago, which may have emphasized a different set of impact variables and therefore been excluded from our review. It is important that the findings of this literature review are interpreted with this in mind.

Given that, at this time, there is no widely agreed-upon analytical framework for describing scaling up of TBEAs (see Section 1), this review adopted some tolerance for uncertainty while applying as formal a structure as possible (e.g., excluding study plots in research centers). The project team regards this Phase 1 effort as a well-structured scoping activity that reveals the prevalence and robustness of different types of information that will be of use in designing subsequent phases of work. For the categories of information that were most prevalent and robust, we have elicited some preliminary observations about TBEA impacts and drivers for further testing. For the types of information that are scarce or weakly supported, we articulate pathways for improving the knowledge base (see Section 7).

The results reported here are of greatest value for synthesizing the set of evidence that is currently available in the peer-reviewed and gray literature, charting the different approaches used to date to characterize TBEAs in practice, and developing some preliminary conclusions to be tested through other methods.

Type and Extent of TBEAs

To understand the drivers of TBEA adoption at scale, it is helpful to put these in context of the types, distribution, and extent of TBEAs implemented around the world. This literature review supports some preliminary observations. The 111 TBEA sites were found in 53 different countries (with more than half in Africa); 10 countries encompassed 70 of the TBEA sites with a wide variety of TBEA types represented. TBEA sites were most commonly located in the humid, semi-arid and tropical zones, and the main agricultural activity was subsistence farming on 5 hectares or less. Studies in only 20 of the 111 sites described more than one TBEA in practice, though it is likely that multiple TBEAs are common.

Extent information in hectares was provided for only 33 sites, however qualitative descriptions (i.e., widespread, common, rare) were given for 36 sites. Several studies described millions of hectares under TBEAs. TBEAs with the greatest reported extent include natural regeneration, trees on sloping lands/afforestation, parkland agroforestry, rubber agroforestry, silvopastoralism, silviculture, and community-based forestry management. Unfortunately the estimations of TBEA extents cannot be summed as many reported sites are likely overlapping (e.g., the several extremely large sites under natural regeneration and parkland agroforestry

Honey can be a valuable non-timber forest product in some types of TBEAs. Photo courtesy of CIFOR.

management in Niger). We lack a description of the exact location to be able to account for this potential overlap in reported TBEA extents.

This literature review does not provide a sufficient basis for conclusions regarding the types and configurations of tree species that are associated with scaled-up TBEAs.

Impacts of TBEAs

This report also asks how well the existing evidence base supports conclusions about the impacts (including positive benefits and negative effects) that result from implementation of different types of TBEAs and the conditions under which these impacts occur.

Drawing on a very large variety of indicators, most documents provided some assessment of TBEA impacts on food security (42 sites; 5 different indicators), climate change resilience (12 sites; 7 different indicators), carbon sequestration (25 sites; 4 different indicators), and income (68 sites; 7 different indicators). All of these reported one or more positive impacts. Positive effects were most commonly reported for one or two impact categories; only two sites (natural regeneration and parkland agroforestry in Niger and Ethiopia) reported positive impacts for three different impact categories of food security, carbon sequestration and income. Negative impacts on income and carbon sequestration were reported for only 6 of 111 sites including unequal benefit sharing for smallholders, reduced production or carbon sequestration coupled with increased income or food security, and displacement of important land uses or economic activities. The overwhelming reporting on positive impact could likely include a publication bias towards success stories on TBEA practices.

While useful to observe the different units of analysis, the wide variety of impact indicators inhibits cross-site comparison. The reviewed documents assessed TBEA impacts using diverse methods including surveys or interviews, field measurements, literature review, scientific experts, and various models. Common methods for assessing impact varied by impact type and extent of the studied area.

Scaling up TBEAs

Governments and their development partners are interested in supporting land management practices that have high potential for achieving social, ecological and economic benefits at scale. Therefore, this review brought particular attention to evaluating which studies described TBEAs that were implemented at scale and understanding the drivers and facilitating factors for scaling up TBEAs.

Weak contextual information in the literature regarding TBEA adoption prevented characterization of TBEAs as at scale. Eleven different quantitative indicators of TBEA adoption are reported for 53 TBEA sites (only 11 sites were quantified as a percentage of a target group); 45 TBEA sites include a qualitative description of adoption level. The TBEAs that were most frequently described as implemented at scale were: i) natural regeneration practices, all in Africa (6), ii) fertilizer trees, all in Africa (5), iii) silvopastoral practices in Latin-America and Europe (4), and iv) homegardens, all reported in Asia (4). It is likely that TBEAs are being implemented at scale in places that have not yet been documented in the literature (e.g., coffee agroforestry in Central America, cocoa agroforestry in Brazil, etc.). TBEAs were described as historically present (over 100 years) at 21 sites and recently scaled up (<10 years) at 19 sites.

To explore whether there are characteristic scaling up pathways associated with specific types of TBEAs, this literature review gathered information about drivers and mechanisms for TBEA implementation or maintenance. The most commonly reported drivers were soil quality improvement, income, and subsistence production of food and fodder. At least one driver was reported for 92% of TBEA sites. Information provided about drivers was determined through interviews, surveys, or local knowledge for only 37 of the 111 sites; otherwise information was obtained by the authors through literature or their common understanding of the area. One or more mechanisms for TBEA implementation or maintenance were described for 83 of 111 sites including 48 sites where interventions by international NGOs were reported as the main mechanism. Local (individual or collaborative) implementation mechanisms were often reported to be driven by the need to improve soil quality, income generation, and household nutrition.

This review found indications that TBEAs were valued for supporting multiple functions as over two-thirds of the studies described two or more drivers. For example, access to fertilizer/ responding to higher input costs and reducing land degradation motivated integration of trees into conservation agriculture systems in Zambia. In Argentina, risk avoidance and market incentives, and shading cattle contributed to silvopastoralism being practiced on over 40,000 hectares in two departments. (Note that information about drivers was only found for 6 studies with TBEAs that were recently taken to scale and the reported drivers were quite diverse.)

A CIPAV silvo-pastoral system at Reserva Natural El Hatico, familia Molina Durán, near Palmira, Colombia. Photo courtesy of Neil Palmer/CIAT.

Interventions by international NGOs were the most commonly reported institutional mechanism for TBEA implementation. Soil quality, income generation, and household nutrition were also the drivers commonly associated with local (individual or collaborative) implementation mechanisms.

Trees in a Landscape Context

The benefits from implementing TBEAs can accrue at household to global scales. Many studies characterize TBEAs at relatively small scales and most describe tree-based interventions without landscape-scale analysis. In this review, we found little assessment of TBEA benefits relative to other land uses in the landscape, of interactions among land uses, or of patterns of tree-growing and impacts across the landscape.

There is in fact a growing literature on impacts of landscape-scale interventions through watershed conservation projects, biological corridors, and other strategies (LPFN, 2012). However, few of these interventions or their methodologies are well-represented in the peer-reviewed literature. The best data on landscape-scale interventions focus on hydrological/ ecosystem impacts with limited data on extent of TBEAs, income benefits for farmers, impacts on agricultural production, or resilience. More rigorous studies require a combination of spatial and household data.

7. CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER ANALYSIS

Analytical Limitations in TBEA Literature and Pathways to Scaling Up

There appears to have been a notable scaling up in investments and programs supporting TBEAs around the world in the last 25 years, as well as efforts in many places to sustain and restore indigenous plant species and TBEAs. Unfortunately, there does not seem to have been a corresponding development of analytical methods and frameworks for understanding the transformation of land use systems, the role of TBEAs in that, or the relative impacts of different strategies for accelerating those changes.

This review presents findings from the body of evidence developed mainly since the late 1990s regarding the types of TBEAs implemented around the world with emphasis on the impacts and drivers for scaling up. Given that only 45 of 111studies deemed eligible for review by the screening criteria convincingly described TBEAs practiced at scale and that these studies were quite diverse, it is challenging to develop clear conclusions regarding typical pathways to scaling up (e.g., farmer-to-farmer, collective action, external interventions) associated with different types of TBEAs. Similarly, we are constrained in our ability to make strong assertions regarding the drivers and facilitating factors necessary for TBEAs to be implemented at scale (i.e., policy, institutional, biophysical, economic, and social parameters) or the role of market incentives or input prices in encouraging TBEA practices.

While many of the individual studies provided valuable insights into scaling up in particular cases, the body of work overall provides weak guidance for large-scale investment and policy planning. Many of the recommendations on methodology made in the early 1990s, based on assessments done in the 1980s, were not applied in these studies. Frank Place, a senior scientist at ICRAF who has been involved extensively in documenting agroforestry development, observes that researchers have devoted much more time towards generating innovations that beneficiaries such as smallholder farmers will use and then assessing the adoption and impact of those innovations. There is a vast 'missing middle' of understanding how innovations are taken up and thus what methods or approaches could be improved to facilitate this process. Lacking are analytical frameworks, methods for testing these types of approaches, and also the skills and interest of scientists. He notes, however, that the Consultative Group on International Agricultural Research (CGIAR) is in the process of reorienting itself towards outcome-driven research, which will help to motivate scientists to devote more time to this neglected area (personal communication, August 29, 2013).

The principal weaknesses and knowledge gaps observed in this study included:

a) Many different types of TBEAs are practiced, but most studies report on only one TBEA type, so there is little evidence about inter-relationships among TBEAs.

b) A few TBEA types are reported to be practiced across a large spatial extent: natural regeneration, trees on sloping lands/afforestation, parkland agroforestry, rubber agroforestry, silvopastoralism, silviculture, and community-based forestry management.

c) TBEAs are implemented in many places (sites in 53 countries were reported), but only 10 countries are home to over 60% of the sites that have been studied.

d) Studies typically report positive TBEA impacts and attention to different categories of impact, but while most identified income impacts (88 of 111), only half evaluated food security (58) and fewer than a fifth documented impacts on carbon sequestration (19) and climate change resilience (17).

e) Evidence of impacts on ecosystem services was not evaluated systematically in this study, but is expected to influence adoption and benefits, as well as strategies for scaling up.

f) Impacts are assessed with a wide variety of indicators and studies typically report one or two indicators. The impact assessment methods varied and were not always clearly described.

g) TBEA adoption level and scaling up is weakly described in most studies. Only 45 of 111 sites were determined to have TBEA implementation at scale and only 19 sites were described as having recently scaled up TBEAs (within the last 10 years). Almost no studies positioned TBEA adoption and scaling within a landscape-scale frame.

h) Interventions by international NGOs were the most commonly reported mechanism for TBEA implementation; it is likely that indigenous practices and national action programs are under-represented in the studies.

i) Information about drivers was acquired through interviews, surveys, or local knowledge for only one-third of the sites. While useful information was available for the diversity of indicators used for different categories of TBEA impacts, this diversity of approaches impeded clear conclusions.

j) This body of studies clearly has some types of biases (e.g., in the geographies and types of TBEAs studied, and towards more 'successful' cases), but it is not clear what other biases there may be.

Recommendations for Further Analysis

The overwhelmingly positive reports regarding TBEA impacts certainly encourage further promotion of TBEAs in a support, test, and learn mode, but a more robust effort is needed to support large-scale investment programs. This literature review has charted the frontier of available evidence for the extent, impacts, and drivers of scaled-up TBEAs. While we were able to identify important patterns, we also found that additional types of analysis are likely to be needed if we are to accurately understand where and how TBEA benefits can be realized at scale. Given that the World Bank plans to build on this literature review through some additional studies, we offer here some recommendations for additional assessment activities.

We recommend five specific areas of action, which are further elaborated on below:

1. Development of a shared conceptual framework and assessment strategy;
2. Spatial analyses to determine whether the geographic distribution represented in the literature accurately reflects where TBEAs are actually implemented around the world;
3. Comprehensive case studies of TBEA practice and scaling at landscape scale;
4. Organization of action research across landscapes where different TBEA interventions are being implemented to better understand how socio-ecological conditions, external interventions, and local institutions (and their interactions) influence TBEA use at scale; and
5. Meta-analysis of existing studies.

1. Development of a Shared Conceptual Framework and Assessment Strategy

It would be useful for development agencies and international research institutions to collaborate on harmonizing and strengthening the foundation for monitoring and evaluation of TBEA implementation. This would involve efforts to achieve agreement across relevant communities of practice regarding a shared conceptual and analytical framework, as well as standard units of analysis and methods for data gathering on scaling up of TBEAs. These should be framed as part of more comprehensive analyses of agricultural and forest land use changes in a dynamic economy and ecology.

The framework can draw from the studies in this literature review, together with earlier literature on changes prior to the 1990s, to critically document the pathways of scaling, and the anticipated interaction between drivers of change favoring TBEAs and institutional mechanisms to promote their widespread use.

This information can be translated into indicative models for scaling up TBEAs in different contexts, while still based on local and decentralized decision-making for local adaptation. These can be structured around questions of where, what and how.

2. Spatial Analyses

Spatial analyses are essential to fill in the gaps of extent information for the studies which do not report on this, to confirm estimates of extent where they are reported, and to understand the spatial features of TBEA practice in relation to other land uses. Time series of spatial data are required to quantify the geographic dimension of scaling up over time.

Building on global mapping work previously undertaken by WRI and partners (Minnemeyer et al., 2011) and ICRAF (Zomer et al., 2009), a spatial analysis of land area suitable for TBEA approaches could be conducted to produce a global map of TBEA opportunity areas that identifies mixed agriculture/forest landscapes with suitable population density. This work could be composed of an initial overview focused mainly on identifying extent and change over time of areas where TBEA can or are likely to practiced, and a subsequent analysis of dynamics related to scaling up. These will enable a more targeted set of spatial analyses that directly reflect the geographic variables explaining local practices identified in this review of literature.

Regional spatial analysis for Africa could build on ICRAF's land health surveys across Africa to calculate extent of TBEAs in the region by deriving variables (e.g., land cover/use, climate variables, agro-ecological zones, soil type, distance to settlements, and population) that explain the location of TBEAs. Projections of potential expansion-suitable areas could be made based on plausible trends in these variables in the coming 10 years.

National and sub-national spatial analysis could be conducted to assess the evolution over time of TBEAs in several countries (or large regions within countries that represent different land management contexts) and to provide more spatially disaggregated analysis of TBEAs (e.g., dynamics of changing species, configurations and locations of tree cover in and around agricultural systems as well as socio-economic variables).

3. Case Studies at Landscape Scale

The greatest weakness in the current literature is the fragmented analysis of the role and dynamics of trees within the broader landscape (McNeely & Scherr, 2008; Minnemeyer et al., 2011). Thus we recommend implementation of a diverse set of landscape-scale case studies where TBEAs have been scaled significantly. These would include analyses of the dynamics of land use change over time and the role of TBEAs in those changes, the distribution of benefits among stakeholder groups, as well as economic and other analyses of drivers, enabling conditions, and impacts.

Landscape-scale spatial analyses could empirically evaluate the relationships between TBEA sites and mapped information on biophysical (e.g., soil, climate) and socio-economic (e.g., population, accessibility) site characteristics. Studies at higher resolution can identify the tree and shrub species typically associated with TBEA types as well as the configurations employed.

4. Action Research on Scaling TBEAs

The most effective strategy to generate robust evidence on scaling up processes and impacts will be to embed data collection, informed by the conceptual/analytical framework and methods in 5.2.1, into action research in a diverse set of implementation programs for sustainable land management (and related focus, such as landscape restoration, landcare, biological corridors, territorial development, etc.). Many such efforts are already underway involving such as through the Evergreen Agriculture project in Africa; the focal and network landscapes collaborating with the Landscapes for People, Food and Nature Initiative; landscape initiatives working with sentinel sites of the CGIAR; the International partnership for Satoyama Initiative; the Model Forest Network; and numerous national and sub-national development programs for sustainable agriculture, agroforestry, and ecosystem management. Diverse approaches can be used, and even diverse means of measurement, so long as there are some key questions in common.

5. Meta-Analysis of TBEAs Impacts and Scaling

Drawing from selected studies in this targeted literature review and the conceptual framework recommended above, hypotheses about different pathways of scaling up of TBEAs could be developed and tested to explore factors that explain TBEA adoption at household, community, and landscape-scale and to distinguish fundamentally different sets of interventions and supportive mechanisms.

A systematic review could include: (1) characterization of in-depth studies according to the scale of impact, drivers, scaling process, socio-economic and institutional context, and other factors; (2) quantitative analyses including frequency patterns for the presence of key variables, factor analysis, multivariate analyses of relationship between drivers, institutional context, and outcomes in terms of tree cover and impacts on indexes of food security, and income benefits.

The insights derived from this literature review are more limited than was originally hoped due to the limited number of comparable indicators provided in the literature. However, additional insights can be gleaned from comparative analysis of a sub-set of studies.

GENERAL REFERENCES

Arnold, J. E. M. and P. Dewees, eds. 1993. Trees in farmers' strategies: responses to agricultural intensification. Oxford University Press: Oxford.

Bradley, P. N. 1988. Survey of woody biomass on farms in Western Kenya. AmbioVol. 17: 40-48.

Current, D., E. Lutz and S. J. Scherr. 1995a. Adoption of agroforestry. In Current, Lutz and Scherr, eds. Costs, benefits and farmer adoption of agroforestry: project experience in Central America and the Caribbean. A CATIE-IFPRI-World Bank Project Funded by UNDP. World Bank Environment Paper 14. World Bank: Washington, DC., pp. 1-27.

Current, D., E. Lutz and S. J. Scherr (eds). 1995b. Costs, benefits and farmer adoption of agroforestry: project experience in Central America and the Caribbean. A CATIE-IFPRI-World Bank Project Funded by UNDP. World Bank Environment Paper 14. World Bank: Washington, DC.

de Foresta, H., E. Somarriba, A. Temu, D. Boulanger, H. Feuilly and M. Gauthier. 2013. Towards the assessment of trees outside forests. Resources Assessment Working Paper 183. Rome, Italy: FAO.

Dewees, P., F. Place, S.J. Scherr and C. Buss (with O.C Ajayi, L. E. Buck, D. Elson, D. Macqueen, E. Majanen, E. Masters, J. C. Milder, C. Saint-Laurent and S. Shames). 2011. Investing in trees and landscape restoration in Africa: what, where and how. Program on Forests (PROFOR): Washington, D.C.

Dewees, P. 1989. An economic and social history of trees and factor processes in Muranga District, Kenya. Oxford Forestry Institute: Oxford.

FAO. 2013. FAOSTAT database. FAO: Rome. http://faostat3.fao.org/faostat-gateway/go/to/home/E

IISD. 2013. Africa food security conference bulletin: A briefing note of the First Africa Food Security Conference – Harnessing Ecosystem based Approaches for Food Security and Adaptation to Climate Change in Africa. IISD. http://www.iisd.ca/food/afsc1/brief/afsc1_brief.pdf

IUCN. 2008. Learning from landscapes. Arborvitae Special Issue. IUCN: Gland.

LPFN. 2012. 23 cases of Landscape Impact. EcoAgriculture Partners for the Landscapes for People, Food and Nature Initiative: Washington, DC.

Lundgren, B. 1987. ICRAF's first 10 years. Agroforestry Systems 5: 197-215.

McNeely, J. A. and S. J. Scherr. 2008. Biodiversity conservation and agricultural sustainability: towards a new paradigm of 'ecoagriculture' landscapes. Phil. Trans. R. Soc. B. 363: 477–494.

Mercer, E. and Miller. 1998. Review of socioeconomic research in agroforestry: progress, projects, priorities. Agroforestry Systems, 38: 11-19.

Minnemeyer, S., L. Laestadius, N. Sizer, C. Saint-Laurent and P. Potapov. 2011. A world of opportunity for forest and landscape restoration. The Global Partnership on Forest Landscape Restoration.

Nair, P. K. R. and D. Garrity (eds). 2012. Agroforestry – the future of global land use. Springer: New York.

Nair, P. K. R. 1989. Agroforestry Systems in the Tropics. ICRAF and Kluwer International: Amsterdam.

Place, F., O. C. Ajayi, and E. Masters. 2011. Tree-based and other land management technologies for landscape restoration and livelihood in Africa. Chapter 1. In Dewees et al., eds. Investing in trees and landscape restoration in Africa. PROFOR: Washington, D.C., pp. 17-41.

Rapidel B., F. DeClerck, J.-F. Le Coq, and J. Beer (eds). 2011. Ecosystem services from agriculture and agroforestry: measurement and payment. London: Earthscan.

Richards, P. 1983. Ecological change and the politics of African land use. African Studies Review, 26: 1-72.

Scherr, S. J. 1993. Evaluation of agroforestry practices over time in the crop-livestock system of western

Kenya. In K. A.Dvorak, ed. Social science research for agricultural technology development: spatial and temporal dimensions. CABI, Chapter 8: 118-143.

Scherr, S.J. 1992. The role of extension in agroforestry development: evidence from western Kenya. Agroforestry Systems, 18: 47-68.

Scherr, S. J. and E. U. Muller. 1991. Technology impact evaluation in agroforestry projects. Agroforestry Systems, 13: 235-257.

Scherr, S. J. and E. U. Muller. 1990. Evaluating agroforestry interventions in extension projects. Agroforestry Systems, 11: 259-280.

Thompson, J., T. Hodgkin, K. Atta-Krah, D. Jarvis, C. Hoogendoorn, and S. Padulosi. 2007. Biodiversity in agroecosystems. Chapter 3, In Scherr S. J. and J. A. McNeely, eds. Farming with nature. Island Press: Washington, D.C.

Wolman, M. G. and F. G. A. Fournier. 1987. Land transformation in agriculture. John Wiley and Sons: New York.

Wood, S., K. Sebastian, and S. J. Scherr. 2000. Pilot assessment of global ecosystems: agroecosystems. World Resources Institute and IFPRI: Washington, D.C.

Zomer, R., A. Trabucco, R. Coe and F. Place. 2009. Trees on farms: analysis of global extent and geographical patterns of agroforestry. ICRAF Working Paper No. 89. Nairobi, Kenya: World Agroforestry Centre.

ANNEX 1. TREE-BASED ECOSYSTEM APPROACHES (TBEA) INCLUDED IN THE STUDY

Afforestation/reforestation Clean Development Mechanism – Land reclamation under the clean development mechanism of the Kyoto Protocol intended to reduce greenhouse gas emissions, while assisting developing countries in achieving sustainable development, with the multiple goals of poverty reduction, environmental benefits and cost-effective emission reductions.

Agroforestry – The use of trees and shrubs for food, fiber, and/or forage, and which can be integrated with annual crops, livestock, or forestry systems.

Agrosilviculture, agrisilviculture – Combining trees or woody shrubs and annual crops in combinations or stages that do not hinder the growth of either.

Agrosilvopastoral – Growing trees that fertilize crops and shade grass pastures to feed and shelter livestock.

Allanblackia – A tree genus that consists of 9 species, all found in the moist forests of Africa, that produce seeds from which high quality vegetable oil can be extracted.

Alley cropping – Alternating strips of perennial plants with pasture or annual crops to provide windbreak, shade and soil nutrient benefits.

Apiculture with trees – Providing beehives for enhanced pollination to high value tree crops, or protecting tree stands that provide exceptional nectar production.

Aquaculture with trees – Planting beneficial tree species around fishponds to provide fish food (e.g. mulberry trees around carp ponds in China).

Banana/coffee mix or organic banana – Alternating strips of banana with coffee to provide shade for improving coffee quality and production.

Boundary planting – Beneficial tree planting that also designates lines of land ownership or demarcates field boundaries.

Climate smart agriculture – A wide array of farming strategies that increases agrobiodiversity, water retention, and carbon sequestration to improve income flows and reduce susceptibility of single crop failure.

Cocoa agroforestry – The use of overstory species that produce harvestable timber and non-timber forest products while providing shade for cocoa.

Coffee agroforestry – The use of overstory species that produce harvestable timber and non-timber forest products while providing shade for coffee.

Community forestry – Forest management through participatory local management bodies that often manage forests as a common pool resource to produce multiple species and forest products.

Community-based forest management – See Community Forestry.

Conservation agriculture with trees – The three main pillars of conservation agriculture—low-till, crop rotation and mulch cover—with trees integrated, often playing a key role in providing of mulch. .

Crop cultivation with trees – See Agrosilviculture.

Evergreen agriculture – Trees on farms that boost crop yields, provide alternative incomes, replenish soil fertility, increase soil carbon retention, increase resiliency against extreme weather events, and protect biodiversity.

Fertilizer trees – The use of trees and shrubs to increase soil fertility, especially leguminous trees that fix atmospheric nitrogen.

Fodder banks – The planting of trees and shrubs that are particularly useful for livestock forage.

Forest farming – Preferential cultivation of tree, shrub, and herbaceous forest species to maximize harvestable products.

Forest gardens – Highly diverse multi-story species mixes to maximize harvests of multiple forest products throughout the year.

Forest landscape restoration – Land reclamation with the intent to re-establish primary forest over the majority of the land area.

Fuelwood production – Diverse tree plantings or natural stands managed primarily for cooking fuel.

Gum-arabic agroforestry – Land use system for gum production based on a bush fallow system. Under this system each plot of land is used to cultivate annual crops for about 4-5 successive years followed by a period of 15-20 years of fallow under regenerating Acacia senegal or A. seyal from which resin is extracted.

Hedgerow – Cultivated or wild shrubs and trees in a narrow strip, typically bordering a road or field.

Hedgerows based on natural vegetative strips (NVS) – Contour hedgerow farming buffer-strip system to conserve soil and sustain yields on steeply sloping cropland.

Homegarden – Diverse multi-story plantings of trees, bushes, and annual and perennial crops immediately adjacent to and surrounding dwellings.

Homegarden, coffee-based – as above with the inclusion of coffee bushes within the shade of overstory species.

Improved fallow – The use of leguminous trees or shrubs grown in absence of crops for a fallow phase, to be followed by crop production on the same plot.

Intensive silviculture – Tree plantations that utilize improved genetic stock and close spacing, combined with commercial or natural fertilizer use, to maximize tree growth and reduce rotation cycles.

Intercropping – Planting species adjacent to each other that have beneficial effects such as fertilizer, pest protection, shade, or differing soil nutrient usage.

Live fence, live fencing – A hedgerow practice that uses living trees and shrubs to delineate fields and/or control livestock movements, as well as provide fuel wood or other tree crops.

Mixed-use landscape – Also known as multiple-use or agricultural mosaic, combines rural land-use needs of forestry, orchards, pastures, cultivated fields, home sites, home gardens, and community/religious spaces.

Model forest – Landscapes based on an approach that combines the social, cultural and economic needs of local communities with the long-term sustainability of large landscapes in which forests are an important feature.

Mosaic landscape with trees – Multiple-use agricultural area that incorporates trees and tree based systems as part of the patchwork of uses.

Multi-purpose forest management – Forests managed for timber, pulp, wildlife, erosion and flood control, recreation, religious/aesthetic values.

Multi-purpose tree lots – Multi-species tree plantings that produce several timber and non-timber products.

Multi-strata systems – Tree-based systems that cultivate overstory, mid-story, understory, and ground species for production.

Multiple land-use production system – See Mixed use landscape.

Multiple use forest – See Multi-purpose forest management.

Natural production forest – The management of native species that regenerate naturally.

Natural regeneration – Trees or tree stands that reproduce without human intervention following clearing, burning or other disturbance.

Natural regeneration, assisted – Tree reproduction based on natural regeneration in which farmers actively promote the growth of shoots of superior quality by pruning away competing shoots and may protect from fire or browsing.

Ngitili – Farmer-led initiatives evolved from traditional strategies for grazing and food security that involves retaining an area of standing vegetation (grasses, trees, shrubs and forbs) from the onset to the end of the rainy season.

Nitrogen-fixing trees – See Fertilizer trees.

Non-timber forest product management – Selection and management of forest products (e.g. fruits, nuts, resin, mushrooms, wildlife) that are not for lumber or pulp.

Parklands – Savannas with a widely spaced tree mix.

Participatory forest management – Forest management by collaborative local citizen groups, similar to Community-based Forest Management.

Participatory tree domestication – Selection, propagation and cultivation of superior tree genotypes by local farmers.

Quesungual agroforestry – A milpa-based system that involves growing maize, sorghum and beans interspersed with trees. Instead of slash and burn, farmers clear old vegetation by hand with a machete. The tallest trees are kept as sources of fruit and timber, as well as providing shade for the crops underneath. A typical plot of one to three hectares consists of approximately 15-20 large timber and fruit trees and numerous smaller trees and shrubs.

Riparian buffer – Trees and shrubs grown along riverbanks to reduce erosion and provide wildlife habitat.

Rubber agroforestry – Smallholder rubber tree production managed in a multi-strata, multi-species agroforestry system.

Rubber Based Agroforestry System (RAS) – A particular set of best practices related to Rubber Agroforestry.

Rubber-Cocoa Intercropping – Mixed companion cropping where rubber trees provide shade for cocoa.

Shade cocoa – See Cocoa agroforestry.

Shade coffee – See Coffee agroforestry.

Shelterbelt – Narrow strips of trees and shrubs planted to protect annual crops or pasture from excessive wind, rain and sun.

Silvopastoral system – Growing trees that fertilize crops and shade grass pastures to feed and shelter livestock.

Smallholder fruit production – Fruit trees grown as minor crop for increased income and/or nutrition.

Sustainable production forest management – A system of limited forest harvest that for reduced erosion, flooding, negative wildlife or cultural impacts, and will not diminish future harvests.

Taungya system – A system whereby villagers and forest plantation workers are given the right to cultivate agricultural crops during the early stages of forest plantation establishment. Cultivation is often allowed to continue until trees shade crops due to canopy closure.

Tree crops – A term brought into common usage by the book, Tree Crops: A Permanent Agriculture by J. Russell Smith. This classic, published in 1929, described traditional tree-based farming systems that provided food for humans and livestock. Major tree crops include coffee, tea, rubber and cocoa.

Tree gardens – See Forest gardens.

Trees in farmland – Trees thinly distributed on farmsteads for multiple uses covering small area.

Trees on sloping lands – Landscape restoration through tree planting for controlling soil erosion, and reduce flooding and drought.

Tropical forage tree – Species well suited to coppicing that provide nutritious fodder for livestock.

Wildlife corridor – Strip or area of forest or bush contiguous with larger, often protected, blocks of forest or suitable habitat for wildlife.

Windbreaks – See Shelterbelt.

Wood lots – A plot or parcel of land planted with trees to provide lumber, poles, and firewood.

Woody biofuels – Perennial crops utilized for fiber or oil for processed or unprocessed fuel consumption.

Woody perennial – Trees, shrubs, and bushes that grow for multiple seasons without reseeding, replanting, or dying back to ground level.

ANNEX 2. DETAILS OF STUDY METHODS

The project team conducted a targeted review of published, peer-reviewed, and informal literature and project documents that described TBEAs in different stages of being scaled up.

Defining TBEAs at scale

For the purposes of this study, the project team and partners developed an operational definition of TBEAs to be considered in the literature review that includes agro-forestry practices (woody perennials in agricultural systems) and forestry systems that are actively managed for multiple objectives. Tree-based systems were only included as TBEA if they embodied an in situ ecosystem approach (i.e., managed to support the delivery of multiple objectives and ecosystem services). Examples of systems that were not considered TBEAS include monoculture tree crops, plantations, and forest actively managed solely for timber production. For documents which describe monoculture tree crop plots as part of landscapes in which farmers or communities also protect or grow a range of other tree species, we report based on the descriptions provided by document authors.

The primary emphasis of this study was to investigate TBEAs that are practiced at scale. This was operationally defined as when a TBEA is a 'common practice' in an area, or in other words, when the TBEA is used by many land managers or communities. This definition does not require that the TBEA be practiced over a large spatial extent, nor that the TBEA has become common practice in recent years (i.e., TBEAs that have been in practice by numerous land managers or communities for generations can offer insights about the site conditions in which they are practiced, TBEA impacts and drivers that support maintenance of TBEA). Recognizing that documents under review were likely to be inconsistent in the information they provided, the project team did not set quantitative thresholds for 'common practice' (e.g., percentage of communities or households in a landscape), rather they recorded any relevant quantitative information provided in individual documents.

Literature search

Three approaches were used to identify documents to be considered for the literature review:

1. Peer-reviewed scientific literature. A Web of Knowledge search of title, abstract and keywords was conducted with a predetermined set of key terms designed to minimize 'false positives' while casting a wide net. The project team listed a wide broad range of agroforestry and multi-objective forestry practices that could be considered a TBEA (see Annex 1). These terms were combined with the terms "food security," "climate change," "resilience," "adaptation," and "carbon sequestration or sequestration" together with "decision making," "driver," "benefit," "scaling up" or "impact." No publication year restrictions were set. The search was conducted in English.
2. Internet search for grey literature. A similarly constructed search for publications was conducted using Google Scholar, university libraries, websites of project partners and other relevant institutions (i.e., CATIE, Conservation International, CIFOR, World Bank, World Vision, and WRI). Grey literature considered for review was prepared for and published or posted by organizations, not individuals.
3. Network-based search for unpublished documents. Project partners at CATIE, CI, ICRAF, and WRI

provided direct access to unpublished reports (from within or outside their organization) and made connections to key contacts, which were solicited for relevant unpublished reports (e.g., project reports and evaluations).

Additionally, project partners were invited to suggest key contacts implementing relevant on-going studies that are not yet published either as foreseen peer-reviewed or gray publication. We did not limit our search to any cut off-dates for document selection.

All reviewed documents were digitally archived an added to a reference manager. A brief, initial scan of each identified document was used to filter out documents that did not meet selection criteria. Documents were included in the review if they described:

1. TBEAs that are practiced at scale or are in the process of scaling up (ie, used by many land managers or communities not just in a research center);
2. A specific site where at least one type of impact of TBEA is reported.
3. Tree-based systems that embodied an ecosystem approach (i.e., managed to support the delivery of multiple objectives and ecosystem services);

Excluded documents were stored separately and a catalogue was kept of reasons documents were rejected for in-depth review.

Literature review

All documents were systematically reviewed and information catalogued using a review template (see Annex 3 for list of review template column headings and multiple choice options). In designing the review template, the project team focused on creating a foundation for evaluating the variables of TBEA extent, location, impacts and drivers as well as determining the feasibility of developing new meta-analyses and spatial analyses by collecting data on impact indicators and provided geographic information.

- Major categories of information compiled included:
- Document description; including type of organization of lead author, country, year
- Site description; including location, size, farming systems, climate, poverty level
- TBEA descriptions; including, type, tree species, extent, level of adoption, years since adoption,
- Drivers and governance mechanisms of TBEA implementation and maintenance
- Impacts of TBEA implementation on food security, climate change resilience, and carbon sequestration and storage; including indicators and methods used, impact, success factors and barriers.

Where appropriate, specific variables in the review template were given defined multiple choice "pull-down" options to streamline the review process and harmonize the collected information. For TBEA impacts, indicators used in each document were reported (i.e., no pre-defined options). Each row in the review template represents a single TBEA implementation site (i.e., if a document described multiple sites, multiple rows were used). The review template was designed to record up to three different TBEAs per site. In reviewing documents, the project team recorded information as provided by document authors rather than applying their own interpretation. For variables that were populated with a diverse set of descriptors, the project team, with input from partners, created aggregated reporting classes.

Analysis of information gathered in the literature review template was focused on the following major topics:

- The characteristics of TBEAs adopted at scale including their biophysical and social context;
- The geographic extent of TBEA adoption;
- The contributions of TBEAs to food security, climate change resilience and carbon sequestration;
- Drivers of implementation and maintenance of TBEAs; and
- Examination and description of methods used in reviewed document to ascertain the robustness of the evidence and suitability of studies

In implementing the literature review, the project team strove to discover all relevant sources of information while recognizing that multiple advisors had indicated that the information base was likely to be "patchy."

ANNEX 3. LITERATURE REVIEW TEMPLATE COLUMN HEADINGS AND PULL-DOWN OPTIONS

Publication title: Not predefined

Name of first author organization and country: Not predefined

Type of first author organization:

Academia, Government, Multi-/Bi-lateral donor, NGO, Private sector

Publication year: Not predefined

Type of publication:

Book, Book chapter, MSc thesis, Peer-reviewed journal article, Peer-reviewed report/book, PhD thesis, Published report, Technical note, Unpublished report

Language:

English, Spanish, French, Portuguese

Continent:

Africa, Asia, Australia/Oceania, Europe, Latin America, US/Canada

Country: Not predefined

Name site/area: Not predefined

Site is a(n):

Community/town, Country, Landscape, Multiple country region, Multiple communities, Sub-national administrative unit, Watershed

Approximate size of site (in ha): Not predefined

Agroecological, vegetation or climate zone:

Arid, Arid & Semi-arid, Humid, Humid tropics, Not reported, Savannah, Semi-arid, Subalpine, Subhumid, Temperate, Temperate drylands, Tropical, Tropical highlands

Reported description of the economic situation at the site: Not predefined

Main farming type:

Cash crop, Crop, Crop (cash/subsistence), Crop (subsistence), Crop/livestock, Crop/livestock (subsistence), Crop/livestock (cash/subsistence), Crop/livestock/horticulture (subsistence), Forestry (cash/subsistence), Horticulture, Horticulture (cash/subsistence), Horticulture/silviculture, Intensive crop/livestock, Livestock, Livestock (subsistence), Not reported, Subsistence

Main crop/livestock types and/or system: Not predefined

Average/median farm size (ha): Not predefined

Reported land use/cover change trends: Not predefined

Site coordinates given?

Yes, No

Tree-based practice type 1:

Afforestation/reforestation, Agroforestry, Agrosilviculture, Agrosilvopastoralism, Allanblackia, Banana/coffee agroforestry, Coffee agroforestry, Community/based forestry management, Conservation agriculture with trees, Evergreen agriculture, Fertilizer trees, Fodder banks, Forest garden, Gum-arabic agroforestry, Hedgerows, Homegarden, Homegarden with bamboo, Improved fallows, Intercropping, Live fencing, Mosaic landscape with trees, Multi-strata agroforestry, Natural regeneration, Ngitili, Parkland agroforestry, Participatory forest management, Participatory tree domestication, Quesungual agroforestry, Rubber agroforestry, Shelterbelts, Silviculture, Silvopastoralism, Taugya agroforestry, Trees in farmland, Trees on sloping lands (afforestation), Wood lots

TBEA #1 Type:

Complex multistrata agroforestry, Forest-based systems, Homegardens, Trees in croplands, Trees in grasslands

Dominant tree species or genus in TBEA: Not predefined

Tree-based practice type 2:

Afforestation/reforestation, Agroforestry, Agrosilviculture, Agrosilvopastoralism, Allanblackia, Banana/coffee agroforestry, Coffee agroforestry, Community/based forestry management, Conservation agriculture with trees, Evergreen agriculture, Fertilizer trees, Fodder banks, Forest garden, Gum-arabic agroforestry, Hedgerows, Homegarden, Homegarden with bamboo, Hutan Kamasyarakatan (social forestry), Improved fallows, Intercropping, Live fencing, Mosaic landscape with trees, Multi-strata agroforestry, Natural regeneration, Ngitili, Parkland agroforestry, Participatory tree domestication, Quesungual agroforestry, Rubber agroforestry, Shelterbelts, Silviculture, Silvopastoralism, Taugya agroforestry, Trees in farmland, Trees on sloping lands (afforestation), Wood lots

TBEA #2 Type:

Complex multistrata agroforestry, Forest-based systems, Homegardens, Trees in croplands, Trees in grasslands

Dominant tree species or genus in TBEA: Not predefined

Tree-based practice type 3:

Afforestation/reforestation, Agroforestry, Agrosilviculture, Agrosilvopastoralism, Allanblackia, Banana/coffee agroforestry, Coffee agroforestry, Community/based forestry management, Conservation agriculture with trees, Evergreen agriculture, Fertilizer trees, Fodder banks, Forest garden, Gum-arabic agroforestry, Hedgerows, Homegarden, Homegarden with bamboo, Hutan Kamasyarakatan (social forestry), Improved fallows, Intercropping, Live fencing, Mosaic landscape with trees, Multi-strata agroforestry, Natural regeneration, Ngitili, Parkland agroforestry, Participatory tree domestication, Quesungual agroforestry, Rubber agroforestry, Shelterbelts, Silviculture, Silvopastoralism, Taugya agroforestry, Trees in farmland, Trees on sloping lands (afforestation), Wood lots

TBEA #3 Type:

Complex multistrata agroforestry, Forest-based systems, Homegardens, Trees in croplands, Trees in grasslands

Dominant tree species or genus in TBEA: Not predefined

Quantified adoption of TBEA (# households, people): Not predefined

Qualitative adoption level of approach:

High, Low, Medium, Not applicable, Not reported

Adoption level reflects a:

Community/town, Country, Landscape, Multiple communities, Multiple country region, Not applicable, Not reported, Sub-national administrative unit, Watershed

Quantified extent of TBEA (ha): Not predefined

Extent assessment method/source:

Interviews/survey, Land use map, Literature, Not applicable, National Census, Not reported, Remote sensing

Qualitative extent of approach:

Common, Not reported, Rare, Widespread

Extent measure reflects a:

Community/town, Country, Landscape, Multiple communities, Multiple country region, Not applicable, Not reported, Sub-national administrative unit, Watershed

Practiced at site since (approximate yr, e.g 1960): Not predefined

TBEA is at scale?:

Yes, No

When brought to scale:

A couple of generation ago (e.g., 10-100 yr), Historically present (>100 yr), Not at scale, Recently (<10 yr), Unknown

Reason for adoption: Not predefined

Driver 1 for implementation or maintenance:

Adaptation to climate change, Avoid/decrease input costs, Improve household nutrition, Improve/maintain soil quality, Increase yield, Increased knowledge and technology, Market opportunity/income, Meet fodder demand, Meet food demand, Meet fuel wood demand, Not reported, Policies and incentives, Preserve environment/biodiversity, Reduced access to fertilizer, Risk avoidance, Traditional practice

Driver 2 for implementation or maintenance:

Adaptation to climate change, Avoid/decrease input costs, Improve household nutrition, Improve/maintain soil quality, Increase yield, Increased knowledge and technology, Market opportunity/income, Meet fodder demand, Meet food demand, Meet fuel wood demand, Not applicable, Not reported, Policies and incentives, Preserve environment/biodiversity, Reduced access to fertilizer, Risk avoidance, Traditional practice

Driver 3 for implementation or maintenance:

Adaptation to climate change, Avoid/decrease input costs, Improve household nutrition, Improve/maintain soil quality, Increase yield, Increased knowledge and technology, Market opportunity/income, Meet fodder demand, Meet food demand, Meet fuel wood demand, Not applicable, Not reported, Policies and incentives, Preserve environment/biodiversity, Reduced access to fertilizer, Risk avoidance, Traditional practice

Method for driver identification:

Interviews/survey, Literature, Local knowledge, Not applicable, Not reported, Scientific expert knowledge

Main driving implementation mechanisms:

Charismatic leadership, International NGO extension, External payment schemes, Farmer-to-farmer extension, Individual decision, International policy, Local stakeholder collaboration, National extension, National policy, Not reported, Private sector promotion, Research site, Traditional practice

Main maintenance mechanisms:

Charismatic leadership, International NGO extension, Individual decision, International policy, Local stakeholder collaboration, National extension, National policy, Not reported, Private sector promotion, Public-Private Partners

Drivers identified?:

Yes, No

Impact indicators improved food security: Not predefined

Impact assessment method food security:

Field measurements, Interview/survey, Literature, Local knowledge, Not applicable, Not reported, Process modelling, Scientific expert knowledge

Impact evidence:

Both positive and negative, Negative, No effect, Not applicable, Not reported, Positive, Unclear

Impact indicators improved resilience to climate change: Not predefined

Impact assessment method climate change resilience:

Field measurements, Interview/survey, Literature, Local knowledge, Not applicable, Not reported, Process modelling, Scientific expert knowledge

Impact evidence:

Both positive and negative, Negative, No effect, Not applicable, Not reported, Positive, Unclear

Impact indicators improved carbon sequestration: Not predefined

Impact assessment method carbon sequestration:

Field measurements, Interview/survey, Literature, Local knowledge, Not applicable, Not reported, Process modelling, Scientific expert knowledge

Impact evidence:

Both positive and negative, Negative, No effect, Not applicable, Not reported, Positive, Unclear

Impact indicator improved income: Not predefined

Impact assessment method income:

Field measurements, Interview/survey, Literature, Local knowledge, Not applicable, Not reported, Process modelling, Scientific expert knowledge

Impact evidence:

Both positive and negative, Negative, No effect, Not applicable, Not reported, Positive, Unclear

Other measured impacts: Not predefined

Are any exact number given to summarize impacts?:

Yes, No

Identified negative impacts TBEA: Not predefined

Identified success factors TBEA impact: Not predefined

Identified limiting factors TBEA impact: Not predefined

Impact measured?:

Yes, No, Unclear

Sound science?:

Yes, No, Unclear

Search type:

Batch search, Papers from additional searches, Documents from partners

ANNEX 4. DOCUMENTS REVIEWED

List of documents reviewed

1. Ahmed, Y. A.-R., Pichler, V., Homolák, M., Gömöryová, E., Nagy, D., Pichlerová, M., & Gregor, J. (2012). High organic carbon stock in a karstic soil of the Middle-European Forest Province persists after centuries-long agroforestry management. European Journal of Forest Research, 131(6), 1669–1680. Retrieved from http://link.springer.com/10.1007/s10342-012-0608-7

2. Ajayi, O C, Akinnifesi, F. K., Sileshi, G., & Kanjipite, W. (2009). Labour inputs and financial profitability of conventional and agroforestry-based soil fertility management practices in Zambia. Agrekon, 48(3), 276–292. Retrieved from http://ageconsearch.umn.edu/bitstream/55046/2/3. Ojayi et al.pdf

3. Ajayi, O. C. (2007). User acceptability of sustainable soil fertility technologies: Lessons from farmers' knowledge, attitude and practice in Southern Africa. Journal of Sustainable Agriculture, 30(3), 21–40. Retrieved from http://dx.doi.org/10.1300/J064v30n03_04

4. Ajayi, Oluyede Clifford, Place, F., Akinnifesi, F. K., & Sileshi, G. W. (2011). Agricultural success from Africa: the case of fertilizer tree systems in southern Africa (Malawi, Tanzania, Mozambique, Zambia and Zimbabwe). International Journal of Agricultural Sustainability, 9(1), 129–136. Retrieved from http://www.tandfonline.com/doi/abs/10.3763/ijas.2010.0554

5. Akhter, S., Alamgir, M., Sohel, M. S. I., Rana, M. P., Ahmed, S. J. M., & Chowdhury, M. S. H. (2010). The role of women in traditional farming systems as practiced in homegardens: a case study in Sylhet Sadar Upazila, Bangladesh. Tropical Conservation Science, 3(1), 17–30. Retrieved from http://tropicalconservationscience.mongabay.com/content/v3/10-03-29_17-30_sohel_et_al.pdf

6. Akinnifesi, F. K., Ajayi, O. C., Sileshi, G., Chirwa, P. W., & Chianu, J. (2010). Fertiliser trees for sustainable food security in the maize-based production systems of East and Southern Africa. A review. Agronomy for Sustainable Development, 30(3), 615–629. doi:10.1051/agro/2009058

7. Alavalapati, J. R. R., Shrestha, R. K., Stainback, G. A., & Matta, J. R. (2004). Agroforestry development: An environmental economic perspective. Agroforestry Systems, 61-2(1), 299–310. doi:10.1023/B:AGFO.0000029006.64395.72

8. Ali, T., Ahmad, M., Shahbaz, B., & Suleri, A. (2007). Impact of participatory forest management on financial assets of rural communities in Northwest Pakistan. Ecological Economics, 63(2-3), 588–593. doi:10.1016/j.ecolecon.2006.12.017

9. Antle, J. M., Stoorvogel, J. J., & Valdivia, R. O. (2007). Assessing the economic impacts of agricultural carbon sequestration: Terraces and agroforestry in the Peruvian Andes. Agriculture, Ecosystem & Environment, 122(4), 435–445. doi:10.1016/j.agee.2007.02.003

10. Asaah, E. K., Tchoundjeu, Z., Leakey, R. R. B., Takousting, B., Njong, J., & Edang, I. (2011). Trees, agroforestry and multifunctional agriculture in Cameroon. International Journal of Agricultural Sustainability, 9(1), 110–119. doi:10.3763/ijas.2010.0553

11. Ayarza, M., Huber-Sannwald, E., Herrick, J. E., Reynolds, J. F., García-Barrios, L., Welchez, L. A., Lentes, P., et al. (2010). Changing human-ecological relationships and drivers using the Quesungual agroforestry system in western Honduras. Renewable Agriculture and Food Systems, 25(3), 219–227. Retrieved from http://journals.cambridge.org/download.php?file=/RAF/RAF25_03/S1742170510000074a.pdf&code=48baf833962db65ed990e75cf703ee45

12. Basinger, M., Chen, J., Jeffrey-Coker, F., Rodriguez-Sanchez, F. S., Singer, T., & Modi, V. (2011). Jatropha adoption: a statistical observational study of factors influencing Malian farmers' decision to grow Jatropha. Agroforestry Systems, 84(1), 59–72. Retrieved from http://link.springer.com/10.1007/s10457-011-9426-z

13. Baynes, J., Herbohn, J., & Russell, I. (2010). The influence of farmers' mental models on an agroforestry extension program in the Philippines. Small-scale Forestry, 10(3), 377–387. Retrieved from http://link.springer.com/10.1007/s11842-010-9154-7

14. Bellamy, A. S. (2013). Banana production systems: Identification of alternative systems for more sustainable production. Ambio, 42(3), 334–343. doi:10.1007/s13280-012-0341-y

15. Birol, E., Smale, M., & Gyovai, Á. (2006). Using a choice experiment to estimate farmers' valuation of agrobiodiversity on Hungarian small farms. Environmental and Resource Economics, 34(4), 439–469. Retrieved from http://link.springer.com/10.1007/s10640-006-0009-9

16. Boulay, A., Tacconi, L., & Kanowski, P. (2011). Drivers of adoption of eucalypt tree farming by smallholders in Thailand. Agroforestry Systems, 84(2), 179–189. Retrieved from http://link.springer.com/10.1007/s10457-011-9451-y

17. Brown, D. R., Dettmann, P., Rinaudo, T., Tefera, H., & Tofu, A. (2011a). Poverty alleviation and environmental restoration using the Clean Development Mechanism: A case study from Humbo, Ethiopia. Environmental Management, 48(2), 322–333. doi:10.1007/s00267-010-9590-3

18. Bucagu, C., Vanlauwe, B., Wijk, M. T., & Giller, K. E. (2012). Assessing farmers' interest in agroforestry in two contrasting agro-ecological zones of Rwanda. Agroforestry Systems, 87(1), 141–158. Retrieved from http://link.springer.com/10.1007/s10457-012-9531-7

19. Cacho, O. J., Lipper, L., & Moss, J. (2013). Transaction costs of carbon offset projects: A comparative study. Ecological Economics, 88(null), 232–243. Retrieved from http://dx.doi.org/10.1016/j.ecolecon.2012.12.008

20. Catacutan, D., & Cramb, R. (2004). Scaling up adoption of contour-hedgerow farming in the southern Phlippines: the landcare approach. 12th Australian Society of Agronomy Conference, 4th International Crop Science Congress. Brisbane, Australia: International Crop Science Congress. Retrieved from http://regional.org.au/au/asa/2004/poster/4/2/1278_catacutan.htm

21. Center for Independent Evaluations (2011). Evaluation of ICRAF's Agroforestry Food Security Programme (AFSP) 2007-2011 (pp. 1–48). Lilongwe, Malawi.

22. CDKN. (2011). An integrated system of agro-forestry in Zambia. Inside Stories on Climate Compatible Development, (December).

23. Chacon-Leon, M., & Harvey, C. A. (2013). Reservas de biomasa de arboles dispersos en potreros y mitigacion al cambio climatico. Agronomia Mesoamericana, 24(1), 17–26.

24. Chakeredza, S., Hove, L., Akinnifesi, F. K., Franzel, S., Ajayi, O. C., & Sileshi, G. (2007). Managing fodder trees as a solution to human-livestock food conflicts and their contribution to income generation for smallholder farmers in southern Africa. Natural Resources Forum, 31(4), 286–296. Retrieved from http://doi.wiley.com/10.1111/j.1477-8947.2007.00160.x

25. Chandrashekara, U. M. (2009). Tree species yielding edible fruit in the coffee-based homegardens of Kerala, India: their diversity, uses and management. Food Security, 361–370.

26. Climate & Development Knowledge Network. (2011). From vulnerability to resilience: Farmer Managed Natural Regeneration (FMNR) in Niger. Inside Stories on Climate Compatible Development, (November), 1–4.

27. Cole, R. (2010). Social and environmental impacts of payments for environmental services for agroforestry on small-scale farms in southern Costa Rica. International Journal of Sustainable Development & World Ecology, 17(3), 208–216. Retrieved from http://people.ucsc.edu/~kholl/Cole 2010 PES.pdf

28. Cubbage, F., Balmelli, G., Bussoni, A., Noellemeyer, E., Pachas, A. N., Fassola, H., Colcombet, L., et al. (2012). Comparing silvopastoral systems and prospects in eight regions of the world. Agroforestry Systems, 86(3), 303–314. Retrieved from http://link.springer.com/10.1007/s10457-012-9482-z

29. Czerepowicz, L., Case, B. S., & Doscher, C. (2012). Using satellite image data to estimate aboveground shelterbelt carbon stocks across an agricultural landscape. Agriculture, Ecosystems & Environment, 156, 142–150. Retrieved from http://linkinghub.elsevier.com/retrieve/pii/S0167880912001934

30. Das, T., & Das, A. K. (2005). Inventorying plant biodiversity in homegardens : A case study in Barak Valley, Assam, North East India. Current Science, 89(1), 155–163.

31. De Jong, B. H. J., Tipper, R., & Montoya-Gomez, G. (2000). An economic analysis of the potential for carbon sequestration by forests: evidence from southern Mexico. Ecological Economics, 33(2), 313–327. doi:10.1016/S0921-8009(99)00162-7

32. De Souza, Helton Nonato, De Goede, R. G. M., Brussaard, L., Cardoso, I. M., Duarte, E. M. G., Fernandes, R. B. A., Gomes, L. C., et al. (2012). Protective shade, tree diversity and soil properties in coffee agroforestry systems in the Atlantic Rainforest biome. Agriculture, Ecosystems & Environment, 146(1), 179–196. doi:10.1016/j.agee.2011.11.007

33. Degrande, A., Tadjo, P., Takoutsing, B., Asaah, E., Tsobeng, A., & Tchoundjeu, Z. (2012). Getting trees into farmers' fields: Success of rural nurseries in distributing high quality planting material in Cameroon. Small-Scale Forestry. doi:10.1007/s11842-012-9220-4

34. Dhakal, A., Cockfield, G., & Maraseni, T. N. (2012). Evolution of agroforestry based farming systems: a study of Dhanusha District, Nepal. Agroforestry Systems, 86(1), 17–33. Retrieved from http://link.springer.com/10.1007/s10457-012-9504-x

35. Duguma, L. A. (2013). Financial analysis of agroforestry land uses and its implications for smallholder farmers livelihood improvement in Ethiopia. Agroforestry Systems, 87(1), 217–231. doi:10.1007/s10457-012-9537-1

36. Enete, A. A., Madu, I. A., & Onwubuya, E. A. (2012). Climate change and the profitability of indigenous adaptation practices in smallholder agriculture in South East Nigeria. Outlook on Agriculture, 41(3), 179–185. doi:10.5367/oa.2012.0092

37. Fifanou, V. G., Ousmane, C., Gauthier, B., & Brice, S. (2011). Traditional agroforestry systems and biodiversity conservation in Benin (West Africa). Agroforestry Systems, 82(1), 1–13. Retrieved from http://link.springer.com/10.1007/s10457-011-9377-4

38. Franzel, S., Denning, G. L., Lillesø, J. P. B., & Mercado, A. R. (2004). Scaling up the impact of agroforestry: Lessons from three sites in Africa and Asia. Agroforestry Systems, 61-62(1-3), 329–344. Retrieved from http://link.springer.com/10.1023/B:AGFO.0000029008.71743.2d

39. Frey, G. E., Fassola, H. E., Pachas, A. N., Colcombet, L., Lacorte, S. M., Pérez, O., Renkow, M., et al. (2012). Perceptions of silvopasture systems among adopters in northeast Argentina. Agricultural Systems, 105(1), 21–32. Retrieved from http://dx.doi.org/10.1016/j.agsy.2011.09.001

40. Galhena, D. H. (2012). Home gardens for improved food security and enhanced livelihoods in Northern Sri Lanka. Michigan State University.

41. Garrity, D. P., Akinnifesi, F. K., Ajayi, O. C., Weldesemayat, S. G., Mowo, J. G., Kalinganire, A., Larwanou, M., et al. (2010). Evergreen Agriculture: a robust approach to sustainable food security in Africa. Food Security, 2(3), 197–214. doi:10.1007/s12571-010-0070-7

42. Gibreel, T. M. (2012). Crop commercialization and adoption of gum-arabic agroforestry and their effect on farming system in western Sudan. Agroforestry Systems, 87(2), 311–318. Retrieved from http://link.springer.com/10.1007/s10457-012-9552-2

43. Glenn, J. V. (2012). Economic Assessment of Landowner Incentives: Analysis in North Carolina and Malawi. North Carolina State University.

44. Godwill, N. (2009). Impact Assessment of Tree Domestication on the Livelihoods of the Local Population: Case Study of the Northwest Region of Cameroon. University of Dschang.

45. Groom, B., & Palmer, C. (2012). REDD+ and rural livelihoods. Biological Conservation, 154, 42–52. Retrieved from http://dx.doi.org/10.1016/j.biocon.2012.03.002

46. Hadgu, K. M., Kooistra, L., Rossing, W. A. H., & Bruggen, A. H. C. (2009). Assessing the effect of Faidherbia albida based land use systems on barley yield at field and regional scale in the highlands of Tigray, Northern Ethiopia. Food Security, 1(3), 337–350. Retrieved from http://link.springer.com/10.1007/s12571-009-0030-2

47. Haglund, E., Ndjeunga, J., Snook, L., & Pasternak, D. (2011). Dry land tree management for improved household livelihoods: farmer managed natural regeneration in Niger. Journal of environmental management, 92(7), 1696–705. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/21458910

48. Hergoualc'h, K., Blanchart, E., Skiba, U., Hénault, C., & Harmand, J.-M. (2012). Changes in carbon stock and greenhouse gas balance in a coffee (Coffea arabica) monoculture versus an agroforestry system with Inga densiflora, in Costa Rica. Agriculture, Ecosystems & Environment, 148, 102–110. Retrieved from http://linkinghub.elsevier.com/retrieve/pii/S0167880911003987

49. Herve B., B. D., & Vidal, S. (2008). Plant biodiversity and vegetation structure in traditional cocoa forest gardens in southern Cameroon under different management. Biodiversity and Conservation, 17(8), 1821–1835. doi:10.1007/s10531-007-9276-1

50. Ihalainen, L. (2007). Improved Rubber Agroforestry System RAS1 in West Kalimantan, Indonesia: Biodiversity and Farmers' Perceptions. University of Helsinki.

51. Irshad, M., Khan, A., Inoue, M., Ashraf, M., & Sher, H. (n.d.). Identifying factors affecting agroforestry system in Swat, Pakistan. African Journal of Agricultural Research, 6(11), 2586–2593. Retrieved from http://www.academicjournals.org/AJar/PDF/pdf2011/4 Jun/Irshad et al.pdf

52. Jaramillo, J., Setamou, M., Muchugu, E., Chabi-Olaye, A., Jaramillo, A., Mukabana, J., Maina, J., et al. (2013). Climate change orrUrbanization? Impacts on a traditional coffee Production system in East Africa over the last 80 years. PLOS ONE, 8(1). doi:10.1371/journal.pone.0051815

53. Jera, R., & Ajayi, O. C. (2008). Logistic modelling of smallholder livestock farmers ' adoption of tree-based fodder technology in Zimbabwe. Agrekon, 47(3), 37–41.

54. Kabwe, G. (2010). Uptake of Agroforestry Technologies among Smallholder Farmers in Zambia. Lincoln University.

55. Leakey, R., & Tentchou, J. (2009). Mid-Term Evaluation: Agricultural and Tree Products Program, Food for Progress 2006 (pp. 1–87). Yaounde, Cameroon.

56. Lembaga Kemitraan Pembangunan Sosial. (2013). Mid Term Evaluation Report: INFOCUS Project (Increase Food Security within the Community through Sustainable Livelihood and Natural Resource). World Vision Indonesia.

57. Lenka, N. K., Dass, A., Sudhishri, S., & Patnaik, U. S. (2012). Soil carbon sequestration and erosion control potential of hedgerows and grass filter strips in sloping agricultural lands of eastern India. Agriculture, Ecosystems & Environment, 158, 31–40. doi:10.1016/j.agee.2012.05.017

58. Lin, B. B. (2007). Agroforestry management as an adaptive strategy against potential microclimate extremes in coffee agriculture. Agricultural and Forest Meteorology, 144(1-2), 85–94. Retrieved from http://linkinghub.elsevier.com/retrieve/pii/S0168192307000548

59. Magcale-Macandog, D. B., Ranola, F. M., Ranola Jr., R. F., Ani, P. A. B., & Vidal, N. B. (2010). Enhancing the food security of upland farming households through agroforestry in Claveria, Misamis Oriental, Philippines. Agroforestry Systems, 79(3), 327–342. doi:10.1007/s10457-009-9267-1

60. Monela, G. C., Chamshama, S. A. O., Mwaipopo, R., & Gamassa, D. M. (2005). A Study in the Social, Economic and Environmental Impacts of Forest Landscape Restoration in Shinyanga Region, Tanzania. Nairobi, Kenya.

61. Mosquera, O., Buurman, P., Ramirez, B. L., & Amezquita, M. C. (2012). Carbon stocks and dynamics under improved tropical pasture and silvopastoral systems in Colombian Amazonia. Geoderma, 189-190, 81–86. Retrieved from http://linkinghub.elsevier.com/retrieve/pii/S0016706112001875

62. Murgueitio, E., Calle, Z., Uribe, F., Calle, A., & Solorio, B. (2011). Native trees and shrubs for the productive rehabilitation of tropical cattle ranching lands. Forest Ecology and Management, 261(10), 1654–1663. Retrieved from http://dx.doi.org/10.1016/j.foreco.2010.09.027

63. Mustalahti, I., Bolin, A., Boyd, E., & Paavola, J. (2012). Can REDD plus reconcile local priorities and needs with global mitigation benefits? Lessons from Angai Forest, Tanzania. Ecology and Society, 17(1). doi:10.5751/ES-04498-170116

64. Nath, A. J., Das, G., & Das, A. K. (2009). Above ground standing biomass and carbon storage in village bamboos in North East India. Biomass & Bioenergy, 33(9), 1188–1196. doi:10.1016/j.biombioe.2009.05.020

65. Ndayambaje, J. D., Heijman, W. J. M., & Mohren, G. M. J. (2012). Household determinants of tree planting on farms in rural Rwanda. Small-Scale Forestry, 11(4), 477–508. Retrieved from http://link.springer.com/10.1007/s11842-012-9196-0

66. Nguyen, Q., Hoang, M. H., Öborn, I., & Noordwijk, M. (2012). Multipurpose agroforestry as a climate change resiliency option for farmers: an example of local adaptation in Vietnam. Climatic Change, 117(1-2), 241–257. Retrieved from http://link.springer.com/10.1007/s10584-012-0550-1

67. Noordin, Q., Niang, A., Jama, B., & Nyasimi, M. (2001). Scaling up adoption and impact of agroforestry technologies: Experiences from western Kenya. Development in Practice, 11(4), 509–523. doi:10.1080/09614520120066783

68. Pagiola, S., Ramírez, E., Gobbi, J., De Haan, C., Ibrahim, M., Murgueitio, E., & Ruíz, J. P. (2007). Paying for the environmental services of silvopastoral practices in Nicaragua. Ecological Economics, 64(2), 374–385. Retrieved from http://dx.doi.org/10.1016/j.ecolecon.2007.04.014

69. Pasicolan, P. N., Udo de Haes, H. A., & Sajise, P. E. (1997). Farm forestry: An alternative to government-driven reforestation in the Philippines. Forest Ecology and Management, 99(1-2), 261–274. doi:10.1016/S0378-1127(97)00212-0

70. Pender, J., Suyanto, Kerr, J., & Kato, E. (2008). Impacts of the Hutan Kamasyarakatan Social Forestry Program in the Sumberjaya Watershed, West Lampung District of Sumatra , Indonesia. Washington, DC.

71. Place, F., & Binam, J. N. (2013). Economic impacts of farmer managed natural regeneration in the Sahel: end of project technical report for the Free University Amsterdam and IFAD. Nairobi, Kenya.

72. Place, F., Roothaert, R., Maina, L., Franzel, S., Sinja, J., & Wanjiku, J. (2009). The impact of fodder trees on milk production and income among smallholder dairy farmers in East Africa and the role of research. Nairobi, Kenya.

73. Pye-Smith, C. (1975). Seeds of hope: a public-private partnership to domesticate a native tree, Allanblackia, is transforming lives in rural Africa. Nairobi, Kenya. doi:10.1038/256248a0

74. Quinion, A., Chirwa, P. W., Akinnifesi, F. K., & Ajayi, O. C. (2010). Do agroforestry technologies improve the livelihoods of the resource poor farmers? Evidence from Kasungu and Machinga districts of Malawi. Agroforestry Systems, 80(3), 457–465. Retrieved from http://link.springer.com/10.1007/s10457-010-9318-7

75. Rasul, G., & Thapa, G. B. (2006). Financial and economic suitability of agroforestry as an alternative to shifting cultivation: The case of the Chittagong Hill Tracts, Bangladesh. Agricultural Systems, 91(1-2), 29–50. doi:10.1016/j.agsy.2006.01.006

76. Reij, C., Tappan, G., & Smale, M. (2009). Agroenvironmental Transformation in the Sahel: another kind of "green revolution". Washington, D.C.

77. Rinaudo, T. (2012). Farmer Managed Natural Regeneration: Exceptional impact of a novel approach to reforestation in sub-Saharan Africa. ECHO Technical Note, 65, 1–16.

78. Rivera, M., Ferreira, O., Amezquita, E., Castro, A., & Rao, I. M. (2010). Potential of Quesungual agroforestry system as a land use management strategy to generate multiple ecosystem services from sub-humid tropical hillsides. 19th World Congress of Soil Science, Soil Solutions for a Changing World (pp. 75–78). Brisbane, Australia.

79. Sanginga, P. C., Kamugisha, R. N., & Martin, A. M. (2006). Conflicts management, social capital and adoption of agroforestry technologies: empirical findings from the highlands of southwestern Uganda. Agroforestry Systems, 69(1), 67–76. doi:10.1007/s10457-006-9018-5

80. Schmitt-Harsh, M., Evans, T. P., Castellanos, E., & Randolph, J. C. (2012). Carbon stocks in coffee agroforests and mixed dry tropical forests in the western highlands of Guatemala. Agroforestry Systems, 86(2, SI), 141–157. doi:10.1007/s10457-012-9549-x

81. Senegal, W. V. (2012). End of project evaluation: Senegal Food and Livelihood. World Vision Senegal.

82. Sibelet, N., & Montzieux, M. (2012). Resilience factors in the coffee sector of Kenya: From food security to product removal. Cahiers Agricultures, 21(2-3), 179–191. doi:10.1684/agr.2012.0563

83. Sirrine, D., Shennan, C., & Sirrine, J. R. (2010). Comparing agroforestry systems' ex ante adoption potential and ex post adoption: on-farm participatory research from southern Malawi. Agroforestry Systems, 79(2), 253–266. Retrieved from http://link.springer.com/10.1007/s10457-010-9304-0

84. Soto-Pinto, L., Castillo-Santiago, M. A., & Jiménez-Ferrer, G. (2010). Agroforestry Systems and Local Institutional Development for Preventing Deforestation in Chiapas , Mexico. In P. Mutinho (Ed.), Deforestation Around the World (pp. 333–350). Rijeka, Croatia.

85. Souza, Helton N, Cardoso, I. M., Fernandes, J. M., Garcia, F. C. P., Bonfim, V. R., Santos, A. C., Carvalho, A. F., et al. (2010). Selection of native trees for intercropping with coffee in the Atlantic Rainforest biome. Agroforestry Systems, 80(1), 1–16. doi:10.1007/s10457-010-9340-9

86. Takimoto, A., Nair, P. K. R., & Alavalapati, J. R. R. (2008). Socioeconomic potential of carbon sequestration through agroforestry in the West African Sahel. Mitigation and Adaptation for Global Change, 13(7), 745–761. doi:10.1007/s11027-007-9140-3

87. Takimoto, A., Nair, P. K. R., & Nair, V. D. (2008). Carbon stock and sequestration potential of traditional and improved agroforestry systems in the West African Sahel. Agriculture, Ecosystems & Environment, 125(1-4), 159–166. doi:10.1016/j.agee.2007.12.010

88. Thangata, P. H., & Hildebrand, P. E. (2012). Carbon stock and sequestration potential of agroforestry systems in smallholder agroecosystems of sub-Saharan Africa: Mechanisms for `reducing emissions from deforestation and forest degradation' (REDD+). Agriculture, Ecosystems & Environment, 158, 172–183. doi:10.1016/j.agee.2012.06.007

89. World Vision. (2012a). LEAP Annual Programme Management Report. East Sumba, Indonesia.

90. Vision, W. (2012b). Turning "Deserts" into Food Bowls by Releasing the Underground Forest Latest developments in Farmer Managed Natural Regeneration (pp. 1–8).

91. Weyerhaeuser, H., Wilkes, A., & Kahrl, F. (2005). Local impacts and responses to regional forest conservation and rehabilitation programs in China's northwest Yunnan province. Agricultural Systems, 85(3), 234–253. Retrieved from http://dx.doi.org/10.1016/j.agsy.2005.06.008

92. Wibawa, G., Joshi, L., Budi, & Akiefnawati, R. (2007). Smallholder Rubber Agroforestry for improved income and sustainable production. Mimeo (pp. 1–16). Bogor, Indonesia.

93. Yamanoshita, M. Y., & Amano, M. (2012). Capability development of local communities for project sustainability in afforestation/reforestation clean development mechanism. Mitigation and Adaptation for Global Change, 17(4), 425–440. doi:10.1007/s11027-011-9334-6.

ANNEX 5. LIST OF 111 TBEA SITES IDENTIFIED THROUGH THE LITERATURE REVIEW

List of 111 TBEA sites identified through the literature review				
Country	**Specific site name (if applicable)**	**Scale of site**	**TBEA practices**	**At scale?**
		Africa		
Benin	Pendjari Biosphere Reserve and surrounding area	Landscape	Natural regeneration	
Burkina Faso	Central Plateau	Sub-national administrative unit	Natural regeneration	Yes
Burkina Faso	Central Plateau	Landscape	Agroforestry	Yes
Cameroon	Southern Camaroon	Sub-national administrative unit	Forest garden	
Cameroon	West and North-West Cameroon	Sub-national administrative unit	Improved fallows	Yes
Cameroon	West and North-West regions of Cameroon	landscape	Participatory tree domestication	
Cameroon	Momo and Mezam Divisions (Batibo, Kugwe, Bafut)	Sub-national administrative unit	Participatory tree domestication, fertilizer trees	
Cameroon	Njinikom Boyo Division	Sub-national administrative unit	Participatory tree domestication	
Cameroon	Bui Division	Sub-national administrative unit	Fertilizer trees, boundary planting, participatory tree domestication	
Cameroon	Koung-Khi Division	Sub-national administrative unit	Participatory tree domestication, fertilizer trees	
Cameroon	northwest Cameroon	Sub-national administrative unit	Participatory tree domestication	
Ethiopia	Humbo	Multiple communities	Natural regeneration	Yes
Ethiopia	Menagesha Suba	Landscape	Wood lots, hedgerows, homegardens	Yes
Ethiopia	Tigray	Sub-national administrative unit	Fertilizer trees	Yes
Kenya	Kiambu	Sub-national administrative unit	Coffee agroforestry	Yes
Kenya	Karatina, Kangema, Embu	Sub-national administrative unit	Coffee agroforestry	Yes
Kenya	Starting in Embu, extending to whole country	landscape	Fodder banks	
Kenya	Western Kenya	Sub-national administrative unit	Improved fallows	

List of 111 TBEA sites identified through the literature review				
Country	**Specific site name (if applicable)**	**Scale of site**	**TBEA practices**	**At scale?**
Kenya, Tanzania, Zambia, Malawi, Zimbabwe, South Africa, Swaziland and Lesotho	East and Southern Africa	Multiple country region	Fertilizer trees, improved fallows, intercropping	Yes
Kenya, Uganda, Tanzania, and Rwanda	East Africa	Multiple country region	Fodder banks, hedgerows, boundary planting	Yes
Malawi		Country	Fertilizer trees	Yes
Malawi	Ntcheu, Salima	Sub-national administrative unit	Improved fallows	
Malawi	11 districts (Mzimba, Karonga, Salima, Dedza, Ntcheu, Ntshisi, Lilongwe, Chikhwawa, Mulanje, Machinga, Thyolo	Sub-national administrative unit	Fertilizer trees, fuelwood production on farmland, smallholder fruit production	
Malawi	Chulu and			
Kasungu-Chipala	Multiple communities	Improved fallows		
Malawi	Songani	Watershed	Fertilizer trees	
Malawi	Kasungu, Machinga	Sub-national administrative unit	Intercropping, fertilizer trees	
Malawi, Tanzania, Mozambique, Zambia and Zimbabwe	not reported	Multiple country region	Fodder banks	
Malawi, Tanzania, Mozambique, Zambia and Zimbabwe	not reported	Multiple country region	Fertilizer trees	Yes
Mali	Koulikoro, Kita and Kati	Sub-national administrative unit	Silviculture	
Mali	Segou	Landscape	Parkland agroforestry, live fencing, fodder banks	
Mali	Ségou region	Sub-national administrative unit	Parkland agroforestry, live fencing, fodder banks	
Mozambique	Gorongosa National Park	Landscape	Agroforestry	
Niger		Country	Natural regeneration, parkland agroforestry	Yes
Niger	Maradi	Sub-national administrative unit	Natural regeneration	Yes

List of 111 TBEA sites identified through the literature review				
Country	**Specific site name (if applicable)**	**Scale of site**	**TBEA practices**	**At scale?**
Niger		Country	Natural regeneration	Yes
Niger	Maradi and Zinder	Sub-national administrative unit	Parkland agroforestry	Yes
Niger	Maradi Region	Sub-national administrative unit	Natural regeneration	
Niger		Country	Natural regeneration	Yes
Niger, Burkina Faso, Mali, Senegal	Sahel	Multiple country region	Natural regeneration	
Nigeria	Enugu and Imo	Sub-national administrative unit	Agroforestry, intercropping	
Rwanda	Central Plateau and Buberuka	Landscape	Agroforestry	Yes
Rwanda	Entire country	Country	Trees in farmland	
Senegal	Thiappy, Fatick, Nguer, East Kaolack	Multiple communities	Natural regeneration	
Sudan	North Kordofan	Sub-national administrative unit	Gum-arabic agroforestry	
Tanzania	Angai Villages Land Forest Reserve	Landscape	Community-based forestry management	Yes
Tanzania	Shinyanga Region	Sub-national administrative unit	Ngitili	Yes
Tanzania, Ghana	Tanzania, Ghana	Multiple country region	Allanblackia, participatory tree domestication	
Uganda	Kabale	Sub-national administrative unit	Fertilizer trees	
Zambia	Eastern-Zambia	Sub-national administrative unit	Improved fallows	Yes
Zambia	Eastern-Zambia	Sub-national administrative unit	Improved fallows	Yes
Zambia	Eastern Zambia (plateau area)	landscape	Fertilizer trees	
Zambia	Eastern Province	Sub-national administrative unit	Improved fallows, fodder banks, participatory tree domestication	
Zambia	Zambia	Country	Evergreen agriculture, conservation agriculture with trees	
Zambia	Central and Southern provinces	Sub-national administrative unit	Conservation agriculture with trees	Yes
Zambia	Not reported	Multiple communities	Fertilizer trees	Yes

List of 111 TBEA sites identified through the literature review				
Country	**Specific site name (if applicable)**	**Scale of site**	**TBEA practices**	**At scale?**
Zimbabwe	Nharira, Chikwaka, Mvuma, Zvimba, Gokwe (5 sites from the Dairy Development Project, probably towns)	Multiple communities	Fodder banks	
		Asia		
Bangladesh	Sylhet Sadar Upazila	Sub-national administrative unit	Homegarden	Yes
Bangladesh	Chittagong	Sub-national administrative unit	Agroforestry	Yes
China	Yellow and Yangtze river basins	Watershed	Trees on sloping lands, afforestation	Yes
China	Zhongyuan	community/town	Trees on sloping lands, afforestation	Yes
India	Kokriguda village	Community/town	Hedgerows	
India	Wayanad	Sub-national administrative unit	Homegarden	Yes
India	Barak Valley	Sub-national administrative unit	Homegarden	Yes
India	Barak Valley	Landscape	Homegarden with bamboo	
Indonesia	not reported	Country	Rubber agroforestry	Yes
Indonesia	Lampung	Sub-national administrative unit	Multi-strata agroforestry	
Indonesia	Sumberjaya	Watershed	Participatory forest management	
Indonesia	West Kalimantan	Sub-national administrative unit	Rubber agroforestry	
Indonesia	East Sumba	Sub-national administrative unit	Natural regeneration	
Indonesia	East Sumba	Sub-national administrative unit	Natural regeneration	
Nepal	Dhanusha	Sub-national administrative unit	Agrosilviculture, fodder banks	Yes
Pakistan	Khwazakhela, Miandam and Odigram	Multiple communities	Agrosilviculture, silvopastoralism	
Pakistan	Mansehra, Swat	Sub-national administrative unit	Participatory tree domestication	
Philippines	Claveria	Sub-national administrative unit	Hedgerows	Yes
Philippines	Claveria, Lantapan	Sub-national administrative unit	Hedgerows	Yes

List of 111 TBEA sites identified through the literature review				
Country	**Specific site name (if applicable)**	**Scale of site**	**TBEA practices**	**At scale?**
Philippines	Leyte Island (Libagon, Dulag, Leyte Leyte and Bato municipalities)	Sub-national administrative unit	Silviculture	
Philippines	Claveria	Sub-national administrative unit	Hedgerows	
Philippines	Northern Luzon	Sub-national administrative unit	Agrosilviculture, agroforestry, intercropping	Yes
Sri Lanka	Jaffna District	Sub-national administrative unit	Homegarden	Yes
Thailand	Chachoengsao, Kanchanaburi, Kamphaeng phet and Khon Kaen	Sub-national administrative unit	Silviculture	Yes
Vietnam	Cao Phong District	Sub-national administrative unit	Afforestation/reforestation	
Vietnam	Cam My	Landscape	Homegarden	
Latin America				
Argentina	Misiones & Corrientes	Sub-national administrative unit	Silvopastoralism	Yes
Argentina	La Pampa	Sub-national administrative unit	Silvopastoralism	Yes
Argentina	Misiones and northeastern Corrientes	Sub-national administrative unit	Silvopastoralism	
Brazil	Northwest Minas	Sub-national administrative unit	Silvopastoralism	
Brazil	Zona da Mata of Minas Gerais state	Multiple communities	Coffee agroforestry	
Brazil	Zona de Mata	Landscape	Coffee agroforestry	
Colombia	Cesar	Sub-national administrative unit	Silvopastoralism	
Colombia	Amazonia	Landscape	Silvopastoralism	
Costa Rica	Central Valley	Landscape	Coffee agroforestry	
Costa Rica	Buenos Aires	Sub-national administrative unit	Trees in farmland	
Costa Rica	not reported	Country	Banana/coffee agroforestry	
Costa Rica, Nicaragua	Rivas, Matiguás, Cañas, Río Frío	Sub-national administrative unit	Agrosilvopastoralism	
Guatemala	Lake Atitlan	Landscape	Coffee agroforestry	Yes
Honduras	Lempira	Sub-national administrative unit	Quesungual agroforestry	
Honduras	Lempa River upper watershed	Watershed	Quesungual agroforestry	

List of 111 TBEA sites identified through the literature review				
Country	**Specific site name (if applicable)**	**Scale of site**	**TBEA practices**	**At scale?**
Mexico	Central Highlands of Chiapas	Landscape	Community-based forestry management	
Mexico	Chilón and Salto de Agua, Chiapas	Multiple communities	Taungya agroforestry, silvopastoralism	
Mexico	Soconusco region of Chiapas	Sub-national administrative unit	Coffee agroforestry	Yes
Nicaragua	Matiguás, Río Blanco	Sub-national administrative unit	Silvopastoralism	
Peru	La Encanada	Watershed	Agroforestry	
Paraguay	NA	Country	Silvopastoralism	
Uruguay	NA	Country	Silvopastoralism	Yes
US/Canada				
USA	Lake Okeechobee	Watershed	Silvopastoralism	
USA	Southeast	Sub-national administrative unit	Silvopastoralism	
Australia/Oceania				
Australia	Gwydir	Watershed	Natural regeneration	
New Zealand	North Island	Sub-national administrative unit	Silvopastoralism	Yes
New Zealand	Canterbury Plains	Landscape	Shelterbelts	Yes
Europe				
Hungary	Devavanya, Orseg-Vend, Szatmar-Bereg	Landscape	Homegarden	
Slovakia	Silica Plateau	Landscape	Mosaic landscape with trees	Yes

ANNEX 6. ADDITIONAL SUMMARY TABLES FROM LITERATURE REVIEW

Table A-1. Climate or vegetation zone of reviewed TBEA sites

Climate or vegetation zone	No. of TBEA sites
Humid	24
Semi-arid	16
Tropical highland	10
Tropical	9
Sub-humid	6
Savannah	4
Temperate	2
Temperate dryland	1
Arid and semi-arid	1
Arid	1
Humid tropics	1
Subalpine	1
Not reported	35

*Table A-2. Number of TBEA sites where different TBEAs are reported, grouped by continent. *Some sites implemented multiple TBEA practices or systems.*

Country	TBEA practices or systems	No. of sites per TBEA practice or system	Total sites in country
Africa			
Benin	Natural regeneration	1	1
Burkina Faso	Agroforestry	1	2
	Natural regeneration	1	
Cameroon	Fertilizer trees	3	8*
	Boundary planting	1	
	Participatory tree domestication	6	
	Forest gardens	1	
	Improved fallows	1	
Ethiopia	Fertilizer trees	1	3*
	Natural regeneration	1	
	Woodlots	1	
	Hedgerows	1	
	Homegardens	1	

*Table A-2 continued. Number of TBEA sites where different TBEAs are reported, grouped by continent. *Some sites implemented multiple TBEA practices or systems.*			
Country	**TBEA practices or systems**	**No. of sites per TBEA practice or system**	**Total sites in country**
Kenya	Coffee agroforestry	1	4
	Fodder banks	1	
	Improved fallows	1	
	Coffee agroforestry	1	
Kenya, Tanzania and Zambia	Fertilizer trees	1	1
	Improved fallows	1	
	Intercropping	1	
Kenya, Uganda, Tanzania, Rwanda	Fodder banks	1	1*
	Hedgerows	1	
	Boundary planting	1	
Malawi	Fertilizer trees	4	6*
	Fuelwood production on farmland	1	
	Smallholder fruit production	1	
	Improved fallows	2	
	Intercropping	1	
Malawi, Tanzania, Mozambique, Zambia and Zimbabwe	Fertilizer trees	1	2
	Fodder banks	1	
Mali	Live fencing	2	3*
	Fodder banks	2	
	Parkland agroforestry	2	
	Silviculture	1	
Mozambique	Agroforestry	1	1
Niger	Natural regeneration	5	6*
	Parkland agroforestry	2	
Niger, Burkina Faso, Mali, Senegal	Natural regeneration	1	1
Nigeria	Intercropping	1	1*
Rwanda	Agroforestry	1	2
	Trees in farmland	1	
Senegal	Natural regeneration	1	1
Sudan	Gum-arabic agroforestry	1	1
Tanzania	Community-based forestry management	1	2
	Ngitili	1	
Tanzania, Ghana	Allanblackia	1	1*
	Participatory tree domestication	1	
Uganda	Fertilizer trees	1	1

Country	TBEA practices or systems	No. of sites per TBEA practice or system	Total sites in country
*Table A-2 continued. Number of TBEA sites where different TBEAs are reported, grouped by continent. *Some sites implemented multiple TBEA practices or systems.*			
Zambia	Conservation agriculture with trees	2	7
	Evergreen agriculture	1	
	Fertilizer trees	2	
	Improved fallows	3	
	Fodder banks	1	
	Participatory tree domestication	1	
Zimbabwe	Fodder banks	1	1
Asia			
Bangladesh	Agroforestry	1	2
	Homegardens	1	
China	Trees on sloping lands, afforestation	2	2
India	Hedgerows	1	4
	Homegardens	2	
	Homegardens with bamboo	1	
Indonesia	Participatory forest management	1	6
	Multi-strata agroforestry	1	
	Natural regeneration	2	
	Rubber agroforestry	2	
Nepal	Agrosilviculture	1	1*
	Fodder banks	1	
Pakistan	Agrosilviculture	1	2*
	Silvopastoralism	1	
	Participatory tree domestrication	1	
Philippines	Agrosilviculture	1	5*
	Agroforestry	1	
	Intercropping	1	
	Hedgerows	3	
	Silviculture	1	
Sri Lanka	Homegardens	1	1
Thailand	Silviculture	1	1
Vietnam	Afforestation/reforestation	1	2*
	Homegardens	1	
	Forest gardens	1	
Latin America			
Argentina	Silvopastoralism	3	3

*Table A-2 continued. Number of TBEA sites where different TBEAs are reported, grouped by continent. *Some sites implemented multiple TBEA practices or systems.*			
Country	**TBEA practices or systems**	**No. of sites per TBEA practice or system**	**Total sites in country**
Brazil	Coffee agroforestry	2	3
	Silvopastoralism	1	
Colombia	Silvopastoralism	2	2
Costa Rica	Banana/coffee agroforestry	1	3
	Coffee agroforestry	1	
	Trees in farmland	1	
Costa Rica, Nicaragua	Agrosilvopastoralism	1	1
Guatemala	Coffee agroforestry	1	1
Honduras	Quesungual agroforestry	2	2
Mexico	Coffee agroforestry	1	3*
	Community-based forestry management	1	
	Taungya agroforestry	1	
	Silvopastoralism	1	
Nicaragua	Silvopastoralism	1	1
Paraguay	Silvopastoralism	1	1
Peru	Agroforestry	1	1
Uruguay	Silvopastoralism	1	1
Europe			
Hungary	Homegardens	1	1
Slovakia	Trees in farmland (Mosaic landscape with trees)	1	1
United States and Canada			
USA	Silvopastoralism	2	2
Australia and Oceania			
Australia	Natural regeneration	1	1
New Zealand	Shelterbelts	1	2
	Silvopastoralism	1	

Table A-3. Reported positive and negative impacts of TBEA implementation unrelated to measured impacts on food security, carbon sequestration, climate change resilience or income.		
TBEA practice/system, or combination of practices	**Other positive impacts**	**Negative Impacts**
Afforestation / reforestation		Decreased carbon sequestration due to shrub removal, displacement of farming activities, increased labor requirements, and uneven distribution of costs and benefits among practitioners
Agroforestry	Job creation, improved soil quality or fertility, increased number of trees on farms, improved groundwater recharge and increased fuelwood production	Increased incidence of pests and pathogens, and loss of income
Agrosilviculture with agroforestry and intercropping	Increased fuelwood production	
Banana / coffee agroforestry		Loss of income when compared with conventional management
Coffee agroforestry	Empowerment of women, benefits for cooperatives, increased access to schooling, reduced incidence of pests and pathogens, and improved soil quality or fertility	Increased damage to crops, and increased labor requirements
Community-based forestry management		Increased dependence on external resources and sources of income, and loss of incom
Conservation agriculture with trees managed as evergreen agriculture	Reduced soil erosion	
Fertilizer trees, boundary planting and participatory tree domestication	Increased number of trees planted per household, increased access to germplasm, and job creation	
Fertilizer trees, fuelwood production on farmland and smallholder fruit production	Increased fuelwood production and nursery establishment	
Fertilizer trees, improved fallows and intercropping	Increased fuelwood production and improved soil quality or fertility	
Fertilizer trees	Improved conflict management and crop yields	Women often receive few or none of the benefits
Fodder banks, hedgerows and boundary planting	Increased fodder production, improved livestock health and nutrition, increased fuelwood production, reduced soil erosion and improved soil quality or fertility	
Fodder Banks	Increased milk production and quality	
Forest gardens	Increased or conserved biodiversity	
Gum-arabic agroforestry		Increased labor requirements

Table A-3 continued. Reported positive and negative impacts of TBEA implementation unrelated to measured impacts on food security, carbon sequestration, climate change resilience or income.		
TBEA practice/system, or combination of practices	**Other positive impacts**	**Negative Impacts**
Hedgerows	Decreased land degradation and reduced soil erosion	
Homegardens	Increased or conserved agrobiodiversity, use of traditional and organic production methods, reduced costs, improved human well-being, increased fuelwood production, shade, improved soil quality or fertility, increased fodder production, availability of fencing and increased medicinal plant production	
Participatory forest management	Improved tenure security and tree stock	Decreased land values
Improved fallows	Increased fuelwood production, improved livestock health and nutrition, improvement of household assets, job creation, increased access to schooling, empowerment of women, reduced labor requirements, improved soil quality or fertility, and reduced costs	Difficulty of management, damage to crops by trees, increased damage to crops by wildlife, increased risk of fire, increased animal grazing in cropland, increased incidence of pests and pathogens, increased labor requirements, increased land area requirements, and slow accrual of benefits
Multi-strata agroforestry	Increased fuelwood and timber production	
Natural regeneration	Increased or conserved biodiversity, establishment of new management systems, improved user rights and tenure, increased fuelwood production, land reclamation, increased tree cultivation, reduced soil erosion, improved soil quality or fertility, increased timber production, reduced human migration, reduced risk of forest fires, increased savings, and decreased time spent gathering fuelwood	Increased crime, increased labor requirements, increased risk of fire, slow accrual of benefits, crop-tree competition, increased land degradation, undermining of cultural norms, and overshading of crops
Ngitili	Increased or conserved biodiversity, reduced effort to gather forest products, increased fodder production, medicinal plant production, and increased fuelwood production	

Table A-3 continued. Reported positive and negative impacts of TBEA implementation unrelated to measured impacts on food security, carbon sequestration, climate change resilience or income.		
TBEA practice/system, or combination of practices	**Other positive impacts**	**Negative Impacts**
Parkland agroforestry	Increased number of trees on farms, improved groundwater recharge, and increased fuelwood production	Increased incidence of pests and pathogens, crop-tree competition, and dense tree plantings lower the water table
Participatory tree domestication with fertilizer trees	Reduced human migration	
Participatory tree domestication	Increased cultivars for sale and for germplasm multiplication, increased tree cultivation and NTFP production, improved health, reduced human migration, increased tourism, and improved watershed management	Loss of income, risk of losing genetic diversity, increased incidence of pests and pathogens, and increased conflicts between land users
Quesungual agroforestry	Reduced soil erosion, improved crop-water productivity, improved water retention, increased livestock and milk production, and establishment of new institutions	
Rubber agroforestry	Increased or conserved biodiversity	
Silviculture	Reduced labor requirements	
Silvopastoralism	Increased or conserved biodiversity, increased charcoal and timber production, frost prevention, improved pasture productivity, increased fuelwood production, reduced risk of fires, reduced incidence of pests and pathogens, and reduced soil erosion	Crop-tree competition, difficulty of management, increased risk of falling trees, loss of income, negative impacts on livestock well-being, increased labor requirements, increased soil compaction, increased animal grazing in croplands, toxic species endanger humans and livestock, overshading of crops, and reduced land for food production resulting in food insecurity
Taungya agroforestry with silvopastoralism	Reduced deforestation, reduced risk of forest fires, and increased institutional capacity	
Trees on farmland	Increased fuelwood production, improvements to existing agroforestry systems, reduced soil erosion, and improved soil quality or fertility	Overshading of crops, increased financial costs and loss of income
Trees on sloping lands, afforestation	Reduced labor requirements	Reduced land for food production resulting in food insecurity

ANNEX 7. TREE SPECIES AND GENUS IN REVIEWED TREE-BASED ECOSYSTEM APPROACHES

Acacia angustissima

Acacia drepanolobium

Acacia kirkii

Acacia mangium

Acacia mearnsii

Acacia mellifera

Acacia nilotica

Acacia polyacantha

Acacia senegal

Acacia senegal (L.)Willd

Acacia seyal

Acacia seyal var. fistula

Acacia sieberiana

Acacia tanganyikensis

Achras sapota

Actinidia chinensis

Adansonia digitata

Aegiphila sellowiana

Albizia adianthifolia

Albizia harveyi

Allanblackia floribunda

Allanblackia parviflora

Allanblackia stuhlmanii

Alocasia macrorrhiza

Anacardium occidentale

Aningeria adolfi-friederici

Aquilaria sp.

Araucaria angustifolia

Areca catechu

Artocarpus heterophyllus

Artocarpus lakoocha

Attalea butyracea

Azadirachta indica

Azanza garckeana

Baccaurea courtallensis

Bagras sp.

Balanitex aethiopium

Bambusa balcooa

Bambusa cacharensis

Bambusa vulgaris

Bauhinia rufescens

Bombax ceiba

Bombax marginatum

Brachystegia spp.

Cajanus cajan

Calliandra calothrysus

Calophyllum brasiliense

Camellia sinensis

Capsicum spp.

Carica papaya

Carici pilosae-Carpinenion betuli

Carissa carandus

Carpinus betulus

Carya illinoinensis

Catha edulis

Cecropia sp.

Cedrela odorata

Cedrela serrata

Ceiba pentandra

Cephalantero-Fagenion

Chamaecytisus palmensis

Chrysophyllum albidum

Chrysophyllum roxburghii

Citrus aurantium

Citrus limon

Citrus sinensis

Cocos nucifera

Coffea arabica

Cola nitida

Combretum glutinosum

Combretum zeyheri

Commiphora africana

Condalia microphylla

Cordia africana

Cordia sinensis

Croton macrostachyus

Cupressus lusitanica

Cupressus macrocarpa

Dacryodes edulis

Dalbergia melanosylon

Dalbergia nigra

Dichrostachys cinerea

Diosopyrus lotus

Diosopytus kaki

Diplorhynchus condylocarpon

Discoglypremna caloneura

Durio sp.

Ecualyptus camaldulensis

Enterolobium cyclocarpum

Eriobotrya japonica

Ervatamia coronaria

Erythrina abyssinica

Erythrina variegata

Eucalyptus camaldulensis

Eucalyptus deglupta

Eucalyptus globulus

Eucalyptus tereticornis

Eucalyptus urophyla

Fagara macrophylla

Fagus sylvatica

Faidherbia albida

Feronia elephantum

Ficus exasperata

Ficus mucuso

Ficus palmate

Flemingia macrophylla

G. arborea

Garcinia gummi-gutta

Garcinia kila

Garcinia kola

Garcinia xanthochymus

Garuga pinnata

Gliricida sepium

Gliricidia sp.

Gmelina arborea

Grevillea robusta

Guarea guidonia

Guazuma ulmifolia

Guiera senegalensis

Hevea sp.

Hovenia dulcis

Indigenous shrubs

Indigofera teysmanni

Inga densiflora

Irvingia gabonensis

Jatropha sp.

Juglans regia

Lanzones

Lavoixia microcarpa

Lawsonia inermis

Legumes

Leucaena diversifolia

Leucaena esculenta

Leucaena leucocephala

Leucaena pallida

Leucaena trichandra

Leuceana leucocephala

Madhuca indica

Madhuca longifolia

Mahogany

Malus pumila

Mangifera indica

Mangium

Marang

Markhamia spp.

Melia azadarich

Mimusops elengi

Monodora myristica

Morus alba

Musa paradisiaca

Myristica fragrans

Nephelium lappaceum

Newbouldia lewis

Ocimum sanctum

Olea africana

Omorcapum trichocarpum

Parinari curatellifolia

Parkia biglobosa

Pausinystalia johimbe

Persea americana

Philiostigma reticulatum

Pinus radiata

Podocarpus falcatus

Pomelo

Popolus nigra

Populus spp.

Prosopis africana

Prosopis caldenia

Prosopis flexuosa

Prosopis juliflora

Prunus africana

Prunus armaniaca

Prunus communus

Prunus persica

Psidium guajava

Pterocarpus angolensis

Pterocarpus erinaceus

Pterocarpus indicus

Pterocarpus lucens

Pterocarpus soyauxii

Pyrus sinensis

Quercion pubescentis-petraea

Quercus pagoda

Quercus petraea

Rattan

Rhamnus prinoides

Ricinodendron heudelotii

Robinia pseudoacacia

Roystonea regia

Salix babylonica

Salix tetrasperma

Samanea saman

Schinus fasciculatus

Sclerocarya birrea

Senna macranthera

Senna spectabilis

Sesbania sesban

Shorea javanica

Solanum mauritianum

Spondias lutea

Strychnos cocculoides

Swietenia macrophylla

Syagrus zancona

Tamarindus indica

Tectona grandis

Tephrosia candida

Tephrosia vogelii

Terminalia amazonia

Terminalia superba

Tetrapleura tetraptera

Tithonia diversifolia

Toona ciliata

Uapaca kirkiana

Ulnus nitida

Vangueria infausta

Vitellaria paradoxa

Vitex sp.

Zanthoxylum rhoifolium

Ziziphus mauritania

Ziziphus rugosa

Willemen, Louise, Hart, A., Negra, C., Harvey, C., Laestadius, L., Louman, B., Place, F., Winterbottom, R., Scherr, S., 2013. Taking Tree-based Ecosystem Approaches to Scale: Evidence of drivers and impacts on food security, climate change resilience and carbon sequestration. *Ecoagriculture Discussion Paper No. 11*. Washington, DC: EcoAgriculture Partners.

PROFOR ecoagriculturepartners