WORKING PAPER

This review is associated with the Evidence-Based Forestry initiative, a collaboration between CIFOR and partner institutions supporting systematic reviews of evidence to enable better-informed decisions about forests and landscapes.

To what extent does the presence of forests and trees contribute to food production in humid and dry forest landscapes?

A systematic review protocol

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CIFOR

Working Paper 168

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Contents

List of tables and figures

Tables

Figures

Acknowledgments

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1 Background

Ecosystem services are crucial for agricultural production at various scales. Food production systems are often embedded within landscapes that include mosaics of forests, forest fragments, agroforestry systems and agricultural systems. The spatial configuration of such landscapes influences a range of biophysical processes. Pivotal amongst these are the contributions, often described as ecosystem services, made by forests and trees in landscapes supporting agricultural systems. Ecosystem services are regarded as the structures and functions of terrestrial and marine ecosystems that result in both goods and services that contribute to human wellbeing (Daily 1997; Boyd and Banzhaf 2007; Fisher and Kerry Turner 2008).

Ehrlich and Mooney (1983) first coined the term 'ecosystem services' to raise awareness that anthropogenic activity was increasingly degrading habitats and subsequently resulting in the degradation of the functions and services provided by such ecosystems. Since then, there has been growing attention and research on ecosystem services from various analytical angles (see Figure 1). The nature and complexity of assessing ecosystems and the services they provide is reflected in the numerous definitions and classifications that exist (Boyd and Banzhaf 2007).

Forest and tree ecosystems underpin the provision of a range of services, and as such, when appropriately managed, can make vital contributions to food production (Metzger et al. 2006). Ecosystem services provisioning by trees include: habitat for pollinators (Kremen et al. 2002; Ricketts 2004; Balvanera et al. 2005; Klein et al. 2007), habitat for beneficial species that contribute to natural pest control (Pickett and Bugg 1998; Klein et al. 2006; Bale et al. 2008; Karp et al. 2013), reduced downstream impacts of nutrient run-off (Logan 1993) and enhanced nutrient availability (Power 2010). These services can be relatively easily assessed at the local and/or farm scale. Meanwhile, at the (sub-)national and global scale (beyond the scope of this review), the contributions of forest ecosystem services include protection of watersheds, carbon sequestration and climate regulation (Daily and Matson 2008) and the evaluation of such services are much more challenging (de Groot et al. 2010). With reference to Daily et al. (1998), Shibu (2009) and Vihervaara et al. (2010), we attempted a classification of forest ecosystem services by spatial scale. The classification (see Table 1) helps to identify local and regional ecosystems services provided by forests and trees that are considered relevant to the scope of this systematic review.

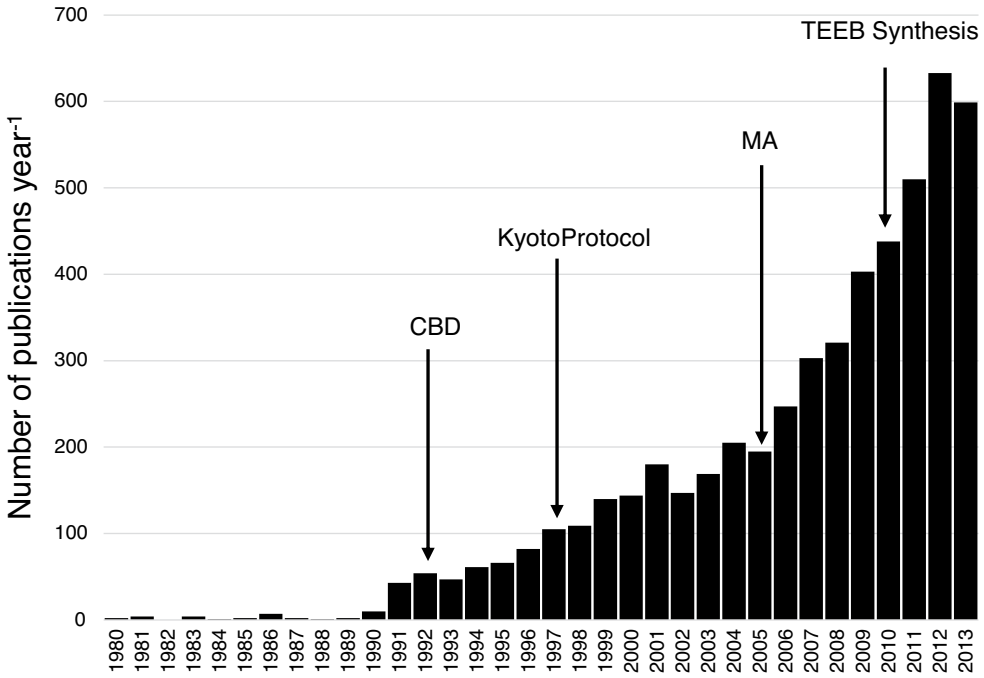

Figure 1. Publications on ecosystems and environmental services over the past three decades with related major international processes. An illustration of the rise in ecosystem services publications since 1980. Rise and awareness and publications linked to international processes on the ecosystem services, environmental sustainability and climate change: the Convention on Biological Diversity (CBD) in 1992, Kyoto Protocol (Kyoto Protocol) in 1997, the Millennium Ecosystem Assessment (MA) 2001–2005 and the most recent 2010 synthesis report from TEEB Foundation (The Economics of Ecosystems and Biodiversity). Data for illustration generated from compiled searches on keywords "ecosystem services", "environmental services" and "natural capital" bibliographic databases: ISI Web of Knowledge, Scopus and CAB Direct.

Table 1. Contribution of forests, trees and agroforestry systems to food production systems at different spatial scales.

Ecosystem services	Spatial scale		
	Farm/ local	Landscape/ regional	Global
Primary production (food and fodder)	x		
Water retention	x		
Nutrient cycling	x		
Pollination services	x	x	
Habitat for beneficial species	x	x	
Natural pest control	x	x	
Soil formation	x	x	
Water regulation	x	x	
Climate regulation	x	x	x
Genetic biodiversity	x	x	x

Summarized from Daily et al. (1998), Shibu (2009), and Locatelli (2012)*: Contributions of forests to agricultural production and food security.

* Locatelli B. 2012. CIFOR-Workshop: The value of forests for agriculture. Center for International Forestry Research, Bogor, October 2012.

Ecosystems research has also established that proximate tree cover can have negative impacts in agricultural systems. Such ecosystem dis-services include damage to crops from pests harbored within the forest and competition for resources, such as light, water, nutrients and pollinators (Zhang et al. 2007). Indeed, studies have shown that in landscapes retaining high tree cover, competition effects have reduced pollinator contributions to crops (Boreux et al. 2013). In contrast, studies in landscapes with heavily deforested areas and low resource availability for pollinators, pollinator diversity and abundance in crop patches was high (Jha and Vandermeer 2010).

In the last half century, agricultural expansion has largely come at the cost of natural forests (Gibbs et al. 2010), but globally, it is estimated that 46% of total agricultural land still retains at least 10% tree cover (de Foresta et al. 2013). Intensification of agricultural systems towards sole dependence on external inputs and strict management of the production environment has resulted in the compromise of our natural resource base (Turner et al. 2001; de Groot et al. 2010). For example, the excessive use of inorganic fertilizers and pesticides can greatly reduce the effectiveness of soil biological processes, nutrient cycling and natural enemies for biological pest control (Brussard et al. 2010). Several such intensified production techniques have caused decline in soil quality, nutrient run-off and water pollution (Logan 1993). Evidence from studies reveal that decline in pollinator diversity and sole dependence on honeybee pollinators can contribute to reduced flowering efficacy, fruit set and yield in pollinator-dependent crops (Garibaldi et al. 2013). Humans have a shared dependency on both forests and agriculture (McKenzie 2013), and as such, agriculture and conservation biology research must adopt a shared responsibility in advancing their sustainability.

Besides the technical advances that downplay the value of nature's services in production systems, agricultural policy and development practice rarely integrate the importance of ecosystem services in food production policy or development initiatives. Instead, priority (indicated by the discrepancies in the literature) often goes for agricultural intensification interventions based on advances in crop and livestock breeding coupled with highly specialized farm management (Tscharntke et al. 2005). However, in the past three decades, there has been considerable attention paid to both research and development in alternative agricultural production methods that aim to reconcile nature's services with food, fiber and fuel production at the farm and landscape levels (Vihervaara et al. 2010). Figure 2 shows a simple illustration of linkages between ecosystem services provisioning and agricultural systems.

It is also recognized that the disciplines of agriculture and other land uses must integrate efforts to achieve sustainable production, conservation and wider development goals (Perfecto 2009; Sunderland 2011). Ecosystems-oriented research is moving from predominantly economic valuation of nature's services (Costanza 1998), to a more integrated landscape approach, in terms of both the biophysical and socioeconomic benefits society derives from these services (Kremen and Ostfield 2005). While economic valuations have succeeded in raising awareness of the value of ecosystems, this alone is inadequate and multiple approaches are required. There is increasing awareness that agricultural production takes place in mixed landscapes of managed and 'natural' mosaics, and hence needs to be addressed as a holistic entity (Perfecto 2009). Additionally, forestry and agricultural research must move away from the traditional and straightforward dichotomy between production and conservation towards more integrated land uses in so-called multifunctional landscapes (Scherr and McNeely 2008; Sayer et al. 2013).

A systematic review summarizing the current evidence base on how forests and trees are integral to fostering sustainable agricultural systems is timely. A robust synthesis can both help our understanding of integrative approaches and also identify areas in agriculture and forestry research where knowledge is lacking.

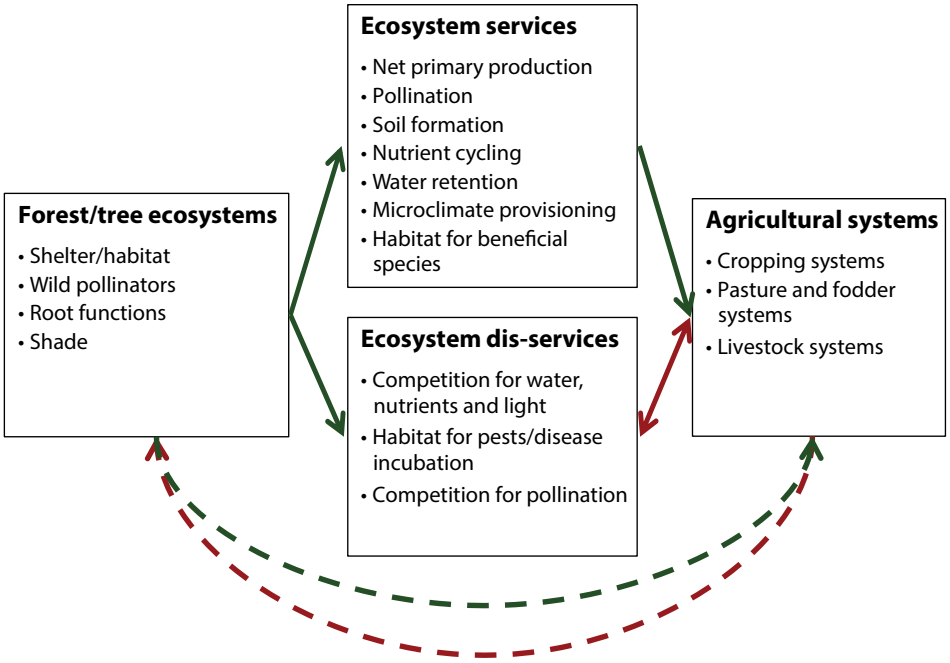

Figure 2. Contribution of ecosystem services and dis-services from trees to agricultural systems.
The contribution of forests, trees and agroforestry to food production systems. Trees and forests regulate functions that produce services and goods directly to produce food or can be transformed indirectly to support crop and livestock production. Forests and trees also compete with agriculture for productions resources. Additionally, tree-based ecosystems may serve as habitat for pests and diseases in what is often referred to as ecosystem dis-services. Adapted from Zhang et al. (2007).

2 Objectives of the review

This review will synthesize the scientific knowledge base on forest and tree-based ecosystem services that contribute to crop, livestock and wider food production at the local (farm) level to regional and/or landscape scale (see Table 2). We intend to analyze (both narratively and quantitatively) the available literature on the positive and negative effects of tree cover on productivity of farming systems in terms of crop and livestock yield and natural resource sustainability.

While ecosystems offer important services at the global scale (i.e. carbon sequestration), this is outside the scope of this review. An indicative list of services (shown in Table 1) has been identified as the ecosystem services provided by forests, trees and agroforestry systems at the selected spatial scale and these will serve as a guide for this study. The study intends to retrieve data from the scientific literature that measures the degree of importance of forests and trees. Second, we will review how forests also perpetuate dis-services in food production systems. By systematically reviewing the literature on both ecosystem services and dis-services, an additional aim of the study is to identify knowledge gaps and make recommendations for future research.

In summary, the review aims to:

1. Identify and appropriately aggregate studies that investigate the contribution of forests and trees to food (crop and livestock) production systems through ecosystem services and dis-services provisioning at farm level and landscape scale.
2. Analyze the identified studies through quantitative synthesis and meta-analysis techniques to establish the effects of forest and tree presence on food production.
3. Assess the literature to determine if there is a systematic publication bias towards certain

Table 2. Study population, interventions, comparators and outcomes (PICO) relevant to the systematic review question.

Population	Interventions	Comparators	Outcomes
Farm (local) and landscape (regional) scale	Tree or forest presence.	Tree or forest absence	Direct and indirect measured effects of tree cover on food production (crop and livestock yield), resource availability and/or competition, utilization and/or conservation

ecosystem services and/or the publication of positive results.
4. Use the findings from the analysis to identify knowledge gaps and recommend future research priorities.

2.1 Primary question

To what extent does the presence of forests and trees contribute to food production in humid and dry forest landscapes?

2.2 Sub-questions

1. How do ecosystem services and dis-services impact food production at farm and landscape scale?
2. How do ecosystem services and dis-services affect natural resource management of production resources (water, nutrients, light, pollination, etc.) at farm and landscape scale?
3. What is the state of the scientific evidence base reporting the effects of different ecosystem services and dis-services on food production, in particular relative differences in the amount and/or quality of studies on, for example, humid vs. dry forest regions, diverse agroforestry vs. 'natural' forest systems, different geographical locations.

3 Methods

3.1 Searches

Experts from invited research institutes and universities met at a workshop held in Noordwijkerhout, the Netherlands, from 29 September to 2 October 2013. The discussions held helped to frame the research question, identify key sources of literature and appropriate experts to advise the review team, and consider the potential outputs of the review and how these might address future decision making in agricultural policies.

Preliminary scoping searches were conducted in November 2013 in Web of Knowledge (WoK), Scopus and CAB Abstracts. Main search terms for the review were established during the framing exercise held in the Netherlands. From this workshop, the main terms were identified as "forests", "ecosystem services", "food production systems", "yield" and "resource management". These main terms were taken forward as the foundation for the initial scoping study. Researchers' own knowledge and thesaurus functions (CAB Thesaurus, Agrovoc and the US National Agricultural Library's (NAL) Agricultural Thesaurus) were applied to expand the main search terms and identify additional terms. The main terms were combined with the Boolean operator 'AND' and this produced 321 hits. Consequently, the main term "ecosystem services" was replaced with specific terms such as "climate regulation", "pollination", etc., and the searches were rerun. This exercise returned over 100,000 publications in total. To improve the specificity, the individual ecosystem services terms were combined into search strings and this trial retrieved approximately 63,000 hits. The preliminary search exercise helped narrow down the scope of the review to exclude "genetic services", "hydrological services" and global climate stabilization services such as "carbon sequestration". The decision was made to exclude these topics due to the sheer mass of their respective publication base, and also considering feasibility regarding the resources and time available for the study. The final lists of the review's search terms and strings are presented in Table 3. Supplementary data on the searches is given in Annex 1.

Search results from all databases used will be exported to Endnote 17 citation manager and cleaned for duplicates. Remaining citations will go through a screening process (guided by the inclusion/exclusion criteria) explained below.

3.1.1 Specialist searches for grey literature

Unpublished literature is likely to be important for this study and will be captured through websites and/or direct emailing of pre-identified institutions that work on issues related to the scope of the review. A flyer calling for grey literature will also be produced and circulated through blog posts and CIFOR social media channels, and distributed at international conferences attended in the early processes of the review. Supplementary data provided as additional file contains the relevant institutions and websites that will be consulted for unpublished literature (see Annex 2). Links to the flyer and blog post calling for grey literature are given as additional files to the protocol (see http://www.cifor.org/blog/seeking-gray-literature-on-contribution-of-forest-ecosystem-services-to-food-production/).

3.2 Internet searches

A search in Google Scholar will test the comprehensiveness of our main searches. The first 300 returned hits will be assessed and any relevant literature not already retrieved from the prior searches will be added to the reference list. Main search terms ("Forest", "Trees", "Ecosystem services", "Farming systems" and "Food production") will be applied for internet searches.

Table 3. Final categories of search terms, phrases and strings that evolved from initial scoping.

Main terms	Expanded terms
1. Forest and trees	*forest* OR tree* OR "humid forest*" OR "dry forest*" OR "tropical forest*" OR agroforest* OR "agro-forest*" OR "primary *forest*" OR "secondary *forest*" OR "forest fragment*" OR "degrad* *forest*" OR planted forest*
2. Ecosystem services	ecosystem service* OR "ecosystem service*" OR "ecosystem function*" OR "ecolog* service*" OR "environment* service*" OR "support* service*" OR "nature* service*" OR "regulat* service*" OR "natur* capital" OR "ecosystem dis-service*" OR "ecosystem disservice*"
2a.	pollinat* OR "animal pollinat*" OR "insect pollinat*" OR "bee pollinat*" OR "wild pollinat*" OR "honey bee*" NOT "wind pollinat*" OR "pollinat* service*"
2b.	Soil* OR "soil regulat*" OR "soil enhanc*" OR "soil protect*" OR "soil fertility" OR "soil quality" OR "soil nutrient*" OR "soil stabiliz*" OR "plant nutri*" OR "nutrient cycling" OR decompos* OR "nitrogen cycling" OR "nitrogen fix*" OR "nitrogen captur*" OR "atmosphere* nitrogen fix*" OR "atmosphere* N* fix*" OR "atmosphere* nitrogen captur*" OR "atmosphere* N* captur*" OR erosion control OR "erosion control" OR "water retention"
2c.	Pest* OR "Crop pest*" OR "pest control" OR "insect pest*" OR "natural enem*" OR "biological control" OR biodiversity OR bio-diversity
2d.	"Climate control" OR "climate regulat*" OR microclimate* OR "climate stabili*" OR "microclimate regulat*"
3. Farming systems	farm* OR agricultur* OR "farm* system*" OR "food produc*" OR "food produc* system*" OR "low input* agricultur*" OR "low input* farm*" OR "low extern* input*" OR "organic farm*" OR "organic agricultur*" OR "biolog* farm*" OR "biolog* agricultur*" OR "biodynamic farm*" OR "bio-dynamic farm*" OR "biodynamic agricultur*" OR "bio-dynamic agriculture*" OR agroforest* OR "agro-forest*" OR "evergreen agricultur*" OR "evergreen farm*" OR "swidden system*" OR "swidden agricultur*" OR "swidden farm*" OR "shifting cultivation" OR "slash and burn" OR "forest* fallow*" OR "permanent fallow*" OR livestock* OR "livestock produc*" OR "crop-livestock system*" OR "crop-livestock farm*" OR "crop-livestock integrat*" OR "silvi-pastoral system*" OR "silvi-pastoral farm*" OR "conserv* agricultur*" OR smallholder produc* OR smallholder agricultur* OR smallholder farm*
4. Food production	Yield* OR "crop yield*" OR "crop produc*" OR "livestock produc*" OR "animal produc*" OR "agricultur* produc*" OR "food produc*" OR "plant produc*" OR "biomass produc*" OR "agricultur* yield*" OR "farm yield*" OR "sustain* yield" OR "sustain* produc*" OR "resource* manag*" OR "natur* resource* manag*" OR "food *security" OR "food system*"

3.3 Study exclusion/inclusion criteria

Studies will be included in the review if they fulfill the criteria outlined below:

Relevant study subject: Studies that measure ecosystem services in agricultural landscapes with tree and/or forest cover. Studies must fall in humid and dry tropics.

Relevant study method/design: Studies use relevant, transparent and repeatable quantitative methodology.

Relevant study comparators: Relevant comparison between agricultural systems with and without presence of forest and/or tree cover.

Relevant study outcomes: Studies measure and report relevant outcomes that show a clear positive, negative or neutral effect of tree/forest presence on ecosystem functions in relevant agricultural landscapes. A preliminary inclusion/exclusion assessment of 100 randomly selected articles will be conducted to test consistency between researchers' screening judgment. Cohen's Kappa metrics will be used to indicate a measure of consistency. A consistency co-efficient of 0.6 or greater is usually accepted as sufficient in the literature (Pullin and Knight 2003).

First stage of inclusion/exclusion entails screening for relevance of articles by title only. Abstracts of remaining articles will be read leaving a smaller number of articles that will be assessed from the full text. The same two researchers will be responsible for the entire screening phase. Researchers will record the study screening process and list all articles that are excluded at each stage as required by systematic review guidelines. This will be provided as supplementary material to the full review paper.

We first become aware of the term 'ecosystem services' being used in the scientific literature in 1983. However, we acknowledge that studies were conducted prior to this on what we now consider to be ecosystem services. We will include all relevant studies dating back to 1950. Searches will be performed in English only. This decision is based on feasibility of study in terms of available time and resources. We will only include studies that are published in English for the same reasons.

3.4 Exclusion criteria

Studies will be excluded from this review if they do not meet inclusion criteria or focus on one or more of the following:

- studies of ecosystem services and dis-services provisioning at (sub)national and global scale
- exploratory studies, conceptual frameworks, methods papers
- general forestry and agricultural policy briefs
- studies that publish benefits of trees and forests to food production without (re)presentation of primary data
- studies solely on economic evaluation and accounting of ecosystem services
- studies outside humid and dry forest regions
- studies on the contribution of wind pollination to crop production
- studies on ecosystem services and dis-services provisioning in agricultural systems without a link/data on the role of forests and trees
- relevant studies but without transparent methodology and/or findings.

3.5 Potential effect modifiers and reasons for heterogeneity

The following are variables that can likely affect outcomes of relevant studies and therefore will be recorded and reported in the full review:

- classification of forests: length of establishment, species mix and proximity to an agricultural system
- type of agricultural system: type of crop(s) and/or livestock
- climate and agro-ecological zone classification
- type of ecosystem service(s) studied

The above is a preliminary list that the researchers intend to amend as further reasons for heterogeneity are identified during the course of the review process.

3.6 Study quality assessment

Study quality assessment will not form part of exclusion/inclusion criteria, i.e. all articles that pass full text screening will be included in the preliminary review synthesis. Further, studies will be assessed for quality in order to conduct a meta-analysis. Studies will be deemed fit for meta-analysis if they present, amongst others, relevant sample means, sample sizes, standard deviations and/or standard errors, etc. During quality assessment, studies will be divided into three categories as: (1) below acceptable quality, (2) acceptable quality and (3) high study quality. Studies categorized as below acceptable quality (1) will be excluded from the meta-analysis. The study quality assessment will be based on:

- duration of experiment
- sound experimental design and analysis
- inclusion of appropriate control treatments
- the extent to which random environmental effects are taken into consideration
- sampling quality (randomization and representativeness) of experimental units
- number of replications, etc.

If studies are highly interesting but do not provide sufficient data, researchers will contact respective authors to access additional data. In the case that extra information cannot be retrieved, studies will be excluded from the meta-analysis.

3.6.1 Data extraction strategy

The following information will be recorded for all included studies/publications:

- title
- author(s)
- journal
- date of publication
- location of study
- scope of study (local/farm or landscape/regional)
- agro-ecological and climatic zone classification (dry forest region, semi-arid Sahel, etc.)
- type of ecosystem service(s) or dis-service(s) studied.
- methodology (i.e. experimental, research station trials, farmer fields or participatory trials)
- type of study (i.e. primary, review or meta-analysis)
- type of food production system (e.g. home garden, agroforestry system, monocropping, crop–livestock systems, etc.)
- dominant landscape configuration (e.g. forest fragments, degraded forests, swidden systems, pastoral systems, etc.)

- proximity to forests and/or tree cover
- type of outcome and effects measured (crop/livestock yields, tree competition for resources, pollination efficacy, reduced pest damage, etc.)
- sample means, standard deviations/errors and correlations of recorded outcomes/effects
- other effect modifiers (e.g. impact of variables other than those studied).

Where data are not completely recorded or missing within the retrieved studies, the reviewers will contact the lead author to see if original data can be obtained. Studies and publications with incomplete data will be excluded from the review.

3.7 Data synthesis and presentation

The systematic review will first and foremost present a narrative synthesis of the data in appropriate categories. Data will be synthesized by region of study, types of forests, types of agricultural systems, types of ecosystem services and dis-services, focus of studies (i.e. on natural resource management, biomass production, yield, etc.). Subsequently, a meta-analysis on sub-groups of the data will be conducted, for example on all studies that measure tree competition effects on crops, or nutrient cycling in agroforestry systems, or water/nutrient/light competition in alley cropping systems, etc. A sub-group meta-analysis is envisioned due to the broad scope of ecosystem services in this review. Within the meta-analysis, a publication bias test will be conducted to elucidate whether certain ecosystem services receive more publications and why. Such a test will also reveal if researchers and publishers systematically report studies that show positive results over others (i.e. neutral to negative results). The aim of the publication bias tests is to help in the identification of knowledge gaps and propose recommendations for further research.

3.8 Dissemination strategy

The full systematic review will be published as a peer reviewed article in *Environmental Evidence*. Findings will be disseminated at international conferences on agriculture and forestry research. The systematic review is additionally intended for a wider audience and will be disseminated as CIFOR Infobrief and in the form of blog posts and policy briefs.

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Annexes

Annex 1. Search strings and combinations developed in scoping study

1. Terms (main and expanded): ((1 and 2) and (3 or 4))
(((*forest* OR tree* OR "humid forest*" OR "dry forest*" OR "tropical forest*" OR agroforest* OR "agro-forest*" OR "primary *forest*" OR "secondary *forest*" OR "forest fragment*" OR "degrad* *forest*" OR planted forest*) AND (ecosystem service* OR "ecosystem service*" OR "ecosystem function*" OR "ecolog* service*" OR "environment* service*" OR "support* service*" OR "nature* service*" OR "regulat* service*" OR "natur* capital" OR "ecosystem disservice*" OR "ecosystem dis-service*" OR "pollinat* OR "animal pollinat*" OR "insect pollinat*" OR "bee pollinat*" OR "wild pollinat*" OR "honey bee*" NOT "wind pollinat*" OR "pollinat* service*" OR Soil* OR "soil regulat*" OR "soil enhanc*" OR "soil protect*" OR "soil fertility" OR "soil quality" OR "soil nutrient*" OR "soil stabiliz*" OR "plant nutri*" OR "nutrient cycling" OR decompos* OR "nitrogen cycling" OR "nitrogen fix*" OR "nitrogen captur*" OR "atmosphere* nitrogen fix*" OR "atmosphere* N* fix*" OR "atmosphere* nitrogen captur*" OR "atmosphere* N* captur*" OR erosion control OR "erosion control" Pest* OR "Crop pest*" OR "pest control" OR "insect pest*" OR "natural enem*" OR "biological control" OR biodiversity OR bio-diversity "Climate control" OR "climate regulat*" OR microclimate* OR "climate stabili*" OR "microclimate regulat*" Watershed* OR groundwater* OR "watershed availab*" OR "watershed* protect*" OR "watershed* regulat*" OR "groundwater* protect*" OR "groundwater* regulat*" OR "groundwater maint*" OR "groundwater stabili*" OR catchment* OR "catchment protect*" OR "water retention*")) AND ((farm* OR agricultur* OR "farm* system*" OR "food produc*" OR "food produc* system*" OR "low input* agricultur*" OR "low input* farm*" OR "low extern* input*" OR "organic farm*" OR "organic agricultur*" OR "biolog* farm*"OR "biolog* agricultur*" OR "biodynamic farm*" OR "bio-dynamic farm*" OR "biodynamic agricultur*" OR "bio-dynamic agriculture*" OR agroforest* OR "agro-forest*" OR "evergreen agricultur*" OR "evergreen farm*" OR "swidden system*" OR "swidden agricultur*" OR "swidden farm*" OR "shifting cultivation" OR "slash and burn" OR "forest* fallow*" OR "permanent fallow*" OR livestock* OR "livestock produc*" OR "crop-livestock system*" OR "crop-livestock farm*" OR "crop-livestock integrat*" OR "silvi-pastoral system*" OR "silvi-pastoral farm*" OR "conserv* agricultur*" OR smallholder produc* OR smallholder agricultur* OR smallholder farm*)) AND ((Yield* OR "crop yield*" OR "crop produc*" OR "livestock produc" OR "animal produc" OR "agricultur* produc*" OR "food produc*" OR "plant produc*" OR "biomass produc*" OR "agricultur* yield*" OR "farm yield*" OR "sustain* yield" OR "sustain* produc" OR "resource* manag*" OR "natur* resource* manag*" OR "food *security" OR "food system*")))

2. Terms (main and expanded): 1 and 2 and 3 and 4
((*forest* OR tree* OR "humid forest*" OR "dry forest*" OR "tropical forest*" OR agroforest* OR "agro-forest*" OR "primary *forest*" OR "secondary *forest*" OR "forest fragment*" OR "degrad* *forest*" OR planted forest*) AND (ecosystem service* OR "ecosystem service*" OR "ecosystem function*" OR "ecolog* service*" OR "environment* service*" OR "support* service*" OR "nature* service*" OR "regulat* service*" OR "natur* capital" OR "ecosystem disservice*" OR "ecosystem dis-service*" OR "pollinat* OR "animal pollinat*" OR "insect pollinat*" OR "bee pollinat*" OR "wild pollinat*" OR "honey bee*" NOT "wind pollinat*" OR "pollinat* service*" OR Soil* OR "soil regulat*" OR "soil enhanc*" OR "soil protect*" OR "soil fertility" OR "soil quality" OR "soil nutrient*" OR "soil stabiliz*" OR "plant nutri*" OR "nutrient cycling" OR decompos* OR "nitrogen cycling" OR "nitrogen fix*" OR "nitrogen captur*" OR "atmosphere* nitrogen fix*" OR "atmosphere* N* fix*" OR "atmosphere* nitrogen captur*" OR "atmosphere* N* captur*" OR erosion control OR "erosion control" Pest* OR "Crop pest*" OR "pest control" OR "insect pest*" OR "natural enem*" OR "biological control" OR biodiversity OR bio-diversity "Climate control" OR "climate regulat*" OR microclimate* OR "climate stabili*" OR "microclimate regulat*" Watershed* OR groundwater* OR "watershed availab*" OR "watershed* protect*" OR "watershed* regulat*" OR "groundwater* protect*" OR "groundwater* regulat*" OR "groundwater maint*" OR "groundwater stabili*" OR catchment* OR "catchment protect*" OR "water retention") AND (farm* OR agricultur* OR "farm* system*" OR "food produc*" OR "food produc* system*" OR "low input* agricultur*" OR "low input* farm*" OR "low extern* input*" OR

"organic farm*" OR "organic agricultur*" OR "biolog* farm*"OR "biolog* agricultur*" OR "biodynamic farm*" OR "bio-dynamic farm*" OR "biodynamic agricultur*" OR "bio-dynamic agriculture*" OR agroforest* OR "agro-forest*" OR "evergreen agricultur*" OR "evergreen farm*" OR "swidden system*" OR "swidden agricultur*" OR "swidden farm*" OR "shifting cultivation" OR "slash and burn" OR "forest* fallow*" OR "permanent fallow*" OR livestock* OR "livestock produc*" OR "crop-livestock system*" OR "crop-livestock farm*" OR "crop-livestock integrat*" OR "silvi-pastoral system*" OR "silvi-pastoral farm*" OR "conserv* agricultur*" OR smallholder produc* OR smallholder agricultur* OR smallholder farm*) AND (Yield* OR "crop yield*" OR "crop produc*" OR "livestock produc" OR "animal produc" OR "agricultur* produc*" OR "food produc*" OR "plant produc*" OR "biomass produc*" OR "agricultur* yield*" OR "farm yield*" OR "sustain* yield" OR "sustain* produc" OR "resource* manag*" OR "natur* resource* manag*" OR "food *security" OR "food system*"))

Annex 2. Relevant institution websites consulted for grey literature

Table 1. Research, development and policy organization websites that were consulted for grey literature.

Organization	Category	Weblink
Center for International Forestry Research (CIFOR)	Research	http://www.cifor.org
World Agroforestry Centre (ICRAF)	Research	http://www.worldagroforestrycentre.org
Forestscience.info	Research	http://cfa.juice-e.co.uk/forestscienceinfo.html
Global Partnership for Forest and Landscape Restoration (GPFLR)	Research	http://www.forestlandscaperestoration.org
World Resources International	Research and Policy	http://www.wri.org
World Environment Library	Database	http://www.nzdl.org/gsdlmod?a=p&p=about&c=envl
Globally Important Agricultural Heritage Systems (GIAHS)	Development	http://www.fao.org/giahs/en
International Model Forest Network (IMFN)	Development and Policy	http://www.imfn.net
International Institute for Environment and Development (IIED)	Research and Development	http://www.iied.org
Terrafrica	Grassroots	http://www.terrafrica.org
United Nations Environment Program–World Conservation Monitoring Centre (UNEP-WCMC)	Research	http://www.unep-wcmc.org
International Union of Forest Research Organizations (IUFRO)	Research and Policy	http://www.iufro.org
The Nature Conservancy (TNC)	Conservation	http://www.nature.org
Ecoagriculture Partners	Research and Development	http://www.ecoagriculture.org
The Consultative Group on International Agriculture Research (CGIAR)	Research	http://www.cgiar.org
Food, Agriculture and Natural Resources Policy Analysis Network (FANRPAN)	Policy	http://www.fanrpan.org
International Institute for Sustainable Development (IISD)	Development and Policy	http://www.iisd.org
Wageningen University and Research Center	Research	http://www.wageningenur.nl
Platform for Agrobiodiversity Research	Research	http://agrobiodiversityplatform.org
Food and Agriculture Organization of the United Nations (FAO)	Development and Policy	http://www.fao.org
The World Bank's Program on Forests (PROFOR)	Development and Policy	http://www.profor.info
Zoological Society of London (ZSL)	Development	http://www.zsl.org

***CIFOR Working Papers* contain preliminary or advance research results on tropical forest issues that need to be published in a timely manner to inform and promote discussion. This content has been internally reviewed but has not undergone external peer review.**

This review assesses the strength of the evidence that reports how forests and trees contribute to agricultural (food) production in order to prioritize further research for better decision-making. The search strategy employs terms from studies on forests, agroforestry, ecosystem services and agriculture across a range of bibliographic databases, internet and specialist search engines and an open call for gray literature. Retrieved articles will be screened by title, abstract and full text and inclusion/exclusion exercise will generate the final list of studies. Data from these studies will be extracted using a coding tool. Due to anticipated heterogeneity in the retrieved data, we will group findings into appropriate categories as an initial presentation of the data. Sub group meta-analysis by types of ecosystem services and other appropriate predictors will be conducted to show the positive or negative effects of forests and trees on food production. We consider there may be significant gaps in the literature with regard to: 1) Which ecosystem services are provided by forests and trees within a landscape; 2) Over what spatial scales are these services transferred, and; 3) To what extent are these services ultimately translated to increased food production?

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This research was carried out by CIFOR as part of the CGIAR Research Program on Forests, Trees and Agroforestry (CRP-FTA). This collaborative program aims to enhance the management and use of forests, agroforestry and tree genetic resources across the landscape from forests to farms. CIFOR leads CRP-FTA in partnership with Bioversity International, CATIE, CIRAD, the International Center for Tropical Agriculture and the World Agroforestry Centre.

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