CEE review 09-012

DO TREE PLANTATIONS SUPPORT HIGHER SPECIES RICHNESS AND ABUNDANCE THAN PASTURE LANDS

Systematic Review Protocol

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Draft protocol published on website: 27 April 2009

Cite as: Felton, A. 2009. Do tree plantations support higher species richness and abundance than pasture lands? CEE protocol 09-012 (SR73) Collaboration for Environmental Evidence: www.environmentalevidence.org/SR73.html.

1. Background

Increased worldwide demand for wood products, coupled with public concern over the loss or degradation of natural forests (Lamb et al. 2001; Lindenmayer and Hobbs 2004), has lead to a steady increase in plantation establishment throughout most regions of the world (FAO 2007). Plantations are being established globally at a rate of 3 million ha per year (2000-2005, FAO 2006) and currently provide almost 50% of the world's wood production (FAO 2007). In some nations, plantations comprise a substantial proportion of national forest area (FAO 2006). The principle benefit of plantations is that they enable large volumes of wood products to be produced per unit of land area (Sedjo 1999), although their capacity to sequester carbon has made this land-use a potential contributor to climate change mitigation efforts (Laclau 2003; Miehle et al. 2006; Paul et al. 2008; Redondo-Brenes 2007).

There is a large literature assessing the relative biodiversity value of plantations versus natural forests (see Barlow et al. 2007; Hartley 2002; Lindenmayer and Hobbs 2004). In almost all cases, plantations contain fewer native fauna and flora relative to that found within natural forests, with a corresponding increased abundance and species richness of exotic species (Barlow et al. 2007; Hartley 2002; Lindenmayer et al. 2002). However, most of the world's new plantations are generally established on former agricultural lands (Sedjo 1999), that are often of declining economic value for grazing or cropping (Lamb et al. 2001). Under these circumstances, plantation establishment may provide both economic and environmental benefits. For instance, plantations can be used to sequester carbon and thereby reduce net greenhouse gas emissions (Jackson and Schlesinger 2004); lower water tables to help reduce dry land salinisation (Walker et al. 2002); and under some circumstances, relieve some of the pressure of timber demands from natural forests (Hartley 2002).

There is an emerging expectation that when established within intensively used landscapes (eg. agriculture), plantations can contribute positively to biodiversity conservation (Hartley 2002; Lugo 1997; Moore and Allen 1999). For instance, the flora and fauna of industrial scale plantations can compare favorably to that found within intensive land uses such as annual crop and pasture lands (Carnus et al. 2006;

Hartley 2002; Moore and Allen 1999). For this reason, there has been promotion of the view that plantations provide higher environmental benefits, associated with increased biodiversity value, than agricultural landscapes (Moore and Allen 1999). We suggest that part of this expectation arises from plantations providing increased structural complexity relative to agricultural landscapes, which increases the variety of available resources upon which greater species diversity can rely (August 1983; Brokaw and Lent 1999; McElhinny et al. 2005). There is empirical and theoretical support for the positive relationship between increasing structural complexity and increases in biodiversity (but see Erdelen 1984; MacArthur et al. 1966; MacArthur and MacArthur 1961; McElhinny et al. 2005). However, if increased structural complexity is to enable plantations to support higher species richness than agricultural areas, then this one factor must dominate other contributing factors to species richness, such as habitat heterogeneity and the presence of native versus exotic vegetation. If generalizations are warranted, and these are to be incorporated into environmental policy and planning, it is important that the form and direction of changes in species richness, abundance and composition associated with these land-uses are identified, as plantations are increasingly replacing a significant percentage of many nations' agricultural lands (Kanowski et al. 2005).

2. Objective of the Review

2.1 Primary question

In this paper our objective was to review existing evidence of how plantations and pasture lands influence species richness and abundance by summarizing the data from the literature using meta-analysis techniques. We formally synthesized the available evidence to test the following hypotheses for different taxonomic groups of flora and fauna,

1) That plantations support higher species richness than pasture lands.
2) That plantations support a high abundance of organisms than pasture lands.

after taking into account available explanatory variables to explain some of the between study variation.

3. Methods

3.1 Search strategy

We define plantations as stands of trees with native or exotic species, created by the regular placement of cuttings, seedlings or seed, selected for their wood-producing potential and managed for the purposes of timber or pulp harvesting (modified from AFS 2003). We define pasture as an area with natural or improved vegetation used for the grazing of livestock. We will search multiple electronic databases and the internet using different combinations of Boolean search-terms. The databases used were Dogpile (http://www.dogpile.com/), Google (http://www.google.com.au/), Google Scholar (http://scholar.google.com.au/), Web of Science (http://www.isiwebofknowledge.com/), and Scirus (http://www.scirus.com/).

We use the following search terms in various combinations: (plantation* OR "planted forest*" OR afforestation OR "production forest*") AND (agricult* OR meadow* OR crop* OR farm* OR grass* OR pastur* OR paddock* OR graz* OR field* OR range*) AND (biodiversity OR diversity OR richness OR abundance OR species OR bird* OR mammal* OR reptile* OR amphibian* OR frog* OR invertebrate* OR insect* OR arthropod* OR plant* OR flora OR fauna). Search terms are run in separate or limited combinations depending on the requirements or limitations of the database used. We also will obtain papers from colleagues and through reference lists from published studies including major review articles and books on plantations (eg. Hartley 2002; Lindenmayer and Hobbs 2004; Moore and Allen 1999; Salt et al. 2004). Furthermore, we will obtain information from some government studies and reports.

3.2 Study inclusion criteria

We seek data for meta-analyses comparing the species richness and abundance of plantations and pasture lands for five taxonomic groups: plants, invertebrates, reptiles/amphibians, mammals, and birds. Studies that provided estimates of mean species richness and/or abundance, and the corresponding estimates of standard deviations and sample sizes, are included in the meta-analysis.

Relevant subject(s): Studies which quantitatively compare species richness or abundance within plantation and pasture lands. Single species studies are not included to reduce the potential for publication bias in favour of those studies for which study species are more likely to show significant differences between the control and treatment.

Types of intervention: Natural experiments are the most likely source of data, whereby researchers use available plantations and pasturelands to compare taxa.

Types of comparator: Species richness or species abundance for both treatment and control.

Types of outcome: Quantitative outcomes comparing species richness or abundance in plantations and pasture lands.

Types of study: All primary studies which report provide estimates of mean species richness or abundance, and the corresponding estimates of standard deviations and sample sizes, are to be included.

3.3 Potential effect modifiers and reasons for heterogeneity:

Studies are likely to vary in the information provided about factors affecting the species richness or abundance of different taxa within pastures and plantations. We are limited to assessing those factors that were consistently reported in the literature. Table 1 shows the covariates which we hope to extract. The variables shown in Table 1 will be fitted as fixed effects to allow us to assess the relationship between the treatment effects and the study characteristics.

Table 1. Explanatory variables sought from primary studies and included in meta-analyses of species richness and abundance for plantations and pasture lands. Potential explanatory variables such as proximity of remnant vegetation, pasture grazing frequency, plantation tree densities, etc., were not provided consistently enough to allow analysis for any single taxa.

Explanatory variable	Description
Climate	Dominant climate where study conducted (tropical, temperate, sub-tropical)
Region	Geographic region were study conducted (Americas, Asia-pacific, Europe, Africa)
Quality	Quality of evidence (see Table 2)
Area	Area in hectares, used for plantation only
Plantation age	Time since last tree planting
Number of trees	Number of tree species planted in the plantation
Native/ exotic	Planting of predominantly native or exotic tree species in the plantation.
Remnant-veg pasture	Retention or absence of remnant vegetation in the pasture
Remnant-veg plantation	Retention or absence of remnant vegetation in the plantation

3.4 Study quality assessment

Variation in the scale of replication and the general quality of experimental design used in the primary studies has the potential to contribute to statistical differences in between-study results. This may result in misleading outcomes from the meta-analysis (Gates 2002), so we assigned each paper a data quality category as outlined in Table 2. Papers were excluded from analyses if they fell into category IV.

Table 2. Hierarchy of quality of evidence based on the information provided in research papers. Modified from Pullin & Knight (2003).

Category	Quality of evidence presented
I	Randomized controlled trial with matched pairs of treatments and controls, Study conducted at an adequate scale for subject taxa
II	Controlled trial of adequate scale for study organism. Unpaired treatments and controls.
III	Unpaired treatments and controls. Scale of study raises potential of confounding effects for the subject taxa considered.
IV	Evidence deemed inadequate due to inherent problems with experimental design.

3.5 Data extraction strategy

Qualitative data will not be used. The primary reviewer will extract all quantitative data, with subsequent checking of a subset of this data by a second reviewer to ensure consistency and validity of extraction technique. All useful data will be stored in a database. See table one.

3.6 Data synthesis and presentation

For all treatments and controls, we will tabulate the estimates of mean species richness and/or abundance, estimates of the standard deviations about the means, and the sample sizes. If an estimate of a standard deviation is not provided, it will be calculated from the estimate of the standard error and sample size. In some cases, the estimate of the standard error will need to be measured from error bars in the figures provided. This information will be presented in forest plots which provide the means and 95% confidence intervals for primary studies in a format which enables ready comparison with a common axis (Whitehead 2002).

For species richness and abundance, a standardized difference between treatment and control means is likely to be used to summarize the findings of each study (Cooper and Hedges 1994, Whitehead 2002). This will be done so that the quantitative findings from the different primary studies are in a standardized form that permits meaningful numerical comparison and analysis across studies. We expect to use the statistic known as Hedges' *g* (Hedges and Olkin 1985)

4. Potential Conflicts of Interest and Sources of Support

This project is financed by the Department of Environment, Water & Heritage, Australia, with the majority of research carried out at The Fenner School of Environment and Society, Australian National University, Canberra. We have no conflicts of interest.

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