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Review article

Forest recovery following shifting cultivation: an overview of existing research

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Abstract

Shifting cultivation is a predominant practice in the majority of tropical hilly tracts. Relatively few studies have examined forest recovery following shifting cultivation and we have reviewed these studies to identify and synthesize general recovery patterns. Most studies report that, although pioneer tree species recover relatively faster, woody biomass of mature forest trees recovers several decades after suspension of cultivation. Analysis of bird-species inventories in 10 studies revealed that up to 70% of mature forest birds may recover in successional sites and that species composition is about 55% similar to that in mature forests within 25 years. Results of mammal studies were likely to have been confounded by hunting effects and therefore the effect of time since suspension of cultivation and hunting impacts need to be investigated separately. As shown by a few studies, we conclude that community recovery can be expected to be accelerated when relatively large forest tracts adjoin a shifting cultivation landscape, in comparison with recovery in sites with shorter fallow cycles in the absence of contiguous forests, which act as sources for recolonization of fauna and vegetation.

Keywords: biodiversity; faunal recovery; secondary forests; species composition; vegetation recovery

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Introduction

Shifting cultivation, also referred to as forest agrarian system, has been widely practised by hill communities in Asia, Africa, and Latin America since the Neolithic period (13,000 to 3,000 BC) [1-2]. The practice is characterized by a cultivation phase, which involves clearing of primary or secondary forest and crop cultivation for one to three years, followed by a fallow phase, during which cultivation is suspended to allow recovery of soil fertility [3]. Conklin [3] defined integral and partial forms of shifting cultivation. The integral form of cultivation, which is primarily practised for farmers' subsistence, includes pioneer swidden farming in which primary or climax forest is cleared annually as well as established swidden farming which involves clearing mostly of secondary forests. On the other hand, partial shifting cultivation is undertaken as a supplementary or temporary activity [3].

Shifting cultivation (*hereafter*, SC) is considered as a major driver of deforestation: globally, until the year 1991, SC had accounted for 61% of overall tropical forest destruction [4]. Nevertheless, the practice persists since it provides subsistence livelihoods to at least 300 to 500 million people worldwide [5] and is intricately linked to cultural, ecological, and economic aspects of communities [6]. While certain ecologists question the sustainability of the practice, since it involves clearing of primary and secondary forests [e.g. 4, 7], others appreciate the existence of the practice for several millennia and acknowledge the fact that timber-felling, monoculture plantations, and other such economic-oriented objectives are also critical drivers of deforestation [e.g. 8-9]. However, when fallow cycles drop below a critical time period due to increased human population leading to unavailability of land, the productivity of the plot as well as forest regeneration are negatively affected [2, 6, 10]. Whitmore [11] suggested that the density of human population SC can sustain is 7 per km^2, which is considerably lower than present densities in SC landscapes in the tropics. Human population density in the year 1995 even in several of the biodiversity hotpots in the tropics was much higher than the world average of 42 people per km^2 [12].

Shifting cultivation throughout the tropics is largely a subsistence activity practised in areas with few alternative options and is therefore a practice that is likely to continue. Secondary forests formed following logging and SC cover more than 600 million hectares and play an important role in biodiversity conservation in the tropics [13]. In this context, studies that research biodiversity in secondary forests formed following SC are of significant value. Studies that have been carried out in various tropical and sub-tropical sites differ in spatial scales of sampling, taxa focused on, and sampling methods used. We therefore found it relevant to review existing research on plants, birds and mammals, which are the groups that have been most researched in SC landscapes and specifically, a) find generalizations in patterns recorded from these studies; b) identify factors possibly responsible for variance in study-results, and c) make recommendations for future studies.

Literature review

We searched for published studies using the ISI web of knowledge (1985-2008) with the combination of keywords *shifting/swidden/slash-and-burn cultivation* and *vegetation/forest recovery*, *avifaunal/bird recovery, faunal/mammal recovery*. Studies on vegetation and mammals in SC landscapes were reviewed qualitatively whereas species inventories in avifaunal studies were analyzed to compare bird species composition in successional sites with that in mature forests. While we realize that avifaunal studies vary in geographic locations, sampling methods, spatial scale of sampling, and features such as extent of anthropogenic disturbances and quality of surrounding forest (mature/ near-mature/ old secondary forest) used for comparison in studies, we have nevertheless undertaken meta-data analyses based on species inventories to generalize recovery patterns. A species list was obtained from other research papers when data from the control forest were not available for comparison (species list was obtained from Karr [14] for Blankespoor [15], which the latter author used for species comparison). We included a study that focused on spatial heterogeneity and its effect on raptor diversity in a SC landscape since a SC mosaic was recorded as spatially more heterogeneous than primary forest, and therefore a direct comparison of species composition in the two habitats was possible [16]. We grouped 10 studies available on recovery of birds following SC in the following time periods since abandonment to track recovery of species over time: 1 to < 5 years, 5 to < 11 years, 11 to 25 years, and sites older than 25 years. These categories were chosen to arrive at approximately equal number of studies in each temporal group.

We calculated Jaccard's index of similarity between bird species recorded from different successional stages and from mature forests in respective studies. We also investigated changes in proportions of mature forest and disturbed habitat species in successional fallows over time. Species that were encountered in the control forest were considered mature forest species, whereas disturbance-associated birds were species that were recorded from 1–5 year fallows. Average values for Jaccard's indices and proportion of mature and disturbance-associated species were calculated when different methods were used for sampling birds in the same study [17].

We summarized results of 33 studies on plants, birds, and mammals in SC landscapes and four review articles on birds and vegetation in anthropogenically disturbed habitats (see Appendix 1). A majority of studies were from South and Central American sites (17), with comparatively fewer studies from African (4) and Asian sites (12). Few studies (6) have focused on mammals in comparison with studies on avifauna (10) and vegetation (17) in SC landscapes. Further, only six studies have been carried out in site adjoining tropical dry and semi-deciduous forests and most of the understanding of recovery following SC comes from sites adjoining humid and moist forests.

Vegetation recovery

Factors that significantly affected the vegetation recovery trajectory in clearings formed following suspension of cultivation were existing seed bank disturbance, presence of resprouters, and poor seed dispersal rates from surrounding forests [18-22]. In general, succession of pioneer vegetation following suspension of cultivation occurred rapidly in the early stages of regeneration, followed by delayed recovery of woody biomass [10, 21, 23].

Plant species richness has been reported to recover to values comparable with those in mature forest in 20-40 years; however, species composition recovery has been reported to take several decades [20, 24-26]. Endemic species, particularly, have been reported to have not fully recovered even after a period of 50-60 years [25]. In contrast, fallows adjoining tropical dry forests in Bolivia accumulated 75 percent of mature forest species within five years of active cultivation, although basal area was comparable with that in mature forests only in 50-year old fallows [27]. Mature forests sampled for comparison also had a disturbance history of fires, some of which may have been anthropogenic, which may have led to underestimates of recovery time from successional to mature forest [27].

The soil seed bank following suspension of cultivation consisted of predominantly pioneer species, herbs, and grasses: about half the seedlings that germinated from the soil seed bank from five-year fallows in Amazonia were of pioneer tree species [21]. Sprouting of tree stumps, roots, and rhizomes played an important role in regeneration in early successional stages [19, 22-23, 27]. In 2- to 15-year-old successional fallows in Paraguay, the number of species recorded resprouting was twice that of mature forest for individuals in the height range 30-130 cm [19]. Regeneration strategies of plants differed with successional stages. Early successional herbaceous species that colonize disturbed habitats were *r*-strategists that were primarily comprised of wind-dispersed or small-seeded vertebrate-dispersed species, whereas late successional primary forest species were *k*-strategists that were large-seeded vertebrate-dispersed species [18, 28-29]. Vertebrate seed disperser avoidance of open habitats prevented the dispersal of relatively large seeds into clearings in early successional stages [21, 30].

The number of years of cultivation as well as number of cultivation cycles affected the recovery process [21, 31]. Vegetation parameters such as canopy cover, tree species richness, percentage of forest species in regeneration, and biomass were considerably higher in plots cultivated for three years in comparison with sites cultivated continuously for six years [21]. Species density and evenness declined considerably with the increase in number of cultivation cycles in SC successional sites in Indonesia [31]. Factors such as harsh microclimatic conditions in clearings, competition with existing vegetation, lack of soil nutrients due to several years of cultivation, and high rates of seed predation and seedling herbivory further impeded plant regeneration [21, 28, 30, 32]. The vegetation recovery period was also affected by the crop cultivated: fields abandoned after cultivation of rice recovered tree species diversity faster than fields cultivated with poppy [33]. Presence of microhabitats such as remnant trees and tall shrubs, which provide sites for seedling regeneration and may improve bat- and bird-dispersed seed arrival, were also identified as important factors in clearings [21, 30].

Fallow cycles as short as 4–5 years in northeast India resulted in arrested succession, since weedy species were not succeeded by pioneer woody species, and over time the soil seed bank was replaced with seeds of weedy shrubs [34]. Fallows as old as 10 years in the region were dominated by bamboo cover [10, 35]. However, early colonizers such as bamboo, with relatively faster growth rates in comparison with woody tree species, may have facilitated soil-nutrient recovery and provided microhabitats for regeneration of shade-loving species [10, 35].

Response of mammals

Generalist mammal species that are adapted to habitat disturbance have been reported to be abundant in successional sites whereas specialist frugivore-foliovore species have been reported to be restricted to mature or primary forest [36-39]. A majority of studies undertaken report that “garden hunting,” a term coined by Linares [40] to refer to hunting of terrestrial mammals that are relatively more abundant close to agricultural habitats and are sources of protein for communities, is common in SC landscapes.

The impact of SC on mammals is relatively less understood and the few studies (6) have been only recently undertaken. Studies of large mammals (size > 2 kg) concluded that these animals may not persist in secondary forests and such sites may therefore harbor populations of fast-reproducing “weedy” disturbance-tolerant species [36-37, 39]. In 13- to 18-year-old secondary forests regenerating after mechanical clearing, mammal abundances were comparable to those in primary forest [37]. However, the composition differed between these forest types, with generalist species occurring in the secondary forest and specialist frugivore species restricted to primary forest [37]. Studies from northeast India reported that species feeding on young leaves and seeds (e.g., Phayre’s leaf monkey, *Trachypithecus phayrei*) persisted in 10-year and older secondary sites to some extent [41]. However frugivore-foliovore species (e.g., Hoolock gibbon, *Hoolock hoolock*, and capped langur, *Trachypithecus pileatus*) rarely occurred far from primary or relatively undisturbed forests [38]. In Peru, the proximity to primary or relatively undisturbed forest was an important determinant of the number of large mammal species and average body mass of wildlife visiting agricultural fields [36].

Disturbance-tolerant small mammal species were also abundant in SC fallows [38]. The hoary-bellied squirrel, *Calloscurius pygerythrus*, a species known to colonize disturbed habitats in India, was frequently encountered in recently abandoned fallows, whereas forest-dependent species such as Malayan Giant squirrel, *Ratufa bicolor,* and the red-bellied squirrel, *C. erythraeus*, were only observed in 25-year and older secondary sites [38]. In contrast with findings of other studies, Medellin & Equihua [42] found that small (approx. 1–3 ha) and relatively young abandoned agricultural fallows (six years old), interspersed with mature forest supported forest-dependent as well as open-habitat small- and medium-sized mammal species. Further, only about a quarter of species sampled in the study were found exclusively in mature forest.

Wilkie and Finn [43] found few significant differences in mammal abundances between successional forests (15–20 years since cultivation suspension) and mature forests in Africa. However, large, wide-ranging species such as leopards, *Panthera pardus,* and okapis, *Okapia johnstoni,* were virtually absent in the former. Both successional and climax sites that were sampled in the study were within 2–6 km from a village and the authors mention that the areas were exploited by local hunters; therefore it is quite likely that hunting may have affected mammal abundances recorded in the sampled sites. Hunting has been reported as a practice often associated with SC [35, 39-40]. In Panama, Smith [27] found that about half the biomass of mammals hunted by the Buglé community was from agricultural fields. This included about a third each from active gardens, fallows younger than five years, and fallows older than five years [39].

Findings of studies that have covered mammal abundances in agricultural habitats suggest that effects of hunting by human communities override the factor of time since abandonment of a field [36, 42]. Therefore, further research on mammal recovery following SC, which incorporates effects of hunting, can contribute significantly to understanding the value of secondary habitats for mammals. It is also critical that studies on the effects of SC on mammals examine more explicitly, the effect of landscape factors such as distance to mature forest, contiguity and the size of patches on species diversity; richness and abundance, which are factors that may affect different groups of mammals differently [36].

Response of avifauna

Avifaunal research in secondary habitats has produced varied results; studies have documented an increase or no effect [16-17, 43-45] as well as a decrease [10, 15, 46-48] in species diversity resulting from converting homogeneous forests into heterogeneous patches of fields and successional fallows interspersed with primary forest. Mean (SE) value of Jaccard's index of similarity increased from 0.26 (0.08) in 1–5 year fallows to 0.55 (0.12) in fallows younger than 25 years (Fig. 1). Within 25 years since suspension of cultivation, the proportion of mature forest species increased from 0.39 (0.14) to 0.71 (0.16), whereas the proportion of disturbance-associated species decreased from 0.58 (0.16) to 0.25 (0.11).

Our analysis of results of 10 studies revealed that birds accumulated relatively rapidly in the first 11 years, and the similarity between birds recorded from SC fallows and mature forest increased from about 25 to 55 percent within 25 years after suspension of cultivation (Figure 1). Within 25 years, only about 25 percent of disturbance-associated species were found in secondary sites and about 70 percent of mature forest species had recovered. Dunn [49], in a review of studies spanning recovery of faunal communities in secondary forests, reports that although species richness in a secondary site may recover within 20–40 years after abandonment, recovery of species composition may take a longer period. Guilds such as large-bodied canopy frugivores and understory insectivores are adversely affected by such habitat modification and are confined to primary or relatively undisturbed forests [10, 43, 45-46]. The type of agriculture system being practised also affected bird species diversity in a SC landscape: the traditional SC mosaic of fallows and forest supported higher diversity and species evenness than a non-traditional practice with a fallow cycle of only four years and a cultivation period of up to six years [48].

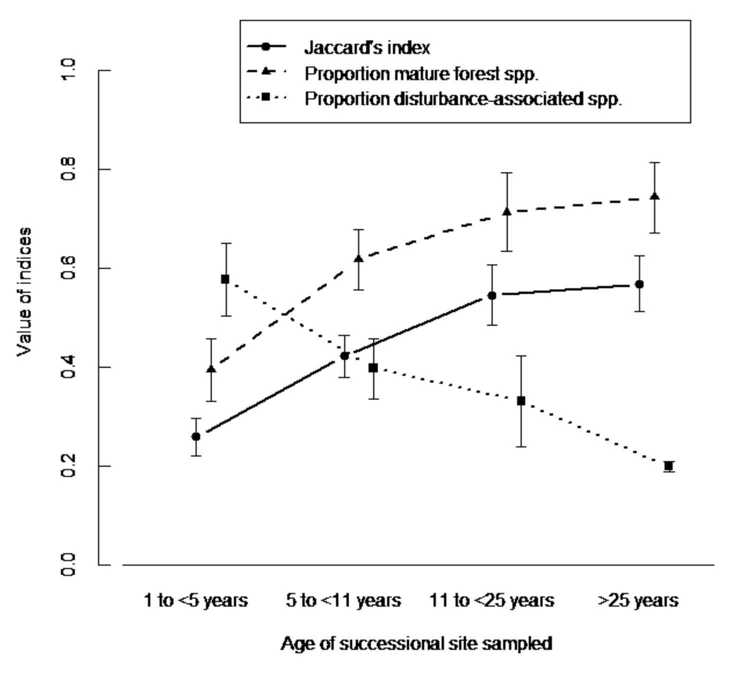

Fig. 1. Jaccard's index of similarity between bird species composition in successional sites and mature forests, proportion of mature forest species, and proportion of disturbance-associated species in different-aged successional sites. Each point represents average value (bars represent standard error) of these indices calculated from species inventories from 10 studies.

Hill and Hamer [50] suggest that results of studies that have recorded a decrease, no effect, or an increase in avifaunal diversity with conversion of homogeneous forest into a heterogeneous SC mosaic are often spatial scale-dependent. Studies that have sampled at smaller scales, mostly using transects or point counts [10 (5 ha), 47 (0.4 ha)], have reported decreased diversity whereas studies that sampled at larger scales generally using mistnets [17 (52 ha), 43 (60 ha)] have reported increased diversity. Barlow and others [51] identify other factors affecting study results; edge effects in a secondary site from surrounding habitat may bias results and near-primary forest considered as a control and assumed to be equivalent to mature undisturbed forest may have been disturbed, leading to an inaccurate comparison of habitats. In the specific case of impact of SC on birds, spatial scales of sampling for most studies are by default small, since across the world the practice is undertaken at relatively small scales in comparison with other landuses such as plantations that are often larger. When sampling scales are large, studies will incorporate effects of surrounding habitat and therefore reflect bird diversity in the agriculture-fallow-forest matrix rather than the diversity in each habitat specifically [17, 43].

Implications for conservation

Shifting cultivation fallows have been shown to recover vegetation faster in terms of basal area, regeneration, and accumulation of species than other human-modified and subsequently abandoned lands such as pastures, agroforestry sites, and plantations [52]. One factor responsible for this is likely to be that the practice is undertaken across the world at small scales in comparison with pastures (for instance, SC fallows in Meghalaya, north-east India ranged from 1–2.5 ha [6], whereas in Amazonia, pastures extended over hundreds to thousands of ha [21]). Another factor is that often SC fallows are interspersed with primary/near-primary forests [53].

Land-use conversions of forest for timber logging, monoculture cash crops, and infrastructural projects such as hydro-electric projects, usually benefit stakeholders not resident in the particular landscape, in comparison with SC which is often a subsistence activity [8]. Alternatives to the practice often recommended, such as intensive sedentary cultivation, monocultures, or agroforestry, have been suggested to possibly have long-term detrimental effect for both farmers and forest [52, 54-55].

SC can be considered as a small-scale high-intensity disturbance when relatively large tracts of primary forest adjoin the mosaic of fallows and active farms [17, 43]. Deleterious effects of SC such as forest and biodiversity loss, soil erosion, and similar environmental impacts are often consequences of shortened fallow cycles which are likely an offshoot of increasing human population. The practice of SC can be sustainable and can also support biodiversity in the overall landscape if large tracts of relatively mature forests are preserved, few trees are retained during cultivation, and fallow cycles are relatively long [21, 26]. Further, regulation of hunting of relatively rare species can ensure retention of high mammal diversity in a SC landscape [36]. Mature forests can act as critical sources for recolonization of plants, mammals, birds, and other groups in secondary sites and therefore can maintain biodiversity in the larger landscape.

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Appendix 1. List of taxon sampled, forest types and major findings of studies reviewed.

Taxon sampled	***Forest type***^{a}	***Focus of study***	***Major findings***	***Reference number***
Plants	TE	Biomass, litterfall, and productivity in a SC site in north-east India	Increased species diversity, reduced species dominance and increased above-ground net primary productivity in a 20-yr-old fallow in comparison with 1-, 10- and 15-yr-old stands	[23]
Plants	TE	Patterns of herbaceous vegetation development and weed potential following SC in northeast India	Density, biomass, and germinable seeds of weed species present in the soil were significantly higher after cycles of 4 and 6 years compared to 10- and 20-yr cycles.	[34]
Plants	HT	Factors controlling succession following SC in Amazonia	High rates of seed removal by animals in 5-yr-old fallows. Primary forest species only represented 7% of all the stems in the stand. Isolated trees in the fallows facilitated plant regeneration.	[21]
Plants	HT	Tree species composition, structure and biomass following SC in Colombia and Venezuela	20- to 40-yr stands had species richness similar to adjoining mature forest. About 190 years was estimated as the period within which a cultivated site can be similar to mature forest in terms of basal area and biomass.	[24]
Plants	TE	Role of bamboo in succession following SC in northeast India	Bamboo regeneration following suspension of cultivation played a significant role in nutrient conservation during SC in northeast India.	[35]
Birds	HT	Response of fauna to SC in Papua New Guinea	Bird diversity increased along a successional gradient of 1-, 2-, 4-, 8-, and 26-yr-old stands. Primary forest was found to support specialist feeder bird groups such as frugivores, nectarivores, and branch gleaners.	[47]
Birds	HT	Bird diversity in SC fallows in West Africa	Between current farms (CF), regrowth forest (RF, 2 yrs old) and a relatively more mature forest (OF, 7 yrs old), bird communities were most similar between CF and RF and least similar between CF and OF	[15]
Birds	HT	Avifauna in a SC habitat mosaic in Colombia	SC represents a high-intensity small magnitude disturbance to the avifauna. Old secondary growth habitats (13 to17 yrs old) and forest understories had similar avifauna.	[43]

Taxon sampled	*Forest type*[a]	*Focus of study*	*Major findings*	*Reference number*
Mammals	TE	Feeding ecology of a mammal species in a SC landscape in northeast India	Phayre's leaf monkey can survive in secondary forests formed after SC if regeneration is allowed to continue for 9-10 years.	[41]
Plants	TD	Post-dispersal seed and seedling mortality after SC in Mexico	Predation rates by terrestrial vertebrates of mature forest tree species seeds were higher in secondary sites than in mature forest.	[32]
Mammals	TE	Impact of SC on mammals in a SC site in northeast India	Disturbance-associated species were less affected by SC than mature forest species. Fallow cycles shorter than 10 years may negatively affect all mammal species.	[38]
Mammals	TR	Mammal abundance in a SC landscape in Zaire	Large wide-ranging mammals were affected by SC; however, few differences in abundances of other mammals between post-agricultural secondary forest and uncut climax forests were recorded.	[43]
Plants	SD	Forest recovery by root suckers and above-ground sprouts following SC in Paraguay and Venezuela	Roots suckers and above-ground sprouts were dominant in early fallows whereas resprout density declined with increasing age of fallows and was lowest in mature forest.	[19]
Mammals	HT	Mammal species richness and habitat use in abandoned cornfields in Mexico	Relatively small abandoned cornfields (1-3 ha, 6 yrs old) embedded within forests can support disturbance-associated as well as mature forest species and therefore can increase overall diversity.	[42]
Birds	TE	Recovery of birds in relation to vegetation succession following SC in northeast India	Canopy insectivores, frugivores and bark feeders are more sensitive to SC than granivores and understory insectivores. Recovery periods less than 25 years for birds and 50 years for vegetation can cause significant community alteration.	[10]
Birds	TE	Landscape heterogeneity and diversity of raptors in a SC landscape in Honduras	Diversity and density of raptors increased with landscape heterogeneity.	[16]
Birds	HT	Bird assemblages in second- and old-growth forest in Costa Rica	Second-growth forest formed following SC had higher species richness of birds than old-growth forests.	[17]

Taxon sampled	***Forest type***[a]	***Focus of study***	***Major findings***	***Reference number***
Birds	SD	Distribution, abundance and diversity of forest birds in SC successional forests in Mexico	A majority of habitat specialist migrant and resident bird species were recorded in late successional forest, although species assemblages were similar among successional stages.	[45]
Plants	TD	Secondary succession following SC in a tropical dry forest in Bolivia	Species richness, canopy cover, and basal area values reached or exceeded 75% levels of mature forest in 23-yr-old stands.	[27]
Plants	HT	Seed dispersal in a SC landscape in Brazil	Percentage of plant species with relatively small seeds was twice that in a younger site (5-30 yrs old) whereas percentage of middle-sized seeds and fruits was almost half that in older sites.	[29]
Plants	TE	Vegetation recovery following selective logging and SC in a Central African rainforest	Recovery in terms of plant species composition and diversity following SC took 30-60 years and endemic species had not recovered even after 50-60 years.	[25]
Birds	TE	Bird diversity in SC fallows in China	Fallows of traditional SC practice with longer fallow cycles had higher bird diversity than those of non-traditional or modified SC practice	[48]
Mammals	HT	Impact of SC and hunting on large mammals in Peru	Large-bodied species were only found close to remote farms where crop and livestock losses of farmers to wildlife were also higher. Large herbivores, large carnivores, and primates may not survive in human-disturbed areas.	[36]
Plants	SD	Post agricultural succession in central America	Height, basal-area accumulation, and recruitment of tree and shrub species were higher in SC successional sites than abandoned pastures and monocultures, indicating faster recovery.	[53]
Plants	TR	Seed dispersal in a SC landscape in Philippines	Wind-dispersed seed numbers outnumbered vertebrate-dispersed seed numbers by a factor of 15; however, few seedlings of wind-dispersed species were recorded in the abandoned farm.	[28]
Plants	MD	Long-term effect of SC on tree diversity in a rainforest in Thailand	Species density and evenness declined with the number of SC cycles.	[31]

Taxon sampled	***Forest type***[a]	***Focus of study***	***Major findings***	***Reference number***
Birds	SD	Community structure of songbirds in a tropical forest-agricultural landscape in Africa	Intact forest supported the most number of species in comparison with regenerating forest (13 yrs old) and active farms.	[44]
Mammals	TE	SC & hunting in Panama	25% of animals hunted by human communities in western Panama were from agricultural habitats.	[39]
Birds	TS	Response of birds to SC in Brazil	Nectarivore/insectivores and frugivore/insectivores were relatively abundant in secondary forests, whereas specialized insectivorous birds such as birds that follow army ants and mixed flocks were more abundant in primary forest.	[46]
Plants	TE	Mechanisms of plant regeneration following SC in Amazonia	Sprouting is a relatively more important succession mechanism than regeneration from seed bank and seed rain in early successional stages.	[22]
Plants	TM	Seed rain in SC successional sites in Mexico	Seed rain numbers and species richness as well as proportion of vertebrate-dispersed seeds increased with stand age.	[18]
Plants	TE	Secondary succession following SC in Thailand	Species composition, diversity,and above-ground biomass recovered faster following suspension of rice cultivation than suspension of poppy cultivation.	[33]
Plants	SD	Secondary succession following SC in Africa	SC may be sustainable if fallows are interspersed with large tracts of forest, remnant trees are preserved, fire is excluded, and fallow cycles are relatively long. The study also concludes that semi-deciduous Afrotropical forests are considerably resilient to the SC practice.	[26]

a. TE = Tropical evergreen forest, HT = Humid tropical forest, TD = Tropical dry forest, TR = Tropical rain forest, SD = Tropical Semi deciduous forest, MD = Mixed dipterocarp forest, TS = Tropical seasonally flooded forest, TM = Tropical montane cloud forest