Secondary forest: a working definition and typology

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SUMMARY

With past and continued destruction of primary forests worldwide, secondary forests constitute a large and growing component of forest cover and have been found to be very important for a wide range of goods and services. Despite its widespread usage, there is considerable ambiguity with regard to the meaning of the term 'secondary forest' and the different forest types it encompasses. This paper reviews existing definitions, or perceptions, of secondary forests and examines the three main points of contention: nature (human or natural) of disturbance, intensity of disturbance, and nature of vegetation development matters in its definition. We then arrive at a broad working definition for secondary forests, and develop a secondary forest typology based on the underlying disturbances or land use practices that create conditions for the appearance of secondary forest. Both the definition and typology are based on clear and objective criteria and are generalizable across regions, which should make them widely applicable.

Keywords: secondary forest, definition, typology

INTRODUCTION

With past and continued destruction of primary forests worldwide, there is increasing interest in secondary forests, their role, structure, and function (Bormann and Likens 1979, Oliver 1981, Keever 1983, Riswan and Kartawinata 1988, Whitney and Foster 1988, Dubois 1990, Abrams and Nowacki 1992, Schelhas and Greenberg 1996, Lugo 1997, Smith *et al.* 1999, Emrich *et al.* 2000). Secondary forests now constitute large areas in many countries (Spurr and Barnes 1980, Brown and Lugo 1990), and are becoming an increasing component of forest cover in many tropical countries as regrowth following deforestation (Brown and Lugo 1990, Dubois 1990, Chazdon and Denslow 1996, Emrich *et al.* 2000, de Jong *et al.* 2001). This large and growing renewable resource can provide a wide range of valuable goods and services important at the local, national, and international levels. In order to establish clear policies with regard to secondary forests, integrate them into land use plans, and guide their management and development along sustainable pathways, it is essential to first clearly identify the true nature of the resource and the different types that it encompasses.

There is considerable ambiguity and confusion in current use of the term 'secondary forest' both in the literature and in people's perceptions (Sips *et al.* 1997, TCA 1997, Emrich *et al.* 2000). Numerous types of forests with varying characteristics, and arising from many different processes are considered to be 'secondary' (Corlett 1995, Sips 1997, TCA 1997, Emrich *et al.* 2000) given regional differences in patterns of disturbance and land and resource use. The need exists to both arrive at a common broad working definition of secondary forests and to identify and elucidate the relevant forest types that would fall under such a definition. This will help to build up data, knowledge, and management expertise on secondary forests; to focus and compare research in different regions; and to develop harmonious statistics (Sist *et al.* 1999, Emrich *et al.* 2000). Further, a coherent working definition and typology based on ecological and management considerations will enable national and other institutions to better identify and categorize forests and develop appropriate policies for the different categories. Definitions and classifications most often involve compromises and may not satisfy all needs, but it helps to have clear and useful criteria that can be applied objectively (FAO 1998).

The term 'primary forest' is commonly perceived to be the 'climax forest type' for a given region and environment, which are thought to be relatively stable. The term 'secondary forest' then relates to successional forests that develop after clearing of the original forest, and secondary succession is complete when they develop again into climax communities or primary forests. However, ecological thinking has evolved from these early concepts that emphasized predictable deterministic succession in plant communities developing into relatively stable climax communities (Clements 1916). Plant succession is seen today as anon-equilibrium spatial process that is the outcome of disturbance and population processes under changing environmental conditions

(Peet and Christensen 1980, Glenn-Lewin *et al.* 1992, Huston 1994). Disturbance and response to disturbance are now recognized as natural processes that lie at the core of forest ecosystem dynamics ('patch dynamics', the 'non-equilibrium' view).

The terms 'primary' and 'secondary' forests continue to be widely used. Given current ecological thinking of non-equilibrium processes, and the integral role of disturbance in forest dynamics, a coherent working definition of these terms in the light of new information is useful for arriving at a common understanding. These terms 'primary forest' and 'secondary forest' can be usefully linked to the scale, intensity and frequency of disturbances. No clear line can be traced between them unless we convene in identifying key indicators and defining at least a broad set of limits or thresholds.

This paper attempts to address the existing ambiguity and confusion with regard to the term 'secondary forests' and the different types it encompasses. Specific objectives of this paper are to:

- review existing definitions or perceptions of secondary forests
- examine points of contention
- arrive at a broad working definition for secondary forests based on clear and objective criteria, and
- develop a useful secondary forest typology with specific nomenclature and definitions, again based on clear and comprehensive criteria

EXISTING DEFINITIONS OR PERCEPTIONS

Numerous definitions of secondary forests exist in the literature and have been grouped below based on their underlying precepts.

Human and/or natural disturbance

- Many authors refer to secondary forests as regrowth after natural and/or human disturbance of the original forest (Steup unpublished, Ford-Robertson 1971, UNESCO 1978, Whitmore and Burnham 1984, Sips 1993, Chazdon and Denslow 1996, Richards 1996, Sips *et al.* 1997, Helms 1998, van der Wal 1998, Sist *et al.* 1999)
- Still others consider only forests formed as a consequence of direct human impacts as secondary (Greig-Smith 1952, Lanly 1982, WWF 1989, Finegan 1992, Peterken 1995, Brown 1996, Finegan 1997, Smith *et al.* 1997b, TCA 1997, Smith *et al.* 1999, Emrich *et al.* 2000, de Jong *et al.* 2001).

Intensity of disturbance

- Many authors refer to secondary forests as woody vegetation regrowing on land which was *totally cleared (or at least 90%) of the original forest* (Greig-Smith 1952, Lanly 1982, Finegan 1992, Sipps 1993, Corlett 1994, Peterken 1995, Finegan 1997, Sips *et al.* 1997, Smith *et al.* 1997b, TCA 1997, Sist *et al.* 1999, Smith *et al.* 1999, Emrich *et al.* 2000, de Jong *et al.* 2001).
- Others consider all disturbed forests as secondary, *irrespective of the intensity of disturbance* (UNESCO 1978, Brown and Lugo 1990, Brown 1996, Zimmerman *et al.* 1996, Wadsworth 1997).
- Ford-Robertson (1971), Helms (1998), van der Wal (1998), and WWF (1989) refer to regrowth after *some drastic or substantial interference* as secondary forest.

Vegetation development process

- Many authors hold that the regrowing secondary forest will differ in canopy species composition from the original forest, undergoing a sequence of floristic changes after the perturbation/s (Whitmore and Burnham 1984, Finegan 1992, Corlett 1994, Richards 1996, Sips 1997, Wadsworth 1997, Sist *et al.* 1999, Emrich *et al.* 2000).
- Others include forests where species regenerating after the disturbance are similar to those in the original canopy, as secondary forest (Greig-Smith 1952, UNESCO 1978, Lanly 1982, Nyerges 1989).

Examples:

- Forests that contain a few very dominant species in their canopies and show little floristic differentiation after disturbance (Greig-Smith 1952, Kapelle et al. 1996, Guariguata et al. 1997). Often forests regrowing on extreme (climatic or soil conditions) sites, where species other than those in the original canopy are inhibited from establishing, show little floristic differentiation after disturbance (Oliver and Larson 1990).
- Forests where trees tend to coppice after cutting (Kammesheidt 1998, 1999).
- Forests developing largely from advance regeneration of late-successional canopy species released on removal of the overstorey through natural or human intervention such as hurricanes or shelterwood cutting (Oliver and Larson 1990, Smith *et al.* 1997a).

MOOT POINTS

In trying to define secondary forests, there appear to be three primary considerations leading to debate and dissent.

1. Can secondary forests arise as a result of natural disturbance or do only human-induced disturbances count?

Interest in secondary forests or secondary succession developed with Thoreau's accounts in the 1860s and then Clements' (1916) under a situation where large-scale human disturbances in historic time had greatly affected

forests. Large-scale land clearing for agriculture in the new-world colonies was followed by abandonment at a later date (Spurr and Barnes 1980, TCA 1997). This may account for the perception of secondary forests as primarily a result of human influences. Also, human disturbances are generally more frequent and therefore remembered by more people (Oliver and Larson 1990). But secondary successions as a result of natural disturbances such as fire and hurricanes were also recognized throughout the period (Skutch 1929, Hough and Forbes 1943, Spurr 1956, Brown 1960, Steup unpublished, Spurr and Barnes 1980, Oliver 1981, Whitmore and Burnham 1984, Perry 1994, Richards 1996). Development agencies and authorities tend to focus on human disturbances because that is an aspect that they can attempt to influence directly through their activities (Dotzauer 1998, Emrich *et al.* 2000).

2. ***Does intensity of disturbance matter in defining secondary forest?***

All forests (primary or secondary) in the world are subject to some form of disturbance, natural and/or human, on a regular basis. However there is a continuous gradient of disturbance, both human and natural (Oliver and Larson 1990), that ranges from selective logging and small wind-throw gaps, to more intensive logging and hurricane damage, to total clearing of forest vegetation due to natural or human causes. Regeneration of a forest (secondary succession) in contrast to regeneration of just a few trees within small gaps (within-patch dynamics) calls for at least significant disturbance of the original forest vegetation *vis-a-vis* minor perturbations within the forest.

On the other extreme, the concept of secondary succession developed in response to observed changes in vegetation following large-scale forest clearing for agriculture in the new-world colonies and abandonment at a later date. Hence, traditionally secondary forests were thought of as forests regrowing on land totally cleared of its original forest vegetation. However, in other parts of the world, particularly in tropical Asia, partially logged-over forests are also viewed as secondary forests because of the intensity of disturbance and major changes in forest structure, composition, and function (TCA 1997). This latter is a relevant viewpoint, given that partial logging can cause significant perturbations and initiate secondary successional processes akin to those occurring on totally cleared land. Accommodating intensively logged-over/disturbed forests calls for a slight expansion of the definition of secondary forests from those developing after total removal of the original forest cover to those developing after significant reduction in the original forest cover.

3. ***Are successional changes in floristic composition a pre-requisite, or can the species tending to dominate after the disturbance be similar to those in the original canopy?***

The concepts of secondary succession and secondary forests refer to observed sequences of vegetational change from dominance of early to later-successional species on cleared sites. However there are other sites where extreme site conditions, limited potential floristic composition, coppice regeneration, or release of advance regeneration of canopy species after overstorey removal may result in floristic composition similar to that of the original forest following a major disturbance. The primary change after significant disturbance on these sites may be one of altered structure alone. Hence a definition of secondary forest which allows for a major change in forest structure and/or canopy species composition from the original forest may be more acceptable as it accommodates all of the above forest types regrowing after significant disturbance. Structural characteristics such as basal area, diameter distributions, and canopy organization are also easy to quantify and assess in the field, enhancing the practical usefulness of such a definition (Clark 1996).

A PROPOSED WORKING DEFINITION

Considering the arguments presented above we propose the following definition of secondary forest:

Secondary forests are forests regenerating largely through natural processes after significant human and/or natural disturbance of the original forest vegetation at a single point in time or over an extended period, and displaying a major difference in forest structure and/or canopy species composition with respect to nearby primary forests on similar sites.

Key characteristics of this definition

- The original forest vegetation was significantly disturbed.
- The disturbance to the original forest vegetation could have been natural and/or human-initiated.
- The disturbance may have occurred all at once or progressively.
- The forest is a regenerating or redeveloping one.
- Most of the regeneration is spontaneous.
- The regenerating forest has significantly-different forest structure or canopy species composition or both, as compared to nearby primary forests on similar sites.

Reasons for such definition

We believe that this definition consolidates most existing definitions and perceptions of secondary forests. It is based on clear and objective criteria and is quite flexible, both of which should make it widely applicable. We explain the reasons for inclusion of each clause in more detail below.

- *Significant disturbance of the original forest vegetation*
  The disturbance need not necessarily involve total clearing but should have been significant enough to potentially allow the regrowth of secondary forest, in contrast to regeneration of just a few trees within small gaps. Forests influenced by minor disturbances such as low-intensity small-scale extractive activities, small-scale natural disturbance, or low-intensity selective logging are not considered secondary forests.

- *Disturbance could have been natural and/or human-initiated*
  Human and natural disturbances are included because both can be significant and result in the formation of secondary forests. Often natural disturbances are initiated or fuelled by human activities, and it may be difficult to partition the source.

- *Disturbance at a single point in time or over an extended period*
  A significant disturbance could occur as a single event or be the accumulated result of smaller-scale activities spread over an extended period, for examplelocal communities extracting forest products over time.

- *Regenerating largely through natural processes*
  Most of the post-disturbance regeneration is spontaneous. With the exception of Helms (1998), this is the common perception of secondary forests. This clause helps classify vegetation that is in the interface between natural forests and plantations. Planted and enriched areas may be included as secondary forests if and when the majority of the vegetation is spontaneous, such as in tembawangs or fruit-forest gardens in Kalimantan (de Jong 1995) and shifting cultivation fallows enriched with rubber in Kalimantan (Penot 1997).

- *Significantly-different structure and/or canopy species composition*
  The regrowing secondary forest has significantly-altered structure, and often significantly-altered canopy species composition as well, as compared to the original forest. The latter however is not a prerequisite given that there are cases where compositional change may not necessarily occur as on sites with limited potential floristic composition, coppice regeneration, or release of advance regeneration of canopy species after overstorey removal.
  However such a definition also includes forests developing from sprouts of canopy tree species in areas affected by frequent hurricanes or fires where successional processes cannot proceed further and the change is primarily structural (see Bellingham *et al.* 1994, Whelan 1995). It can be argued that such hurricane or fire-disturbed forests represent the final potential forest condition in the area. In other words, that frequent major disturbances are part of their natural dynamics and thus they would not qualify as secondary forests. They could be considered a potential exception to such a definition.

- *Significantly different with respect to nearby primary forests on similar sites*
  The clause 'significant difference with respect to nearby primary forests on similar sites' helps to quantify and render operational the definition in the field. After a long period of time with relatively minor disturbances, the developing secondary forest becomes more structurally and floristically similar to primary forests growing on similar site conditions in the area (Bormann and Likens 1979, Whitmore and Burnham 1984, Riswan and Kartawinata 1988, Corlett 1994, Richards 1996, Sips 1997). The secondary forest can then be said to have reverted back to primary forest (Lanly 1982, WWF 1989, Brown and Lugo 1990, Corlett 1994, Emrich et al. 2000).

Additional secondary forest specifications could include *land ≥ 0.5 ha in area and width of more than 20 m, with > 10% crown cover of trees = 5 m in height.*

These minimum criteria are based on FAO's (1998) definition for a forest patch. The area of ground coverage suggested at 0.5 ha has relevance at both local (for management purposes) and at very large (for remote sensing purposes) scales. Narrow forest strips (< 20 m in width) are excluded because they do not form integral forest, having very high edge to area ratios. The clause '> 10% crown cover of trees > 5 m in height' provides a threshold for when the developing secondary vegetation could be called a secondary forest. Smith *et al.* (1999) use vegetation (rather than trees) > 5 m in height as the threshold.

Additional specifications are important mainly for practical reasons in order to better identify and quantify secondary forests on the ground. However, the thresholds presented above are arguably arbitrary in nature and may need more refinement to be meaningful. Thresholds could also be developed for 'significant disturbance' and 'major change in canopy species composition and structure', perhaps on a more specific regional basis by researchers working in each major forest type.

SECONDARY FOREST TYPOLOGY

There are several possible means of classifying secondary forests, for example,based on stand age, features of the vegetation, biophysical conditions of the growth site, and others. The typology presented here is based on the underlying causes that create conditions for the appearance of secondary forest. Common disturbances and land use practices that give rise to secondary forests include catastrophic natural disturbance (fire, flooding,

hurricanes), intensive tree extraction, swidden agricultural cycles, low-intensity management of areas with a planted component, abandonment of areas under agriculture or other land use, and rehabilitation efforts on degraded lands. The resulting secondary forests in some instances may be quite similar in species composition or structure, or there may be large differences in composition and structure even within a particular type. Also one secondary forest type could be transformed into another following subsequent disturbance or change in land use, for e.g., catastrophic fire following significant timber extraction.

Based on the above definition of secondary forests and the common types of disturbance or land use practices giving rise to secondary forests across the globe, seven major types of secondary forests were identified. Definitions and specific nomenclature were developed for the different types and are presented below, along with examples and an illustration of the main processes that initiate their formation.

1. **Post-catastrophic secondary forests** – Forests regenerating largely through natural processes after significant reduction in the original forest vegetation due to a catastrophic natural disturbance or succession of such disturbances, and displaying a major difference in forest structure and/or canopy species composition with respect to nearby primary forests on similar sites. Catastrophic natural (often involving a human element) disturbances include fires, tornadoes, hurricanes, landslides, and floods. Depending on the nature of catastrophic natural disturbance, numerous subtypes can be further distinguished, e.g., post-fire, post-flooding, etc.

Forest Catastrophic → natural disturbance → Natural regeneration

Examples:
a) White spruce (*Picea glauca*) stands transformed into aspen (*Populus tremuloides*) and paper birch (*Betula papyrifera*) following fire in boreal forests of Alaska (Whelan 1995).
b) Dipterocarp-dominated forests transformed into *Melaleuca* spp. forests in swamp ecosystems of southern Sumatra following logging and fire (Giesen 1991).
c) Mature rainforest damaged by Hurricane Joan in 1989, colonized by fast growing short-lived (Croton smithianus) and long-lived (Vochysia ferrugina) pioneer trees in eastern Nicaragua (Vandermeer *et al.* 1998).

2. **Post-extraction secondary forests** – Forests regenerating largely through natural processes after significant reduction in the original forest vegetation through tree extraction at a single point in time or over an extended period; and displaying a major difference in forest structure and/or canopy species composition with respect to nearby primary forests on similar sites.

Forest → Harvest → Natural regeneration

Examples:
a) Dipterocarp-dominated forests transformed into forests dominated by *Macaranga* spp. and *Trema* spp., among others in East Kalimantan following intensive logging (Abdulhadi *et al.* 1981).
b) Dipterocarp-dominated forests transformed into forests dominated by short-lived *Trema orientalis* and *Macaranga* spp., *Alphitonia* sp., and *Mallotus* spp. following intensive logging in the Philippines (Weidelt and Banaag, 1982).
c) Rainforests in the Peruvian Amazon transformed into forests dominated by bat- and bird-dispersed pioneer tree species such as *Cecropia* spp. after strip clearcutting (Gorchov et al. 1993).
d) *Pentaclethra macroloba*-dominated forests in the wet lowlands of Costa Rica transformed into secondary forests of the same species but with altered structure following clearcutting (Guariguata et al. 1997).

3. **Swidden fallow secondary forests** – Forests regenerating largely through natural processes in woody fallows of swidden agriculture for the purposes of restoring the land for cultivation again.

Forest → Clear & burn → Crop → Fallow regeneration
↑ ↓

Examples:
a) Tropical rainforest of *Terminalia amazonia* transformed to forests dominated by *Trema micrantha* and *Heliocarpus appendiculatus* in the Chinantla, Mexico following swidden cultivation (van der Wal 1998).
b) Lower montane rain forests transformed into forests dominated by *Schima wallichii*, *Eurya acuminata*, *Castanopsis armata,* etc. in shifting cultivation fallows of northern Thailand (Schmidt-Vogt, 1999).

4. **Secondary forest gardens** – Considerably-enriched swidden fallows, or less- intensively managed smallholder plantations or home gardens where substantial spontaneous regeneration is tolerated, maintained, or even encouraged.

Secondary forest gardens have a substantial planted or tended component, but the majority of the vegetation is of spontaneous origin. Where the planted or tended component increases, this type turns into agroforests.

Forest → smallholder plantation (low-intensity management) + Natural regeneration
or
Forest → Clear & burn → Crop → Considerably-enriched fallow regeneration

Examples:
a) Dipterocarp-dominated forests converted to jungle rubber systems after swidden cultivation in Kalimantan (Penot 1997).
b) Semi-deciduous moist forests of *Sterculiaceae* and *Ulmaceae* transformed to mixed cocoa agroforests in the Tikar plains on Cameroon or lowlands of Sao Tome (Dounias 1999).

5. **Post-abandonment secondary forests** – Forests regenerating largely through natural processes after total abandonment of alternative land use (plantations, agriculture, pasture, etc.) on formerly forested lands. Depending on the nature of alternate land use prior to abandonment, numerous subtypes can be further distinguished, e.g., post-agriculture, post-ranching, etc.

   Forest → Alternative land use → Abandonment → Natural regeneration

Examples:
a) Northern hardwood forests of the lowlands of central New England, USA transformed to white pine (*Pinus strobus*) or successional hardwood (*Betula* spp., *Populus* spp., *Acer rubrum*) forests following clearing for cultivation or pasture and subsequent abandonment of agricultural use in the early 1900s (Foster 1992).
b) Mixed tropical rainforests of coastal areas in Gabon transformed into pure stands of *Aucoumea klaineana* following clearing for cultivation and subsequent abandonment of agricultural use in the 1950s (White *et al.* 1996, Nasi 1997).

6. **Rehabilitated secondary forests** – Forests regenerating largely through natural processes on *degraded lands**, often aided by rehabilitation efforts, or the facilitation of natural regeneration through measures such as protection from chronic disturbance, site stabilisation, water management, and planting.

   **Degraded lands* - formerly forested lands severely impacted by intensive and/or repeated disturbance (such as mining, repeated fires, or overgrazing) with consequently inhibited or delayed forest regrowth. These include barren areas, *Imperata* grasslands, brushlands, and scrublands.

Forest → Degraded land → Rehabilitation + Natural regeneration

Examples:
a) Native plant species recruitment in North Queensland following rehabilitation efforts on degraded forest lands (grasslands and eroding river banks). Most common species regenerating were *Omalanthus novo-guineensis* and *Cryptocarya triplinervis* (Tucker and Murphy 1997).
b) Establishment of natural fast-growing genera such as *Albizia* and *Milletia* on degraded forest lands (grasslands) in Kibale National park, West Uganda following rehabilitation efforts including planting of *Pinus caribeae* (Fimbel and Fimbel 1996).

Reasons for such a typology

Such a classification based on the type of disturbance that gives rise to it is useful because it is highly generalizable and applicable across regions, and over a wide range of biophysical and social environments. A typology linked to causative factors allows for the development of appropriate management options and policy initiatives. Thus, by addressing the underlying disturbance and land use dynamics they arise from. they can guide the different secondary forest categories along sustainable pathways. In addition, it is possible to relate the growth of the different types of secondary forest to the broader patterns and trends in disturbance and land-use practices at different levels of aggregation.

Common types of forests that would not be included under the above definition of secondary forests are

1. Forests subject to low-intensity selective logging
2. Forests subject to low-intensity, small-scale extractive activities (e.g., for non-timber forest products)
3. Forests affected by small-scale natural disturbance
4. Intensively-managed plantations
5. Forests regenerated largely through planting

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