AGROFORESTRY AND BIODIVERSITY: ARE THEY COMPATIBLE?

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Abstrak

Agroforestri mampu menyediakan hasil-hasil pertanian, di samping dapat mempertahankan fungsi ekologi dari hutan. Terdapat banyak spesies alami dalam sistem agroforestri, sehingga ahli agroforestri seringkali menekankan bahwa agroforestri dapat memberikan kontribusi penting dalam usaha melestarikan biodiversitas. Namun pada umumnya tidaklah demikian, paling tidak pada sebagian besar biodiversitas global yang paling terancam. Terdapat empat alasan mengapa agroforestri dan strategi *'melestarikan dengan memanfaatkan'* lainnya tidak dapat sepenuhnya menggantikan daerah yang mutlak penting untuk konservasi.

Alasan pertama, species yang sangat sensitif terhadap gangguan aktivitas manusia tidak dapat dilestarikan dengan cara tersebut di atas. Kedua, banyak binatang liar yang merupakan hama bagi agroforestri, sehingga cenderung untuk diberantas, meskipun sebenarnya mereka dapat hidup dalam agroforestri tersebut. Kedua hal tersebut menunjukkan bahwa pada sistem agroforestri di tingkat bentang lahan jumlah species asal hutan tidak dapat dipertahankan. Adanya tarik-ulur (*trade-off)* antara eksploitasi dan biodiversitas membuktikan pada kita semua bahwa hanya hutan perawan yang tidak terjamahlah yang dapat sepenuhnya menjamin pelestarian biodiversitas. Mengingat banyaknya kendala untuk memperoleh produksi pertanian yang maksimum, maka usaha pelestarian biodiversitas pada tingkat bentanglahan dipisahkan (*segregate*) dari usaha lain yang berbeda tujuannya.

Masalah yang ketiga adalah bahwa biodiversitas lebih dapat dipertahankan di daerah belantara yang luas daripada di daerah yang terpecah-pecah menjadi beberapa bagian kecil yang terpisah satu sama lain (*isolated fragments*). Hal ini karena banyak species yang hilang dengan cepat atau secara bertahap di bagian yang terisolasi tersebut (*relaxation*). Untuk mempertahankan produksi pertanian yang memuaskan, daerah yang tersisa harus dimanfaatkan secara intensif, sehingga agroforestri dapat berperan dalam pelestarian biodiversitas hanya di lokasi yang sensitif secara ekologi. Lebih jauh, agroforestri adalah eksponen bentanglahan yang terfragmentasi, dan tidak berperan dalam menurunkan proses fragmentasi. Jadi, mendorong petani untuk mempraktekkan agroforestri seringkali justru meningkatkan fragmentasi. Fragmentasi juga menunjukkan bahwa agroforest cenderung kehilangan banyak species yang semula ada di tempat tersebut.

Akhirnya, karena agroforestri seringkali merupakan fase transisi dalam tahapan perkembangan dan cenderung digantikan oleh penggunaan lahan yang lebih intensif, maka kemampuan agroforestri dalam mempertahankan biodiversitas sangatlah terbatas. Secara keseluruhan, agroforestri hanya memberikan kontribusi yang terbatas dalam mempertahankan biodiversitas, dan sesungguhnya dapat berdampak negatif terhadap biodiversitas jika agroforestri berbagi ruang dengan hutan belantara dalam suatu bentanglahan yang sama.

Abstract

Agroforestry can provide agricultural products while partially maintaining the ecological services provided by forests. Because agroforestry systems contain many natural species, its proponents often stress that agroforestry can make vital contributions to the preservation of biodiversity. This is generally not the case, however, at least not for the parts of global biodiversity most under threat. Four reasons are discussed why agroforestry and other 'conserve through use' strategies cannot be a full substitute for the setting aside of substantial areas with an uncompromised conservation status.

First, species sensitive to human activity, because they are exploited commercially or merely sensitive to human disturbance, cannot be maintained this way. Second, several wild animals are pests in agroforestry, and will tend to be eliminated, even though they could in principle live in agroforests. These two effects together imply that a predictable portion of the species of old-growth forests will not survive in agroforestry landscapes. The presence of a trade-off between exploitation and biodiversity implies that only unexploited old-growth forests guarantee the full preservation of biodiversity. Given the constraint of sufficient agricultural production, we should therefore favor a segregation of functions at the landscape level from the perspective of biodiversity preservation.

A third problem is that biodiversity is best maintained in large wildlands rather than in isolated fragments, as a result of immediate and subsequent gradual species loss in these fragments ('relaxation'). In order to maintain sufficient overall agricultural production, the remaining areas will have to be used intensively, leaving a role for agroforestry in biodiversity preservation only in ecologically sensitive sites. Moreover, agroforests are an exponent of fragmented landscapes and do not contribute to reducing fragmentation. Encouraging agroforestry in practice will often result in increased fragmentation. Fragmentation also implies that agroforests, where they are stable, will tend to lose many of the species they currently harbor.

Finally, because agroforests are often a transient phase in the developmental sequence and tend to be replaced by more intensive land uses, their ability to contribute to biodiversity perpetuation is limited. Overall, then, agroforestry will make only a limited contribution to biodiversity preservation, and may in fact adversely affect it if it competes with wildlands for space in the landscape.

1. Introduction

Agroforestry can contribute to a 'healthy agriculture' in important ways, as it allows for sustainable production, protecting essential soil and water resources for the future, while allowing a gradual domestication of 'forest products', such as honey, meat, fruits, resin, timber, rattans and bamboos. Agroforestry can provide important 'environmental services', such as watershed functions (stabilization of stream flow; minimization of sediment load), soil and nutrient conservation and carbon storage, while it provides refuges for ecologically useful species (pollinators, predators of pests). But can agroforestry also play a role in global biodiversity preservation? Because agroforestry systems contain many natural species, its proponents (Michon and De Foresta, 1995; Leakey, 1999) often stress that agroforestry can make vital contributions to the preservation of biodiversity. In this contribution some counter arguments are presented to this assertion.

A simple conceptual framework for these discussions can be found in the 'segregate versus integrate' analysis (Van Noordwijk et al., 1997, 2001). In its most simple form, two extreme solutions exist to any question on how to meet two functions: to spatially ***segregate*** them (reserve part of the land for function A, e.g. agricultural production, and another part for function B, e.g. biodiversity conservation), or ***integrate*** them, and try to achieve both functions simultaneously (Fig. 1).

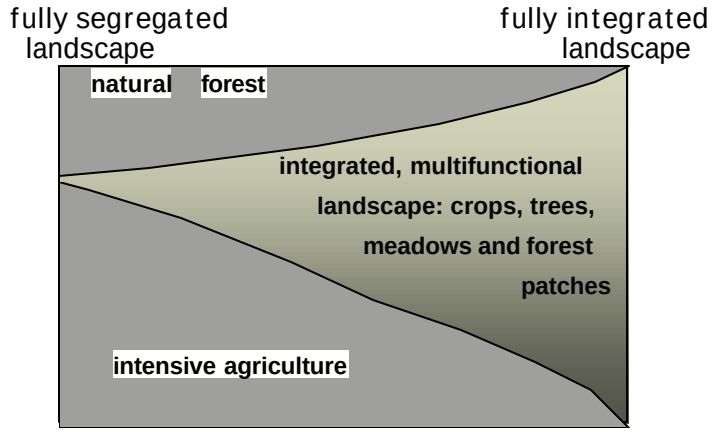

Figure 1. Schematic representation of fully segregated, fully integrated and mixed or intermediate ways of trying to achieve agricultural production as well as forest functions such as biodiversity conservation (Van Noordwijk et al., 2001).

Van Noordwijk et al. (1997) analyzed the segregate-integrate dilemma along the lined of intercropping studies with a 'replacement series' design, and concluded that in all situations where the trade-off curve between production and biodiversity value is convex, segregated solutions provide more overall value to society at large, while for concave curves integrated solutions are to be preferred (Fig. 2). The analysis by Sitompul (this volume) of Relative Agricultural Functions (RAF) and Relative Environmental Functions (REF) leads to the same conclusion.

Very little is actually known about the shape of the curve describing the trade-off function. If the relationship is curved-in (concave), even modest productivity gains cause great loss of biodiversity. If the relationship is curved-out (convex), biodiversity loss is relatively slow for initial increases in productivity. In this case, raising productivity to an intermediate level may involve a modest trade-off in terms of biodiversity loss.

Both segregated and integrated solutions will not provide automatically for 'biodiversity conservation' even if we agree that that is desirable for society at large. In 'integrated' solutions, the external stakeholders in environmental services still have to provide sufficient incentives and rewards to maintain the function, otherwise private decisions by the farmer may favour intensification of

land use and loss of environmental functions. In the 'segregated' solution the opportunities for exploitation of the land reserve provide a continuing threat of encroachment, and the search for socially acceptable but effective boundaries and transition zones is still on (Terborgh et al., 2002).

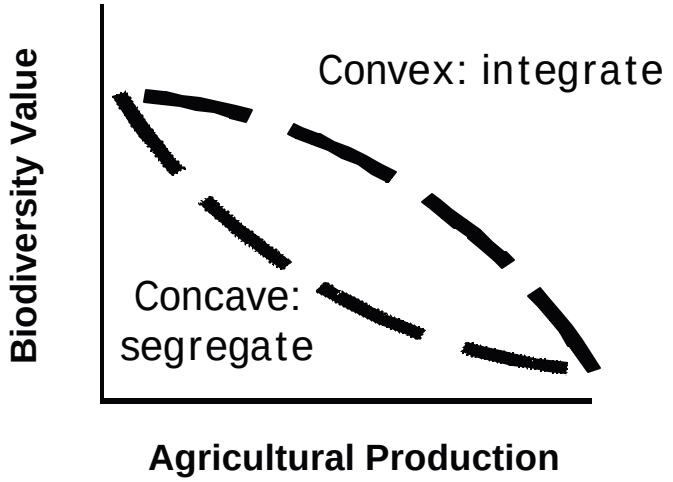

Figure 2. The shape of the trade-off curve that describes how 'biodiversity value' changes with management activities that lead to higher agricultural production determines whether a 'segregated' or 'integrated' landscape configuration provides the best solution to 'society at large.

Thus, the role of agroforestry in biodiversity conservation (Williams et al., 2001) may depend on the answer to two questions:

- what is the shape of the curve describing biodiversity value versus agricultural production value? And
- what factors influence the biodiversity of the complex, multistrata agroforests as productivity of their components increases?

So while there may be a tradeoff between potential profitability and aboveground biodiversity in tree-based production systems, this requires further verification.

This contribution to the discussion on 'healthy agriculture' will first discuss the compatibility of agroforestry and biodiversity, and then focus on the segregate-integrate question.

2. Can agroforestry help to preserve biodiversity?

In general, the answer probably is negative, because:

- Species sensitive to human exploitation will disappear and may include the most valued elements of global biodiversity
- Species that interfere with agroforestry function will be eliminated.

Let's have a closer look at the arguments.

First, species sensitive to human activity, cannot be maintained in agroforestry systems because they are exploited commercially or merely sensitive to human disturbance. Examples include exploited tree species such as gaharu (*Aquilaria*) and gemur (*Litsea*) and many animal species that either avoid people or are commercially exploited by humans. Likewise, species requiring conditions usually only present in old-growth forest will suffer, e.g. those dependent on the microclimate available in dense understories (e.g. ferns with very thin leaves), or on large dead trees for breeding (e.g. hornbills). Not surprisingly, therefore, comparisons indicate that even mature and structurally complex agroforests have fewer species than nearby old-growth forests: 30% fewer plant species and over 50% fewer bird species. This assessment is still conservative because it assumes that all these species actually reproduce in the agroforests.

Second, several wild animals are pests in agroforestry, and will tend to be eliminated, even though they could in principle live in agroforests. Examples of such species are pigs and many primates (including endemic species of leaf monkeys and orang utan) feeding on human crops, elephants that destroy crops or dwellings, tigers that prey on livestock, etc. Thus, for a significant part of biodiversity agroforests will not provide refuge, in particular for the species most in need of protection due to their vulnerability to human presence or exploitation or due to conflict with humans.

At the 'plot' level, these two processes, incompatibility from the perspective of the organisms and from the4 perspective of the farmer, can be responsible for a lower species richness. The data in Figure 3 suggest a reduction in plants species richness of 30 %, and of birds of more than 50 % when old growth (or 'primary') forest is compared to agroforest

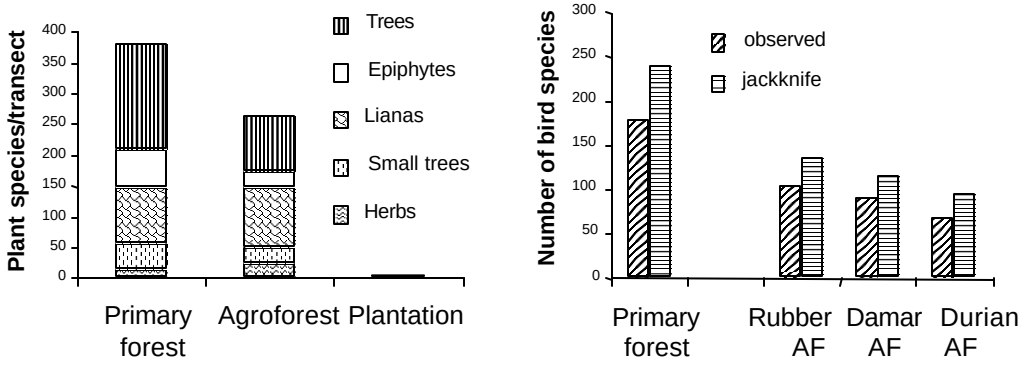

Figure 3. Data on plant (left) and bird (right) species richness in plot-level studies by Michon and de Foresta (1995) and Thiollay (1995).

Plot-level species richness data as in Figure 3 only give a first indication, as the species richness of agroforests can largely derive from a replacement of 'forest' species by species typical of half-open landscapes (Fig. 4A). Also, the interplot-diversity of agroforests tends to be lower than that of more natural forests (Fig. 4B), leading to lower relative richness when the evaluation is made at landscape rather than at plot scale (Fig. 4B).

These two effects together imply that a predictable portion of the species of old-growth forests will not survive in agroforestry landscapes. The presence of a trade-off between exploitation and biodiversity implies that only unexploited old-growth forests guarantee the full preservation of biodiversity.

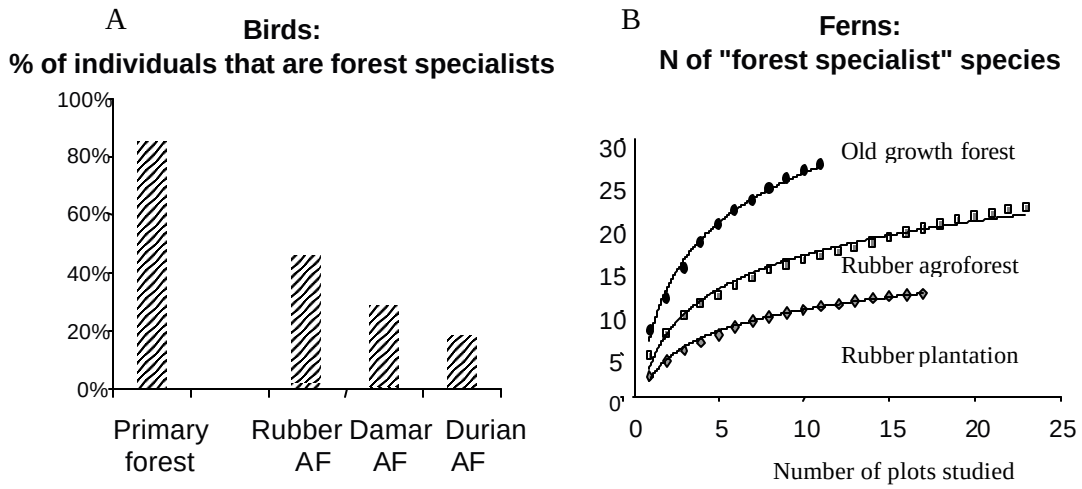

Figure 4. **A.** Proportion of forest birds (based on generally known distribution data) in the studies by Thiollay (1995); **B.** Increase in forest fern richness with increase in number of plots studied (data: Beukema, in press).

When we compare the shape of the curve in Figure 5 with the convex and concave shapes in Figure 2, we can recognize both a convex start of the curve, indicating rapid loss of biodiversity on initial human exploitation, and a concave part, indicating a phase where relatively resilient species can be maintained in extensive forms of agriculture, while they get lost in further intensification. Where global biodiversity values are at stake, the convex shape leads to a preference for 'segregation' of functions, setting aside land for an uncompromised form of conservation.

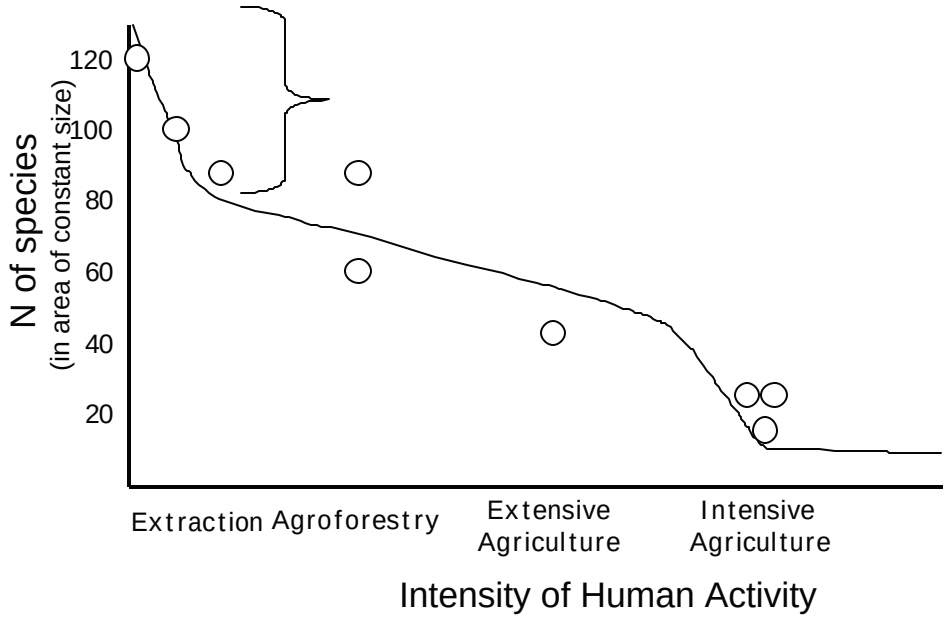

Figure 5. Plant species richness across a land use intensity gradient in Jambi (Murdiyarso et al., in press); the accolade indicates species that go locally extinct when humans are active: they are either exploited or sensitive to disturbance.

3. Landscape level effects of segregation and integration

Biodiversity is best maintained in large wildlands rather than in isolated fragments, even when the latter have the same total area, as a result of immediate and subsequent gradual species loss in these fragments ('relaxation', Fig. 6, 7, 8; Rosenzweig, 1995).

Causes of relaxation include:

Natural processes:

- deterministic: species with large area requirements
- stochastic: random local extinction less likely to be followed by recolonization
- semi-deterministic: cascading effects due to local extinction of some species and hyperabundance of others
- negative "edge effects" (small scale)

Human Activities:

- human-wildlife conflicts (especially on the edges)
- extraction from wildland (especially on the edges)

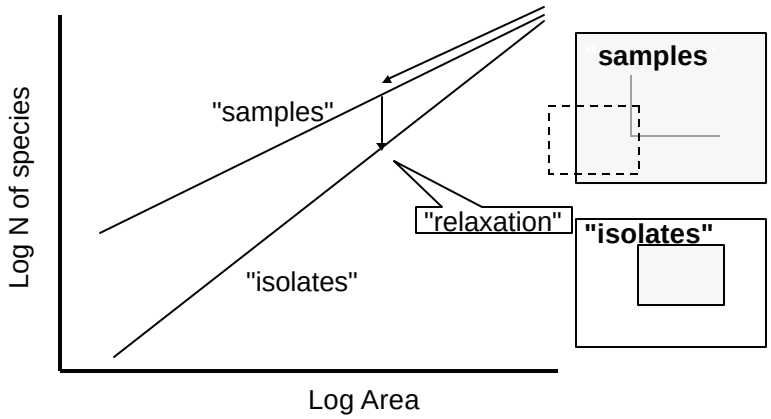

Figure 6. Species-Area curves tend to be lower for 'isolates' than for samples of the same size taken in a continuous habitat; the difference is known as 'relaxation' and increases with time after isolation started due to habitat fragmentation (Kramer et al., 1997).

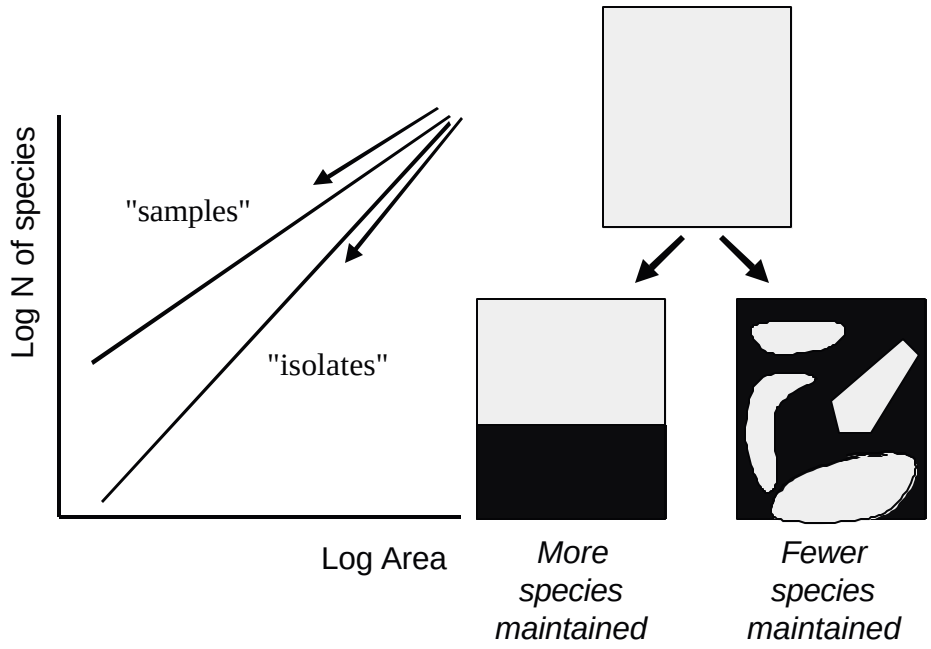

Figure 7. Relaxation effects are likely to be larger when the forest habitat becomes fragmented over several smaller areas rather than remaining as a block.

As regards the long-term potential of agroforests to preserve biodiversity the empirical database is scarce. But we can safely assume that agroforests are likely to lose many species in the coming decades now that connections to natural forests are increasingly severed.

Agroforests tend to occur in fragmented landscapes, with gradients in intensity of use from the village going outwards.

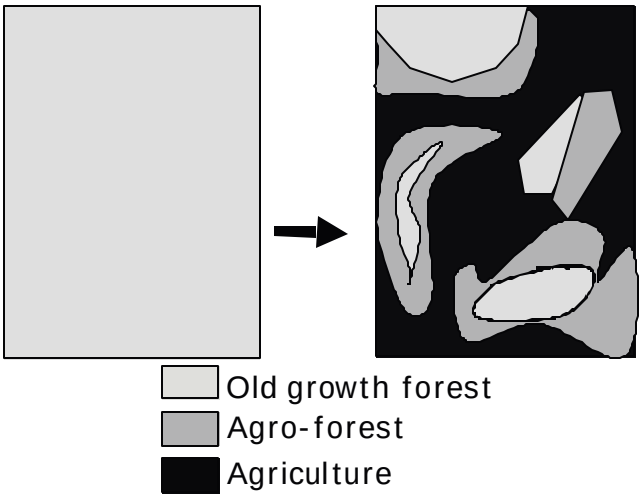

Figure 8. Typical configuration with 'agroforest' in a fragmented landscape, with a gradient in land use intensity from the village radiating outwards.

4. Segregate or integrate?

If a certain part of the land available has to be 'reserved' for conservation purposes, and overall agricultural production has to meet the increasing demands, the remaining areas will have to be used intensively. This may leave a role for extensive forms of agroforestry in biodiversity preservation only in ecologically sensitive sites (Fig. 9).

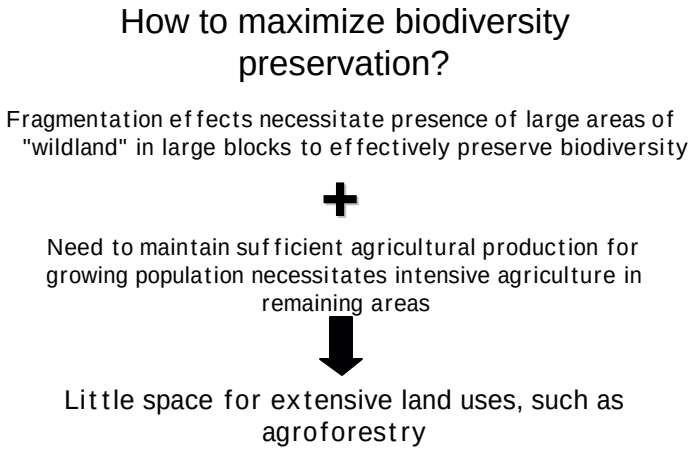

Figure 9. Summary of the arguments in favour of largely segregated landscape (left-of-the-middle on the X-axis of Figure 1).

Moreover, agroforests are an exponent of fragmented landscapes and do not contribute to reducing fragmentation. Encouraging agroforestry in practice will often result in increased fragmentation. Fragmentation also implies that agroforests, where they are stable, will tend to lose many of the species they currently harbor.
Even if agroforests could form larger units with remaining old-growth forests, they are often a transient phase in the development process (Fig. 10).

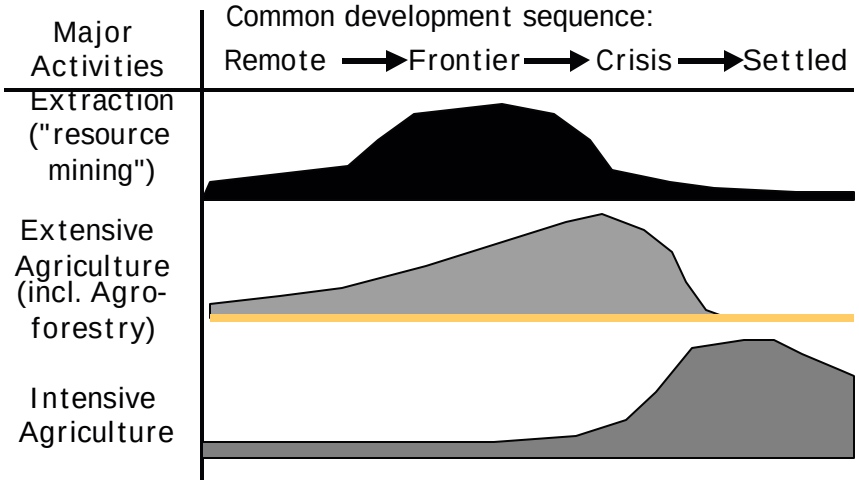

Figure 10. Agroforestry and land-use development.

Because agroforests are often a transient phase in the developmental sequence and tend to be replaced by more intensive land uses, their ability to contribute to biodiversity perpetuation is limited. Overall, then, agroforestry will make only a limited contribution to biodiversity preservation, and may in fact adversely affect it if it competes with wildlands for space in the landscape.

5. Conclusion

Agroforestry cannot replace the role of protected areas with unexploited communities in preservation of biodiversity (esp. rare and vulnerable species; Kramer et al. 1997; Terborg et al., 2002). Parks and protected areas are the only real hope for saving land and biodiversity in those regions. Rather than giving up on parks that are foundering, ways must be found to strengthen them, and 'make parks work' (Terborgh et al., 2002). Parks face a variety of problems, but policies and practices can be found for coping with the mounting pressures of an overcrowded world

However, agroforestry areas enhance biodiversity in intensively farmed landscapes where they provide natural elements and refuges for economically

important species. Landscapes dominated by intensive agriculture still need natural elements, especially when belowground biodiversity is considered as well (Hairiah et al., 2001). In these essentially segregated landscapes, agroforests can play an important positive role in biodiversity preservation by providing islands of semi-natural vegetation where many species can be found that would otherwise be totally absent. They can also support agriculture by serving as refuges for econo mically important species, such as pollinators or predators of agricultural pests.

References

Beukema HJ and M Van Noordwijk. 2002. Terrestrial pteridophytes as indicators of a forest-like environment in rubber production systems in the lowlands of Jambi, Sumatra. Agriculture Ecosystems and Environment, *in press*

Hairiah K, Williams SE, Bignell D, Swift M and M Van Noordwijk. 2001. Effects of land use change on belowground biodiversity. ASB-LN 6A. *In* Van Noordwijk M, Williams SE and B Verbist (Eds.), Towards integrated natural resource management in forest margins of the humid tropics: local action and global concerns. ASB-Lecture Notes 1 – 12. International Centre for Research in Agroforestry (ICRAF), Bogor, Indonesia. Also available from: http://www.icraf.cgiar.org/sea/Training/Materials/ASB-TM/ASB-ICRAFSEA-LN.htm

Kramer R, Van Schaik CJ and J Johnson (Eds.). 1997. Last Stand: Protected Areas and the Defense of Tropical Biodiversity. Oxford University Press, New York. 242 pp.

Leakey RRB. 1999. Agroforestry for biodiversity in farming systems. *In* Collins, WW and CO Qualset (Eds.), Biodiversity in Agroecosystems. CRC Press, Boca Raton, USA, pp. 127-145.

Michon G and H De Foresta. 1995. The Indonesian agro-forest model. Forest resource management and biodiversity conservation. *In* Halladay P and DA Gilmour (Eds.), Conserving biodiversity outside protected areas. The role of traditional agro-ecosystems. IUCN Forest Conservation Programme, Andalucía, pp. 90-106.

Murdiyarso D, Van Noordwijk M, Wasrin UR, Tomich TP, and AN Gillison. 2002 (in press). Environmental benefits and sustainable land-use options in the Jambi transect, Sumatra, Indonesia. Journal of Vegetation Science, *in press*

Rosenzweig ML. 1995. Species diversity in space and time. Cambridge University Press, Cambridge.

Sitompul SM. 2002. Analisis sistem: LovESys akar pertanian sehat. *In* Sitompul SM and SR Utami (Eds.), Akar Pertanian Sehat. Proc. Seminar Ilmiah, 28 June 2002, Brawijaya University, Malang. pp 1-10.

Terborgh J, Van Schaik CJ, Davenport L and M Rao (Eds.) 2002. Making Parks Work: Strategies for Preserving Tropical Nature. Island Press, 511 pp.

Thiollay JM. 1995. The role of traditional agroforests in the conservation of rain forest bird diversity in Sumatra. Conserv. Biol. 9: 335-353.

Van Noordwijk M, Tomich TP, De Foresta H and G Michon. 1997. To segregate or to integrate? The question of balance between production and biodiversity conservation in complex agroforestry systems. Agroforestry Today 9(1): 6-9.

Van Noordwijk M, Tomich TP, Gockowsk JI and S Vosti. 2001. Analysis of trade-offs between local, regional and global benefits of land use, ASB-LN 10. *In* Van Noordwijk M, Williams SE and B Verbist (Eds.), Towards integrated natural resource management in forest margins of the humid tropics: local action and global concerns. ASB-Lecture Notes 1 – 12. International Centre for Research in Agroforestry (ICRAF), Bogor, Indonesia. Also available from: http://www.icraf.cgiar.org/sea/Training/Materials/ASB-TM/ASB-ICRAFSEA-LN.htm

Williams SE, Gillison AN and M Van Noordwijk. 2001. Biodiversity: issues relevant to integrated natural resource management in the humid tropics. ASB-LN 5. *In* Van Noordwijk M, Williams SE and B Verbist (Eds.), Towards integrated natural resource management in forest margins of the humid tropics: local action and global concerns. ASB-Lecture Notes 1 – 12. International Centre for Research in Agroforestry (ICRAF), Bogor, Indonesia. Also available from: http://www.icraf.cgiar.org/sea/Training/Materials/ASB-TM/ASB-ICRAFSEA-LN.htm