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To segregate—or to integrate?

The question of balance between production and biodiversity conservation in complex agroforestry systems

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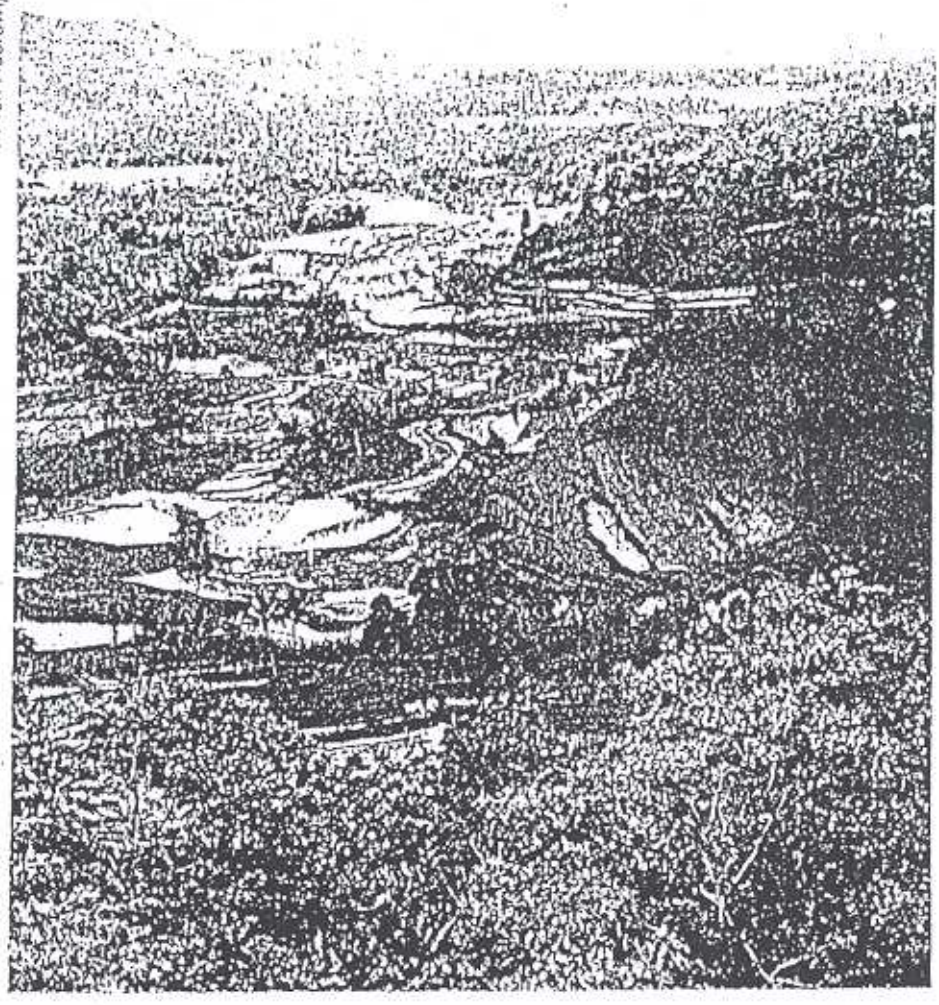

Farmer management aimed at increasing profitability of systems often decreases biodiversity, especially if we take a global view

Indonesian farmers have their splendid agroforests—jungle rubber, other complex systems based on fruit trees and also the damar forest gardens. Farmers in northern Thailand and southern China have their 'jungle tea' agroforests. Past issues of this magazine have documented several of these agroforestry systems. See, for example, 'Agroforests in Sumatra—where ecology meets economy' (*Agroforestry Today* 6(4):12–13); 'Taking the jungle out of the rubber—improving rubber in agroforestry systems in Indonesia, (*Agroforestry Today* 8(1):8–10).

Such agroforests of the humid and subhumid forest zone of Southeast Asia retain and harbour a good deal of the flora and fauna of the natural forests they have replaced. All look like showcases for systems that combine the function of production with that of conservation of natural resources—but is integration of these 2 functions really the best way to pursue the global agenda on biodiversity conservation? Or would it be more effective to segregate the functions—production and conservation—and produce the rubber, damar resin, fruits and tea in more intensively managed systems on smaller areas of land, parcelling off larger chunks of natural forest for complete protection? It is not easy to answer such questions, but before we get carried away by the sighting of a rhino in an agroforest and conclude that all agroforestry systems play an important role in biodiversity conservation (see box p7), we have to be clear on what options exist and how we can evaluate them. The ICRAF team in Southeast Asia have just begun such an analysis (Van Noordwijk and others 1995).

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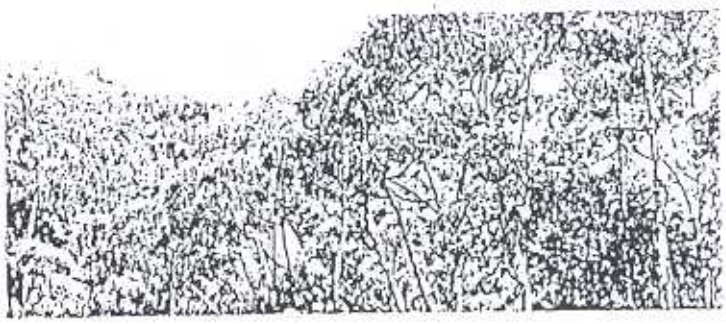
Trade-offs in farmers' fields

The segregate-integrate issue is not unique to the combination of production and biodiversity conservation. It recurs in almost any analysis of multiple functions of land use at any level. However, the issue has particular relevance for complex, multistrata agroforestry systems, precisely because they have numerous components with numerous functions and interactions. Naive early views that interactions in agroforestry would all be positive have now been replaced by a more realistic appreciation of potential competition as well as complementarity among various parts of an agroforestry system. Combining as many different trees and crops as possible on a small plot to serve a whole range of functions for the environment and to provide a whole range of products is an extreme view of the integration pathway to development. At the other end of the spectrum, where segregation of land use is emphasized, are large-scale monocultures of food crops, plantation forests and national parks. Mosaics and patchworks in the landscape are intermediate options, having aspects of both segregation *and* integration at different scales—regional, local and household. The question of whether—and at which scale—trees and crops can be mixed for their productive functions has been asked often. What *is* new is the incorporation into that question of environmental functions such as conservation of biodiversity.

In intercropping, the yield of each species is normally reduced, but the overall profitability of the system may—or may not—be increased. Consider the simple case of a mixture of 2 crops. The profitability of the mixture—compared with growing each crop separately—depends on the change in the total value of outputs from both crops in the mixture, minus the change in total production costs for the intercropped system. On the cost side, intercropping may involve either conflicts or complementarities in, for example, labour and management of various tasks such as control of pests and diseases or application of water and nutrients. The relative benefits of the intercropped system depend crucially on the trade-off function between the 2 yields (how much do the 2 crops hinder or improve each other's production?) and the relative value of the outputs of each crop. The situation becomes even more complex if the 2 crops are valued differently by different actors—men and women, for example, or in the case of the taungya or shamba system, forestry agents and farmers. If intercropping has no net benefit or if the actors involved cannot agree how to share benefits, it usually is better to grow each crop, or trees and crops, on separate plots.

We can apply the same thinking to analyse the options for integration of production and biodiversity conservation. Farmer management aimed at increasing



Forest biodiversity and agroforests

We use Indonesian examples to define the agroforests that are used here as a reference for integrated systems. By agroforest we mean the mature productive phase of complex agroforestry systems, specifically systems that begin with slashing and burning existing vegetation, planting various commercial and useful tree species, followed by successive phases of production and development that compare with successional phases in forest regeneration processes. Agroforests have a complex multistrata structure—with a closed or almost closed canopy—that is usually dominated by a few plant species. However, in agroforests, farmers do not systematically eliminate other species but allow the regeneration and preservation of numerous forest species, those that are perceived as having no detrimental impact on the system's production.

This agroforest model is at the extreme 'forest' end of the wide spectrum of agroforestry systems and is almost unique in how it conserves forest species of both animals and plants (Michon and de Foresta 1995). In no way can these features be extended to—or expected of—all agroforestry systems, such as alley cropping, trees scattered in or bordering on fields of crops, simple associations involving a single crop and 1–2 species of shrubs or trees or contour hedgerow systems. These agroforestry systems are no better at conserving forest biodiversity than is monoculture.

Full integration—an option?

Agroforests are an unrivaled system for 'conservative production', but they are not meant for conservation; they are primarily for production. They simply cannot compete with the biodiversity of undisturbed 'primary' forests. While many local forest species are preserved in agroforests, an almost equally important part of forest biodiversity is lacking. The farmers who have developed

and who maintain these agroforests do not see conservation of forest biodiversity as a goal in itself. Rather it is seen as a gift—a bonus—that comes with the management of ecologically and economically complementary tree species for multipurpose production on the same piece of land. Compared with other agricultural, silvicultural or agroforestry systems, the relatively high numbers of species in agroforests *do* produce much higher numbers of commodities. But management in agroforests implies a necessary loss in biodiversity compared with natural forest—in examples studied so far, tree diversity is always highly reduced in agroforests. So it is unrealistic and misleading to assume that an even-close-to-perfect agroforest can play the same role that a natural forest does in biodiversity conservation.

If we want to preserve biodiversity as a whole and not just certain sets of species, a network of natural forest reserves is necessary, regardless of what other options there are for land use leading to development. There is simply no way that some forest species groups could be preserved if all such natural systems were to be converted to agroforest. This point is crucial in understanding the issues in the 'integrate or segregate' debate: with biodiversity conservation in view, forest reserves should not be considered as a part of the segregate option only, but as an inevitable and key component of both options.

An all too real world . . .

This being clarified, in many regions where natural forests have already vanished, as in the lowlands of Sumatra, it would be quite counter-productive for biodiversity conservation to disregard existing integrated systems such as jungle-rubber agroforests just because they are not pristine forests. Because they represent one of the main reservoirs of forest species in this region, they should instead be considered as reference ecosystems in the assessment of segregate–integrate options—is productivity improvement within the jungle agroforest system the best way, or wouldn't it be more efficient for development and biodiversity conservation to help farmers establish more profitable systems on part of their land while old agroforests are preserved as forest ecosystems? Considering the various threats impeding the very survival of agroforests (see for instance *Agroforestry Today* 8:3:22–23), this question is far from being academic. Clear answers are urgently needed, before the segregate–integrate issue becomes an issue of the past, with no natural forest but also no integrated systems left.

profitability of systems often decreases biodiversity, especially if we take a global view. For example, the profits gained by introducing exotic species may 'add' some biodiversity from a purely local perspective, but this also carries the risk of extinction of indigenous species through loss of habitat or increased competition. Whether or not this apparent trade-off between profitability and biodiversity is inescapable is still the subject of debate—and it needs further research. Even if such a trade-off were inevitable, however, it would still not be enough for us to take a stand in the segregate–integrate debate.

What *is* important is the shape (concave or convex) of the curve when we plot profitability and biodiversity on a graph, as in the *hypothetical* relationships shown in figure 1. We know very little about the shape of this trade-off function (or even whether a trade-off always exists). If the curve is convex, even modest initial productivity gains cause a great loss of biodiversity. In this case, segregation of land use may be the way to go, conserving biodiversity in specialized forest reserves or natural parks. Here, the more profitable the production system is the more scope there is for maintaining natural forest reserves—at least in principle. Attempts to intensify production can backfire under certain conditions, however, and accelerate deforestation or lead to land degradation instead of high—and sustainable—profits. If the curve is concave, biodiversity loss is relatively slow for *initial* increases in profitability. In this case, raising profitability to an intermediate level involves a modest trade-off in terms of biodiversity loss. This may mean that integrating functions in a land-use system is a better way to meet multiple goals, particularly if enforcement of boundaries of parks and nature reserves is socially, economically or administratively infeasible.

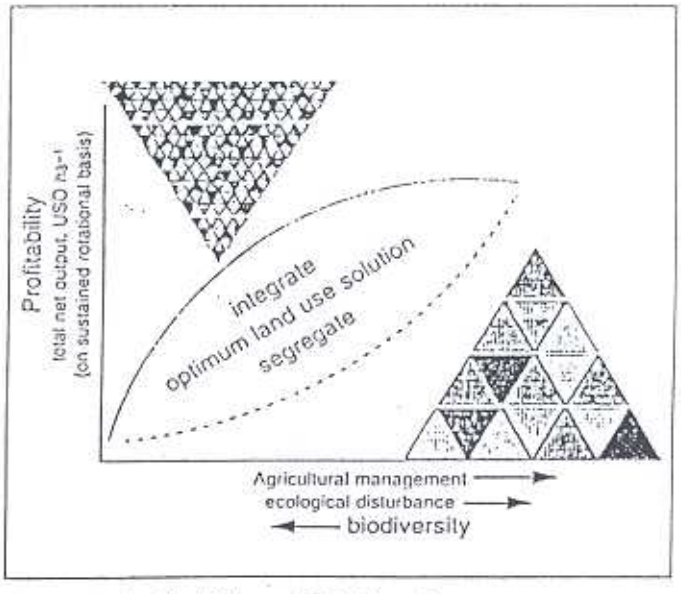


Figure 1. Profitability and biodiversity

Based on this analysis, ICRAF researchers and their partners in Indonesia are working to quantify the relationship between profitability and biodiversity within rubber production systems ranging from agroforests through intermediate levels of production to high-output monoculture. At the same time, the research team is working to increase profitability of rubber agroforests with a minimum loss to existing biodiversity by testing higher yielding rubber germplasm, which was initially selected for large-scale monoculture plantations, in smallholder agroforest systems.

Scaling up to the landscape level

The recent definition of agroforestry proposed by Leakey (1996) and refined on page 5 stresses integration of functions and the positive attributes of increased diversity in agroecosystems. The reality so far has been that development in both temperate and tropical zones has been largely based on specialization of functions (segregation). If we believe it is desirable to reverse this trend and maintain—or even increase—complexity (integration) of land-use systems at a range of scales, rigorous assessment of segregate–integrate trade-offs deserves high priority in our research. Otherwise we may repeat the mistake that led so many researchers to leap prematurely onto the alley-cropping bandwagon.

Our analysis suggests that there may be a relatively simple criterion that can shed light on the segregate–integrate debate. It does this by supplementing heartfelt concern about biodiversity conservation and poverty alleviation through productivity growth with hard-headed observation of empirical relationships. That criterion, which is a necessary (but not sufficient) aspect of the analysis of options, is the shape of the trade-off function between profitability and biodiversity.

Measuring biodiversity, however, is not straightforward. It is possible to count organisms from various taxonomic or functional groups in a range of land uses to obtain an indication of biodiversity richness of alternative production systems. But this approach alone cannot answer the question of how much biodiversity will be lost for each hectare of forest converted to another land use. The main methodological gaps have to do with scaling over space—that is, looking at these relationships at different levels—and over different lengths of time.

As one samples biodiversity over larger and larger areas within the same ecosystem, the number of additional species observed will increase, but at a decreasing rate. Some of the species found in each new sample plot will have been encountered already in previous plots; only a fraction will be observed for the first time and the size of this fraction tends to diminish as the sample size increases. This complementarity across space means that one cannot simply add biodiversity values across plots. Nor can the number of species seen on a small study area tell us how much land is needed to conserve those species. If that piece of land were to be surrounded by land under different uses, the number and type of species could change dramatically. The long-term survival prospects of these species depend on the extent of their habitat, but this is influenced by the pattern of land cover in the landscape.

The data available to date for agroforests in Sumatra do not allow us to scale up our analysis to the landscape level. Although the plots of rubber agroforests studied so far may harbour half to two-thirds of the biodiversity of an equivalent area of natural forest, we don't know whether the same is true if we scale up to compare a million hectares of rubber agroforests with an equal area of natural forest. ICRAF researchers and their partners in Southeast Asia are trying to address the problems of scale in assessing biodiversity values by looking at the diversity in indicator groups over larger study areas and in various landscape mosaics.

Whether empirical analysis of the shape of the trade-off function between production and biodiversity points to segregation or to integration, the myriad constraints and the more nuanced objectives of the real world will necessarily involve a richer mix of solutions than appear in this abstract model. Which among these real-world issues are likely to most shift the balance between segregate or integrate? Constraints on public funds, land-tenure security, social balance in the distribution of development benefits, and limited administrative capacity are 4 important practical considerations. These constraints mean that, for the foreseeable future, much of the land use in Sumatra will be neither for conservation reserves nor for highly intensified agriculture. The remaining middle ground is where the agroforest pathway may conserve more biodiversity than a wide range of alternate land uses. From this standpoint, perhaps the most important question for research is: what factors influence the biodiversity of these complex, multistrata systems as productivity of their components increases?

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