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Imperata economics and policy

T.P. TOMICH[1,]*, J. KUUSIPALO[2], K. MENZ[3] and N. BYRON[4]
[1] *Southeast Asian Regional Research Programme, International Centre for Research in Agroforestry;* [2] *Reforestation and Tropical Forest Management Project, Enso Forest Development Ltd. and FINNIDA;* [3] *Centre for Resource and Environmental Studies, Australian National University;* [4] *Centre for International Forestry Research (*Corresponding address: Southeast Asian Regional Research Programme, International Centre for Research in Agroforestry, P.O. Box 161, Bogor 16001, Indonesia)*

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Abstract. Should policymakers – or anyone else – care about millions of ha of *Imperata* grasslands? The answer depends on the balance between costs of conversion to other uses and the net benefits produced in economic growth, poverty alleviation, and protection of the environment. The first section on *Imperata* economics sets up the analytical framework to address this question and draws on the wider development economics literature to consider whether growth and poverty alleviation are conflicting or complementary objectives. Although evidence is limited, it suggests smallholder-based agroforestry could provide the same economic growth with greater poverty alleviation than large-scale forestry estates. There is, however, no substitute for project appraisal for specific settings. The second section on *Imperata* policy reviews whether policy distortions and market failures provide a sufficient rationale for direct policy intervention to promote tree planting on *Imperata* grasslands. Estimates of imputed values of carbon sequestration to alleviate global warming are presented for *Acacia mangium* and rubber agroforestry. The conclusion summarizes the policy research agenda and examines the desirability and feasibility of policy intervention to promote carbon sequestration through *Imperata* grassland conversion to tree-based systems.

Introduction

There are countless references to the 'problem' of *Imperata cylindrica* grasslands in a variety of sources, including the leading textbook on economic development (Gillis et al., 1996). Garrity et al. (this issue) estimate that there may be as much as 57 million ha of *Imperata* grasslands in Asia. By their reckoning, *Imperata* covers much of Indonesia (4% of the area of its land), India (3%), and the Philippines (17%) and almost one quarter of the land area of Vietnam.

There has been almost no economic analysis of agroforestry approaches to conversion of *Imperata* grasslands. Indeed, Nair's general observation (1992, p. 426) that 'economic and financial studies in agroforestry have been grossly inadequate' is indisputable regarding its potential role in *Imperata* grassland conversion. For example, although Turvey (1994, p. 35) emphasized the importance of research to address the 'sociopolitical context within which the *Imperata* land systems are managed or mismanaged', his definitive survey of the literature for Southeast Asia does not contain a single reference to any study of the financial or economic feasibility of agroforestry applications for *Imperata* grassland conversion. In one publication where these tools were applied to *Imperata* grassland conversion, agroforestry systems were not analyzed as a land use alternative (Burbridge et al., 1981). However, an ongoing research project led by K. Menz promises to narrow the gap in our understanding of the microeconomic aspects of smallholder agroforestry systems as a means of *Imperata* conversion in Southeast Asia (see for example Menz and Wibawa, 1995; Menz and Grist, 1995a, b; and Grist and Menz, 1995).

But are the vast *Imperata* grasslands really an economic problem that merits the attention of policymakers? The answer depends on the balance between costs of conversion and the net benefits produced in economic growth, poverty alleviation, and protection of the environment. Because of scant evidence, the purpose of this paper is to set up an analytical framework and to frame hypotheses for further research on this topic.

Imperata economics

What do we hope to change? Why? *Imperata* grassland conversion is *not* a policy objective. The public policy objectives that in principle could be served though conversion of these grasslands to other uses include:

- economic growth,
- poverty alleviation,
- environmental protection and natural resource conservation.

We will consider growth and poverty alleviation in this section and will take up environmental and natural resource conservation issues in the next section. The question is not simply whether tree planting (in whatever configuration) can contribute to these objectives; but will it provide greater benefits for a given expenditure than alternatives?

Economic growth

Imperata grassland conversion is an investment decision. To be both feasible and desirable in economic terms, any investment must be profitable financially (from a private perspective) and socially (from a public perspective). As always, the economic case for public policy intervention rests on particular kinds of divergence between financial and social profitability.

Consider the four cases in Table 1, which refer to the profitability of the last additional unit of a specific economic activity. Pollution is the standard example for Case 1. In that case, additional activity is profitable financially but not socially and policy intervention is justified to reduce the level of

Table 1. Scenarios for financial and social profitability of an investment.

	Financially profitable	Financially unprofitable
Socially unprofitable	1	2
Socially profitable	3	4

pollution arising from the activity. Case 2, where the last unit of activity is unprofitable from either perspective, is easy: the activity is unprofitable (so no one will do it) and undesirable (so society would lose if anyone did). Case 3 mirrors Case 2, with the same implications. Neither Case 2 nor Case 3 require policy intervention since private incentives lead to investment decisions consistent with broader social objectives.

The belief that there is 'too much' *Imperata* grassland, if true, falls under Case 4 in Table 1: additional conversion is socially profitable, but financial incentives are insufficient to induce the necessary investment. This specific divergence can be stated as a pair of hypotheses that can be tested empirically regarding *Imperata* grassland conversion. The case for policy intervention to promote grassland conversion rests on both of these hypotheses.

Hypothesis 1. Although grassland conversion is a gradual, ongoing process, it is not financially profitable to convert large areas of existing *Imperata* grasslands under current technologies, prices, and policies.

Hypothesis 1 is consistent with the existence of large areas of grasslands in Asia. If conversion of these grasslands were financially profitable, there would be no *Imperata* 'problem' because the land would already be in other uses.

Hypothesis 2. Even though it is not financially profitable (Hypothesis 1), conversion of some **additional** *Imperata* grassland is socially profitable.

If Hypothesis 2 were false, there also would not be any *Imperata* 'problem' since no significant social benefits are being lost. Thus, taken together, Hypotheses 1 and 2 are (or should be) necessary conditions for policy intervention.

Three things are needed from a policy perspective. The first is a means to determine conditions where conversion is socially profitable but not financially profitable. The second requirement is a way to understand the causes of this divergence. Finally, an appropriate policy instrument – meaning one that is cost effective, administratively feasible, and compatible with efficient production and investment incentives – is needed if, in fact, this particular type of divergence exists, and action is justified. Instead of an 'all or nothing' proposition regarding grassland conversion, policy intervention would shift the balance of profitability at the margins of grasslands, which are constantly being created and converted.

Measuring profitability of conversion. Profitability of conversion to other uses depends on biophysical, geographic, economic, and social aspects of land use alternatives at specific sites. The starting point in building an analytical framework for empirical assessment of Hypotheses 1 and 2 is provided by well-known techniques for the appraisal of agricultural investment projects; Gittinger (1982) is the standard reference. Whether it is undertaken by a large plantation company or by a smallholder, the appropriate measure for a multi-year investment like grassland conversion is *the net present value* (NPV) defined as:

$$\text{Net present value (NPV)} = \sum_{t=0}^{T} \frac{(B_t - C_t)}{(1+i)^t}, \tag{1}$$

where t = time (denoting years),
T = life of investment (in years),
B_t = benefits at year t,
C_t = costs at year t,
i = discount rate.

Ignoring risk and other market imperfections for now, the following definitions are used in calculation of the financial NPV:

B_t = market value of outputs plus capital gains on land and other assets;
C_t = market value of inputs, wages and salaries, land rent or the 'opportunity cost' of the profits foregone for the best alternative use, investment costs, and taxes;
$B_t - C_t$ = cash flows valued at market prices;
i = financial cost of capital.

An investment is appraised as profitable if the estimated NPV is greater than zero. This simply means that, subject to the assumptions underlying the analysis, the activity is expected to be more profitable than alternatives. If this is not the case from the perspective of an individual firm ($NPV_{financial} < 0$), there is no apparent financial incentive for someone to make the investment of time and money. Indeed, they would be better off doing something else, even doing nothing.

Productivity of grasslands. One cost of conversion, which neither can be delayed nor reduced and which typically is overlooked, is the loss of existing uses of *Imperata* grasslands. (In the jargon of economics, this is the 'opportunity cost' of conversion.) These grasslands are not 'wastelands'; careful fieldwork has demonstrated that they have a number of uses for local people (Dove, 1986; Brookfield et al., 1995; Potter, this issue). Even if these uses are of relatively low value, they are important to the people who use them.

Technology. Other articles in this issue demonstrate that there are plenty of techniques to control *Imperata*; many already are used by smallholders. However, there are big differences between control of small patches of *Imperata* in farmers' fields and conversion of grasslands spanning tens of thousands of ha, which are the topic of this article. Indeed, no single technological panacea exists for conversion of these large contiguous blocks of *Imperata* grassland to other uses. And even if one system were technically feasible for the entire area, wholesale conversion to 57 million ha of any single alternative (rubber, oil palm, even timber) would in time be sure to drive down prices. Thus, instead of a single technique or production system, profitable conversion will involve myriad strategies, each suited to a particular place and time.

Anything that increases or hastens benefits or that decreases or delays costs will have a positive impact on financial profitability of conversion of these grasslands to other uses. Further applied research is needed to adjust and expand the range of techniques for *Imperata* control in ways that will reduce farmers' costs. In particular, more input is needed from farmers in setting priorities for applied research on land rehabilitation. Without such input, the practical problems farmers face may be overlooked by researchers. Linking researchers with farmers also is crucial in realising the potential to raise returns to smallholders through improvement of the quality and yield of indigenous tree species in complex, multistrata systems as alternatives to monoculture plantations (Leakey and Newton, 1994; see also Leakey and Izac, 1996).

Access to markets. The formula for net present value shows clearly that any effort to establish alternative land uses on *Imperata* grasslands depends on access to markets, which determine prices paid for inputs and received for outputs. Marketing opportunities, in turn, depend mainly on access to roads. Markets for tree products also can be distorted by transport restrictions and local levies, barriers to market participation, and price distortions in the public sector (taken up in the next section on *Imperata* policies) as well as mismanagement of macroeconomic policies (including the interest rate, with its obvious effect on profitability in the NPV calculation, and the exchange rate, which affects the prices of tradable commodities).

Road construction to improve market links and thereby promote conversion of *Imperata* grasslands to more productive uses is one case where public investment in infrastructure runs little risk of contributing to forest conversion and may even help offset deforestation. Of course, public investment in roads must meet the same criteria as grassland conversion. Appraisal of road construction projects is complicated by their sweeping effects on people's access to a variety of resources and the marketing links that determine the profitability of production and investment throughout the region in question. Roads affect opportunities for local entrepreneurs, including activities linked economically to forestry and agriculture (nurseries and seed producers, processors, traders, and transport companies).

It is worth noting that widespread conversion of *Imperata* grasslands to more productive uses potentially could have similar regional economic impacts. A pathbreaking study in Malaysia found that regional multipliers and spillover effects were a big share of the net benefits from infrastructure investments to irrigate rice (Bell et al., 1982), but no studies have been conducted of the regional-level economic effects of *Imperata* conversion.

Nor have there been any studies of the spatial dimension of the economics of *Imperata* conversion. *Imperata* grasslands have retreated gradually in some regions through farmers' efforts. This is most likely where land is scarce and market links are good (both usually occur as population densities increase). These conditions are met in Java, where *Imperata* grasslands documented in the 19th Century virtually disappeared (Dove, 1981, p. 172, fn. 13). Research elsewhere in Indonesia (de Jong, 1994) and the Philippines (Garrity and Augustin, 1995) has documented cases where smallholders converted *Imperata* grasslands through their own initiative by planting trees, including timber species. Similar processes have been observed in Vietnam and other countries in Asia.

Even simple comparisons of the financial profitability of alternative land uses are scarce – and none provides a comprehensive analysis of the profitability of relevant alternatives. One of the most important alternative uses for labor and capital is to clear additional natural forest. As long as there is essentially open access to adjacent forests, conversion of forest land to other uses may often be more attractive than investing to convert grasslands. This landscape-level link is taken up again below regarding other policy failures that undervalue products of natural forests, thereby undermining incentives to invest in sustainable production elsewhere (including through conversion of grasslands).

Table 2 presents one comparison of land use alternatives in Indonesia compiled by the World Bank (1990, p. 32). Details of the underlying calculations are not available, but these estimates clearly have some shortcomings: the discount rate of 10% probably is too low; and they were not intended to assess costs of conversion nor is the opportunity cost of grasslands' present

Table 2. Estimates of net present value of alternative production systems, Indonesia, 1987.

Production system	10% discount rate	
	Operating unit (ha)	NPV (US$/ha)
Shifting cultivation	12	53
Timber	1.0	128–553
Low-input foodcrops	1.5	446
Rubber plus house garden	2.5	1,065
Smallholder rubber	2.0	1,182

Source: World Bank (1990, p. 32).

uses included. (As a rule, such estimates also tend to be based on overly optimistic assumptions.) However, since a $NPV_{financial}$ greater than zero is the criterion for financial profitability, these features also have an important advantage for present purposes since the estimates of NPV per ha are a reasonable upper bound for the maximum feasible costs for land use conversion. (A greater cost of conversion in the first year would yield a negative NPV.)

The World Bank's figures in Table 2 suggest that additional conversion costs of only about US$500 per ha would overturn profitability of conversion of *Imperata* grasslands to foodcrops or timber plantations; but conversion costs could be up to about US$1,000 per ha higher before the rubber-based systems become unprofitable.

It should be clear already that more empirical evidence is needed; there is no substitute for appraisal of alternatives for specific settings. The results in Table 2 do not provide much of a basis for judging Hypothesis 1, that relatively little **additional** *Imperata* grassland conversion is financially profitable under current technologies, prices, and policies. Technology and access to markets are two important determinants of the financial profitability of smallholder initiatives; we now turn to two others: natural risks, especially fire, and insecure claims over the products of the hard work required to convert grasslands to other uses.

Risks from fire and tenure insecurity. There are no *a priori* reasons to suspect that products from agroforestry systems on converted grasslands face any greater price risk in markets compared to the same commodities produced in other settings. The frequency of fire, on the other hand, obviously is a distinctive source of yield risk characteristic of production systems set amidst *Imperata* grasslands (see also Wibowo et al. in this issue). Effective fire control is a prerequisite to establishment of trees on these grasslands. *Imperata* is particularly flammable in the dry season and usually is burned (deliberately or accidentally) every year, producing useful fodder (Dove, 1986; Potter, this issue). Such repeated annual burning destroys trees, whether planted or naturally regenerated. The *Imperata* survives – even flourishes – because of these fires.

Frequency of fire is bound up with tenure insecurity, which itself contributes additional risk and uncertainty regarding prospects for returns on investments in *Imperata* grassland conversion. At least in Southeast Asia – perhaps more generally – large areas of *Imperata* grassland are on land that is designated as State Forest Land. Local people are formally prohibited from using these grasslands but, in practice, it is difficult to exclude established communities. Under these circumstances, local people may perceive substantial insecurity regarding any investments to raise productivity on these grasslands.

Risk can be incorporated in the NPV analytical framework by modifying Equation (1) as follows:

$$E\,(\mathrm{NPV}_{\mathrm{financial}}) = E\left[\sum_{t=0}^{T} \frac{(B_t - C_t)}{(1+i)^t}\right], \tag{2}$$

where E is the expectations operator (Anderson et al., 1977, pp. 249–252). One additional step produces an expression that is sufficient to demonstrate the impact of risks from destruction by fire and from tenure insecurity on incentives to convert *Imperata* grasslands to alternative uses:

$$E\,(\mathrm{NPV}_{\mathrm{financial}}) = \sum_{t=0}^{T} \frac{s_t(B_t - C_t)}{(1+i)^t}, \tag{3}$$

where s_t is the probability the activity survives to year t. Increased risk of fire or expropriation in any year reduces s_t, the probability the activity will continue for that year and all subsequent years; as a result, expected NPV falls. For example, on-site fire risks in rubber agroforestry systems would be particularly high after the initial phase of intercropping with annuals and before canopy closure is sufficient to shade out *Imperata*. Fire during those years would be likely either to destroy the investment before the onset of production or to stunt tree growth, thereby delaying production and reducing yields. Of course, fire risks persist, especially if the plot is adjacent to *Imperata* grasslands.

The frequency of fire in *Imperata* areas should make it possible to gather data on these risks with household surveys. Fire from off-site sources may be an even more important risk, which might be assessed through analysis of remote sensing data on land use and incidence of fires. Although it is technically feasible to obtain the necessary data, we know of no published studies addressing the economic aspects of fire risk in *Imperata* grasslands.[1] It seems obvious, however, that these risks can only reinforce Hypothesis 1.

Community-based fire control. Although published evidence is scant, it also seems obvious that community-based initiative for prevention and control is a necessary ingredient for reducing risks of fire in grasslands. Local people are in the best position to know about fire risks and to know when a fire starts. Moreover, although they may not be able to manage all fire risks among themselves, local people are in a good position to take timely, on-the-spot actions to extinguish fires while they still are small. Just as important, they also can take simple precautionary measures to reduce fire risks.

More research is needed to understand existing community-based fire control initiatives and to identify ways in which government can help strengthen (or, at least, avoid retarding) those efforts. Public fire services will still be needed, especially to assist with big fires. But more effective community-based fire control would reduce demands on the limited resources of the fire service for monitoring and fighting small fires, allowing the fire service to focus on its essential role in fighting big fires.

Tenure security. By the same reasoning, secure tenure would seem to be a prerequisite for the community-based ingredient of fire control. A stake in preventing damage to personal property creates incentives for appropriate action to prevent, detect, and control fires.

Secure tenure (either in land or trees) also is necessary as an incentive for people to undertake the hard work to establish trees in the first place. Tenure security depends on clear, stable policies that protect legitimate property rights. However, formal tenure – say through registered land titles – is *not* a necessary condition for tenure security. Informal property rights become a problem only when there is a perception of imminent risk of expropriation. For example, Feder et al. (1988) found insecure tenure had a negative effect on land investment by squatters on state land in Thailand. Overlapping public and private claims, and contested claims generally, undermine incentives for investment and resource management on both sides. Common property is another situation where overlapping claims can arise, but elements of these institutional arrangements for community-based resource management may be superior to private property under some circumstances (Arnold, 1992). The likely complexity of these issues in *Imperata* grasslands means there could be a high payoff to field work to gain better understanding of indigenous tenure systems in these settings.

Poverty alleviation

Other articles in this issue describe a number of agroforestry systems and other land uses that could be sustainable alternatives for conversion of *Imperata* grasslands by smallholders. Together, these represent a new perspective on grassland conversion that focuses on expanding opportunities for individual smallholders to undertake a range of viable land use alternatives, including re-establishing trees. This new perspective contrasts with the more conventional view emphasising the role of large-scale plantation forestry.

Production by smallholders versus large-scale plantations. Are the goals of economic growth and poverty alleviation compatible in this context? Or is the (apparently) limited scope for financially profitable grassland conversion by smallholders under current technologies, prices, and policies simply evidence that these tasks are better left to large-scale plantations?

We know of no published studies comparing the economics of smallholders' systems and large-scale plantation activities on former grasslands. There is, however, a huge body of literature that does address this issue more generally for agriculture in developing countries. Although faith in the existence of economies of scale in agriculture is one of the most widespread and durable notions in thinking about economic development, it also happens to be false. As long as wages are low, there are *no* economies of scale in agricultural production and there is an inverse relationship between farm size and output (Tomich et al., 1995, Chapter 4; see also Hayami, 1993).

Possible exceptions in the specific case of *Imperata* conversion might include land preparation or timber harvesting in tree-based alternatives. For example, Page et al. (1976) found evidence of economies of scale in logging in Ghana. Yet more labor-intensive methods may be cheaper means of accomplishing these tasks under some circumstances and, when they are not, both mechanical land preparation and timber harvesting could be done on a contract basis. (These mechanical processes also can involve higher internal and external costs from soil compaction and erosion compared to labor-intensive alternatives.)

Moreover, smallholder-based approaches have better prospects for successful fire control than large-scale, estate-based schemes. The advantages of community-based fire control were elaborated above. Large-scale operations are at a relative disadvantage in virtually every aspect of fire control. Monitoring fire risks is extremely difficult when operations span thousands of ha. Instead of the preventive measures and on-the-spot action to control small fires that are cheap, simple, and effective for smallholders to implement, intervention by large operations typically comes after fires start and are big enough to be noticed at a distance. Large estates may have an advantage over smallholders in fighting these big fires, but by then a lot of damage already has been done. Since effective fire control is a necessary condition for successful *Imperata* grassland conversion, smallholders' advantages in monitoring fire risks and detecting fires before they get out of control may give smallholder-based strategies a decisive advantage over large-scale estates.

Why not pursue both strategies simultaneously, one for smallholders another for large-scale plantations? Scarcity of open land means the two approaches are mutually exclusive in many places. These grasslands are not empty. Indeed, it is surprisingly hard to find large blocks of grassland that are not already used by local people. In Indonesia, for example, a 300,000 ha block of grassland in Kalimantan that was believed to be 'empty' was designated for an industrial timber plantation. After the project started, it was discovered that the entire block was claimed and managed by local villagers. These overlapping claims create tenure insecurity for local people *and* forestry companies alike.

Tenure conflicts undermine incentives for sustainable resource management on both sides and increase the risks of fire for plantations on contested land. Local people will have little or no incentive to prevent or control fires that threaten investments by a company that, from their perspective, unjustly occupies the villagers' land. More to the point, arson is one of the most effective means for local communities to strike back in what otherwise can be a rather one-sided contest over land claims (see for example Brookfield et al., 1995, p. 200).

To sum up, the broader evidence from the development economics literature and the specific human ecology of *Imperata* grasslands both are consistent with the following hypothesis:

Hypothesis 3. There is no trade-off between economic efficiency and pursuing poverty alleviation objectives through smallholder-based strategies for *Imperata* grassland conversion. Indeed, economic growth and poverty alleviation objectives appear to be complementary.

Marketing and processing. Unlike most of the relevant production activities, marketing and processing of primary products often are characterized by increasing returns to scale. This is the case for at least three important land use alternatives for *Imperata* grasslands in the tropics – rubber, pulp, and oil palm – and could also be the case for the products of certain indigenous tree species that could be domesticated for use in these settings. The major producers of natural rubber (Thailand, Indonesia, and Malaysia) each provides an excellent example of the efficiency with which markets can integrate low-cost production by smallholders with processing in crumb rubber factories that achieve economies of scale. The successful experience of the Philippine Paper Corporation (PICOP) with outgrower schemes to produce trees for pulp is another (albeit more limited) example of successful integration of smallholder production and large-scale processing (Hyman, 1983; Kato, 1996). Oil palm conventionally has been viewed as an estate crop in Southeast Asia (but not in Africa) because of its perishability. Even in this case, however, small-scale production is profitable in Malaysia (Barlow, 1986) and oil palm production on independent plots as small as one ha began to emerge in Sumatra in the 1980s.

Despite these and other successful examples, processors often seem to prefer vertical integration. Why do they opt for management of large plantations? One factor could be the desire to obtain control of large areas of land, which may appreciate in value. Another could be subsidized credit and other investment incentives extended to large-scale operators, often based on misguided notions of economies of scale in production. But it also must be recognized that dealing directly with large numbers of smallholders may entail substantial transaction costs[2] if harvesting and processing must be coordinated closely. At the same time, potential for local monopsony power arising in these marketing arrangements raises legitimate concerns from the perspective of the smallholder producers. The efficiency and equity of outgrower schemes, contract farming, and other institutional arrangements that can minimize these transaction costs deserve priority for future research.

Imperata policy

The first section highlighted tenure insecurity as a key factor depressing expected financial returns of conversion of *Imperata* grasslands to other uses – especially uses requiring investments over a number of years. The ideal response, at least in theory, is to establish complete, secure property rights. That will not be a practical option under many circumstances because of the political sensitivity regarding boundaries of State Land and limitations on administrative capacity to issue formal certificates. In light of these constraints, the following policy recommendation may be the single most effective step governments could (or would) adopt in order to promote the financial profitability of conversion by smallholders.

> *Policy recommendation:* For large blocks of State Forest Land covered by *Imperata* grassland, farmers who convert that grassland by planting and managing trees in small plots should receive property rights over all their products, including the timber. This policy should apply only to *existing* grasslands; it should not be applied to forests cleared in the future in order to avoid creating perverse incentives that could accelerate conversion of forest to grasslands.

This partial step would grant smallholders tenure over trees and other products, but not the land itself. While short of an ideal solution, establishing secure use rights for smallholders instead of full land ownership has some pragmatic advantages as a first step. This approach is one way to postpone (or avoid) the extremely difficult political issue of clarifying boundaries of State Lands. Administrative complications and time required for land title certification for numerous small plots would delay action if it were a precondition for legitimating smallholders' use of these grasslands. Particularly if land ownership is not expected, the work required to establish trees will help to screen out opportunists and to restrict benefits to local people. If tree planting is financially profitable, local people will do it once they are convinced they will reap the rewards of their work. If it is not financially profitable, the land will stay as it is.

From financial profitability to social profitability

Aside from addressing tenure insecurity, does it make sense to undertake any other policy initiatives to promote conversion of grasslands to other uses? As emphasized from the outset, that depends on whether net benefits to society at large (social profits) are significant for activities that are not profitable in financial terms. In other words, do markets and policies create the right incentives? Although in practice it is hard to obtain the data necessary to answer this question, conceptually it is straightforward to adapt Equation (3) to incorporate broader social objectives, including environmental issues:

$$E\,(\mathrm{NPV}_{\mathrm{social}}) = \sum_{t=0}^{T} \frac{s_t(B_t - C_t + E_t + G_t)}{(1+i)^t}. \qquad (4)$$

As before, t denotes time, T is the life of the activity (both t and T are in years), and s_t is the probability the activity survives to year t. The following definitions distinguish the expected *social* NPV from the *financial* NPV measures introduced in the last section:

B_t = economic value of outputs plus capital gains on land and other assets;
C_t = economic value of inputs, wages and salaries, rent, investment costs;
$B_t - C_t$ = cash flows valued at economic prices;
E_t = economic value of externalities;
G_t = economic value of public goods;
$E_t + G_t$ = economic value of market failures (in this case, value of environmental services);
i = economic cost of capital.

Most divergences between social and financial NPV can be subsumed under two broad categories: *policy distortions* and *market failures*. The social NPV is adjusted to eliminate policy distortions by dropping direct taxes and transfers and revaluing cash flows at economic prices; usually with reference to world market prices for tradable commodities. Market failures, which include *externalities* and *public goods*, are cases where no market price exists; they must be estimated using non-market valuation techniques and are added to the social NPV calculation.[3] Effects of externalities and public goods may be felt locally, regionally, or globally. Because little work has been done on these topics regarding *Imperata* grasslands, the balance of this section aims to identify 'best bet' topics for empirical, policy-oriented research.

A third category, *market imperfections*, includes the combined effects of uncertainty and irreversibility[4]; regional growth linkages and spillovers; and economies of scale in processing that were mentioned in the first section. Among these are factor market imperfections such as insecure tenure, which was highlighted in the first section. Interlinked factor market imperfections can create significant differences between the financial and economic costs of capital, which can have a strong differentiating effect between social and financial profitability of multi-year investments. But alleviation of capital market imperfections should be viewed as a broader development objective rather than a precondition for a smallholder-based strategy for grassland conversion. Fungibility of funds means targeted credit programmes (say for rehabilitation of *Imperata* grasslands through agroforestry) rarely achieve their objectives. It is especially difficult to administer credit programmes for tree planting (Tomich, 1991). New thinking on rural finance emphasizes building banking services that respond to rural people's needs rather than credit for a specific commodity or activity.

Policy distortions

Mismanagement of macroeconomic policy instruments (the exchange rate, fiscal and monetary policy) is the most powerful potential source of divergence between financial and economic valuations of cash flows. For example, overvaluation of the exchange rate decreases prices of exportable outputs. For particular countries, macroeconomic policy mismanagement may create important disincentives to grassland conversion. While analysis of these macroeconomic policies may help to explain land use, it would be naive to think that these calculations have any implications for macroeconomic policy itself since, for example, no country would devalue its currency to dispatch *Imperata*.

Analyses of *Imperata* economics have more policy relevance concerning sectoral price and trade policies. Pricing policy for herbicides is an example on the input side. Even in this case, use on *Imperata* is likely to be only a fraction of total demand. So the economic benefits of introducing an herbicide subsidy to promote *Imperata* grassland conversion would have to be weighed against the economic distortions arising from leakages to other activities (not to mention the environmental effects).

There is a fundamental distinction between the economic implications of price and trade policies tailor-made to *create incentives* for land use change compared to policy reform to *remove distortions*, including disincentives to grassland conversion. Narrow benefits of tailor-made incentive schemes involving price or trade policies usually will be swamped by inefficiencies induced in other economic activities. In contrast, reversing certain policies that spawn general economic distortions may also enhance profitability of grassland conversion.

Indonesia provides abundant examples of trade policy distortions that are bad for the economy and bad for the economics of grassland conversion. Tomich and Mawardi (1995) analyzed Indonesian trade restrictions that significantly reduced profitability of investments in oil palm; some of these policies still are in place. Natural rubber trade is relatively free (Tomich, 1991), but local levies, complex administrative requirements, confusion from frequent changes in regulations, and export taxes result in an effective ban on purchases of smallholder rubber wood (Suyanto and Tomich, 1996). The taxes on rubber wood are but one case among scores of prohibitive export taxes on sawn timber and on raw and semi-finished rattan. According to the World Bank (1996, p. 109), the rattan export taxes are wiping out producers and processors by depressing local prices. More generally, incentives for any timber-based investments to convert *Imperata* grasslands are undermined by restrictions on timber exports and by supplies of timber from natural forests that are artificially cheap as a result of public sector pricing policies intended to favor domestic processing. Indonesia is not unique regarding such policy distortions affecting trees in general and timber trade in particular; any assessment of prospects for *Imperata* grassland conversion in a particular country must consider such policies.

Regional environmental externalities

The environmental impacts of these externalities span scales ranging from the local community up to cross-border effects on neighboring countries.

Candidates for research on regional externalities that could be influenced by large-scale conversion of *Imperata* grasslands include:

- the effect of the risk of fire on investment decisions (already covered above);
- agricultural losses from pests harbored in grasslands;
- siltation;
- effects on local climate and hydrology;
- disruption of civil aviation and public health problems from smoke.

Agricultural pests. We know of no systematic studies comparing *Imperata* with forests and other tree-based systems as sources of vertebrate pests, much less the range of taxa that contribute to losses in agriculture. Although *Imperata* grasslands provide habitat for few mammal species compared to forest (Table 3), the four reported by Whitten et al. (1987, p. 484) all are rats, which are among the most serious foodcrop pests. Thus, these grasslands could be a serious source of pest problems for surrounding cropland. On the other hand, Dove (1986, pp. 174–175) claims that wild pigs, which are a top pest for some treecrop systems, prefer forest to grasslands, at least on Java. Sumatran farmers report rats as the major pests in areas adjacent to 'degraded land' and pigs and monkeys as major pests at the forest margins (van Noordwijk et al., 1995, p. 61). Ongoing research by R. Gauthier (forthcoming) in Lampung, Sumatra, indicates an inverse relationship between distance to the forest margins and depredation by wild pigs and monkeys.

Since grasslands and tree-based systems both provide habitat for certain agricultural pests, conversion of *Imperata* grasslands to tree-based systems may simply substitute one pest problem for another. This could have important implications for land use choices (foodcrops versus tree-based systems, for example). However, the net result of conversion from *Imperata* grasslands to tree-based systems may be small because of the offsetting effects.

Erosion and siltation. One study (cited in Doolette and Smyle, 1990, p. 40) found no difference in surface runoff on slopes of 36–70% among *Imperata*

Table 3. Total number of non-flying mammal species and the percentage of introduced species in six types of vegetation, Sumatra.

Vegetation	Mammal species (number)	Introduced species (percent)
Primary forest	30	0
Selectively logged forest	33	6
Secondary forest	11	9
Secondary growth	11	28
Scrub	7	44
Imperata grassland	4	100

Source: Whitten et al. (1987, p. 484, adapted from Figure 11.10).
Note: 'Introduced species' all are rats.

grasslands, forest plantations, and secondary forest. This is because densely-rooted grasses generally stabilize soil and reduce erosion. Data for the Philippines (Table 4) indicate that well-established *Imperata* is nearly identical to forest cover in this regard. (Heavy grazing and burning, however, can lead to erosion problems.) In cases of light grazing, Table 4 suggests that conversion to agroforestry or timber plantations might yield some soil conservation benefits, but the difference is not dramatic and those benefits depend on management practices prevailing before and after conversion. Furthermore, conversion carries substantial risks of soil erosion if land goes through a stage of bare soil, which is often the case with mechanical land clearing.

Local climate and hydrology. Extensive conversion of *Imperata* grasslands to tree-based systems *might* significantly increase precipitation.[5] However, especially in archipelagic nations such as Indonesia and the Philippines, these effects are moderated by marine influences (Tinker et al., 1994, p. 20). Even if land use conversion results in greater precipitation, this does not translate directly into increased water yield or a desirable pattern of water release. Bruijnzeel (1990, p. 179) cautions that, except under certain conditions, 'one has to expect a more or less serious reduction in [water] yield upon foresting

Table 4. Crop cover coefficients (*C* values) for Philippine watersheds.

Cover	*C* value	Ratio over that for primary forest
Bare soil	1.0	1,000
Primary forest with dense undergrowth	0.001	1
Second-growth forest with good undergrowth and high mulch cover	0.003	3
Mixed stand of industrial timber plantation species, eight years or more	0.07	70
Mixed stand of agroforestry species, five years or more with good cover	0.08	80
Imperata, well established and undisturbed, with shrub	0.007	7
Imperata, slightly grazed, with patches of shrub	0.15	150
Grassland, moderately grazed, burned occasionally	0.2–0.4	200–400
Overgrazed grasslands, burned regularly	0.4–0.9	400–900
Annual crops	0.2–0.6	200–600

The crop cover coefficient (*C* value) is a factor in the Modified Universal Soil Loss Equation (USLE), $E = R * K * LS * C * P$,

where E = soil loss rate in tons/hectare/year;
R = rainfall erosivity index;
LS = length – slope factor which may be approximated on the basis of percent slope;
C = cover factor value;
K = soil erodibility;
P = product of the conservation or management factors that are being practiced.

Source: World Bank (1989, pp. 131–132) based on W.P. David (unpub.).

degraded lands, particularly during dry seasons' because of greater evapotranspiration by the trees. (A result that may depend on the tree species.) Yet this also is complicated because the increased evapotranspiration produces water vapor that will fall as rain somewhere else (Leakey, 1994). This is another case of potentially large environmental effects of conversion where further empirical research is warranted.

Smoke. Smoke can be a highly-visible nuisance. In the long dry season of 1994, to take a memorable example, large amounts of smoke from fires in Sumatra and Kalimantan disrupted civil aviation and threatened public health within Indonesia and in Singapore and neighboring areas of Malaysia. It may never be possible to determine which of the many sources of this smoke were most important. In particular, neither the contribution of fires on *Imperata* grasslands nor the costs imposed on others by the smoke from burning grasslands has been estimated. However, estimates of the health costs of urban air pollution in Indonesia run to US$500 million per year (World Bank, 1996, pp. 35–36). Health costs of fires in the rural landscape likely would be only a fraction of this total for several reasons. First, suspended particulate matter from fires is only one component of urban air pollution; among these it is not the greatest health hazard. Second, significant fires like those in 1994 do not happen every year; in recent times their frequency has been roughly every five to ten years in Indonesia. Third, the air quality effects of such fires typically last 2–3 months, not a full year. Even if the same number of people were affected to the same degree as urban air pollution – which seems unlikely – the maximum annual average health costs that are likely to be attributed to landscape fires might be on the order of US$10–20 million for Indonesia; and *Imperata* grassland fires contribute only a portion of this.

Global public goods

With our current level of understanding, the list of potential global environmental public goods has only two candidates: *biodiversity conservation* and reduction of emissions of greenhouse gases linked to *global climate* change.

Biodiversity conservation. Table 3 shows that *Imperata* grasslands are impoverished relative to forests regarding mammal species. Since *Imperata* grasslands are essentially a monoculture, they also offer almost nothing by way of diversity of vascular plant species. Kuusipalo et al. (1995) have shown that a significant portion of the indigenous biodiversity of forest vegetation can be restored through natural regeneration in the understory of forest plantations. Rubber agroforests in Indonesia appear to conserve an even greater proportion o. the diversity of natural forests (van Noordwijk et al., 1995b; also see de Foresta and Michon, in this issue).[6]

Conver·ion of grasslands, which already have lost much biodiversity, obviously ‹annot substitute for conservation of natural forests. However, for areas adjoining patches of natural forest, conversion of *Imperata* grasslands to complex, multistrata agroforestry systems (agroforests) would improve prospects for forest species since the larger the habitat, the greater the chances for survival.

Carbon sequestration. The organic carbon stock of a typical mature primary forest in the lowland humid topics of Asia is about 365 tons of carbon per ha (365 t C/ha), comprising some 235 t C/ha aboveground (stems and branches 205, leaves 5, litter 25 t C/ha), and the rest belowground in the roots (60 t C/ha) and soil humus (70 t C/ha). Conversion of an old-growth Dipterocarp forest to *Imperata* grassland drastically reduces the organic carbon stock. Table 5 gives some rough estimates from M. van Noordwijk (pers. comm.) of the orders of magnitude involved. *Imperata* grassland has an aboveground carbon stock of about 15 t C/ha, with about the same amount in the roots. Assuming that soil humus remains the same (it may diminish somewhat with each fire, an annual event in many *Imperata* areas), transformation of Dipterocarp forest into *Imperata* grassland diminishes the total carbon stock from 365 t C/ha to perhaps 90 t C/ha.[7]

In time, conversion of *Imperata* grasslands to tree-based systems increases the organic carbon stock significantly. For example, establishment of a rubber agroforestry system or an *Acacia mangium*-based system will raise levels up to or above 200 t C/ha, more than double the carbon stock of *Imperata* grasslands. Re-establishing Dipterocarps ultimately would restore levels to the original 365 t C/ha, although that would take at least 40 years, perhaps a century. On the other hand, converting *Imperata* grasslands to annual crops typically would decrease carbon stocks because of the loss of the perennial rhizomes.

The marginal cost of carbon emissions is estimated to be at least US$5 per ton, rising to US$20 per ton over the next century (Nordhaus, 1993); some current estimates range well over US$100 per ton.[8] For a value of US$10 per

Table 5. Estimates of peak carbon stocks (t C/ha) of various tropical vegetation types.

Vegetation	Total	Aboveground biomass and litter	Roots and rhizomes	Soil humus
Dipterocarp forest	365	235	60	70
Rubber agroforest	215	120	30	65
A. mangium plantation	200	105	30	65
Imperata grassland	90	15	15	60
Annual foodcrops	63	7	1	55

Source: M. van Noordwijk (pers. comm.). Estimates are based on an aboveground: belowground ratio of 4:1 for forest and tree-based systems and 1.5:1 for *Imperata* grassland.
Note: These figures only illustrate relative magnitudes; they are not precise estimates. Better estimates should be available after completion of work planned in Indonesia by the Alternatives to Slash and Burn (ASB) Research Consortium (Tomich and van Noordwijk, 1996, pp. 34–35).

ton of carbon, conversion of *Imperata* grasslands to *Acacia mangium* would accumulate an environmental benefit of about US$1,100 per ha just prior to harvest. On the other hand, eventual conversion to a mature Dipterocarp forest would sequester carbon from the atmosphere worth US$2,750 per ha, albeit over a much longer period. (Under either alternative, elimination of annual *Imperata* fires also would help reduce greenhouse gas emissions.)

When interpreting Table 5, it is important to recall that these figures are for peak carbon stocks of the various systems. As already noted, carbon is accumulated over a period ranging from 8–40 years or more for the tree-based systems in the table. In each case, the average stock sequestered at steady state depends on the replanting cycle (M. van Noordwijk, pers. comm.) and the fate of the organic carbon at the time of replanting. The illustrative calculations presented below use a constant rate of carbon accumulation over the life of the system. Refining this to give a more realistic pattern of carbon accumulation would have a relatively small effect on the quality of the estimates, especially in light of our limited knowledge of carbon stocks.

Imputed value of carbon sequestration for conversion to Acacia mangium. Apart from the output price (which is determined by world markets, national policies, and local transport costs), profitability of timber-based systems depends largely on timber yield. Even considerable savings in investment costs cannot offset losses from low yield. Thus, any investor – whether a large-scale plantation company or a smallholder – must be concerned with determinants of yields: species and provenance selection, quality of planting material, spacing, and weed and fire control during establishment are of crucial importance. Fast early growth and early canopy closure are essential for suppression of *Imperata* and fire. The same points hold true even if the criterion is environmental rather than financial, since faster growth and higher timber yield also lead to more rapid carbon sequestration.

Some indicative results for financial profitability of an *Acacia mangium*-based system in South Kalimantan, Indonesia, are presented in Table 6. (The details of the assumptions underlying this analysis are in Kuusipalo and Hadi [unpub.] and Menz and Grist [1995b].) Note that, in financial terms alone, the system is profitable at a real discount rate of 15% but not as high as 20%; this is comparable to the range of commercial interest rates prevailing in Indonesia net of inflation. These rough estimates suggest that conversion of grasslands to *Acacia mangium* is a marginal investment; financially profitable in some settings but not in others. This is consistent with Hypothesis 1 if the real opportunity cost of capital falls somewhere between 15–20%: $NPV_{financial}$ is near zero on the margin and is negative for isolated locations.

Since *Acacia mangium* is primarily a pulpwood species, a substantial portion of the carbon sequestered while the tree is growing will eventually be offset by release of carbon from disposal of paper products. For example, 80% of the value of carbon sequestered by the growing trees is offset by these emissions at a zero discount rate, assuming the half life of paper is 2.5 years

Table 6. Illustrative calculations of financial profitability and imputed value of net C sequestration for various values of sequestered carbon, for one eight-year planting cycle of *Acacia mangium* in South Kalimantan, Indonesia, 1995.

Discount rate	NPV (US$/ha) 0%	NPV (US$/ha) 10%	NPV (US$/ha) 15%	NPV (US$/ha) 20%
Financial profitability	1189	337	97	–73
Imputed value of C sequestration, with C valued at:				
US$5/t C	272	199	175	156
US$10/t C	544	399	351	313
US$20/t C	1087	798	701	626
Imputed value of C release after harvest, with C valued at:				
US$5/t C	–218	–85	–56	–38
US$10/t C	–435	–171	–112	–75
US$20/t C	–870	–341	–224	–150
Finanacial profitability plus imputed value of net C sequestration, with C valued at:				
US$5/t C	1243	451	216	46
US$10/t C	1298	565	336	165
US$20/t C	1406	793	574	403

Source: Authors' calculations.
Notes: Neither the opportunity cost of conversion from *Imperata* grassland nor fire risk are included in these calculations. Secure tenure is assumed. It is assumed *Acacia mangium* is harvested after eight years. Since wood is used for pulp for paper manufacture, it is assumed that carbon release begins the year after harvesting and that the carbon in paper has a half life of 2.5 years.

(Table 6). This effect diminishes as the discount rate increases so that the offset is only 32% for a discount rate of 15%, at least under the assumptions used in this model.

At a real discount rate of 15%, the imputed values for carbon are 23% larger than financial profits if carbon sequestration is worth US$5 per ton; this jumps to an almost four-fold difference for carbon valued at US$20 per ton. For discount rates of 15% and below, the imputed values for carbon simply reinforce financial profitability in the estimates presented in Table 6. At a discount rate of 20%, the imputed carbon values are large enough to counterbalance negative financial profitability. If the real opportunity cost of capital is as high as 20%, this example is consistent with both Hypothesis 1 and Hypothesis 2. In other words, at that interest rate, socially profitable activities would not be undertaken because they are not financially profitable (Case 4 in Table 1) in the absence of payments for carbon sequestration.

Imputed value of carbon sequestration for conversion to rubber agroforestry. Estimates comparing financial profitability and the imputed value of carbon sequestration for an Indonesian rubber agroforestry system are presented in Table 7. (For details of the assumptions underlying the financial calculations, see Grist and Menz [1995].) These calculations are based on planting 'unselected' seedlings. Under certain circumstances, yields of latex and marketable rubber wood could be higher with clonal planting material, but this would only reinforce the conclusions here. In purely financial terms – and ignoring risks from fire and tenure insecurity – conversion of grasslands to rubber agroforestry is profitable up to a real discount rate of almost 15%. As with the preceding example for *Acacia mangium*, this result is consistent with Hypothesis 1 since the real opportunity cost of capital probably falls somewhere between 15–20% in Indonesia.

In addition to carbon sequestered in standing biomass (Table 5), the latex harvested from rubber trees is essentially carbon (and water). Most of the natural rubber produced by smallholders in Indonesia is exported and ulti-

Table 7. Illustrative calculations of financial profitability and imputed value of net C sequestration for various values of sequestered carbon, smallholder rubber agroforestry in Indonesia, 1995.

Discount rate	NPV (US$/ha) 0%	NPV (US$/ha) 10%	NPV (US$/ha) 15%	NPV (US$/ha) 20%
Financial profitability	5741	581	–9	–274
Imputed value of C sequestration with C valued at:				
US$5/t C				
tree biomass	138	45	33	26
latex yield	40	13	10	8
total	178	58	43	34
US$10/t C				
tree biomass	276	90	65	52
latex yield	80	26	19	15
total	356	116	84	67
US$20/t C				
tree biomass	552	181	131	103
latex yield	160	53	38	30
total	712	234	169	133
Financial profitability plus imputed value of net C sequestration, with C valued at:				
US$5/t C	5919	639	34	–240
US$10/t C	6097	697	75	–207
US$20/t C	6453	815	160	–141

Source: Authors' calculations.
Notes: Neither the opportunity cost of conversion from *Imperata* grassland nor fire risk are included in these calculations. Secure tenure is assumed. It is assumed rubber is replanted after 32 years. Since latex is used in tire manufacture and rubber wood is used in furniture, molding, and flooring, it is assumed that carbon is sequestered indefinitely for the purposes of these calculations.

mately is used in tire manufacture. Unless old tires are burned, that carbon is unlikely to enter the atmosphere for some time.

In the case of rubber agroforestry in Indonesia, virtually all of the biomass is burned when trees are replanted (after say 20–35 years). The estimates in Table 5 for the imputed value of carbon sequestered in standing biomass consider only marketable rubber wood (30–40 t C/ha), which is used in furniture, moldings, and floor panels. (As mentioned above, whether or not this wood actually is marketed depends on reform of policies that effectively ban trade in rubber wood produced by smallholders in Indonesia.) If the entire biomass were considered net of carbon released by burning prior to replanting, the estimates for value of carbon sequestered would increase for any real discount rate above zero.

Compensation for the imputed values for carbon would raise the estimated NPV above zero for a discount rate of 15% in Table 7 with carbon sequestration valued at only US$5 per ton. Despite that, however, imputed values for carbon are not large enough to offset the negative NPV for a 20% discount rate, even with carbon valued at US$20 per ton. Thus, for the assumptions underlying this model, Hypothesis 2 receives some limited support at the margin.

To conclude this section it is worth emphasizing that the estimates of profitability and imputed values for carbon sequestration for *Acacia mangium* (Table 6) and rubber agroforestry (Table 7) are not directly comparable because the rotational cycle for the former is about eight years why the latter is productive at least three times that long. To establish a basis for comparison with rubber agroforestry, estimates for four cycles of *Acacia mangium* spanning 32 years were calculated (Table 8). Given the sensitivity of such estimates to underlying assumptions and the tremendous cross-site variation in production and marketing conditions, it is impossible to say that one or the other system is superior.

Table 8. Illustrative calculations of financial profitability and imputed value of net C sequestration for various values of sequestered carbon, for four eight-year planting cycles of *Acacia mangium* in South Kalimantan, Indonesia.

Discount rate	NPV (US$/ha) 0%	NPV (US$/ha) 10%	NPV (US$/ha) 15%	NPV (US$/ha) 20%
Financial profitability	4755	601	142	–95
Financial profitability plus imputed value of net C sequestration, with C valued at:				
US$5/t C	4902	800	315	59
US$10/t C	5049	998	489	213
US$20/t C	5342	1394	836	520

Source and notes: Same as Table 6.

Conclusions: an agenda for policy research

Success of any effort to establish trees on *Imperata* grasslands depends on at least three necessary elements that have a big effect on expected profitability: access to markets, fire control, and secure tenure. Government can support local farmers' initiatives through policies and programs that reduce risks and the costs of conversion and that increase the returns to smallholders' investments in trees. A policy to establish secure property rights over all products – including the timber – for smallholders who convert plots of grassland by planting and managing trees is an important first step in addressing the problem of tenure security and in creating incentives for community-based fire control. If such policies are to be adopted, more research is needed to identify workable means for implementation.

Financial and economic appraisals are necessary to test the three hypotheses put forward in this article:

1. Under current technologies, prices, and policies, conversion to other land uses is not financially profitable for large areas of existing grasslands.
2. It is nevertheless socially profitable to convert large areas where investments to establish other land uses are not financially profitable.
3. There is no trade-off between economic growth and poverty alleviation in pursuing smallholder-based strategies.

Much work remains to be done because nothing can substitute for appraisal of smallholder and large-scale alternatives in specific settings. There is little hard evidence regarding any of these hypotheses.

The two sets of illustrative calculations presented for Indonesia suggest that rubber agroforestry and growing *Acacia mangium* for pulp are marginally profitable under current technologies and prices prevailing in Indonesia, thereby providing some (albeit far from definitive) support for Hypothesis 1. But it is important to emphasize that those calculations are based on the unrealistic assumptions of tenure security and effective fire control. Quantification of the impact on expected profitability of these investments arising from the significant risks from tenure insecurity and from fire can only strengthen the case for Hypothesis 1. Indeed, favorable results of these (admittedly preliminary) economic analyses suggests that tenure insecurity and fire (and possibly other risks) are important barriers to what otherwise could be profitable investments in some areas.

The two examples only include the effect on profitability of compensation for the imputed value of carbon sequestration and ignore the environmental externalities reviewed in this paper. Thus, these calculations are insufficient to test Hypothesis 2. In order to assess the merits of direct policy intervention, much more work would have to be done to estimate the value of other environmental externalities and public goods; we simply do not know much about these values at this time. For Hypothesis 3, the agricultural development literature and the human ecology of *Imperata* grasslands both suggest that smallholder-based strategies can be at least as profitable as large-scale plantation forestry if the three necessary elements (markets, fire control, and secure tenure) are present.

Conversion of *Imperata* grasslands to agroforestry offers few (if any) additional soil conservation benefits and may even risk increasing erosion. Additional empirical research would be needed to value other regional externalities associated with *Imperata* grasslands and alternative land uses, especially regarding agricultural pests, local climate and hydrology, and the financial and public health effects of smoke. Data on these regional externalities are not sufficient at this time to make a case for direct policy intervention to promote *Imperata* grassland conversion. For agricultural pests, the net result of conversion from *Imperata* grasslands to tree-based systems may be small because of offsetting effects (fewer rats but more damage from wild pigs and monkeys). The effects of grassland conversion on local climate and hydrology and on smoke could be substantial, but no one has attempted to put a value on these externalities.

Under some circumstances, conversion to certain tree-based systems may complement natural forests' role in biodiversity conservation. Prospects are dim, however, that a specific value (or even an order of magnitude) could be attributed to this complementary function since it is not yet possible to put a value on species conserved in natural forests. Fairly robust evidence is available, however, on the carbon sequestration value of conversion. Because changes in land use bring big changes in carbon stocks, compensation for carbon sequestration through investment to establish tree-based systems can significantly raise profitability of grassland conversion. This result holds even for a very conservative estimate of the marginal value of sequestered carbon.

Is it socially desirable to compensate carbon sequestration resulting from grassland conversion? Policy implications of the analysis of environmental externalities and public goods arising from multiple land use alternatives always will be complex (Baumol and Oates, 1988, Chapters 7 and 8). But even barring the discovery of an offsetting market failure (bad hydrological effects? pollution from pulp mills or rubber processors?) the case has not yet been made that attaining the social optimum for area of *Imperata* grasslands depends on some direct policy intervention to raise incentives for conversion for either of the examples considered above. Only for the illustrative example of investments to establish *Acacia mangium* discounted at a very high real rate of 20% per annum do we obtain clear cut results consistent with the necessary conditions for intervention (Case 4 in Table 1): an investment that is socially profitable but where free markets alone would fail to provide sufficient financial incentives for investment. Our estimates for rubber agroforestry indicate that it is neither financially nor socially profitable at a 20% discount rate. For real discount rates up to almost 15% for rubber agroforestry and a bit above 15% for *Acacia mangium*, our illustrative calculations reveal no policy problem: wherever investment is socially profitable, it is financially profitable.[9] (These results correspond to Case 3 in Table 1, not Case 4.) To be sure, compensation for carbon sequestration would raise the profitability of these investments significantly. But for circumstances under which our models might apply, this compensation would simply raise profits on investments that would have been undertaken anyway. In other words, these are not 'incremental benefits' in the jargon of the Global Environmental Facility (GEF). The case has yet to be made that *Imperata* grasslands constitute a 'problem' that merits GEF (or anyone else) compensating the imputed value of carbon that could be sequestered in tree-based systems.

Is it even feasible to compensate carbon sequestration resulting from grassland conversion? Prospects also look bleak when we consider financing and implementation of such a policy. Whatever today's socially optimal area is for *Imperata* grasslands, it is not zero. But conversion of only one quarter (14 million ha) of Asia's large-scale *Imperata* grasslands easily could accrue a US$20 billion bill for 'environmental services' over about a decade. At an annual average rate of US$2.0 billion, this far exceeds the entire budget of the GEF; which totals US$2 billion over three years.

Even if billions of dollars were to be spent, there remains the question of how to transfer the money. One can be sure that mailing a check to each nation's capital city will *not* establish appropriate incentives for smallholders. Aside from food subsidies – which have a record of inefficiency in meeting policy objectives – there has been little experience in developing countries with such a large transfer spread over so many households. Greater economic benefits (probably environmental benefits too) would be likely from smaller investments to improve transport infrastructure in *Imperata* areas.

As a general rule, the larger the scale of a market failure, the higher the transaction costs of dealing with it. In this regard, conversion of *Imperata* grasslands to tree-based systems may have advantages over other measures to address the failure of markets to create an adequate supply of global public goods. Mass communications make it easy to get a message out about an incentive for establishing trees; the trick is identifying and monitoring changes on the ground. But the change from grassland to trees – perhaps also the growth of those trees – can be monitored by satellite, even for relatively small plots of a few ha. This stark transformation should make is feasible to locate and monitor progress on grassland conversion. If such information could be linked with a workable transfer mechanism for financial incentives, it might be feasible to 'internalize a global externality' associated with *Imperata* grassland conversion for large numbers of smallholders.

But, as we have emphasized, the case for attempting such a transfer remains to be made. Until then, governments should focus their efforts on establishing clear, secure tenure over products of alternative land use systems and on removal of policy distortions. Financial profitability of grassland conversion can be overturned by a number of policy distortions, including macroeconomic, trade, and pricing policies that depress output prices. These distortions arise from national and local policy decisions and, hence, should be analyzed on a country-by-country basis as a component of appraisal of alternatives. It is important to distinguish reform to *remove distortions*, including disincentives to grassland conversion, from price and trade policies tailor-made to *create positive distortions* (incentives) for *Imperata* conversion. Whether the subsidy is for herbicide, fertilizer, fencing wire, diesel fuel – or whatever – benefits of such tailor-made price and trade policies usually will be swamped by economic inefficiencies induced in other activities. Thus, such tailor-made conversion incentives are to be shunned. Eliminating current policy failures and distortions that retard grassland conversion are prerequisites to any policy intervention to promote it.

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Notes

1. Recently completed work by Hugh Bagnall-Oakley and co-workers in South Sumatra should provide a basis to begin to quantify some of these issues.
2. Transaction costs are costs of exchanging a good or service in the market that are not reflected in the market price. These include costs of negotiating, monitoring and enforcing contracts, organizing groups, building institutions, and other non-market interactions among people that, nevertheless, have economic significance. Transaction costs may be financial, but often are uncompensated use of people's time and effort.
3. The term 'externality' refers to the effect of activities by one economic agent on another that is not reflected in market prices. Externalities may have positive and/or negative effects. The two defining characteristics of 'public goods' are (1) their use by one person does not prevent full benefits being enjoyed by others and (2) it often is difficult to exclude users, hence it may be excessively costly to charge them.
4. Choices whose consequences are very costly (if not impossible) to reverse.
5. Although not directly concerned with conversion of *Imperata* grasslands, research by Giambelluca and Ziegler (1996) has important implications for the question at hand. Precipitation has been shown to vary inversely with shifts in the ratio of short-wave reflectance to incident short-wave radiation, the albedo ratio. Among land uses in the tropics, forests have the lowest albedo ratio and grasslands typically have the highest. Preliminary evidence from work by Giambelluca and Ziegler in Northern Thailand suggests two-year-old tree-based systems (including secondary regrowth, forest plantations and tea gardens) approximate the albedo of natural forests. However, the albedo ratio was even lower for younger regrowth because it had been burned and because darker soil reflects less. Frequent burning is, of course, also a feature of many *Imperata* grasslands.
6. Agroforests contain considerable biodiversity value because the planned biodiversity of planted trees is augmented by natural regeneration. Results summarized in van Noordwijk et al. (1995b) suggest that a rubber agroforest ('jungle rubber') in the lowlands of Sumatra

contains half the bird species, 70% of the higher plants, and about the same biodiversity of soil mesofauna as a comparable plot of primary forest.

7. Although it once was believed that there was a significant reduction in soil carbon for *Imperata* grasslands compared to forests, Ohta et al. (1995) found no consistent difference between forest and *Imperata* grasslands in East Kalimantan regarding soil carbon stocks.
8. Since no effective market yet exists for global carbon sequestration services, any estimates of the 'price' of carbon sequestration must be treated with a considerable degree of skepticism. We used the lower end of the range of available estimates. As will be discussed in the conclusion, even these conservative estimates raise serious questions about how a policy to compensate carbon sequestration services could be funded or implemented.
9. For investment in rubber agroforestry discounted at 15%, the NPV of US$-9 in Table 7 is not substantially different from zero.

References

Anderson JR, Dillon JL and Hardaker B (1977) Agricultural Decision Analysis. Iowa State University, Ames, IA, USA

Arnold JEM (1992) Production of forest products in agricultural and common land systems: economic and policy issues. In: Sharma NP (ed) Managing the World's Forests: Looking for Balance Between Conservation and Development, pp 433–453. Kendall/Hunt Publishing Company, Dubuque, IA, USA

Barlow C (1986) Oil palm as a smallholder crop. Occasional Paper No. 21, Palm Oil Research Institute of Malaysia (PORIM), Kuala Lumpur, Malaysia

Baumol WJ and Oates WE (1988) The Theory of Environmental Policy. Cambridge University Press, Cambridge, UK

Bell C, Hazell P and Slade R (1982) Project Evaluation in Regional Perspective: A Study of an Irrigation Project in Northwestern Malaysia. Johns Hopkins University Press, Baltimore, MD, USA

Brookfield H, Potter L, and Byron Y (1995) In Place of the Forest: Environmental and Socio-economic Transformation in Borneo and the Eastern Malay Peninsula. United Nations University Press, Tokyo, Japan

Bruijnzeel LA (1990) Hydrology of Moist Tropical Forests and Effects of Conversion: A State of Knowledge Review. Faculty of Earth Sciences, Free University, Amsterdam, the Netherlands

Burbridge P, Dixon JA and Soewardi B (1981) Forestry and agriculture: options for resource allocation in choosing lands for transmigration development. Applied Geography 1: 237–258

de Foresta H and Michon G (1997) The agroforest alternative to *Imperata* grasslands: when smallholder agriculture and forestry reach sustainability. Agroforestry Systems 36: 105–120 (this issue)

de Jong, W (1994) Spontaneous intensification of swidden agriculture. APANews 9: 10–11. Asia Pacific Agroforestry Network, Bogor, Indonesia

Doolette JB and Smyle JW (1990) Soil and water conservation technologies: review of literature. In: Doolette JB and Magrath WB (eds) Watershed Development in Asia: Strategies and Technologies, pp 35–69. World Bank Technical Paper No. 127. International Bank for Reconstruction and Development, Washington, DC, USA

Dove M (1986) The practical reason of weeds in Indonesia: peasant versus state views of *Imperata* and *Chromolaena*. Human Ecology 14(2): 163–190

Feder G, Onchan T, Chalamwong Y and Hongladarom C (1988) Land Policies and Farm Productivity in Thailand. Johns Hopkins University Press, Baltimore, MD, USA

Garrity DP and Augustin PC (1995) Historical land use evolution in a tropical acid upland agroecosystem. Agriculture, Ecosystems and Environment 53: 83–95

Garrity DP, Soekardi M, van Noordwijk M, De La Cruz R, Pathak PS, Gunasena HPM, Van

So N, Huijun G and Majid NM (1997) The *Imperata* grasslands of tropical Asia: area, distribution, and typology. Agroforestry Systems 36: 3–29 (this issue)

Gauthier R (forthcoming) Vertebrate pests, crops and soil: the case for an agroforestry approach on recently deforested land in North Lampung. Paper presented at the National Seminar on Biological Management of Soil Fertility, Brawijaya University, Malang, Indonesia. Forthcoming in Agrivita

Giambelluca TW and Ziegler AD (1996) Climatological and hydrological implications of land cover change in highland Southeast Asia. In: Rerkarsen B (ed) Proceedings of the International Conference on Montane Mainland Southeast Asia in Transition. Chiang Mai University, Chiang Mai, Thailand

Gillis M, Perkins DH, Roemer M and Snodgrass DR (1996) Economics of Development. Norton, New York, NY, USA

Gittinger JP (1982) Economic analysis of agricultural projects. Economic Development Institute, International Bank for Reconstruction and Development, Washington, DC, USA

Grist P and Menz K (1995) Modeling the economics of *Imperata* control in smallholder rubber plantations. *Imperata* Project Paper No. 1995/5. Center for Resource and Environmental Studies, Australian National University, Canberra, Australia

Hayami Y (1993) Peasant and plantation in Asia. In: Hayami Y and Kawagoe T (eds) The Agrarian Origins of Commerce and Industry, pp 121–134. St. Martins Press, New York, NY, USA

Hyman EL (1983) Pulpwood treefarming in the Philippines from the viewpoint of the smallholder: an ex post evaluation of the PICOP project. Agricultural Administration 14(1): 23–49

Kato T (1996) Towards sustainable treefarming by small farmers: key factors derived from the experience of PICOP. Paper presented at the International Conference on Community Forestry as a Strategy for Sustainable Forest Management. Department of Environment and Natural Resources, Manila, the Philippines

Kuusipalo J, Adjers G, Jafarsidik Y, Otsamo A, Tuomela K and Vuokko R (1995) Restoration of natural vegetation in degraded *Imperata cylindrica* grassland: understory development in forest plantations. Journal of Vegetation Science 6: 205–210

Leakey RRB (1994) Supporting capacity building in forestry research in Africa, pp 59–67. AAS/IFS Symposium, 28 June – 1 July, ICRAF, Nairobi, Kenya

Leakey RRB and Izac A-M (1996) Linkages between domestication and commercialization of non-timber forest products: implications for agroforestry. In: Leakey RRB, Temu AB and Melnyk M (eds) Domestication and Commercialization of Non-Timber Forest Products for Agroforestry, Non-Wood Forest Products No. 9. FAO, Rome, Italy

Leakey RRB, and Newton AC (1994) Domestication of Tropical Trees for Timber and Non-Timber Products. MAB Digest 17, 94 pp

Menz K and Grist P (1995a) Shading *Imperata* with rubber. *Imperata* Project Paper No. 1995/4. Center for Resource and Environmental Studies, Australian National University, Canberra, Australia

Menz K and Grist P (1995b) Assessing opportunities for smallholders to combine pulpwood trees and food crops. *Imperata* Project Paper No. 1995/1. Center for Resource and Environmental Studies, Australian National University, Canberra, Australia

Menz K, and Wibawa G (1995) Economic aspects of *Imperata* control on rubber smallholdings in Indonesia. *Imperata* Project Paper No. 1995/4. Center for Resource and Environmental Studies, Australian National University, Canberra, Australia

Nair PKR (1992) Agroforestry systems design: an ecozone approach. In: Sharma NP (ed) Managing the Worlds Forests: Looking for Balance between Conservation and Development, pp 403–432. Kendall/Hunt, Dubuque, IA, USA.

Nordhaus W (1993) Optimal greenhouse-gas reductions and tax policy in the 'DICE' model. American Economic Review 82(2): 313–317

Ohta SK, Morisad K, Tanaka N, Kiyono Y and Syarif E (1995) Status of total C, N and P in soils under degraded ecosystems: comparison of *Imperata* grasslands, degraded secondary forests and primary forests in East Kalimantan, Indonesia. In: Simorangkir D (ed) Proceedings of the International Congress on Soils of Tropical Forest Ecosystems, Vol 8, pp 295–301. Mulawarman University Press, Samarinda, Indonesia

Page JM, Pearson SR and Leland HE (1976) Capturing economic rent from Ghanaian timber. Food Research Institute Studies 15(1): 25–51

Potter LM (1997) The dynamics of *Imperata*: historical overview and current farmer perspectives, with special reference to South Kalimantan, Indonesia. Agroforestry Systems 36: 31–51 (this issue)

Suyanto and Tomich TP (1996) Trade policy, poverty, and the environment: the case of rubber wood. In: Tomich TP and van Noordwijk M (eds) A Journey of Discovery, pp 19–20. ASB-Indonesia Report No. 5, ICRAF SE Asia Regional Research Programme, Bogor, Indonesia

Tinker PB, Ingram JSI and Struwe S (1994) Effects of slash-and-burn agriculture and deforestation on climate change. In: Sanchez P and van Houten H (eds) Alternatives to Slash and Burn Agriculture. Symposium ID-6, 15th International Soil Science Congress, Acapulco, Mexico, 1994. International Centre for Research in Agroforestry and International Society for Soil Science, Nairobi, Kenya

Tomich TP (1991) Smallholder rubber development in Indonesia. In: Perkins D and Roemer M (eds) Reforming Economic Systems in Developing Countries, pp 249–270. Harvard Studies in International Development, Harvard University Press, Cambridge, MA, USA

Tomich TP and Mawardi S (1995) Evolution of palm oil trade policy in Indonesia, 1978–1991. Elaeis 7(1): 87–102

Tomich TP, Kilby P and Johnston BF (1995) Transforming Agrarian Economies: Opportunities Seized, Opportunities Missed. Cornell University Press, Ithaca, NY, USA

Tomich TP and van Noordwijk M (eds) (1996) A Journey of Discovery. ASB-Indonesia Report No. 5, ICRAF SE Asia Regional Research Programme, Bogor, Indonesia

Turvey ND (1994) Afforestation and rehabilitation of *Imperata* grasslands in Southeast Asia: identification of priorities for research, education, training, and extension. ACIAR Technical Report No. 28. Australian Center for International Agricultural Research, Canberra, Australia

van Noordwijk M, Tomich TP, Winahyu R, Murdiyarso D, Suyanto, Partoharjono S and Fagi AM (eds) (1995a) Alternatives to Slash-and-Burn in Indonesia: Summary Report of Phase I. ASB-Indonesia Report No. 4, ICRAF SE Asia Regional Research Programme, Bogor, Indonesia

van Noordwijk M, van Schaik CP, de Foresta H and Tomich TP (1995b) Segregate or integrate nature and agriculture for biodiversity conservation? Paper presented at the Global Biodiversity Forum, Jakarta, Indonesia, 4–5 November 1995. ICRAF SE Asia Regional Research Programme, Bogor, Indonesia

Whitten AJ, Damanik SJ, Anwar J and Hisyam N (1987) The Ecology of Sumatra. Gadjah Mada University Press, Yogyakarta, Indonesia

Wibowo A, Suharti M, Sagala APS, Hibani H and van Noordwijk M (1997) Fire management on *Imperata* grasslands as part of agroforestry development in Indonesia. Agroforestry Systems 36: 203–217 (this issue)

World Bank (1989) Philippines: Environment and Natural Resource Management Study. International Bank for Reconstruction and Development, Washington, DC, USA

World Bank (1990) Indonesia: Sustainable Development of Forests, Land, and Water. International Bank for Reconstruction and Development, Washington, DC, USA

World Bank (1996) Indonesia: Dimensions of Growth. International Bank for Reconstruction and Development, Washington, DC, USA