Fire as an Economic Disincentive to Smallholder Rubber Planting in *Imperata* Grassland Areas of Indonesia

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Abstract Farm survey work was carried out in 1995 and 1996 to gain an increased understanding of the nature and importance of fires in *Imperata* for smallholder rubber producers. A fire dimension was incorporated into an existing bioeconomic model of a smallholder rubber agroforestry system, with *Imperata* as the understorey to rubber. The model was then able to trace the physical and economic consequences of fire. *Imperata* and fire are closely linked in the model. The risk of fire was demonstrated to be an economic disincentive to rubber growing in *Imperata* areas. Even a modest fire risk of 10% per year considerably reduced expected profit from rubber growing. In addition to these private costs imposed by the risk of fire, there are 'social' costs resulting from fire spreading across farm boundaries. If one farmer reduces the understorey *Imperata* fuel load (eg. via tree planting), fire risk is reduced *for all neighbouring farmers*. Fire risk can be regarded as an 'economic externality' similar to herbicide drift. This implies that some of the responsibility for fire control appropriately rests with communities, or governments as their representatives, rather than solely with individuals. Government intervention may be justified in promoting fire control techniques. An empirical example of the benefits from community action, through a coordinated approach to rubber planting, is presented, based upon the modelling work.

1. Introduction

Recent research has shown tree growing to be an option for the *Imperata* grassland areas of Southeast Asia (Gunawan et al. 1996; Pasicolan and Tracey 1996). In this context, fire is seen as a major constraint (Turvey 1994, Wibowo et al. 1997). In this paper, the physical impacts, the private and social economic costs of fire, associated with rubber planting, are examined.

The geographical focus of the study is South Sumatra, Indonesia. Semi-structured group interviews were used to get smallholder rubber producers to describe and discuss the fire problem. These were followed by participatory mapping (ie. by the farmers) of the local area, showing where fires had occurred in relation to various topographical features, human settlements and land uses; including the areas of immature rubber destroyed or damaged by fires. Based upon findings from the surveys, a simple conceptual model of fire, in relation to rubber in *Imperata* areas, is presented. This 'fire model' is then incorporated within an existing bioeconomic model of a smallholder rubber agroforestry system involving *Imperata* (Menz and Grist 1996). Rice is initially the understorey to rubber followed, after two years, by *Imperata*.

2. Fire in Smallholder Rubber Plantations in *Imperata* Areas

Imperata grass is a fire climax vegetation type. The subsoil rhizomes of *Imperata* are stimulated by fire to grow rapidly, so fires perpetuate *Imperata*. Gunawan et al. (1997) found that some farmers consider the fire hazard posed by *Imperata* to be as serious a threat to their immature rubber as the direct competitive effect of *Imperata* on rubber growth. This dual impact of *Imperata* on tree growth is shown in Figure 1. The circularity of competition between *Imperata* and rubber is also shown in figure 1 - increased *Imperata* groundcover provides more competition for the tree, which reduces tree growth and shading capacity, with consequences for the level of *Imperata* groundcover.

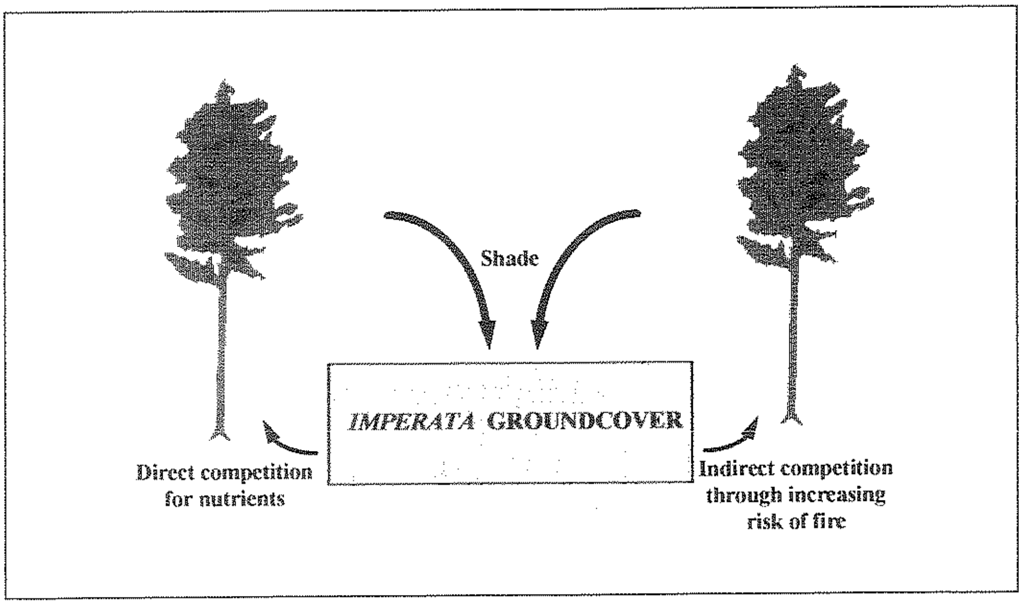

Figure 1. The dual competitive effect of *Imperata* and the circularity of competition between *Imperata* and rubber.

The risk of fire is deemed to be most significant following the conclusion of rice intercropping (usually the first two years after planting). This risk remains, but diminishes until the time of canopy closure as portrayed in Figure 2. Susceptibility in this period of immature rubber relates to the presence of highly flammable *Imperata* growing as the understorey (Pickford et al. 1992).

A more economically meaningful interpretation of Figure 2 was constructed after consultation with staff at the Indonesian Rubber Research Institute (IRRI) at Sembawa, near Palembang, South Sumatra. This interpretation is portrayed in Figure 3, as a '**fire damage function**', showing damage caused by a fire *within a rubber plantation* for various levels of *Imperata* groundcover *within the plantation*. The function is based upon the accumulated experience and perceptions of IRRI staff.

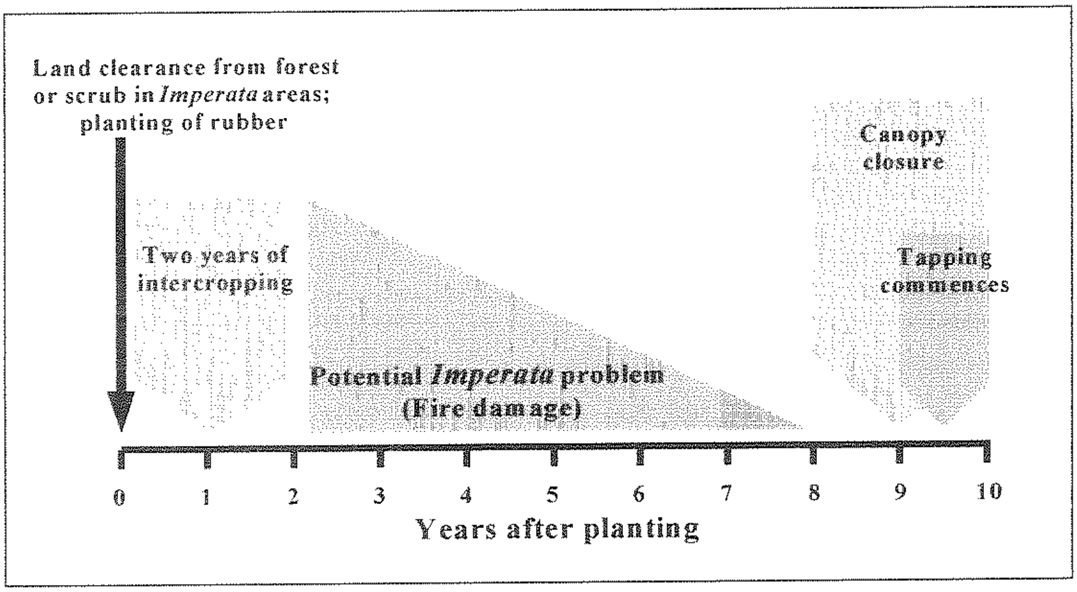

Figure 2. Period between planting seedling rubber and canopy closure, when *Imperata* is likely to be a fire hazard

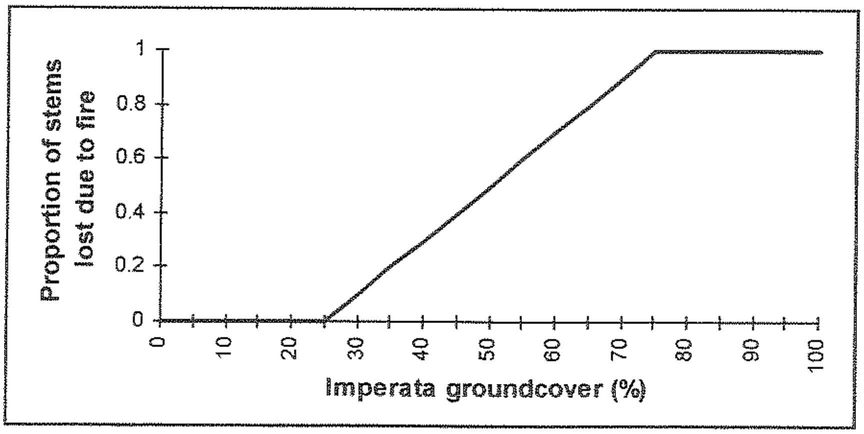

Figure 3. Fire damage function: proportion of rubber stems lost in a dry season fire, in relation to the level of *Imperata* groundcover *within* the plantation.

The nature of the surrounding vegetation will influence the risk of fire entering a plantation. In this paper, the risk of fire entering a plantation ('**fire risk**') is taken to be the product of the probability of fire ignition and proportion of *Imperata* groundcover *in the surrounding areas*.

Probability of fire entering a plantation (fire risk) = (probability of fire ignition) x (proportion *Imperata* groundcover in areas surrounding the plantation)

....................................**Equation 1**

An average annual probability of fire ignition was used for the expository purposes of this paper. The probability of ignition was initially set at 0.1 (10%) per year. So, with an *Imperata* groundcover of 100% surrounding a plantation, fire risk would be 0.1 x 1 = 0.1, or 10% per year. This average-year approach avoids the complexities involved with a stochastic model, and, in South Sumatra, small fires affecting 20 to 250 hectares appear to be more common than large fires (Gunawan et al. 1997). The number of rubber stems lost to fire per year is thus the risk of fire entering a plantation (from Equation 1) times the prevailing *Imperata* groundcover *within* the plantation (from Figure 3).

3. The Rubber Plantation Model and Key Assumptions in the Analysis

The bioeconomic rubber agroforestry model, RRYIELD, is described in Grist et al. (1995). The focus of the model is on smallholders, rather than estates. The RRYIELD model includes a section dealing with the competitive effect of *Imperata* on rubber tree growth (Menz and Grist 1996).

Imperata groundcover is the key variable in both the fire risk and fire damage calculations. In the work to be reported in this paper, 'fire damage' and 'fire risk' parameters were calculated and incorporated within the RRYIELD model, based upon the logic outlined in the previous section. *Imperata* groundcover *within* the plantation is calculated in the model, based upon light intensity passing through the rubber canopy. The *Imperata* groundcover *surrounding* the plantation can either be specified by the user, or it can be simulated by RRYIELD. The latter method is the appropriate one to use where the *surrounding* areas also contain rubber plantations of comparable age. All output from the RRYIELD model is determined on an annual basis.

The physical outputs obtained from the RRYIELD model are translated into economic terms via a companion economic model, RRECON, which calculates net present value (NPV) from the annual cash flows of alternative scenarios. A (real) discount rate of 10 per cent is used. Price and cost data were obtained for the Palembang region in South Sumatra (Grist et al. 1995). The model was initially run three times:

1) with the probability of fire ignition set at 10% per year and the surrounding *Imperata* at 100% **(the 'fire$_{100}$' scenario)**
2) with the probability of fire ignition set at 10% per year and the surrounding *Imperata* at 50% **(the 'fire$_{50}$' scenario)**
3) with the probability of fire ignition set at 0% per year **(the 'no fire' scenario)**

The first two situations represent an individual planting rubber in a plantation surrounded by high and moderately *Imperata* infested areas, respectively.

4. The Economic Costs of Fire in Rubber

The results of the modelling exercise, in terms of net present value (NPV, as determined using a 10% discount rate) and total latex production, are shown in Table 1. The $fire_{100}$ scenario caused a reduction in latex yield over the life of the plantation of 2.6 tonnes/ha which led to a reduction in NPV of Rp 224 000/ha. (One US dollar equals Rp 2 200.) These figures are indicative of the cost of fire for this type of circumstance, or alternatively, of the value of eliminating the risk of fire. NPV is calculated after allowing for payment to labour (ie. NPV is net of labour costs), so a small proportional change in latex revenue can give a large change in NPV.

Table 1. NPV and total latex production per hectare over the 30 year life of a smallholder rubber plantation for the one 'no fire' and two 'fire' scenarios, using unselected rubber seedlings as the planting material.

	Net Present Value (Rp '000)	difference due to fire	**Latex Production** (tonnes)	difference due to fire
No fire	471	-	17.8	-
$Fire_{50}$	401	70	16.9	0.9
$Fire_{100}$	247	224	15.2	2.6

Net present value was determined using a 10% discount rate.

In the $fire_{100}$ situation the number of trees reaching tappable age was reduced by 22 per cent. *Imperata* groundcover was higher than the no fire scenario. This is due to the increased light penetration through the canopy as the density of trees is reduced by fire. The extra *Imperata* groundcover competes with rubber. It also increases fire risk in subsequent years. There is an economic cost associated with both of these effects.

Individual trees in the $fire_{100}$ scenario actually grew at a slightly faster rate in the model than the trees unaffected by fire, due to the reduced tree density as a result of fire. The additional competition from a higher *Imperata* groundcover was approximately equal to the competitive effect of the trees in the no fire scenario. As a result, tapping commencement time was approximately the same in the $fire_{100}$ and no fire scenarios. Since fire did not reduce tree girth increment or tapping commencement time, the net negative effect of fire was to reduce tree numbers. The difference in total latex production was largely due to the greater number of stems in the no fire scenario. Since costs were approximately equal in all scenarios, (except for lower tapping and harvesting costs per hectare following fire), NPV is lower with $fire_{100}$ by Rp 224 000 (48%). Up to Rp 224 000 could be profitably be spent in achieving fire control where a smallholder is planting rubber in an area surrounded by 100% *Imperata*. With surrounding *Imperata* groundcover at 50%, up to Rp 70 000 could be spent (see Table 1).

Results obtained with a higher probability of fire risk

The effects of fire risk levels greater than 10% per annum were assessed. Fire risk is calculated as the product of ignition probability and surrounding *Imperata* density, so for this analysis it was not important which of the latter two factors was manipulated - only the product (fire risk) was altered. The 'break-even' point, where NPV approaches zero, was found to be where fire risk was 13% per annum. For fire risk values above 25% per annum, fire damage in seedling rubber was extensive, canopy closure was not achieved, and tree establishment costs were not recouped. Under these conditions, rubber growing is not economically viable.

5. Fire Control via a Co-ordinated Approach to Tree Planting

Fire spreading across farm boundaries can be regarded as an 'economic externality' similar to herbicide drift, or a weed spreading, from farm to farm (Menz et al. 1984). The value of fire control consists not only of the private benefits from control (Table 1) but also of the 'social' benefits stemming from a reduction in fire risk to neighbouring farmers, through a reduction in *Imperata* groundcover. If one farmer reduces fuel load (eg. via tree planting), then the fire risk is reduced *for all neighbouring farmers*.

This implies that some of the responsibility for fire control appropriately rests with communities, or governments as their representatives, rather than resting solely with individuals. Tree planting can be regarded as a form of fire control, since the risk of fire entering a farm is conditioned by the fuel load characteristics on neighbouring farms (refer Figures 1 and 2). A relatively simple, and low cost, approach to reducing fire risk would be for groups of smallholders with land containing sheet *Imperata* to *simultaneously* undertake rubber planting.

This approach was examined with the aid of the models. The previous results for the $fire_{100}$ and the $fire_{50}$ scenarios (shown in Table 1), showed latex yield and net present value on the assumption that no *Imperata* control was undertaken on surrounding farms. Where a farmer and his/her neighbours undertake simultaneous, or co-ordinated, rubber planting, fire risk is lowered *for all farmers* because the *Imperata* density of surrounding farms is reduced. Such co-ordinated planting has been noted in farm interviews in South Sumatra (Gunawan et al. 1997).

The benefit from a co-ordinated approach to planting was found to be Rp 133 000 (per hectare in NPV terms) for the $fire_{100}$ scenario, and Rp 29 000 for the $fire_{50}$ scenario (this compares with a saving of Rp 224 000 per hectare achieved by the complete elimination of fire in the $fire_{100}$ scenario). There were corresponding increases in latex yield of 1.4 tonnes and 0.4 tonnes per hectare, respectively, over the life of the plantation from coordinated planting. The benefits from co-ordinated planting may be obtained at lower costs than the benefits from more conventional fire-fighting techniques. The only cost is that of the co-ordination itself.

A co-ordinated approach to planting rubber has added advantages in terms of the cost of constructing fire breaks. Firebreaks in South Sumatra are generally made by slashing the vegetation and then turning over the land with a *cangkul* (a mattock-like agricultural implement) and are 3m wide or greater (Gunawan et al. 1997). This, therefore represents a cost in terms of labour usage. However, fire breaks are not fully effective. When farmers plant their immature rubber plots adjacent to each other, the cost of surrounding the plots with a fire break, and maintaining it, would be shared by the farmers involved. Costs per farm would be reduced due to the reduction in perimeter size per unit area planted.

6. Conclusions

The risk of fire was demonstrated to be an economic disincentive to tree growing. Even a modest fire risk of 10% per year was shown to considerably reduce expected profit from rubber growing. A fire risk greater than 13% resulted in economic non-viability of rubber growing under the specified conditions. Total control of fire, in a plantation surrounded by 100% *Imperata*, would return an additional Rp 224 000 in terms of NPV. A simple, low cost, fire risk reduction technique in highly *Imperata*-infested areas, would be for all smallholders to *simultaneously* plant rubber. This policy would provide approximately one half of the economic benefits obtained by complete elimination of fire. Other forms of fire risk reduction such as fire breaks and care with lighting fires in windy conditions are feasible.

In addition to the direct economic impact of fire risk on the profitability of neighbouring farms, there are other external costs associated with fire (land degradation, smoke haze, reduction in carbon sequestration) which have not been examined in this paper. For example, in Indonesia in 1994, smoke haze from fires caused airline flight disruptions in the area, and the pollution which spread to Singapore and Malaysia became a diplomatic issue with these neighbouring countries (Gunawan et al. 1997).

In general fire risk lessens as grassland areas become more developed (Magcale-Macandog and Galinada 1996). The issue of fire risk is most pertinent in the less densely populated, *Imperata* dominated areas. The calculations here were for non-clonal planting material.

The fire damage function used in the empirical models is admittedly somewhat speculative. Yet it is in accordance with observed general relationships between fire and *Imperata* groundcover, and with tree losses over time. The fire ignition probability is genuinely speculative, but at 0.1 per year is thought to be conservative.

Precision in estimation was not the objective. Rather it was to demonstrate a framework for conceptualising fire risk and damage in relation to tree growing in *Imperata* areas, to demonstrate that the social costs of fire may be substantial, in terms of the economic disincentive to neighbouring farms, and to demonstrate the promise of a co-ordinated community approach to fire control. Smoke haze, global warming (through emissions of carbon and reductions in tree planting) and land degradation are other social costs emanating from fire. If account were taken of the impacts of fire control with respect to these issues, total social benefits would be higher than indicated here.

7. Acknowledgments

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