

Impact of rubber tree planting pattern on *Imperata cylindrica* dynamics - Exploring weed control through shading using SExI-FS, a forest stand simulator

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SUMMARY

Imperata cylindrica ((L.) Beauv.) is a problem weed throughout tropical and subtropical regions of the world. It is a major impediment to reforestation efforts in Southeast Asia. When rubber (*Hevea brasiliensis*) is planted in areas invaded with *Imperata*, this aggressive light-demanding weed very much delays the growth of young rubber trees through competition (Mulyoutami *et al.*, this workshop) and may even threaten their survival through its combustibility in the dry season. As *Imperata* extends the unproductive period of the rubber plantation, its control is a major concern for the smallholder.

A Spatially Explicit Forest Stand simulator (SExI-FS) is used to explore alternative planting strategies for shading out the grass in rubber plantation. Strategies examined include various initial planting patterns in pure rubber plantations and interplanting with a faster growing, denser crown tree species such as *Acacia mangium*. The latter is not only more efficient in shading out *Imperata* but also more competitive towards rubber. Hence the model is used to assess under what management scenario (planting pattern, *Acacia* cutting stage) a mixed planting scheme may be beneficial to rubber growth.

The model works on a yearly time step. Competition of tree on *Imperata* is considered to be mediated only through pre-emptive light capture (shading effect). Conversely competition of *Imperata* on tree component is mediated through below-ground competition only. Competitive strength of *Imperata* is assumed to be proportional to its biomass. Inter-tree competition involves both aboveground and belowground components.

Model runs indicate that manipulating planting pattern and/or introducing a competitive tree species in the system (which is easily controllable) is a technically viable alternative. However simulations also indicate that to be successful careful timing and management is required.

INTRODUCTION

Imperata is shade intolerant, although little is known of the relative roles of competition for light, water and nutrients in suppressing its growth (MacDicken *et al.*, 1997). A recent report from Purnomosidhi and Rahayu (2002) states that *Imperata* above ground biomass was decreased by more than 50% after eight months under 88% artificial shading.

Acacia mangium has been planted in Kalimantan to control *Imperata* grasslands. Otsamo (1996) reports that *Imperata* biomass decreased to 12% of its initial value two years after the plantation of *Acacia*. *Acacia* has been selected among other fast growing species for its better ability to compete with the *Imperata* (Otsamo *et al.*, 1996). Recent results from Rubber Agroforestry Systems experiments conducted by ICRAF however, indicate that while *Acacia* and other fast growing species are able to partially shade *Imperata*, their effect on rubber tree growth can be considerable (Mulyoutami *et al.*, this workshop).

In rubber plantation, *Imperata* is the principal weed problem in immature rubber, both in relation to competition and dry season fires, for most smallholder rubber producers in Malaysia (Faiz, 1993) and Indonesia (ICRAF, unpublished). *Imperata* is usually no longer a problem 10 years after rubber planting as it is then suppressed by the shade of the rubber trees (Bagnall-Oakeley *et al.*, 1997). However *Imperata* will delay by several years the beginning of the production period, provided that fire can be avoided during the immature phase.

METHODS

A modelling approach is used to evaluate the impact on rubber growth of various spatial and temporal arrangements of mixed rubber and *Acacia* plantings in *Imperata*-dominated grassland. Tree growth in mixture is simulated using SExI-FS (http://www.worldagroforestry.org/sea/Products/AF_Models/SExI). A specific module to simulate the grass component was developed for the occasion. Competitive effect of *Imperata* is mediated through the belowground competition index and is assumed

to be proportional to the grass aboveground biomass. Aboveground biomass of *Imperata*, in turn, is made from a simple function of light available at ground level.

Tree species parameterization is based on data gathered from the literature (dbh potential growth function) and additional field work survey conducted purposefully (allometric relations). Data concerning

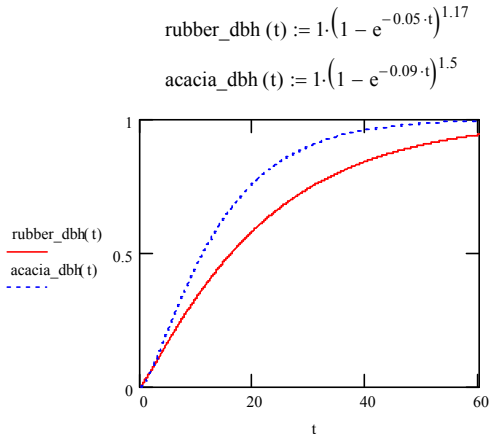


Figure 3 Growth functions of Rubber and *Acacia*, DBH (m) against Time (year).

The rubber growth function is based on ICRAF unpublished data. *Acacia* growth function builds on various published reports including Awang (1993), Lim (1991) and Eldoma (1999).

Allometric relations between tree and stem diameter or crown width and stem diameter were established

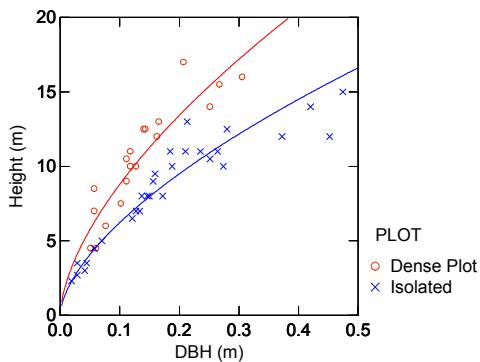


Figure 5 Height function of *Acacia mangium* growing in dense plots (Height=35.84*dbh^{0.61}) and isolated (Height=25.36*dbh^{0.61}), with Flexi = 0.41

Imperata growth

The *Imperata* biomass is based on a function of light availability. Data shown in Figure 5 are from an

Imperata growth in relation to light level come entirely from literature.

MODEL CALIBRATION

Rubber and Acacia characterization

The growth functions of rubber and *Acacia* are:

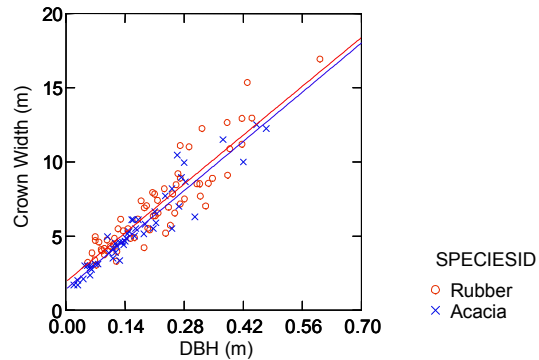


Figure 4 Crown Width - DBH function of rubber (CW = 1.91 + 23.54*DBH) and *Acacia* (CW = 1.41 + 23.73*DBH)

through purposive sampling of selected trees growing either in dense stands or as isolated individuals. From the data collected the flexi parameter (a measure of height growth ratio under contrasted light gradient) of each species was estimated.

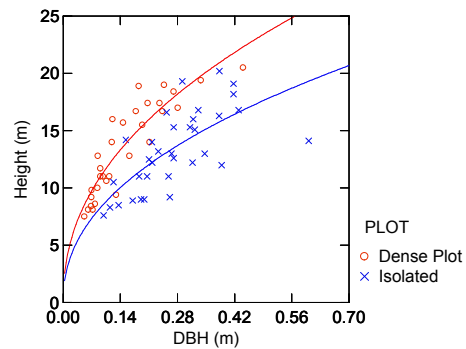


Figure 6 Height function of *Hevea brasiliensis* in dense plots (Height=32.26*dbh^{0.45}) or isolated (Height=24.29*dbh^{0.45}), with Flexi = 0.4

artificial shading experiment (Purnomosidhi and Rahayu, 2002). The function used for biomass is a Chapman-Richard function of relative light.

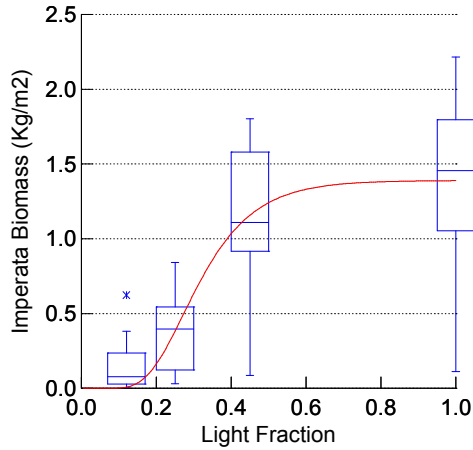


Figure 7 Light – *Imperata* biomass relation, the biomass unit is kg/m², light is expressed as a fraction of full sunlight, biomass data is recorded after 11-16 months.

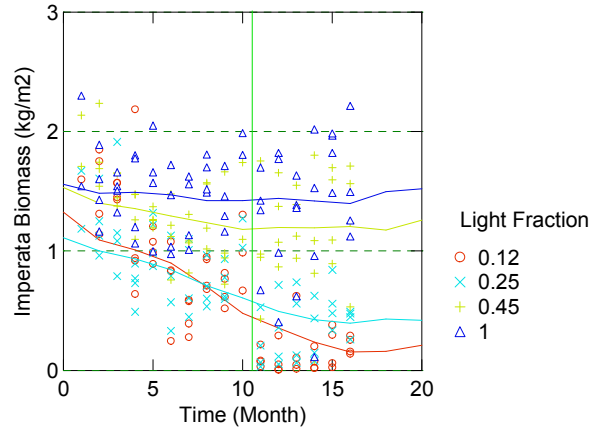


Figure 8 *Imperata* mortality for 16 months, the *Imperata* biomass at kg/m²

$$imperata_biomass = 1.39 * (1 - e^{-9.557 * light})^{13.382}$$

For each 1 m² cell, the function above is used to derive local *Imperata* biomass from local light availability. Here it is assumed there is no additional control of *Imperata* by farmer. Biomass of *Imperata* is updated on a yearly basis: change in light availability, which occurs within the year, is not considered. This appears to be reasonable simplification given that it seems to take around 12 months for *Imperata* biomass to adjust to a particular light level (Figure 6). Under well lighted conditions, *Imperata* can reach maximum biomass between 1-2 years (Figure 9).

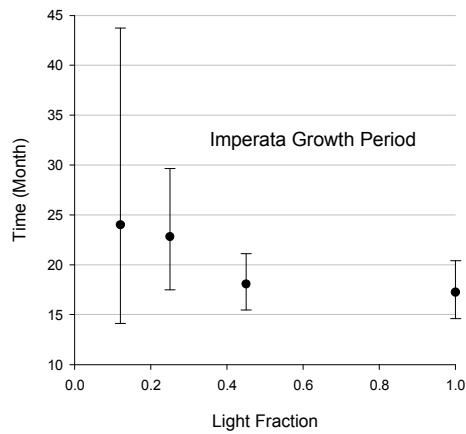


Figure 9 The growth period of *Imperata* decreases with increase in light availability.

SIMULATION RESULTS AND CALIBRATION

Figure 10 shows the effect of *Imperata* on rubber growth, the harvest size (15cm DBH) is delayed by about five years, and this is close to observations at ICRAF experiments in West Kalimantan. Increasing the plot density to 3x3 spacing did not reduce *Imperata* effect (Figure 11); rubber growth was actually lower than for 3x6 m spacing.

RUBBER PLANTATION

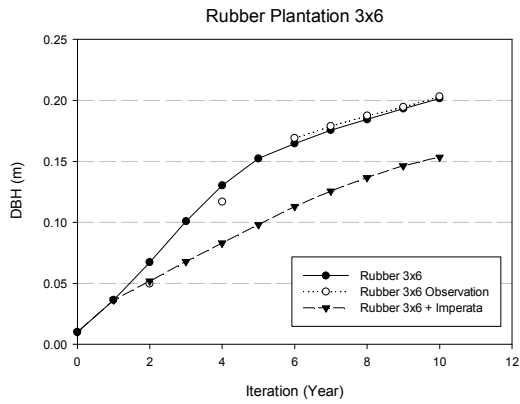


Figure 10 Rubber growth on 3x6 m plantation based on actual data and SEI-FS simulation; data from GT1 clone at Sembawa Research Station.

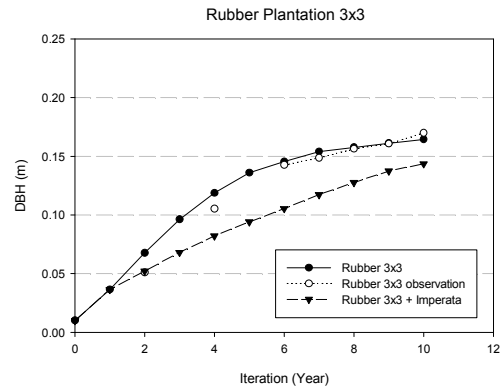


Figure 11 Rubber growth on 3x3 m plantation based on actual data and SEI-FS simulation; data from GT1 clone at Sembawa Research Station.

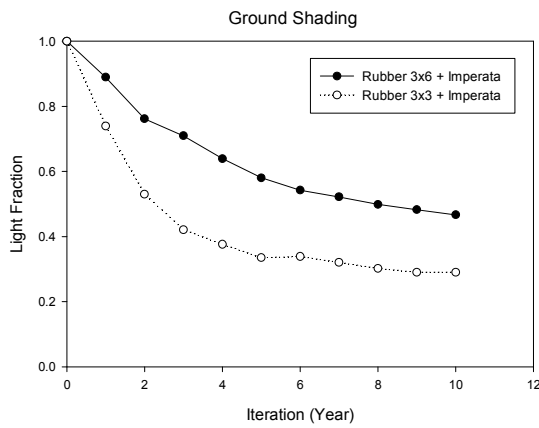


Figure 12. Ground shading inside rubber plantation.

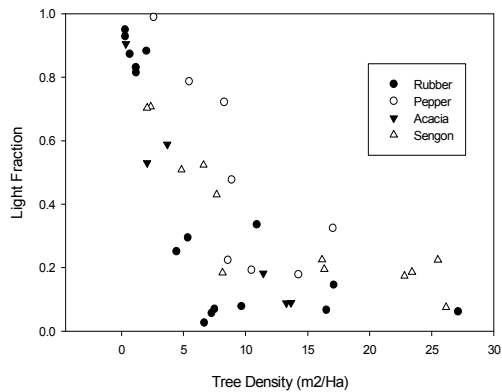


Figure 13 Light fractions on different tree species plantation and density

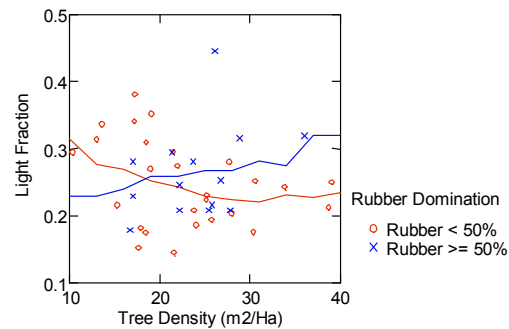


Figure 14 Relative light fraction inside rubber agroforest

Although less light is available inside 3x3 plantation (Figure 12), Imperata remains competitive up to about 60% light. Higher tree density did not increase shading. Ground shading under different species and density is shown in Figure 13. The light fraction decreases until 10 – 15 m² ha⁻¹ basal area after which shading remains constant. Light monitoring under high tree densities under rubber agroforests indicated little effect of changing tree density on light fraction. Light level remaining constant above a threshold density sounds logical as this is perhaps the level where the canopy is fully closed and increase in stocking density cannot increase canopy closure.

RUBBER AND ACACIA COMBINATION

Data from experiments using different patterns of planting rubber and combining with other species are not yet available; but suggestions of modified patterns are being made (Gede Wibawa, pers.

comm.). Simulation of these modified patterns was done to assess the shading intensity and effect on rubber growth. Figure 15 and Figure 16 are two possible scenarios simulated.

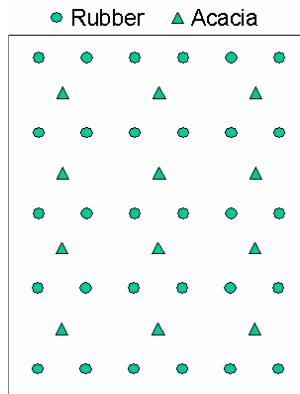


Figure 15. Rubber plantation 3x6m with alternating *Acacia* rows.

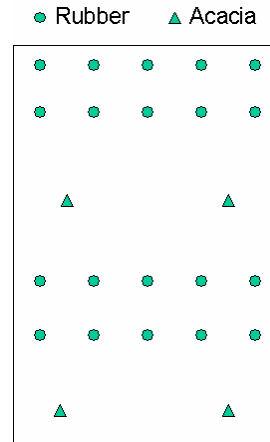


Figure 16. Double row rubber planting pattern 3x3x9 and 3x4x16 with *Acacia* between double rows of rubber.

Figure 17 and Figure 18 show the effects of *Acacia* on rubber trees under different patterns. Removal of *Acacia* after three or five years did not enable rubber trees to recover. This however contradicts the observations in West Kalimantan where rubber recovered slightly after removal of *Acacia*. The

double row pattern actually showed reduced growth of rubber trees compared to normal single row pattern (Figure 18). This could be due to the combined effect of competition from *Acacia* and increased inter-rubber tree competition.

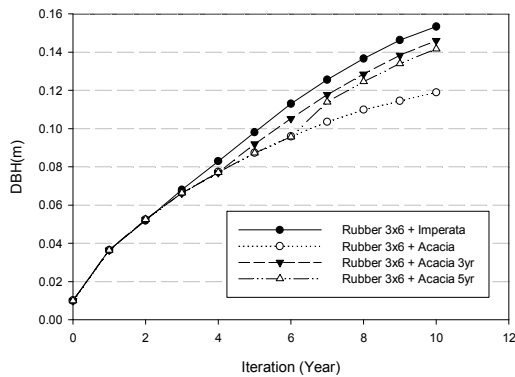


Figure 17 Simulation output of rubber growth in 3x6m spacing with alternating rubber-*Acacia* mixture; *Acacia* felled at 3 and 5 years.

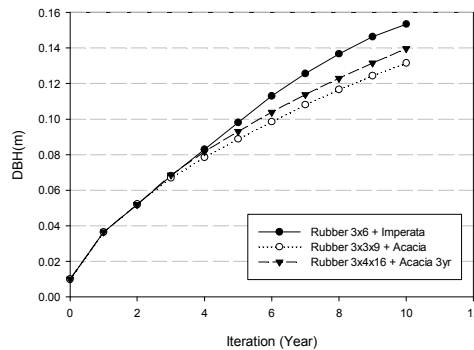


Figure 18 Double row pattern of rubber with *Acacia* interplanting.

The simulation showed that rubber-*Acacia* combination with normal rubber density (3x6 m) and single row pattern, the shading increases rapidly and reaches more than 60% shading in about three years (Figure 19). If *Acacia* is removed at year 3, the canopy opens up and shading intensity decreases to about 30%. Cutting of *Acacia* at year 5 also showed similar result. Simulation using the double rubber

row pattern (3x3x9 m with same stem density as with 3x6m spacing) shows similar shading increase with time. However, using 3x4x16 m (reduced stem density), shading is significantly less throughout the simulation period of 10 years. This will probably allow *Imperata* to remain vigorous and competitive. Recently established trials by ICRAF in Kalimantan may provide more information on this.

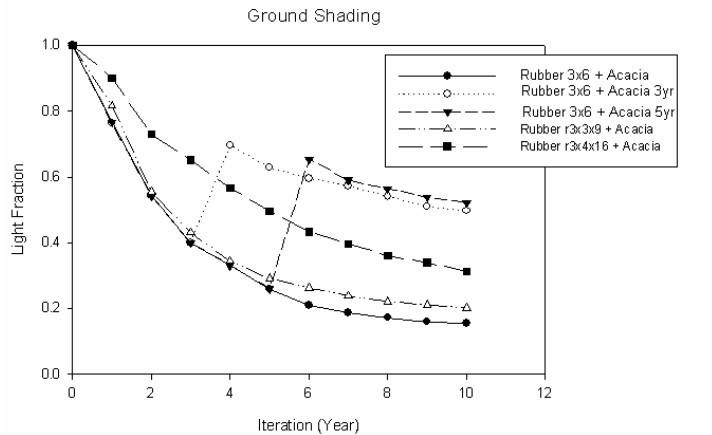


Figure 19. Shading from rubber-Acacia combination under different scenarios.

CONCLUSIONS

In this preliminary exercise, a simple implementation was chosen to calibrate *Imperata* growth function and some other relationships. Instead of modelling the growth dynamics of *Imperata*, the grass biomass at the end of a given year of growth was related through a sigmoid function to the light level at ground floor at the beginning of the same year based on experimental data of artificial shading.

Comparison of artificial shading and planting density experiments suggest that, contrary to our earlier assumption, belowground competition effect of trees on grass component is probably not negligible and may need to be considered in addition to the shading effect of trees. This will require developing and calibrating explicit functions of live biomass over time, and calibrating the shading and belowground competition growth reducers for *Imperata cylindrica*.

The results of the simulation using SEI-FS can still be improved through better parameterisation and using now-available field data. However, the current attempt of incorporating a herbaceous component into a tree stand simulator like SEI-FS is feasible and can yield useful insights for establishing rubber plantations in *Imperata* grasslands. The possibility of testing new scenarios with different patterns and species makes this modelling approach a potentially powerful tool for planning rubber research and development work.

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