# Technology development of slash-and-mulch and of fallow enrichment in shifting cultivation systems of the Eastern Amazon

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## ABSTRACT

Focusing on the objectives to replace slash-and-burn by fire-free land preparation and to accelerate biomass accumulation during fallow, technology modules have been developed to assume new challenges and to overcome change related obstacles. In fire-free land preparation motorized mechanization is being developed to slash-and-chop the fallow vegetation to form a mulch layer. Losses of mineral nutrients and of organic matter are avoided. Fertilization, weeding, crop varieties, water and nutrient dynamics, planting date and period are being studied and readjusted in field trials. Fallow biomass accumulation is accelerated by enrichment plantings with fast growing tree legumes, allowing fallow periods to be shortened. Choice of adequate indigenous or introduced tree species, planting densities, timing of tree-planting are being studied and readjusted with respect to mutual effects of the enrichment trees with the surrounding natural secondary vegetation and with the crop, aiming at maximum biomass accumulation, at efficient nitrogen fixation and at functional biodiversity.

## RESUMO

No enfoque de dois objetivos principais, substituir a prática de derruba-e-queima pelo preparo de área sem fogo e acelerar o acúmulo de biomassa durante o pousio, vários módulos tecnológicos têm sido desenvolvidos, visando assumir novos desafios e superar obstáculos. A técnica de corte e tritura (moto-mecanizada) da vegetação secundária forma uma camada de "mulch". Consideráveis perdas de nutrientes minerais e de matéria orgânica são assim evitadas. Estão sendo estudados em experimentos de campo: adubação, invasoras, variedades, dinâmica de água e nutrientes, data e período de plantio. O plantio de enriquecimento com árvores leguminosas de rápido crescimento permite reduzir o período de pousio. A escolha de espécies nativas ou introduzidas, densidades de plantio, época de plantio estão sendo estudados com respeito a efeitos mútuos das árvores enriquecedoras em relação à vegetação secundária que as circunda, assim como em relação às culturas, visando a acumulação máxima de biomassa, a fixação efetiva de nitrogênio e a biodiversidade funcional.

## ZUSAMMENFASSUNG

Innerhalb der zwei Hauptforschungslinien, das Schlagen-und-Brennen durch brandlose Feldvorbereitung zu ersetzen sowie die Biomasseakkumulation während der Brache zu

beschleunigen, wurden Technologiemodule entwickelt, um neue Herausforderungen zu ergreifen und um änderungsbedingte Hindernisse zu überwinden. Durch einen traktorbetriebenen Gehölzmähhäcksler wird eine Mulchdecke bereitet, die Nährstoffverluste und Verluste organischen Materials verringern hilft. Düngung, Unkrauthacke, Sorten, Wasser-/Nährstoffdynamik, Pflanzzeitpunkte und Vegetationsperiode werden in Feldversuchen untersucht und angepaßt. Anreicherungspflanzungen mit schnellwachsenden Baumleguminosen verkürzen die Brachezeit. Heimische und eingeführte Arten, Pflanzabstände und Pflanzzeitpunkte werden hinsichtlich wechselseitiger Wirkungen der Anreicherungsbäume mit der sie umgebenden natürlichen Sekundärvegetation und den Ackerfrüchten mit dem Ziel hoher Biomasseakkumulation, effizienter Stickstofffixierung und funktioneller Biodiversität untersucht und angepaßt.

## INTRODUCTION

The present work is an overview of current and future activities of the project "Secondary forests and fallow vegetation in the Eastern Amazon Region - Function and Management", short "SHIFT *Capoeira*" conducted in Eastern Amazonia in collaboration with the institutions: Institute of Agriculture in the Tropics (University of Göttingen) and EMBRAPA Amazônia Oriental.

The Eastern Amazon region, or, more precisely, the Bragantina region, is largely deforested and dominated by subsistence food crop production of small holders. Shifting cultivation is the system being used most within the lots of 25 ha (Silva et al., 1998). Traditionally, slash-and-burn is applied as the only land preparation means. During fallow periods spontaneous secondary vegetation (*capoeira*) is allowed to grow without human interference. So far, fallow management is not a common practice. Nowadays, total cycle times of about 4 years as given in the example of Figure 1 are prevailing in the region, wherever land is being utilized for cropping.

Consequently the frequently repeated burnings represent an unsuspended extraction of soil minerals and organic matter (Hölscher et al. 1997a, b), which enhances soil degradation and productivity decline. Together with increasing population pressure this leads to an expansion of the cropped area within the limited farmland, thus, accelerating the crop-fallow cycle in an unfavorable manner.

The projects objectives are to break the vicious circle 1) by reducing physical, chemical and biological soil degradation with the introduction of fire-free land preparation and 2) by shortening the fallow period with the introduction of fallow improvement. Both increase crop productivity per unit area and time.

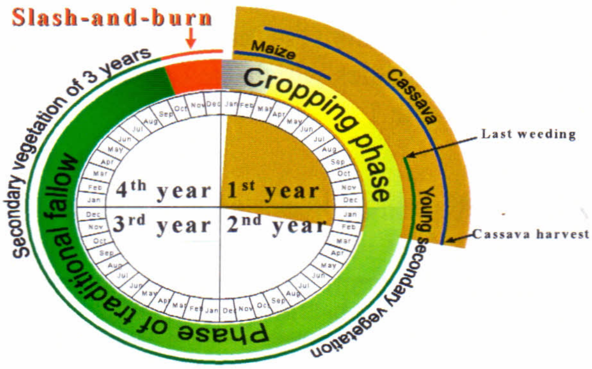


**Figure 1:** Traditional 4-year crop-fallow cycle in shifting cultivation systems with annual crops (common case)

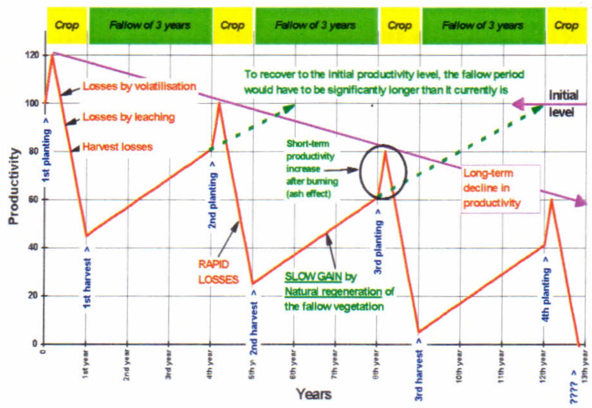


**Figure 2:** Productivity decline as a function of short fallow periods and repeated burnings (schematic and hypothetical)

## APPROACH

Conceptually speaking the slopes of the zigzag of the productivity line in Figure 2 have to be adjusted by turning the lines in their joints as shown in Figure 3. In technical terms these are the crucial transition phases before and after cropping, which is where the project lays its main emphasis's.

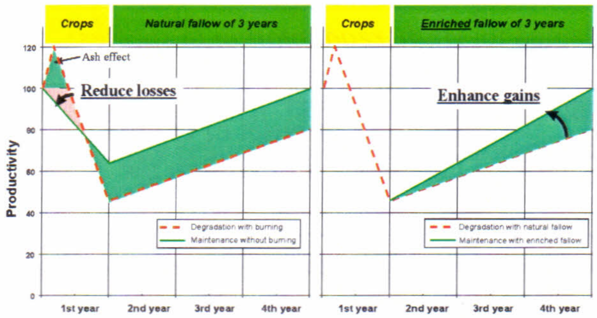


**Figure 3:** Mulch technology (left) to reduce system losses and fallow enrichment (right) to enhance system gains (schematic and hypothetical charts; dotted red line = critical, solid green line = improved)

1) Mulching as opposed to burning would set off at a productivity level of 100 and continue with a minor decline (Figure 3 left, solid green line). However, due to the lack of the initial ash effect, profits will only be noticeable towards the end of the cropping period (solid green line crosses dotted red line). As a result of mulching, productivity does not drop as rapidly and reaches the initial productivity level earlier in the recovery process of the fallow.
2) Tree enrichment of the fallow vegetation causes a greater inclination of the recovery curve (Figure 3 right, solid green line) bringing about faster biomass accumulation. Increased levels of organic matter and mineral nutrients lead to an earlier accession of the initial productivity level.

## MULCH TECHNOLOGY

The mulch technology is being realized by cutting and chopping the material with the TRITUCAP, a tractor driven mobile bush chopper (for more details see Denich et al. 1998a) developed by the project. Advantages, new challenges and obstacles which are caused by this new technology as opposed to slash-and-burn are listed in Table 1.

**Table 1:** Effects of two different land preparation methods on important parameters of sustainability

| | Slash-and-Burn | Slash-and-Chop (Mulch) |
|---|---|---|
| Coverage | Ashes, soil exposed | *Mulch cover, soil not exposed* |
| Organic matter and Carbon | Rapid oxidation losses, $CO_2$ emission | *Slow biological oxidation, carbon sequestration* |
| Mineral components | More than half of the essential elements are lost, nitrogen over 90% | *Elements essential for crop nutrition remain in the system* |
| Soil: pH | *Liming effect of ashes* | Acid |
| Soil: nutrients | *Nutrients left in the ashes are available to crops immediately,* risk of leaching | Temporary immobilization, *extended availability* |
| Soil: chemical | Inert | *High cation exchange capacity* |
| Soil: physical | Compacted, midday heat-peaks, topsoil frequently dry | *Good structure (aggregates), cool, topsoil mostly moist* |
| Biodiversity | Low, species composition adapted to frequent burnings | *High, readaptation of species composition expected* |
| Fertilization | *Short-term ash effect,* rapidly used up | Required at onset of cropping, *late nutrient release in the decomposition process* |
| Weeds | *Superficial weed seeds and* eyes destroyed, grasses encouraged | *Weeds suppressed (especially grasses),* eyes remain intact |
| Pests and diseases | *Superficial soil sterilization* | *Biological balance* |
| Crop varieties | Need of adapted varieties (i.e. to soil pH) for either situation | |
| Planting date and period | Fixed (only in January after burning in the dry season), shorter planting period due to rapid dry-out | *Flexible (Cut, Chop and Mulch done in any weather, long planting period > mulch conserves water)* |
| Realization, (stress, prelim. cost calculation) | manually, humanly and ecologically stressful 15 mandays $ha^{-1}$ * 8.-- = 120.—R$ | *mechanized with TRITUCAP, unencumbered, 5h* $ha^{-1}$ * *25.-- = 125.-- R$* |

Typesetting: underlined = adverse effects, *italics* = favorable effects, normal = neutral/undecided

Sustainability is ensured considerably better by the slash-and-chop technology. In the following sub-chapters some of the mentioned effects are being outlined by referring to research works already completed or under way and the respective contributions in the present proceedings.

### Fertilizer input

Fertilizer input in non burning systems is required. Field trials have shown that already moderate fertilizer inputs to both systems make slash-and-chop as productive as slash-and-burn, even if looked at the first nutrient demanding crop of the cycle, such as upland rice (Kato et al. 1998a). In the mulching system long-term nutrient release, following decomposition, reflects in higher yields of crops planted later in the season or in a second cropping cycle (Kato et al. 1998a, Silva Jr. et al. 1998).

In order to eventually elaborate fertilizer recommendations for non burning situations a pilot study on fertilizer response (N,P,K) was conducted in 1997 (Bünemann et al. 1998). Phosphate deficiency was found to be the limiting factor to such an extent that high fertilizer inputs of N and K without P, came close to no fertilization at all.

### Flexibilization of planting date and period

In non burning systems land preparation can be disconnected from the dry season, which permits the choice of a more adequate planting date with respect to agronomic objectives, to labor distribution over time, and to market demand. Moreover, the water conserving mulch layer allows extended cropping even of demanding crops into the dry season, which is currently being approached by the project in systematic field experimentation.

### Crop varieties

The use of crop varieties adapted to the new conditions (seed germination and early growth under thick mulch layer, soil acidity, nutrient availability) are of great importance to successfully realize the mulch technology. Adequate varieties have been pre-selected in first field experiments (Kato et al. 1998b). The results on rice yields with the most successful variety Progresso (3 t $ha^{-1}$) were promising enough to give substantial hope for the re-establishment of rice cultivation in the Eastern Amazon region with the more appropriate land-use system.

### Size class distribution and quality of chopped material

Decomposition rates are strongly influenced by size classes of the chips and the degree of tearing. The first work done in location with the newly developed bush chopper "TRITUCAP" showed that 50% of the vegetal material is being chopped to pieces smaller than 4 cm (Denich et al. 1998a). Moreover, the very intensive tearing exposes a substantial total surface to be attacked by microorganisms. Decomposition studies have yet to reveal the actual decomposition rates.

### Water and nutrient dynamics

Since considerable influences on water and nutrient dynamics are expected from the mulching technology, comparative studies are currently being conducted to measure the on-site impacts. Furthermore soil water extraction by the natural secondary vegetation was studied (Sommer et al. 1998) comparing methodologically the climatic approach (Bowen ratio) with direct soil water measurements in order to confirm the previously found results (Hölscher 1995, p. 48f) on water consumption of the secondary vegetation which would correspond to a depletion during the dry season up to 4 m depth.

### Further studies

To examine diversity changes in the soil the faunal activity was studied comparing different land preparation systems (Leitão et al. 1998). Furthermore, a first attempt to estimate energy requirements of the non-burning to the traditional burning systems was done (Jönsson et al. 1998)

## ENRICHMENT TECHNOLOGY

For the improvement of the fallow the enrichment technology is being realized by planting fast growing- (quick biomass accumulation) tree- (deep roots for nutrient recycling) legumes (biological nitrogen fixation) into the natural vegetation. This is already done before crop harvest, as can be seen in Figure 5 and Figure 6. Biomass production is being supported considerably by tree enrichment (Silva Jr. et al. 1998, Brienza et al. 1998) (compare Figure 4 and Figure 5).

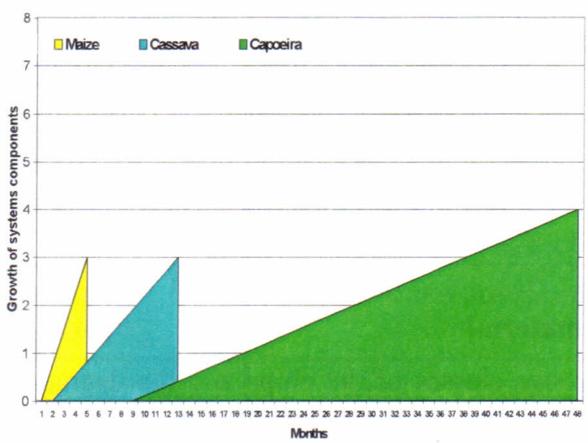


**Figure 4***: Natural fallow without enrichment in a traditional crop-fallow cycle

* Simplified linear growth model (plant height).

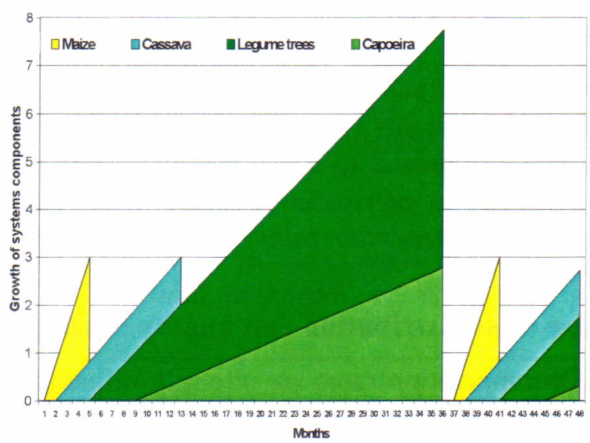


**Figure 5*:** Fallow enriched with fast growing tree legumes in an improved crop-fallow cycle

## Biomass production and biodiversity

One major research work on the enrichment technology was concluded, recently. Biomass production of the enriched fallow vegetation was accelerated by using the leguminous tree species *Acacia auriculiformis*. Total dry matter of trees plus fallow vegetation reached 49 t $ha^{-1}$ within 21 months, which more than doubles a non-enriched stand of the same age (20 t $ha^{-1}$) and comes close to the biomass of a natural secondary vegetation of 7 years (53 t $ha^{-1}$) (Silva Jr. et al. 1998).

In another experiment similar results were found for *Acacia mangium* as enrichment tree. Biomass production within the first 12 month reached a total of 18 t $ha^{-1}$ DM which is double of the non-enriched control (9 t $ha^{-1}$ DM) and about as much as a 4½-year-old non-enriched fallow vegetation. Depending on planting densities also the other species *Acacia angustissima*, *Clitoria racemosa* and *Inga edulis* had higher biomass production than the control. Increasing planting density of the enrichment trees also shifted biomass distribution between trees and natural vegetation in favor of the trees (Brienza et al. 1998).

Similar results were found for biodiversity, which differed substantially as a function of tree specie and planting density, the greatest effect of planting densities being registered with *Acacia mangium* (Wetzel et al., unpublished). According to these results a reasonable functional diversity may be maintained at the greater spacings of 1 m x 2 m or 2 m x 2 m, which are also economically more feasible with respect to purchase of planting material but still gives satisfactory biomass results.

## Nitrogen fixation

In order to look at net nitrogen input of the enrichment trees in tree enriched fallows, one intensive work is currently under way comparing two direct measurement methods, the $^{15}N$ labeling method with the $^{15}N$ natural abundance method ($^{15}$NNAM). A preliminary study in primary forest and in natural secondary vegetation succession, giving some ideas about potentials and problems of $^{15}$NNAM, has just been concluded (Thielen-Klinge et al. 1998). In this work, a first idea is given on how BNF may be influenced by the age of the secondary forest suggesting that fixation is being reduced as a function of age and an increasingly balanced nitrogen budget in the system of short-cut nutrient cycles.

## Rooting depth

Since nutrient recycling processes are being expected from the legume trees, vertical fine-root distribution was investigated by auger and trench wall methods as well as root morphology by excavation method in plots of five enrichment tree species *A. mangium*, *A. angustissima*, *C. racemosa*, *I. edulis* and *Sclerolobium paniculatum*, (Fisher et al. 1998). Even though total root biomass at 0 cm to 80 cm depth was less in the enriched plots, rooting depth of some enrichment species was great enough to resist the 1997 dryness of El Niño, i.e. *A. mangium*, whereas others shed leaves, i.e. *A. angustissima*.

## Further studies

In a number of further studies the following results were obtained:

- Under the prevailing conditions and the utilized trees, competition with crops was negligible at any planting density (Brienza et al. 1998).

- Faunal diversity was influenced by the enrichment trees into different directions when comparing to the natural fallow. With *Inga edulis* total individuals per $m^2$ were increased whereas with *Acacia mangium* and *Sclerolobium paniculatum* the individuals number as well as the number of taxonomic groups was lower than in the non-enriched control (Leitão et al. 1998).
- Penetration of photosynthetic active radiation was reduced considerably in enriched plots suggesting light competition to accompanying spontaneous fallow vegetation (Sá et al. 1998a). This corresponds to the findings on biodiversity, mentioned above.
- In order to better understand water vapor exchange and water stress behavior of secondary vegetation species as well as enrichment species, stomatal conductance and leaf water potentials were studied (Sá et al. 1998b). *A. mangium* had highest water vapor exchange rates compared to natural fallow species and to the other enrichment species. Physiologically this is due to presence of stomata on both sides of the pseudoleaves, the prolonged conductance during dry spells and the deep reaching roots (see Fischer et al. 1998), suggesting that the strategy of *A. mangium* leads to elevated water depletion of the soil during dry seasons.
- The tree enrichment technology, originally intended to improve fallows, was used to recuperate a degraded pasture with the goal to return to crop production and the shifting cultivation system (Fernandes et al. 1998). *A. mangium,* planted at a spacing of 1 m x 1 m to obtain a most rapid closing of the canopy to shade out the prevailing *Brachiaria humidicola* pasture grass, established best when seedlings were used and the area was slashed but not burned.

Furthermore, decomposition of enriched mulch, nitrogen and phosphorus mineralization, as well as studies on vegetative resprouting of enrichment species are important investigations still under way.

## CONCLUSIONS AND PERSPECTIVES OF THE TWO TECHNOLOGIES

Either one of the two technology packages can effectively contribute to a more sustainable land-use in the Eastern Amazon region. Greatest impact, however, is only obtained when combining the technologies to reveal their synergistic effect. Especially, the advantages of tree enrichment can be partially lost if land preparation is done by burning the fallow vegetation, afterwards.

As an overall result of the maintenance of the productivity level by slash-mulching and of the shortening of the fallow periods by fallow enrichment, the future crop-fallow cycles of the region may look as shown in Figure 6 and productivity level may be maintained in the long run as shown in Figure 7. The unsuspended extraction of soil minerals and organic matter, formerly caused by burning, will be reduced to almost the mere harvest losses. If the cycle is repeated before total decomposition of organic material has taken place, that is, if building up is going to be faster than breaking down, there is sufficient indication for sequestration of carbon in the system, especially if the woody component is maintained in the fallow vegetation (Denich et al. 1998b, c).

Hence, an increase of productivity per unit area or time (compare Figure 2 and Figure 7), may improve life conditions to such an extent, that populational migration to the cities as well as further occupation of virgin forest areas will be reduced.

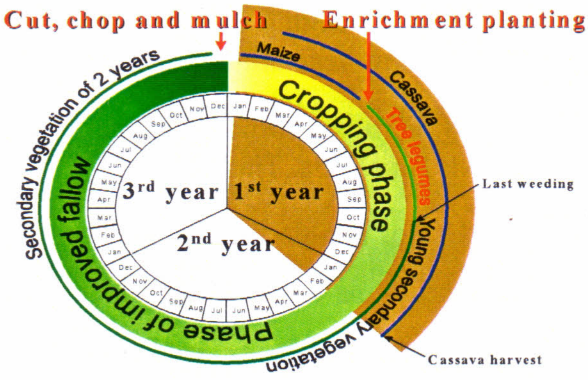


Figure 6: Improved 3-year crop-fallow cycle in shifting cultivation systems with annual crops

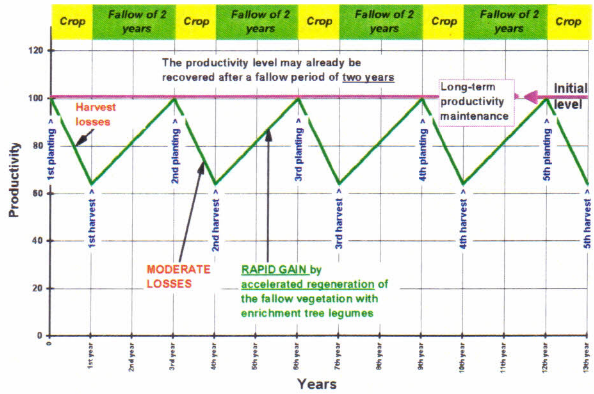


Figure 7: Maintenance of productivity as a function of fallow enrichment and fire-free land preparation

## FURTHER COMPREHENSIVE STUDIES AND OUTLOOK

In order to better understand the prevailing situation of the shifting cultivation system of the region, basic studies continue, such as the cyclic behavior so soil quality in rotational land-use systems (Diekmann et al. 1998), modeling of fine root distribution under secondary vegetation (Wiesenmüller et al. 1998) and testing of non-destructive methods to determine above- and below-ground biomass of secondary vegetations (Cattânio et al. unpublished).

Most of the above mentioned activities are currently being conducted as researcher managed on-farm field experiments. An increasing farmers participation is planned for the future, in order to be guided towards farmers needs, more effectively. A recently conducted intensive rural appraisal in collaboration with the SHIFT project "Small farmers in the Eastern Amazon", will give the required baseline data for the participatory effort (Silva et al. 1998). The participatory approach, on the other hand, will open the opportunity to measure off-farm impacts of the modified land-use systems, since a big number of farmers can be included to adapt the proposed changes, such as fire-free land preparation and fallow enrichment. The research work is intended to examine nutrient and sediment flows on a micro-watershed level of first and second order streams. The currently conducted remote sensing work on landscape structure in slash-and-burn agriculture (Metzger et al. 1998) and on land-use systems in two rural communities of the region (Sampaio et al. 1998) is being utilized to identify adequate watersheds with respect to hydrological and land-use aspects.

Furthermore, inclusion of livestock in the small-holder system requires in-depth research activities in order to attend peasants increasing demand of animal integration in a balanced and sustainable manner (Rischkowsky et al. 1998). By middle of 1998 the final approval of a respective SHIFT project "Role of cattle in the fallow systems in Eastern Amazon region", short "SHIFT *Pecuaria*" was expressed to the collaborating institutions: Tropical Animal Production (University of Göttingen) and EMBRAPA Amazônia Oriental.

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