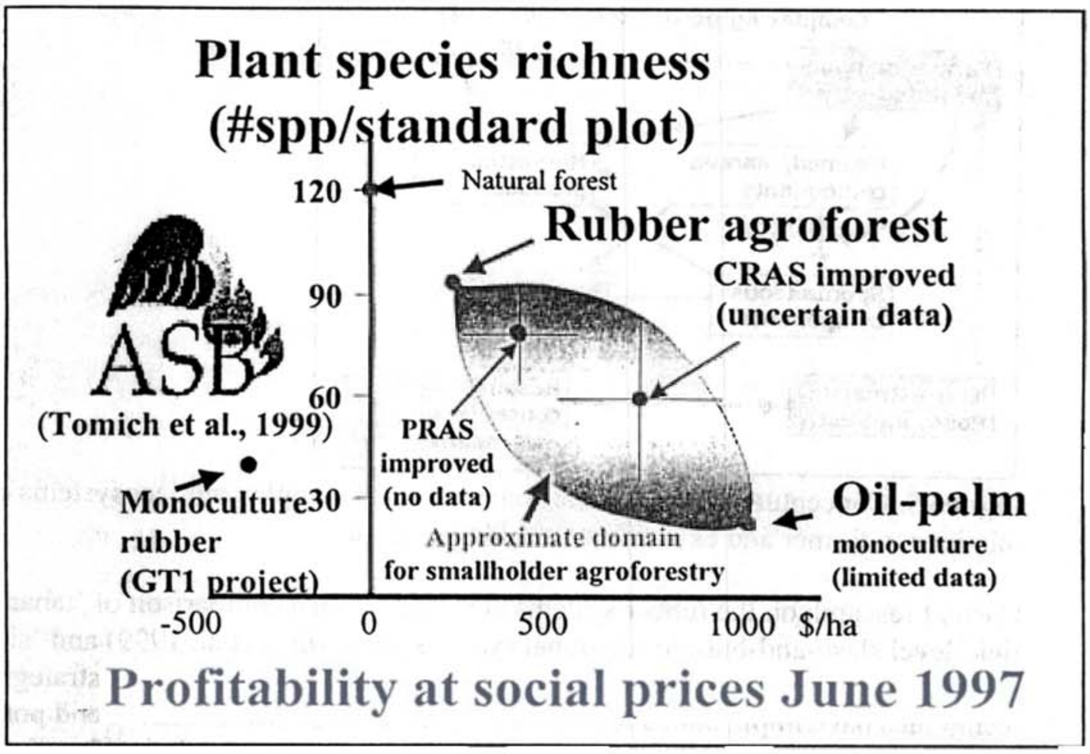


Figure 4. Trade off between biodiversity (as indicated by plant species richness) and profitability of tree crop production systems based on rubber or oil palm, with a current estimate of the domain of possible land use systems; PRAS refers to permanent rubber agroforestry systems (gap-level renewal, 'sisipan') and CRAS to cyclical systems, with slash-and-burn based land clearing at the end of each production cycle (Tomich et al., 1998c)

Our analysis has lead to a focus on 'complex agroforests' and 'complex agro-ecosystems' as a category of land use systems little understood by researchers but prominent in the livelihood strategies of smallholders. These systems combine 'planned' components with a substantial role for 'spontaneous' components (incl. trees and herbs), that =can lead to harvested products as well. The harvested component leads to profitability, but the non-harvested component contributes to resource conservation and sustainability. Most of the belowground biodiversity falls in the 'spontaneous' and 'non-harvested' category. This does not mean that it is not an important part from a longer term perspective but it is little visible to farmers.

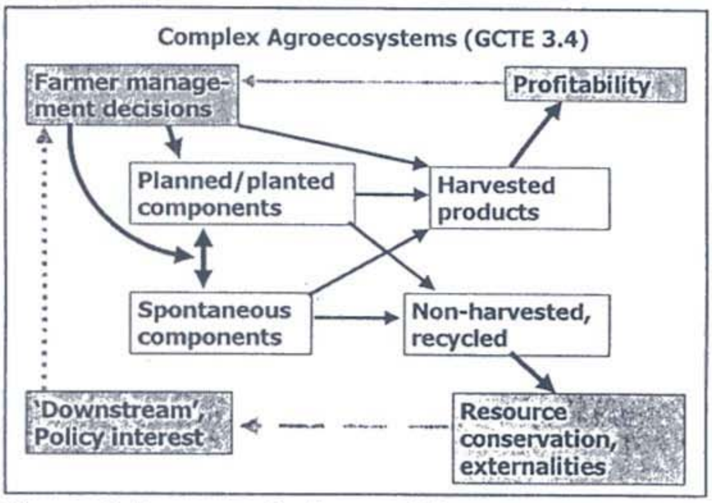


Figure 5. Conceptual scheme of the components of complex agroecosystems and their relations to farmer and external stakeholder interests

Current research on the rubber systems is focussing on a comparison of 'tanam' (with field level slash-and-burn in rotational systems, Ketterings et al. 1999) and 'sisipan' (gap-level interplanting as a basis for tree-level rejuvenation) as two farmer strategies. The two techniques have implications for cash-flow, investment, risk of failure and potential profitability; we now understand that sisipan is the poor man's choice. It offers opportunities for maintaining and enriching productive tree diversity and maintaining a higher C stock. Consequences for 'white root disease' in rubber are being explored. An 'in situ' grafting method may allow the inclusion of more productive rubber germplasm as a component into this system.

Some food for thought on biodiversity research

Biodiversity research sometimes appears to be so focussed on quantifyingh species richness, that the biological logic seems to play no role (Figure 6). A major challenge still is how to rediscover the logic to include knowledge on food chains and dispersal/ migration into biodiversity survey methods that allow scale transitions (Fig. 7) as well as longer term stability evaluations.

Figure 6. Biodiversity research seems to lead to just counting species, as if these can be added up without further understanding of their role and relationships

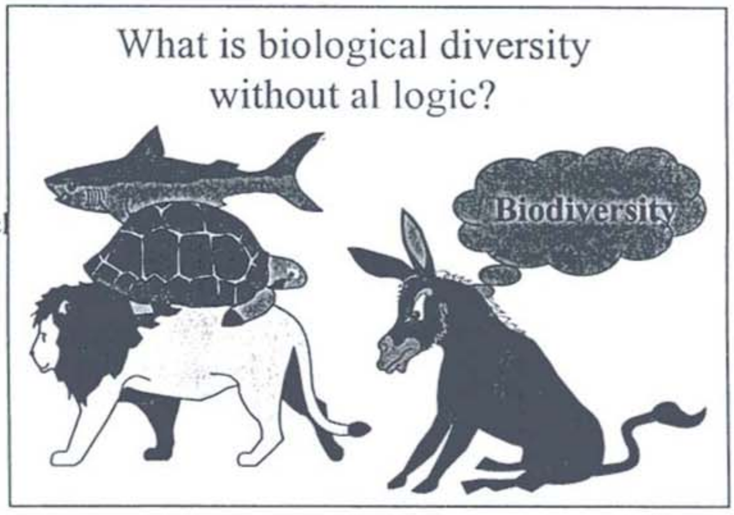
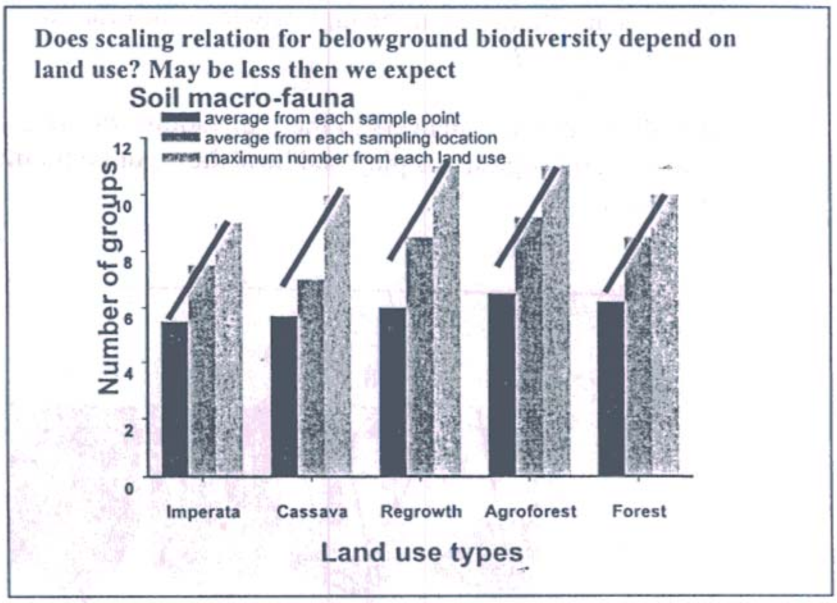


Figure 7. Initial surveys of belowground biodiversity in a range of lands use systems in Jambi and Lampung revealed less differences in level or scaling rules between land use types than expected



Key soil functional groups to be considered in the context of Maglus include:

- soil engineers responsible for creating, maintaining or modifying soil structure with impacts on infiltration and movement of water, gasses and roots,
- antagonists of pests and (soil-born) diseases with impacts on yields and the (perceived) need of using chemical pesticides,
- symbionts with impacts on nitrogen and phosphorus nutrition of (tree) crops, with impacts on yields and the (perceived) need of using chemical fertilizer,
- the belowground food web of comminutors and decomposers maintaining the nutrient cycle and modifying the rate and soil depth at which mineralization occurs,
- roots (belowground parts of planned and spontaneous plant components, Van Noordwijk *et al.*, 1998c) which respond to as well as modify soil structure, nutrient and water balances,
- gas exchangers in the C and N cycle (including CH_4 and N_2O absorption and emission).

All these groups are likely to be of direct importance for the on-site productivity of an agro-ecosystem, but the biological functions can be substituted by technical means to a different degree. The 'soil engineers' with their impact on lateral and vertical flows of water (nutrients and gasses) are of direct relevance for the external impact of land use practices as well. These relations are of particular importance in the new focus on vegetative filter zones at landscape level for upper/middle watershed zones

Key questions on the way vegetative filters function are:

* How effective are different types of filters?
* How quickly will they saturate under high sediment inflows from eroding zones uphill?

* How fast can the filters regenerate between rainfall events by stabilization of sediment received (initial steps of soil formation) by combined actions of roots and soil biota?
* How can filters retain the high water infiltration rates that are required for their effectivity?

It is likely that the answers to these questions will require a better understanding of the role key soil organisms play and how they can be maintained at desirable population densities.

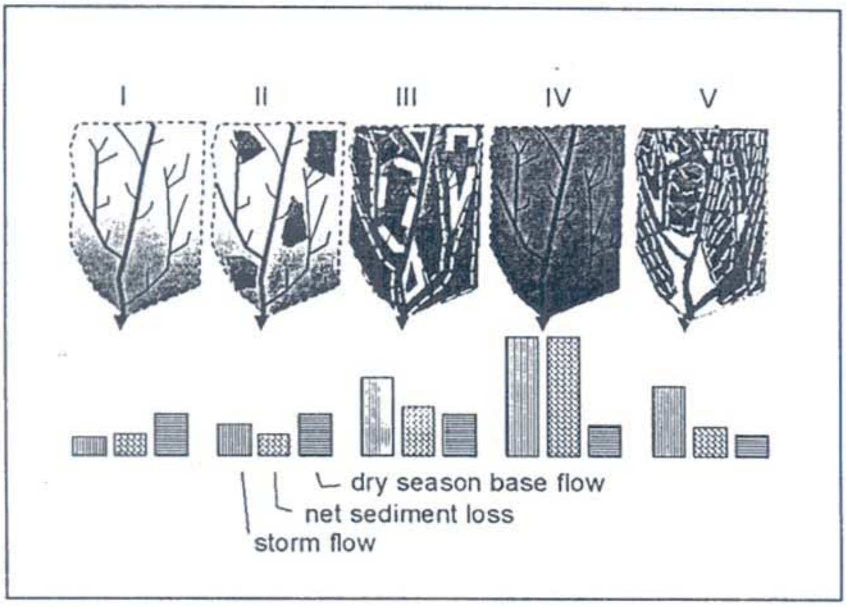


Figure 8. Tentative classification of landscapes ranging from fully forested (I) to fully converted to agriculture (IV), with the targets for 'rehabilitation' (V) in restoring the lost filter functions (Van Noordwijk *et al.*, 1998b).

The way forward

The three circles of Figure 1 represent logical components of a research program:

1) surveys across representative gradients of land use systems (the forest, agroforest, simple tree crop plantations, rotational systems, grasslands spectrum) and gradients within the major ones (rubber and coffee based systems provide a wide range of intensities) to quantify the primary impacts of land use change on soil biota and their diversity,
2) experiments that involve specific manipulations of soil organisms (and their diversity...) to test their direct impacts and functions, and synthetic, process based models that relate soil biological properties to better known aspects of soil organic matter, water and nutrient balances; use of ecological and food web models to inter- and extrapolate across spatial and time scales

3) inventories of farmer knowledge and perceptions, calibration of their observation and monitoring systems and incorporation of soil biodiversity impacts at landscape level in appropriate modeling and extrapolation frameworks.

At all three levels of activities the existing network of researchers and contacts in the ASB benchmarks can form a valuable background for new and focussed activities.

References

Ketterings, Q.M., Wibowo, T.T., Van Noordwijk, MN. and Penot, E., 1999 Slash-and-burn as a land clearing method for small-scale rubber producers in Sepunggur, Jambi Province, Sumatra, Indonesia. Forest Ecology and Management 120: 157-169

Tomich, T.P., Van Noordwijk, M., Vosti, S. and Whitcover, J., 1998a. Agricultural Development with Rainforest Conservation: Methods for Seeking Best Bet Alternatives to Slash-and-Burn, with Applications to Brazil and Indonesia. Agricultural Economics 19: 159-174

Tomich, T.P., Thomas, D.E. and Van Noordwijk, M., 1998b. Policy research for sustainable upland systems Agroforestry Today 10(2): 23-25

Tomich, T.P., Van Noordwijk, M., Budidarseno, S., Gillison, A., Kusumanto T., Murdiyarso, D. Stolle, F. and Fagi, A.M., 1998c. Alternatives to Slash-and-Burn in Indonesia, Summary report and synthesis of Phase II. ICRAF S.E. Asia, Bogor, Indonesia, 139 pp

Van Noordwijk, M., T.P. Tomich, R. Winahyu, D. Murdiyarso, S. Partoharjono and A.M. Fagi (editors) 1995. Alternatives to Slash-and-Burn in Indonesia, Summary Report of Phase 1. ASB-Indonesia Report Number 4, Bogor, Indonesia

Van Noordwijk, M., Lusiana, B., Suyanto and Tomich, T.P., 1996. Soil and other constraints to agricultural production with or without trees in the North Lampung benchmark area of the 'Alternatives to Slash and Burn' project. AGRIVITA 19: 136-145.

Van Noordwijk, M, T.P. Tomich, D.P. Garrity and A.M. Fagi (editors), 1997. Alternatives to Slash-and-Burn Research in Indonesia. ASB-Indonesia Report Number 6. Agency for Agricultural Research and Development, Bogor, Indonesia

Van Noordwijk, M., D. Murdiyarso, K. Hairiah, U.R. Wasrin, A. Rachman and T.P. Tomich, 1998a. Forest soils under alternatives to slash-and-burn agriculture in Sumatra, Indonesia. In: A. Schulte and D. Ruhiyat (eds.) Soils of Tropical Forest Ecosystems: Characteristics, Ecology and management. Springer-Verlag, Berlin. pp 175-185

Van Noordwijk, M., Van Roode, M., McCallie, E.L. and Lusiana, B., 1998b. Erosion and sedimentation as multiscale, fractal processes: implications for models, experiments and the real world. *In:* F. Penning de Vries, F. Agus and J. Kerr (Eds.) Soil Erosion at Multiple Scales, Principles and Methods for Assessing Causes and Impacts.. CAB International, Wallingford. pp 223-253.

Van Noordwijk, M., Martikainen, P., Bottner, P., Cuevas, E., Rouland, C., Dhillion, S.S., 1998c Global change and root function. Global Change Biology 4: 759-772