Agroforestry on the interface of climate change mitigation, adaptation and sustainagility[1]

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Abstract

The global challenge of climate change is a symptom of unsustainable development pathways. It also is a direct cause of concern through its impacts on lives and landscapes in the countries that have large emissions as well as those without. Indonesia is part of the global problem, mainly due to the high emissions from peatlands and forest fires, and will have to be part of the solution. Globally, the excess of 'ecological footprint' over available space urges for a more efficient use of space, with multifunctionality and the co-production of goods and services as a requirement. Forms of agroforestry are well placed to provide such multifunctional solutions, even if they involve tradeoffs and compromises internal to the system. These tradeoffs can only be managed if goods and services are both rewarded at appropriate levels. Compared with the traditional professional training of foresters and agronomists, the current requirements for integrated natural resource management are much broader and indeed integrated. Adaptation to the shifting opportunities and challenges of climate, on top of shifts in globalizing markets and transforming economies and adjustments in the balance of power between local, national and global governance, will require a high degree of 'sustainagility' rather than adoption of pre-conceived plans. A mix of analytical and synthetic skills is needed from our next generation of professionals and leaders, as well as an ability to assist multiple stakeholders in the negotiation of multifunctionality in rapidly changing landscapes..

contents

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1. Climate change as symptom of unsustainable development

The IPCC (2007) has compiled strong scientific evidence that the global climate is changing at rates not seen in recent geological history. This change is causally linked to changes in the composition of the atmosphere, which in turn is largely caused by an increase of the greenhouse gas effect due to emissions from CO_2 that had been stored in the past as energy-rich organic compounds or as calcium carbonate and is released by use of fossil fuel or cement. About 20% of the increase in greenhouse gasses is caused by the release of CO_2 that has been stored for hundreds or thousands of years, respectively, in aboveground forest biomass or peat soils. International agreement on emission reduction is hard to reach, due mainly to the large differences in per capita emissions between countries.

While the Kyoto accord related emission reduction targets to the 1990 emission levels, a further reduction will have to provide a pathway towards globally equitable emissions, but not exceeding the carrying capacity of the atmosphere and oceans. Rapid increases in the greenhouse gas effect can lead to positive feedback loops by triggering release of CO_2 and CH_4 from boreal zones, reduction of uptake capacity by the oceans and/or changes in circulation patterns of the oceans (the 'conveyor belt' that links all oceans) or atmosphere ('tropics'). Indonesia will be affected by climate change, but it is also co-responsible for the change. If the recent estimates of emissions from peat soils and forest fires are correct (Fig. 1) the per capita emissions of Indonesia are 30% above those for most European countries, but still below those for the USA, the only Annex-I country that has not ratified the Kyoto agreement.

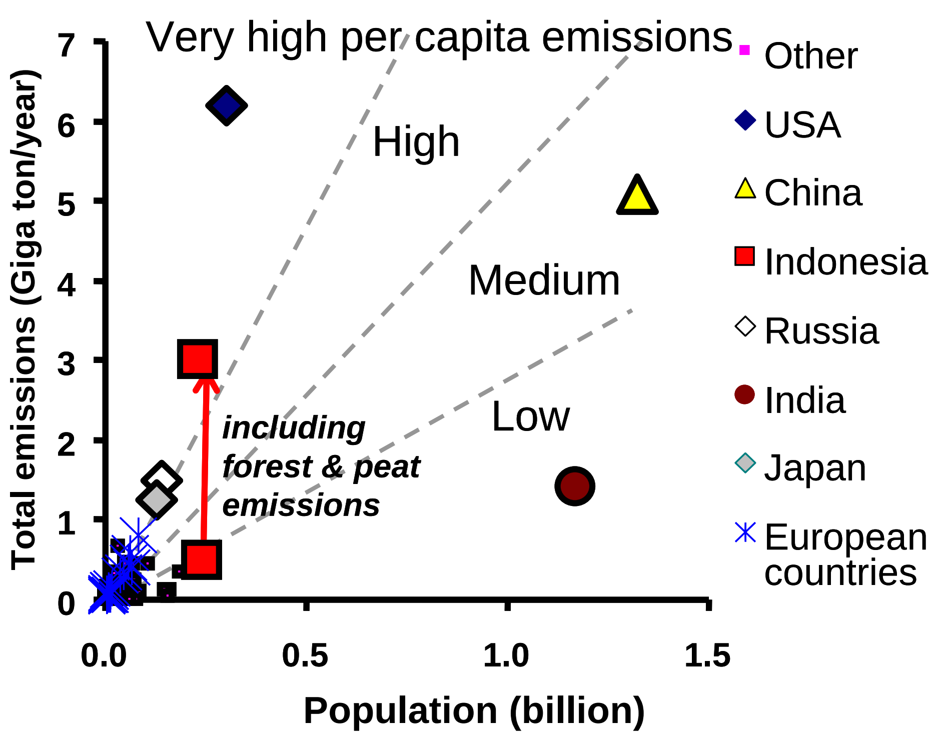

Figure 1. Relationship between human population and annual emissions of greenhouse gasses; two versions are presented for the Indonesia data, one with and one without emissions from peatland use and forest fires (data for Indonesia: PEACE, 2007)

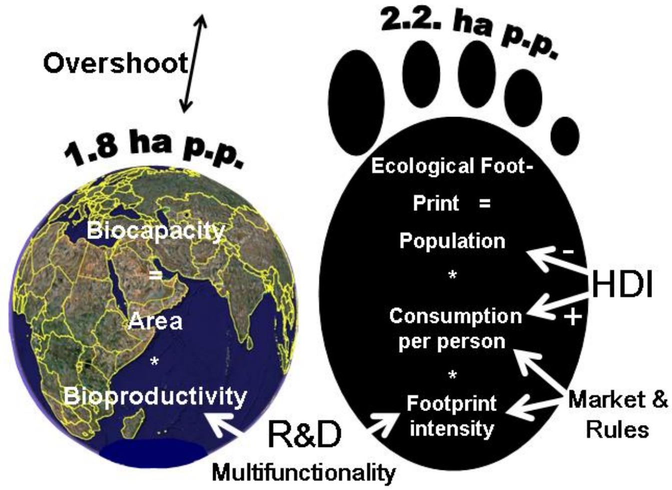

Figure 2. The concept of ecological footprint compares the amount of space needed to provide all the production and environmental services needed per capita, with the amount of space available on planet Earth; data for 2003 indicate overshoot

Global warming can be seen as a 'spill-over' effect, as a symptom of unsustainable development and excessive use of resources. While the planet earth has 1.8 ha of usable land available per person, the average global citizen already uses 2.2 ha (Fig. 2). We can see this as an imbalance between 'supply' (area *times* bioproductivity) and 'demand' (population *times* consumption per person *times* footprint intensity per unit consumption).

It is often stated that the poor majority of the world's population will suffer the consequences of a problem caused by the rich minority – and there is a lot of truth in that. However, the aspiration of most of the 'poor' is to catch up with the 'rich', while the current level of consumption and pollution already exceeds what the earth can deal with. The world has, without exception, agreed on the Millennium Development Goals (www.un.org/millennium**goals**/) of halving poverty by 2015 as a step towards its eradication. While the goals that relate to health and education have clear targets, the 'sustainable development' goal (MDG7) is lacking in quantitative targets and indicators, because it does not provide a clear criterion. A candidate for such criterion is based on the relationship between Human Development Index (a measure of health, education and expenditure) and Ecological Footprint, or the area required to produce the consumptive needs of a single person (Fig. 3).

If we formulate as the target of sustainable development a level of resource use (as expressed in the per capita footprint) that is below the fair share of the world carrying capacity (at current levels of technology), in combination with a Human Development Index above 80, we have to conclude that there are no 'role models', at least not at national scale. All developed countries use too many resources, while the developing countries do not yet meet the HDI target. The calculation of the ecological footprint is based on national statistics of imports, exports and consumption, and accounts for a substantial land area outside of national borders that is associated with the consumption levels of rich countries. The export opportunities that that provides have been the basis of the economy of many developing countries – but the terms of trade are usually not favourable for the producing countries, yet most of the side effects for environmental services are born locally.

Analysis of the components of the Ecological Footprint (Fig. 3A) reveals that there is one component with a negative association with HDI, the provision of fuelwood .

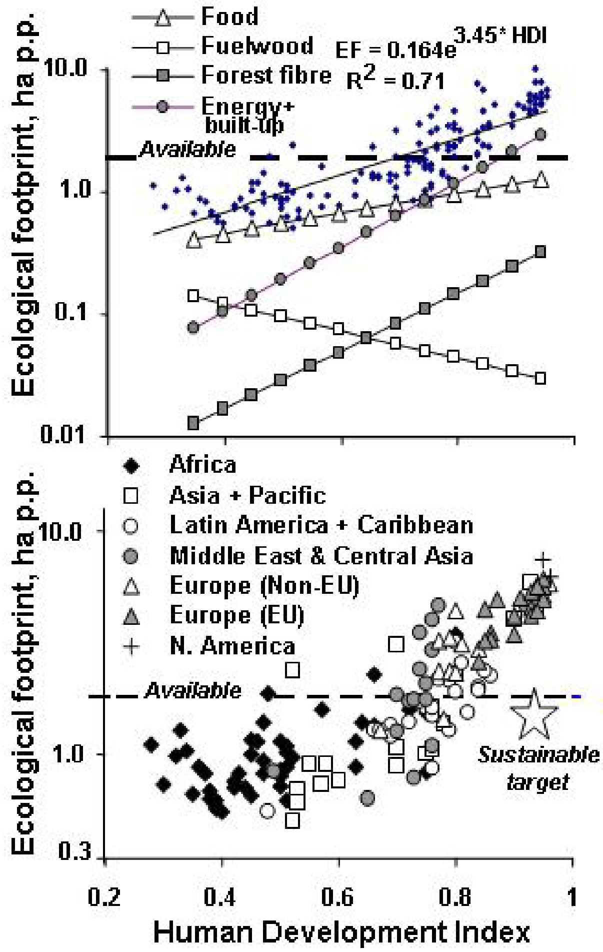

Figure 3. Relationship between components of the total ecological footprint and the human development index (upper panel), and the total ecological footprint by Human Development Index (HDI) per geographical grouping of countries (lower panel);. Sources: Rees, 2002

Around a HDI of 70, approximately Indonesia's position, a number of crossovers occur in the components of ecological footprint: forest fibre (incl. paper, furniture) non-wood energy (incl. compensation for fossil fuel use) starts to exceed food supply as dominant component, and the total footprint starts to exceed a fair share of the global carrying capacity. Indonesia's current footprint (which is based on its domestic production, not on the footprint of its export with high emissions from peat soils…) is about what is possible. Increases in components that help the 20% of rural poor, will have to be accompanied by reductions elsewhere. Meanwhile the economic basis of exports of high-footprint commodities has to be reconsidered as part of a real sustainable development strategy for Indonesia.

Global scale adjustment to sustainable levels of resource use will have to deal with the two main drivers of emissions of greenhouse gasses: the fossil fuel use directly associated with urban lifestyles and the land-based emissions linked to land use and forest conversion (Fig. 4). The two are linked and inseparable. The Kyoto protocol focussed on the fossil fuel part in the developed ('Annex-I') countries – but this lead to perverse incentives for increasing landbased emissions in developing

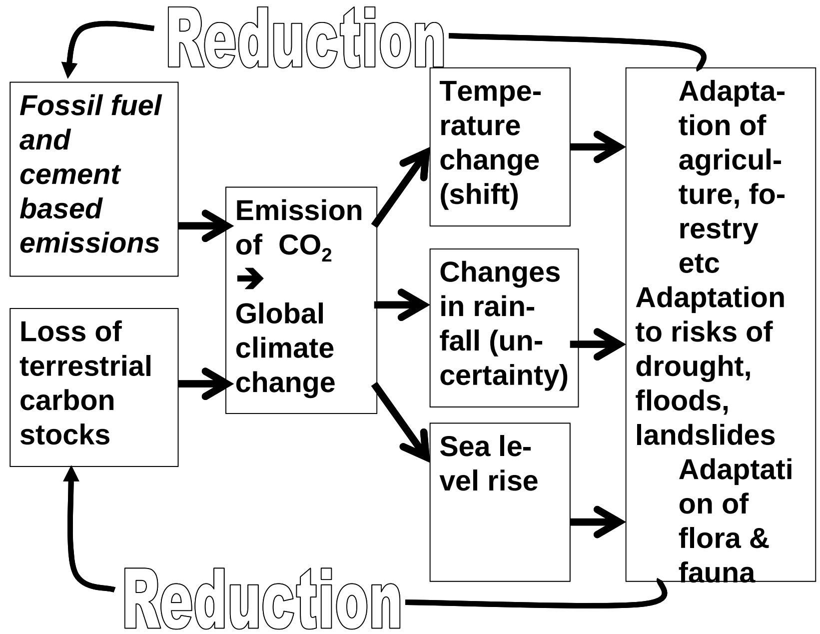

Figure 4. The pathway of drivers of emissions, consequences for climate and consequences for human and natural ecosystems requires adjustment in both the fossil fuel/industrial emission pathway (adjustment of lifestyles) and the landbased emissions (adjustment of land use patterns)

countries, because their emissions caused by the production of biofuels for Annex-I countries are not accounted for in the global rules. Currently, rules for attaching the 'carbon footprint' to all globally tradable goods are being developed to fill these gaps in the accounting system.

2. Multifunctionality of land to meet demand for goods and services

In figure 3a number of current trend and options are indicated that influence the 'supply' and 'demand' sides: the demand side will increase with increasing HDI, at least if the global pattern of substitution of plant-derived staple foods by increased animal protein with relatively high 'footprint' is followed. In the longer run, population growth may decrease, especially if the Millennium Development Goal of better education for girls is met. However, increased consumer awareness and active selection of products with low footprint will be needed to make space for the growth in population and reductions of global poverty. On the supply side there isn't much space left for expansion of the area base, so most will have to come from increased production of 'goods + services' per unit area.

Many previous assessments of the world food situation have focused on the food production component of bioproductivity – and have usually concluded that hunger is primarily a distributional issue, not an absolute shortage of potential crop growth. The recent surge in world food prices, however, linked to a modest target of substituting fossil fuels for the transport sector by 'biofuels' (von Braun et al., 2007), indicates that the supply-side elasticity is less than was expected.

The intercropping literature has many examples of 'over-yielding', where a mixture performs better than the weighted sum of its component monocultures, by about 30%, and a few where this reaches 50% (van Noordwijk et al., 2004a) For the joint production of marketable goods and environmental services there is little systematic comparison as yet (Constanza, 2000). We may expect that carbon storage is proportional to 'overyielding' in biomass production, while in biodiversity both 'overyielding' (for organisms that tolerate intermediate intensities of land use) and 'underyielding' (for organisms that do not tolerate human use of their habitat and/or are overhunted) is to be expected (Swift et al., 2004). In watershed functions we may well have the biggest opportunities for co-production, as agroforestry systems with partial tree cover in strategic positions can approximate forests as regulators of sediment-free water flow, while providing marketable products as well (Agus et al., 2004; van Noordwijk et al. 2006, 2007a).

The 'overyielding' opportunities of agroforestry, however, are not properly recognized, because the mindset of foresters suggests that forests have a monopoly on the provision of watershed protection services, and much of public opinion and policies has followed their lead. The recent Spatial Planning Law for Indonesia prescribes 30% forest cover as target for all provinces, regardless of terrain, climate and other characteristics. Such a legal requirement, if it would be implemented, may stand in the way of a rational analysis of local requirements. The dominant paradigm of public policies is still one of 'segregation' rather than 'integration' (Fig.. 4)

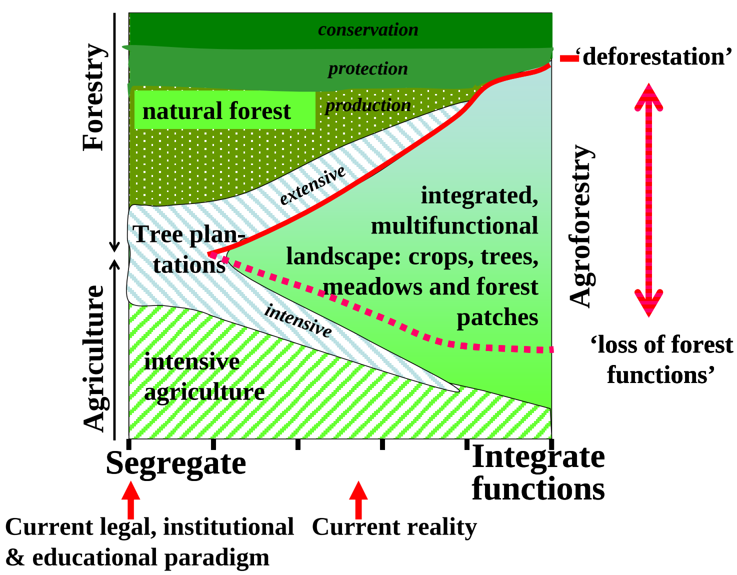

Figure 5. The dominant institutional paradigm is still based on a segregation of 'forest' and 'agriculture', while in fact much of the landscape is a more integrated and multifunctional mix of crops, trees, livestock and forest patches; the interactions between these elements are as important as their properties taken in isolation

3. The segregation of domains of knowledge

Integrated Natural Resource Management (INRM) not only requires an approach to multifunctionality of the landscape (van Noordwijk et al. 2001, 2004b), but also needs to bridge between the ways of knowing that where historically separated when 'science' was carved out into a niche where it is less influenced by stakeholder positions, emotions and political interests. A review of the long history of the 'forests and water' debate will show that this separation was never completely achieved and real independent science is still scarce. Nevertheless, a more explicit approach to knowledge management is needed that recognizes the differences, values diversity and seeks synergy (Fig. 5, 6).

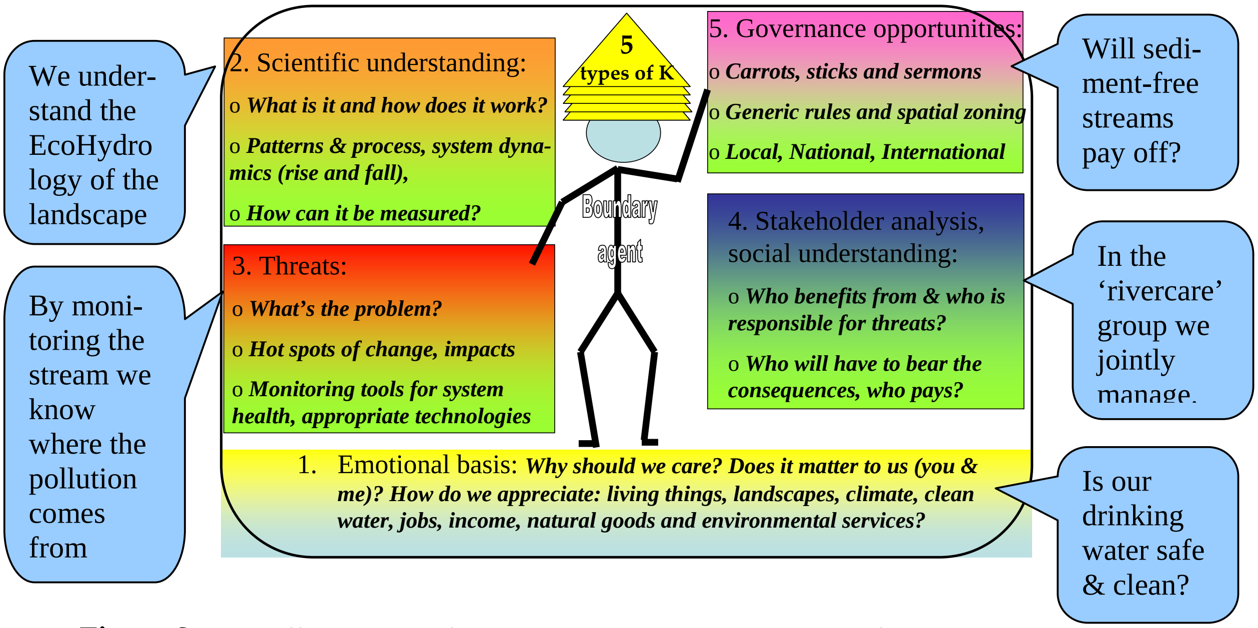

Figure 6. Five different ways of knowing about water and watershed functions that all need to be acknowledged in 'integrated natural resource management' in landscapes with multiple stakeholders, associated with multiple functions and perspectives

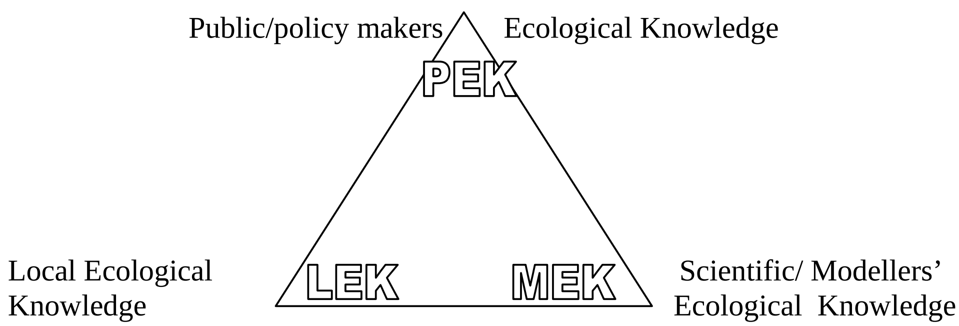

Figure 7. Classification of ecological knowledge by the primary holder, associated with distinct ways of generating, maintaining and modifying knowledge

This recognition of multiple ways of knowing and differences between the knowledge that various stakeholders generate and maintain, leads to a perspective on the role of science that is essentially different from a pure => applied science => application pathway that still dominates research management systems. As explored by Clark (2007) and Stokes (1997), a category of 'use-inspired' research can be distinguished that seeks advances in both our basic understanding of principles and the support of application – with the French Microbiologist Louis Pasteur as a role model, as he established medical microbiology as a discipline while solving the cause and suggesting remedies for a number of illnesses.

There are many words and terms for different aspects of linking knowledge to action, many of which come in three parts – one essentially to the ***where/when/what***', one to the '***how***' and one to the '***so what***' (Table 1).

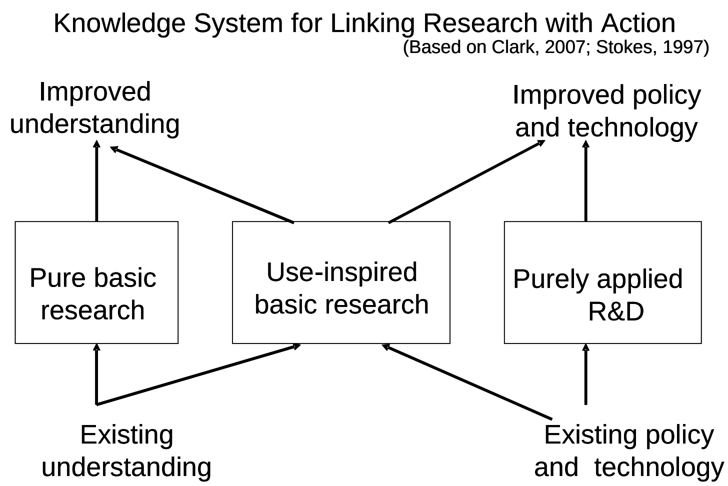

Figure 8. Map of relationships between different types of research and development (R&D) and their links between knowledge and action

Table 1. Key questions in local knowledge systems, pure and applied science

	Where/when/what	How	So what
Local knowledge systems	Context (place, time, setting, conditions)	➔	Outcome
Pure science		Mechanism ➔ (generic principle)	Outcome
Use-inspired basic research	Context +	Mechanism ➔	Outcome

4. Agenda for agroforestry as unifying concept in multifunctionality

Our primary reason for interest is not that it exists, has suited large numbers of farmers in the past or that it is a fascinating field of study, although all of these arguments apply. Agriculture without trees is possible in some landscapes, especially those on flat land without major wind erosion issues, but these situations are a minority. In many landscapes trees can contribute to a more healthy form of agriculture, apart from being a source of major commodities and tradable goods.

The trees on farm and the people managing them, however, are being pulled in at least four directions: **I**. poverty and associated Millennium Development Goals that may lead to over-use or removal of trees in short term strategies, **II**. economic growth and global market integration that often drives towards specialization and loss of local diversity, if not monocultures (to provide consumers to diversity of products), **III**. concerns for environmental services and the ecological footprint that may lead to exclusion of farmers from parts of the landscape by those who set policies, and **IV**. governance systems that vary between phases of strong centralization and more decentralized local control, with ‘elite capture’ at the local level as risk. These four ‘forces’, in pair-wise fashion, determine four major themes for agroforestry research and development:

A. Poverty reduction through linking trees and markets, linking economic growth and the local utility of trees in poverty alleviation,

B. Markets for environmental services and other ways of providing economic incentives to give 'services' the attention they deserve relative to 'goods'; this may require a form of commoditization of the services, packaging them in entities (e.g carbon emission reduction credits) that can be subject supply/demand feedback control
C. Land use zoning, rules for resource access to various types of 'forest' and incentives for collective action in the context of multifunctionality
D. Capacity of agroforesters (or segregates farmers and foresters) and their institutions to link Millennium Development Goals at appropriate levels of local governance.

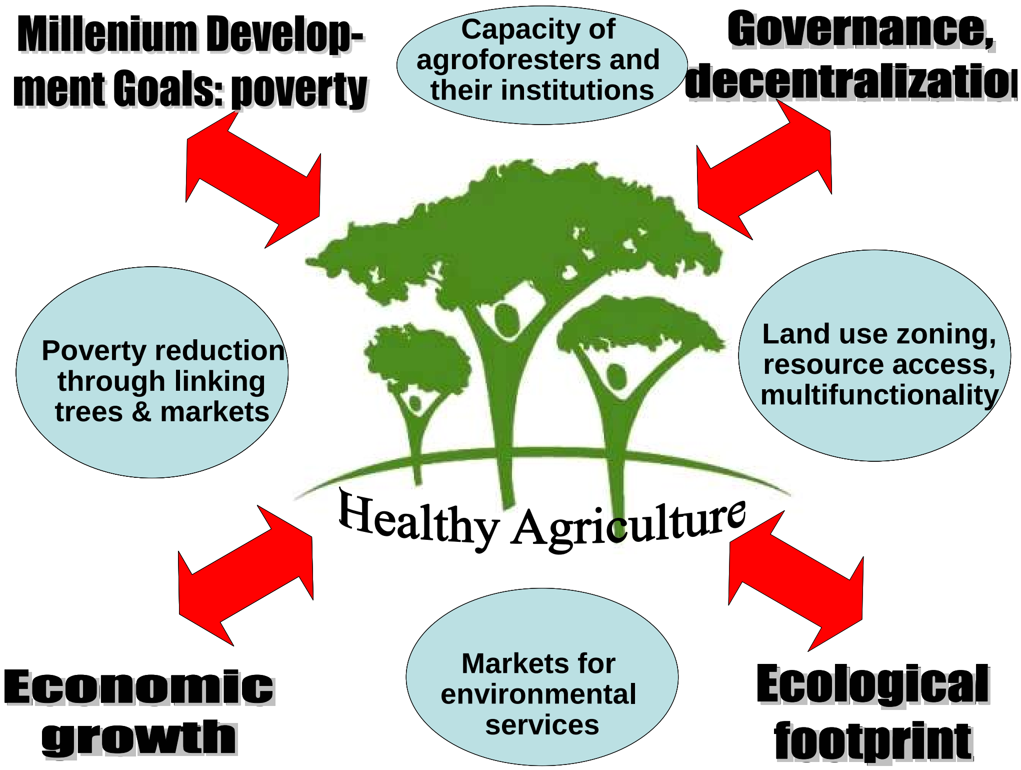

Figure 9. Four forces pulling the use of trees on smallholder farms in different directions, and four themes that combine two adjacent forces and their tradeoffs

In each of these four thematic areas the flow of information is governed by the dimensions of ***salience*** ('so what'), ***credibility*** (answering the 'how' question) and ***legitimacy*** (relating to local context) and in adjusting existing systems for research and development an analysis of the relative strength and weaknesses across these three dimensions can help in charting improvement in effectiveness (Table 2).

The landscape context for this differs (Chomitz et al., 2007) between the last remaining 'core forest' areas, the active forest margins (usually with contested land tenure) and the forest-patch/agroforestry/agriculture mosaics. In the latter we may see a secondary increase in forest cover, if the 'forest transition' is completed (Mather, 2007), as appears to have happened in China and Vietnam.

Table 2. Further characteristics of information needs for development (expanding from table 1)

	Where/when/what	How	So what
Use-inspired basic research	Context +	Mechanism ➔	Outcome
Key criteria for any one to take note of new information	Legitimacy: Is the information derived from (and thus applicable to) our context, because it was derived by people we know and who we trust?	Credibility: Is it based on appropriate and up-to-date methods, aligned (or convincingly contrasted) with generally accepted knowledge and supported by reputable scientists	Salience: Is there an 'impact pathway', a way the outcomes will matter for people, planet and/or profit?
Knowledge types	Local ecological knowledge (LEK)	Scientific (modellers') ecological knowledge (MEK)	Policy/public ecological knowledge (PEK)
Characteristics	Diagnosis, Participatory appraisal	Hard science, hypothesis testing	Application, Policy focus
Criteria for rewards for environmental services (RES)	Voluntary	Realistic	Conditional
Climate change paradigm	Adapt (respond to local signals, using local networks)	Be Adept (increase capacity to learn, interpret early warning signals, be ready to switch technology	Adopt (government approved master plan)
Examples of development support programs	Rights & Resources	Biotechnology	Integrated Natural Resource Management

5. Planned adaptation or sustainagility

The high level definition of 'sustainable development', meeting current needs without compromising the future, is fine. However, when 'sustainability' is defined for sub-systems, such as agriculture, a cropping system or the use of a specific genotype of a crop or domesticated animal, the criteria for sustainability focus on 'persistence' of the current system rather than an evaluation of the options for future change. Persistence is measurable, while change is subject to speculation. The concept of 'sustainagility', the ability of the system to support future change, was defined as complement to 'sustainability' to recognize the dynamic dimension in 'adaptation' (Fig. 10; Verchot et al., 2007).

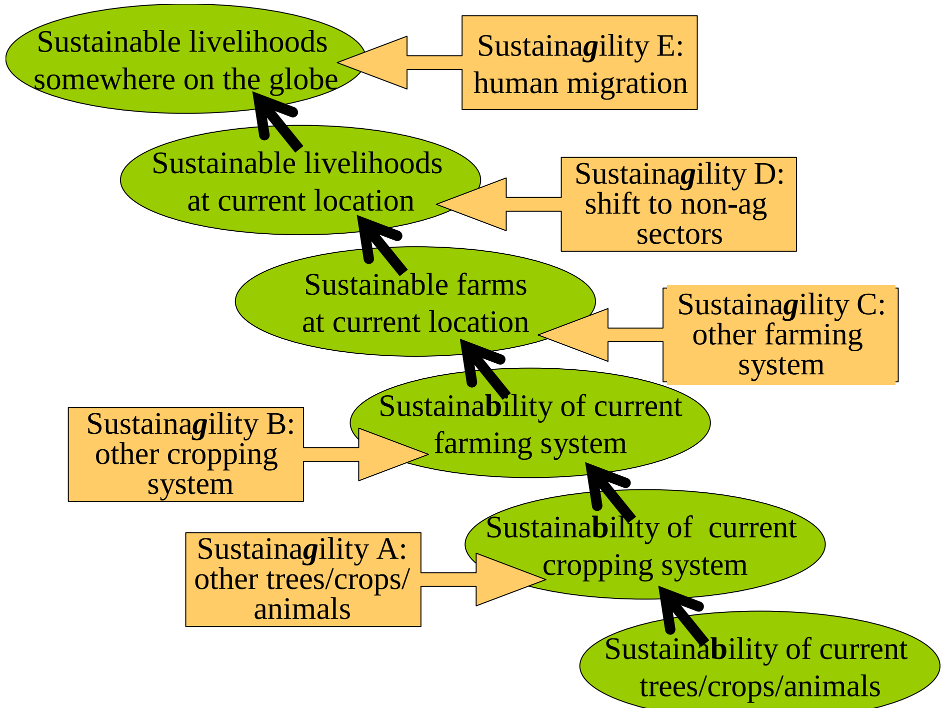

Figure 10. Sustainagility, the support and resource base for future change and adaptation complements the 'persistence' axis of sustainability criteria across scales (Verchot et al., 2007)

In the discussion of 'adaptation' to climate change, two situation occur:

1. We can predict the direction and size of the change and can adjust what we do,
2. There is uncertainty on direction and size of local change but greater variability is likely: we need to increase buffering and resilience.

The first situation calls for technical planning of specific interventions, the latter for support of diversity, resilience and buffering. So far, however, the main attention and financial resource allocation has been for the former, as this appears to be more tangible. The main role of agroforestry in climate change adaptation is probably in the maintenance or enhancement of diversity and buffering. Given existing uncertainty in markets and climate, this is probably a 'No regrets' approach, focusing on what makes sense anyway.

6. Emission reduction through agroforestry

Agroforestry covers a broad range of land use systems that are intermediate between 'forest' and 'open field agriculture'. The impacts of agroforestry on greenhouse gas emissions range according to the aboveground biomass, the litter layer that protects the soil surface, the degree of soil compaction that influences gas exchange with the atmosphere and the level of aeration in the soil, and with the nitrogen balance of the system (Kandji et al., 2006; Verchot et al., 2004). Emissions of nitrous oxide (N_2O) are associated with excess nitrogen under partial aeration – this can occur in systems with an abundance of biological N_2-fixation, as well as in systems that use large amounts of chemical fertilizer (Fig. 11).

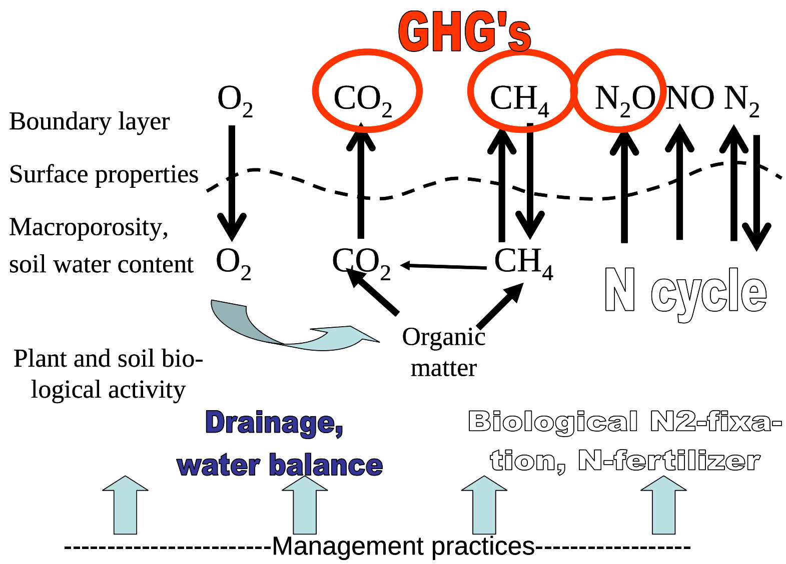

Figure 11. Processes of gas exchange between soil, vegetation and atmosphere that influence the net release of the various greenhouse gasses explain the response to management factors such as drainage, soil compaction and nitrogen supply

Where agroforestry replaces forest, the net effect on greenhouse gas emissions is negative, but less negative than it would have been if open-field agriculture or pastures would have replaced the forest. Where agroforestry starts in a degraded starting position it leads to a net sequestration of CO_2. The perspective on a net positive or negative effect will thus depend on the starting point. Looking at oil palm production in Indonesia from an outside perspective, it is clear that all current oil palm land was derived from forest, and nearly all in the last century – clearly oil palm leads to emissions. Looking at it from an individual plantation or company the story of oil palm planting may well have started on land that was already deforested or degraded. Calculating net emissions thus depends on the starting point, the attribution for past changes and current politics – the science part of it is easy, compared to these political complications. International agreements, such as the Kyoto protocol, tend to resolve part of this by choosing a historical reference date: deforestation before 1990 no longer counts, but recent changes do.

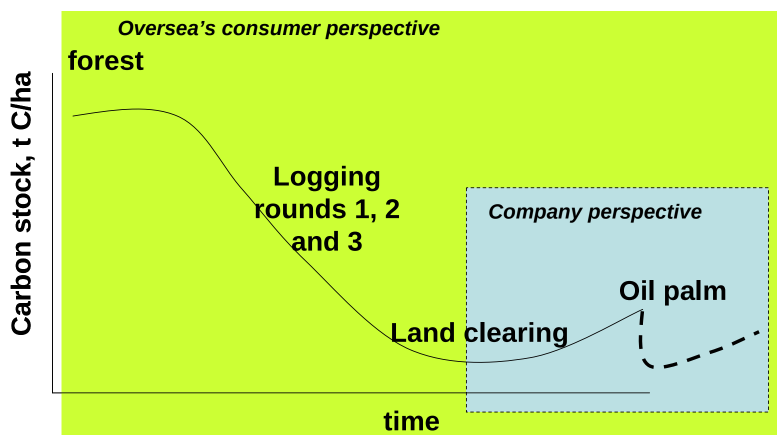

Figure 12. Scale dependence of the perspective on responsibility for past emissions: a company or enterprise (e.g. oil palm producers) will start counting from land that was already deforested, an external view on the sector as a whole will attribute the 'deforestation' losses to the subsequent user

7. Consequences for university education

The next generations of professionals and policy-shapers will have to deal with all this complexity and intermingling of biophysical, socio-economic and political aspects of land use. Is the current education system preparing them for such tasks?

Agroforestry, connecting the worlds of agriculture and forestry is easy at the level of farmers: they build on thousands of years of practical experience in managing landscapes and farms with trees. In the world of government, however, institutions for forestry differ in culture, mandate and agenda from those of agriculture. Trees are artificially divided over these two institutions, with trees such as rubber or coffee belonging to the agricultural domain. Although the ecological processes and principles apply across the spectrum of annual to perennial plants with less or more woody stems, there is a tradition that places 'forestry science' in a separate category from 'agricultural' science. To prepare students for jobs in these separate worlds of agriculture and forestry, academic conventions created different faculties. Southeast Asian countries and their universities followed this tradition of separate study programs. Thus, the segregation continued, and both agriculture and forestry schools missed out on important parts of the reality of the landscape and the rural people – who one side sees as 'farmers' and the other as 'forest dependent people' or 'local community' – that is if they have learnt to see them at all (van Noordwijk et al., 2007b,d; Kusters et al., 2007; Michon et al., 2007).

When thirty years ago the term 'agroforestry' was coined, it was meant to bring science and education closer to the practices, opportunities and constraints of the rural landscapes with trees and their struggle with the rules and bureaucracies of their countries. Agroforestry was focused on bridging between the two sides and on integration of economic and environmental goods and services that can be obtained.

Competing with this focus on 'integration' has been a tendency for the newly emerged agroforestry institutions to define and defend their turf, to demonstrate that agroforestry is a separate type of ***science*** and requires separate streams for ***education,*** while it requires a separate niche in the governments institutions as well. At the start, the Southeast Asia Network for Agroforestry Education (SEANAFE) was part of this movement to create new streams of education, get recognition for a new type of professionals and for the academic curricula and study programs that prepare them for a new type of jobs. However, reality was that these new streams would grow out of existing schools of forestry or agriculture. Rarely would they be connected to both in equal measure…

A number of distinct competencies and skills are needed for different aspects and stages of 'negotiation support' (van Noordwijk et al., 2001; Tomich et al., 2007), to assist lowland and upland, external and local stakeholders to negotiation rules and rewards for managing the landscape aligned with the multiple functions needed. Salience, credibility and legitimacy are all needed before ***information*** has a chance to be incorporated into ***knowledge,*** but even that is not enough to lead to ***action***. The incentives for action will have to come from a combination of carrots, sticks and sermons: positive incentives for voluntary action, enforcement of rules for minimum acceptable behaviour and enhancement of self-regulation by focus on negative consequences of short-term behaviour (Fig. 13).

The new study programs for Agriculture in Indonesia will recognize an 'agribusiness' and an 'agro-eco-technology' stream for professional education. The first will focus on the external relations of agricultural landscapes, the second on the internal ones. The interfaces between *internal* and *external*, however, will have to take a prominent place in both, as the reality of current-day farms is determined by a complex network of relations (Fig. 14).

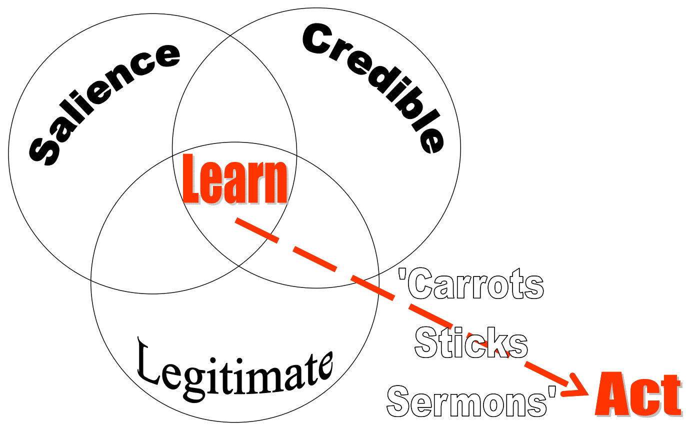

Figure 13. Linking knowledge to action requires incentives in the form of carrots, sticks and/or sermons

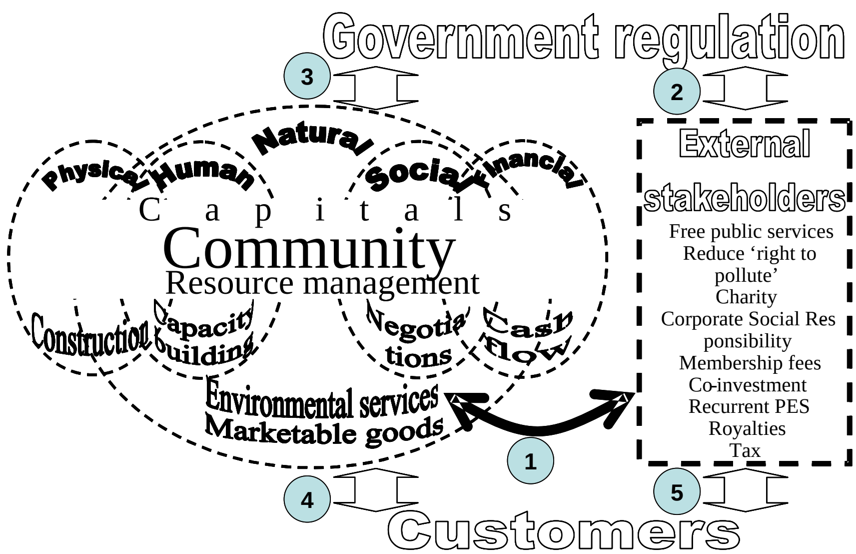

Figure 14. The rural landscape mosaics of forest, agroforestry and agriculture are producers of both environmental services and marketable goods, by combining the flows derived from natural, physical, human, social and financial capital stocks; the demand for these goods and services by 'customers' is modulated by various types of 'agribusiness' and intermediaries; the types of land use that can produce these goods and services is influenced by 'external stakeholders', who may try to get a continuation of past services for free, based on regulation, and by existing government regulation

Many of the graduates from either stream in agriculture, forestry or agroforestry will have to function as 'boundary agent, able to link the 5 ways of knowing, assisting stakeholders in negotiating realistic, voluntary and conditional (outcome-based) business deals, whether aimed at conventional markets for goods ('agribusiness'), or at maintenance or increase of environmental services (Swallow et al., 2007; van Noordwijk et al., 2007c).

Analysis of the stages that are necessary to bridge across the multiple knowledge (LEK, MEK, PEK) (Joshi et al., 2004)and actor perspectives in the negotiation of local resource management agreements, suggests that the ‘realistic’, ‘voluntary’ and ‘conditional’ aspects of such agreements need attention in different stages of the process (van Noordwijk et al. 2001; 2007c) (Fig. 15). A number of rapid appraisal tools for hydrology, agrobiodiversity, carbon stocks, market access and land tenure claims are now available for testing.

Scoping: K⇔ K ***Realistic***	**Stakeholder identifi-cation: A ⇔ A** ***Voluntary, Pro-poor?***
Negotiation: (K ⇔ K) ⇔ (A⇔ A), aiming for (unified K ⇔ unified A) ***Conditional***	
Implementation, Monitoring and Learning: unified K ⇔ unified A (or reverting to (K ⇔ K) ⇔ (A⇔ A) ***Transparent***	

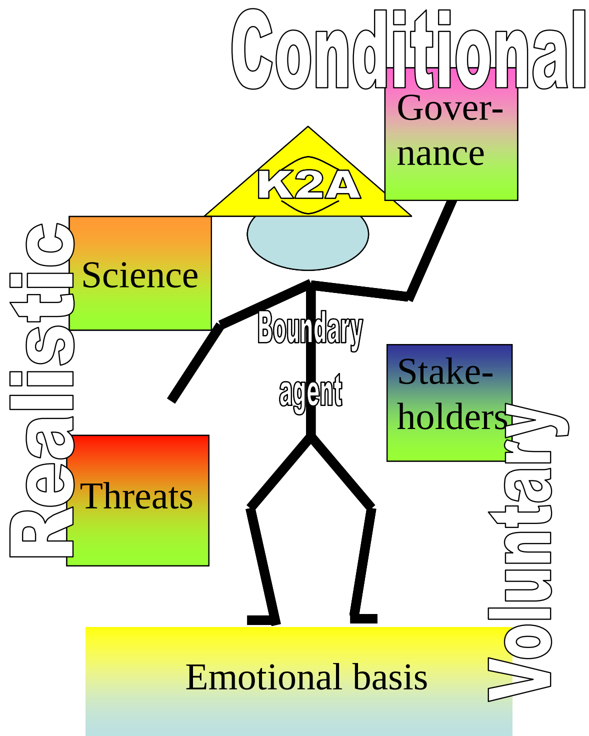

Figure 15. The boundary agent and her/his ability to link 5 ways of knowing and the emergence of realistic, voluntary, conditional ‘deals’ through a process of negotiation; K = knowledge, A = actor.

In redesigning the curricula of colleges and universities, the simple context + mechanisms => outcome scheme can be of use:

Context + Mechanism ➔ Outcome

Skills, values, aspirations of students ; opportunities of the local environment ; abilities of the faculty staff

Design of curriculum as series (or menu) of learning experiences to build up credibility & legitimacy

Monitoring process and product for quality control; dynamic alignment with national standards

If this is done well, Indonesia will have competent, professional and agile guides on the complex pathway to a future where globalization and climate change will compete for attention as the major determinants of change in the livelihoods of rural and urban people. Sustainable development can not be charted, but many negatives conditions can be sufficiently defined to avoid them, and the skills/competencies needed to negotiate the corners that we'll all have to take can be defined.

Box 1. Some key points for further discussion:

The world brings more diversity to most urban consumers while it is rapidly losing global diversity

When criteria for environmental services are defined, forms of agroforestry (such as 'kebun lindung') may be able to meet them and the monopoly of 'forest' as providers of such services is undermined

Climate change implies changes in demand for goods and services as well as ability of trees to provide: adaptation is needed at tree/farm/landscape scales; yet current change via markets will likely remain dominant

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