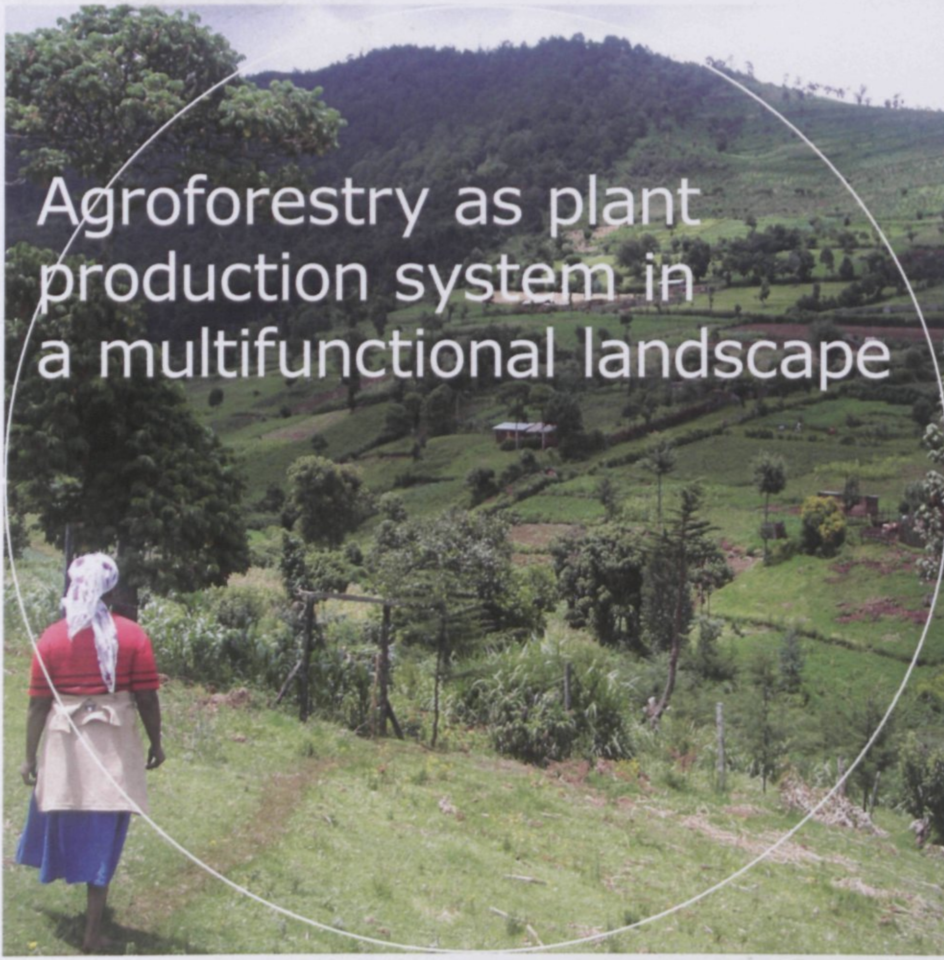
Agroforestry as plant production system in a multifunctional landscape



Prof. dr Meine van Noordwijk

Inaugural lecture upon taking up the post of Special Professor of Agroforestry at Wageningen University on 16 October 2014

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Introduction

Agroforestry[1], the topic of this public lecture, refers to the (re-) integration of agriculture and forestry. It includes trees on farms, farmers in the forests and the manifold interactions between agriculture and forestry as the basis of rural livelihoods, as components of landscapes, as sectors of the economy and as opportunities and challenges to achievement of sustainable development goals in general.

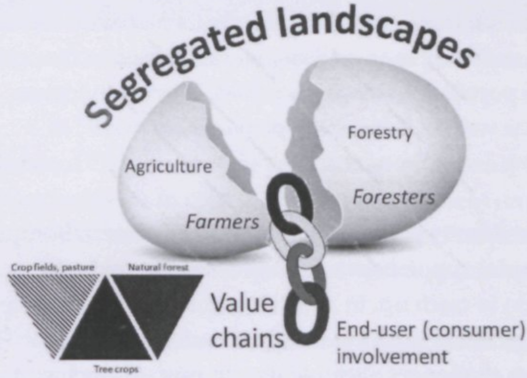


Figure 1. *The counterfactual to agroforestry is a world where agriculture and forestry are handled as separate domains of practice, science and policy*

For a long time the dominant paradigm was that the world would be a better place if ***'forests'*** and ***'agriculture'*** would be handled as separate domains of policy, institutions and disciplines for applied science. It's time for that 'theory of change' to change itself. Coining the term agroforestry, some 40 years ago, has created some space to do so, as we will see, but more is needed.

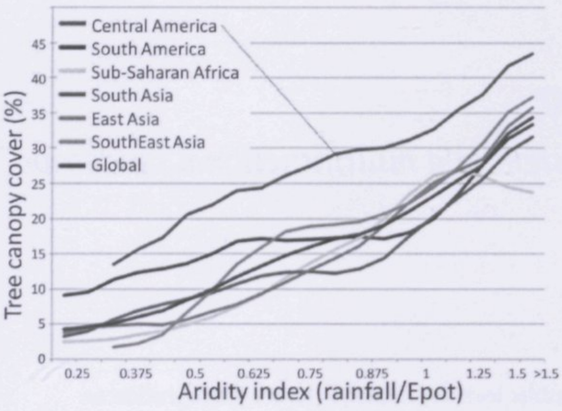


Figure 2. Tree cover in agricultural lands in 2010 in relation to an aridity index, by region[2]

According to the most recent global data set on 'trees on farms', compiled by Robert Zomer and colleagues[2], 43% of agricultural land, with 30% of the global rural population, has at least 10% tree cover. Between 2000 and 2010, the area involved increased from 8.8 to 9.6 million km². Yet, there are substantial regional differences, which primarily relate to rainfall, as captured in an aridity index as shown in the graph. The relationship with human population density is mixed. There is evidence for a '***more-people-less-trees***' phase as well an '***even-more-people-more-trees***', as known from site-specific case studies[3].

Relative to the climatic potential, tree density on farms is low in northwestern Europe and, as mine is the first-ever professorial appointment at Wageningen tasked with agroforestry, there is some work to do to catch up. In 20% of my time I'll have to help Wageningen understand the 43% of global agriculture that is, in fact, agroforestry. There may be opportunities as well as challenges ahead of me. Of course, much is going on already under other names but more coherence and coalitions on trees in the agricultural landscape may help.

Innovative research that started over 20 years ago in southern France by Christian Dupraz and colleagues has shown that high-value timber trees can be well integrated in mechanized, intensive cropping systems[4]. As long as the economic value per unit resources captured by trees matches that by crops[5], an economic break-even scenario is possible, with opportunities for risk reduction, protection during climatic extremes, and ecological co-benefits.

Figure 3. Examples of current agroforestry practices on European and tropical farms

Rebecca Chaplin-Kramer and colleagues[6] recently showed that the primary sources of micronutrients in diets are far more dependent on pollinators than the staple food crops that provide calories; and trees in agricultural landscapes with their understorey can support pollination functions, although further quantification is desirable.

Fine-tuning agroforestry systems to meet local conditions is hard work, as there are strong positive plus strong negative interaction terms at play, above- as well as belowground[7], but where farmers get organized to take up the challenge, real progress can be made. The primary obstacle, especially in a European context, has been that the rules, subsidies and incentives for 'forest' have developed in institutional isolation from those for 'agriculture'. Until recently agroforestry experiments in France were 'illegal' and only as recent as 2005 did the EU acknowledge that partial tree cover on farms exists and might even be functional. It is now included in the Common Agricultural Policy (CAP)[8], thanks to persistent lobbying by the European Agroforestry Federation (EURAF). A cultural, political economy lens may be needed to understand the forces at play, as the bureaucratic jungle is bewildering for a simple agroecologist.

In my opening sentence I mentioned 're-integration' of agriculture and forests and, indeed, if we go back, say, 10,000 years[9] we can see trees, crops, livestock and farms interacting with semi-natural vegetation, land and water, as well as budding urban markets, long before 'forests' were defined as an institutional entity. In the Greek and Roman literature, a differentiation between *hortus* and *ager* was made: differentiated by the presence of tree crops versus prevalence of tillage. However, *sylva* or woodlands were associated with shipbuilding and 'wilderness' in both its negative (security) and positive (romantic) associations. In northwestern Europe, the first traces of the segregation of land claimed by nobility or the Crown as privileged hunting grounds versus land belonging to village communities occurred over 1000 years ago. Lines were drawn on maps with a sylva *forestis*, or woodland behind the border. Forests, thus defined as lands beyond a boundary, out of reach of the village, were controlled by the elite.

The Magna Carta, drawn up to appease a revolt against the politically weak King John in the England of 1215, includes a clause that promises to 'deforest' land recently claimed by the Crown, returning it to be commons (or to local elites?). The importance of large trees for ships' masts brought in the navy as key stakeholder of forests; the first English-language treatise on forests was commissioned by the navy and written by John Evelyn[10], who was otherwise fond of, and an expert in, apple trees. The further history of how forestry developed into a timber-based economic enterprise, often in conflict with villagers and their livestock, has been well described. Forestry became a separate institution, foresters a separate tribe with their own cultural traditions, music and uniforms, trained in separate schools, supported by separate research institutions, laws, taxes and incentive schemes.

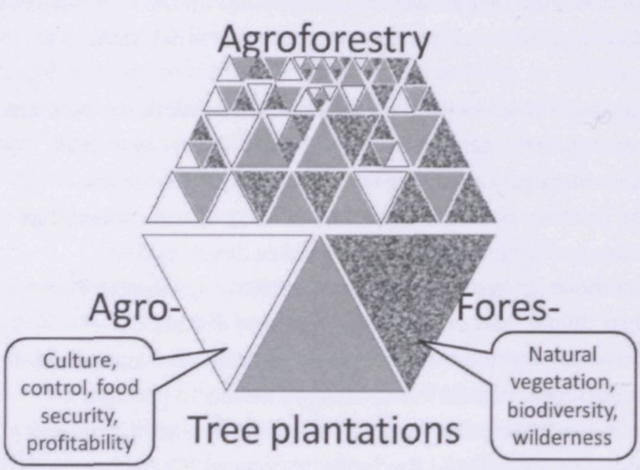


Figure 4. *Spatially segregated (bottom) or integrated (top half) approaches to crops, trees and forests as part of multifunctional landscapes*

Meanwhile, trees disappeared from the farmlands as they were 'invisible' to the powers that saw the political relevance of cheap food for the urban masses and industrial workforce as justification for substantial public investment in 'land reclamation' schemes, reorganizing the landscape and replacing the fine-grained mosaics of the past with a much coarser pattern. The planners might have seen three elements: agriculture, production-forest plantations and conservation (wilderness) areas but were charmed by an 'apartheid' thinking that favoured spatial segregation. Yet, the same three colours can be used to describe more integrated landscapes; and the empirical question is under what conditions coarser—or finer-grained—mosaics will emerge in response to the demand for multiple functions. The likely answer is that a diversity of solutions is superior to any single one.

The question 'who decides' has many answers and the negotiated outcome is based on many different ways of interpreting the history, current challenges and future opportunities of any place. Protecting a part of the landscape has wider external implications for loss of forest in adjacent areas than often is appreciated[11].

Three knowledge value-chains as basis for this lecture

In trying to appreciate how the relevant people act, we need to acknowledge three broad categories of knowledge systems, each with their own dynamics, rules of the game and internal distinctions and differentiation. The Local Ecological Knowledge (LEK) of farmers, the Public and Policy Ecological Knowledge (PEK) of public discourse, policies and legislation, and the modellers' or scientists ecological knowledge (MEK) of science with all its many disciplines.

Agroforestry exists on the interface of these three knowledge systems and science can only hope to contribute insights to farmers and society at large if it makes an effort to appreciate the three systems on their own and in interaction.
For the remainder of this lecture we'll do just that. First, delving a bit deeper into the policy dynamics and perspectives (PEK), as this may determine the salience or impact potential of the agroforestry science we want to develop. We will then explore the science of agroforestry (MEK) and its credibility in reviewing, revising and changing theories of how things work and how they can be influenced. Lastly, we focus on the practice and LEK, and the 'theories of change' that are currently framed as pathways to facilitate farmers to fully benefit from trees. We'll close with some comments on education and the need to reconcile LEK, MEK and PEK with the T-shaped skills (breadth and depth) that Wageningen stands for with its theories and policies of education.

A. Policy: willingness and ability to act

A1. Political economy of the Agriculture vs Forest segregation as historical pattern

As stated, policy attention on forests has for a long time been based on hunting privileges and ship building. However, since the 19th century, a German school of plantation-forest management gained a following in the tropics, with the Java-based teak enterprise as a prime example.

After forests were segregated from village land, the challenge for forest managers was to gain access to a labour pool. In more remote areas this meant attracting temporary labour for logging or the labour-intensive tree-establishment phase and moving to new frontiers for the subsequent decades of low-maintenance tree growth. Instead of paying for the labour, foresters found that allowing local people to grow food crops between the trees in the early stages provided sufficient incentive, cutting costs for the forest enterprise and potentially reducing conflict with forest-edge villages. The *taungya* system was born, borrowing the name from a form of swidden management in mainland Southeast Asia. But it has taken several decades of further evolution before forest managers understood that the villagers need to have a real economic stake in success of the trees. Otherwise their management of the agroforestry plots is centred on finding new ways to slow down but not completely kill the trees to retain longer access to the plots

Anecdote 1: Not everybody likes trees. A retired farmer lived in a small house at the foot of the dyke and found that a willow tree blocked his view of who all were passing by, which had become his major pastime. The willow tree grew on the dyke and could not be removed without conflict with the authorities. But he was allowed to water the tree. Every morning after boiling water for his coffee, he poured a kettle of hot water on the roots of the tree and it finally died; so he had a view. This farmer's father, son and three great-grandsons were called Meine, including your speaker.

The farmer of the story was my great-grandfather, whose character and interest in an open world view, beyond an interest in roots and trees, I inherited. According to the most recent visit to the place with Google Streetview, the trees are back.

Forests as institution: new relations with 'community'

You may have the impression by now that I don't like foresters, even though I deeply care about forests. That's not the whole story and there has luckily been substantial change in the way forestry as an institution interacts with the people who share their landscape with the remaining forest. In what is loosely called 'community forestry', important steps have been made towards a better balance, while recognition of indigenous rights has a good track record of maintaining forest conditions and functions whereas state-sanctioned concessions to large-scale operators have a miserable track record in many parts of the world (while doing better in others).

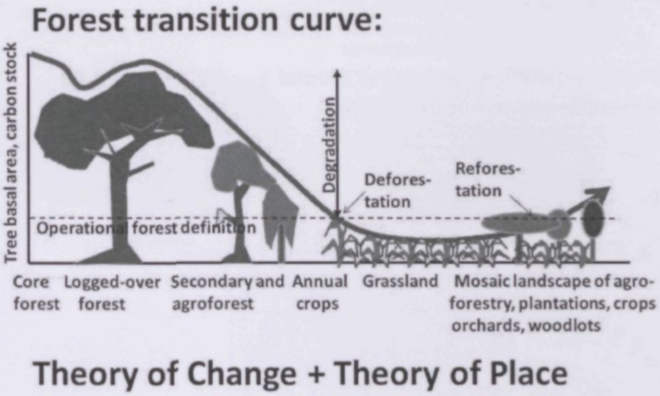


Figure 5. Forest transition as a theory of change (predicting change towards the right) and/or as a theory of place (describing existing spatial gradients)

In the analysis of changes in forest condition, the concept of a 'forest transition' has been helpful[12,13]. Deforestation and forest alteration lead to a loss of tree cover and a shift from diverse, naturally regenerated trees to a prominence of planted and genetically selected trees of only a few species, compared to the 100 000 tree species that are estimated to exist[14]. A shift to increasing total forest cover after a period of decline, the 'forest transition point' can actually occur at almost any human population density and any forest fraction.

In most cases, a change in the tenure regime for forests and a shift from conflict to cooperative relations between forest authorities and local communities preceded this transition.

In policy terms, there had to be 'willingness to act', with a longer term perspective on the net benefits of such policies. In the global experiments of the last decade to find effective ways to reduce greenhouse-gas emissions from deforestation and forest degradation in developing countries, this lesson is gradually emerging[15]. In summary: ***Successful forest policies hinge on reinventing functional relations with farmers and the market forces they respond to.***

A2. Agricultural policy focused on yield gaps: the rediscovery of trees

In the meantime, large amounts of public funding were used to remove trees from the agricultural landscape, with the Netherlands as front runner. In 1840, when von Thünen described the economic geography of rural landscapes in a self-sufficient economy, he described a sequence of segregated zones. Note that the *Forst Wirthschaft* was located close to the centre as wood was the major source of energy for cooking and was best grown close to the homes to reduce transport costs and keep an eye on it.

Spatial organization of productive landscapes around a town as represented by von Thünen (1842)

Figure 6. *Spatial organization of productive landscapes around a town as represented by von Thünen (1842)*[16] *for a self-sufficient state: a zone of* Freie Wirtschaft *providing vegetable, dairy and other products with short shelf life is surrounded by an (agro-) forestry* (Forst Wirthschaft) *zone providing wood fuel and other tree products with high transport costs, before zones of crop rotations* (Fruchtwessel, Dreifelder) *and animal husbandry* (Vieh Zucht)

But when wood energy and utility wood for farm implements lost their key role in the farm economy, replaced by fossil fuel and industrial products, trees were removed from the landscape. Agricultural modernization meant larger fields for larger machines, with deeper groundwater levels so they could get onto the field earlier in Spring.

The reference point for climate (temperature, humidity and wind-speed monitoring) had already been the conditions on airfields, sufficiently far from the disturbing effects of trees. Removing trees from the agricultural landscape changed the microclimate but provided a closer match with the weather data that were used in crop growth models. How much effect do trees and forest remnants have on maximum temperature in crop fields? The data vary but 2 °C is a fair guess[17]. What level of global warming is seen as a threshold we don't want to pass? Two degrees Celsius. Does any of the leading research into climate change and agriculture take the microclimatic effects of trees seriously? Not yet.

Yet, incorporating trees in the thinking about agricultural land use is likely to help in several of the emerging sustainable development goals[18]. In summary: ***Successful agricultural policies hinge on reinventing the relations farmers have with trees.***

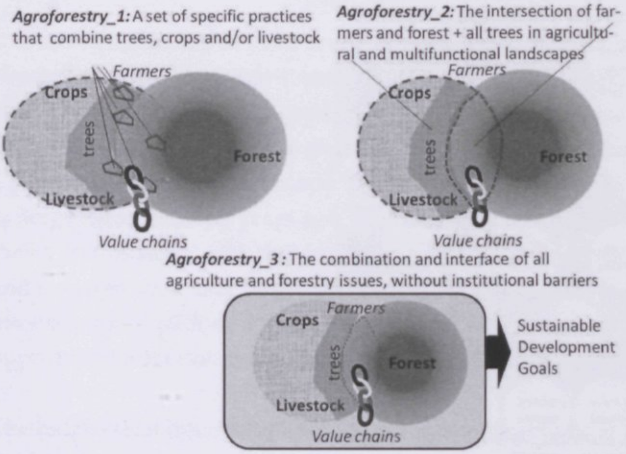


Figure 7. Three interpretations of the scope of agroforestry, relative to a counterfactual of the fully segregated agriculture versus forestry articulation of Figure 1

In this policy context, we see a third concept of what agroforestry is.

1. A set of technologies using trees, crops and animals.
2. The forest–agriculture interface, with trees-on-farms = trees-outside-forests, and farmers-in-forests, responding to market opportunities and policy constraints.
3. The sum total of agriculture and forestry, as there is no universally valid way to draw lines within the landscape continuum and we won't want to replace the complex issue of defining forests as different from agriculture to be further complicated by a boundary between agriculture and agroforestry plus one between agroforestry and forests. We need performance-based functional distinctions as the basis for policy, not rules based on form and or history.

B. Science: from fundamental understanding to practical solutions

B1. Tree–soil–crop interactions

In the first definition of agroforestry—as a set of practices that combine trees, crops and/or livestock—the primary focus of scientific analysis has been on the biophysical interactions between system components (trees, crops, soil, animals), within the constraints of climate, water and nutrient supply and pest and disease pressures. Measurements showed that the aggregate effect is based on potentially strong negative plus strong positive interactions, with a net effect that is neutral, negative or positive depending on circumstances[19]. At combined system level, resource capture tends to be larger in agroforestry, as the perennial component complements the phenology of annual components.

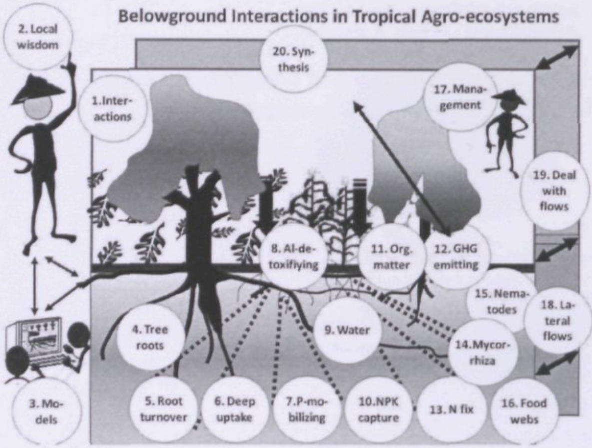


Figure 8. Belowground interactions in tropical agroecosystems[7]

The higher complexity of the belowground part of the system allows for more complementarity than the aboveground part, where the balance of negative and positive effects of shading and microclimate modification depend on the crop and overall water and nutrient stress in the system. Models that relate structure and architecture to function exist and perform reasonably well to account for these interactions. The biotic part of the story–pests, diseases, antagonists, pollinators—has wider gaps in our knowledge but it is also more likely to lead to positive interactions except where the trees act as alternate hosts for major crop pests. I will not dwell here on the many, very interesting details of this type of research, but refer you to synthetic models and reviews of the science[20].

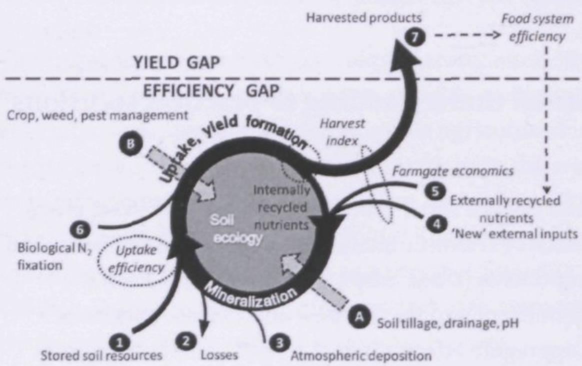


*Figure 9. Schematic representation of a nutrient cycle in agricultural systems, with yield gap (1-yield/ potential_yield) and efficiency gap (1-output*potential_input/(input*potential_output)) as summary parameters*[20]

In a recent summary of yield and efficiency gaps in agriculture[21], we found that these two gaps are not as tightly linked as many think. Where part of the literature assumes that closing yield gaps will automatically increase resource-use efficiency and others that the two gaps are negatively related, the empirical evidence supports a perspective of intrinsic independence, with opportunities for carefully crafted synergy. More than 25 years ago, my colleague Peter de Willigen and I defended the thesis, in this same aula, that knowing roots helps improve resource-use efficiency[22] and research since that time has further supported what is now called the 'ecological intensification' pathway. With perennial components, as in agroforestry, the opportunities for enhanced water and nutrient use-efficiency increase.

The biophysical interactions are the basis of interactions at the farm-economy level. Temporal complementarity of labour demand and partial independence of price fluctuations adds flexibility to farm management: they counteract positive economies of scale that favour specialization. Trees can provide high returns to labour, if one has the time to wait. Not putting all eggs in one basket is the popular version of economic portfolio theory. Key is the partial, neutral or even negative correlation between the fates of the baskets.

Anecdote 2: : To continue the family tree: the next generation, a Meine, was at some point in his career director of a secondary school. The school had a garden and the teachers agreed that teachers and pupils would be more directly involved in the maintenance of that garden. As director, he kindly offered to take the lead and take charge of the month of January. He understood that the only things above the ground in that month were trees and they don't require a lot of work.

Beyond the plot- and farm-level interactions between components of agroforestry systems, science has over the last one or two decades developed new insights in the interactions and system behaviour at landscape and community scale. This scale proved to be an essential step towards understanding interactions with global climate, global markets, global environmental conventions and the dream of sustainable development.

B2. Tree and climate interactions

The rates of photosynthesis, carbon capture, evapotranspiration and nutrient uptake, expressed per unit leaf area, are not drastically different between trees and annuals but the residence time in biomass differs by one-to-three orders of magnitude, from less than half to several hundreds of years. This storage in biomass means that cutting trees and converting forests brings carbon and nutrients back into circulation and allows stored bioenergy to be used. The climatic consequences of this release—that can be avoided by maintaining residence time—have received an inordinate amount of attention in the effort to slow global climate change. The more direct effects of trees on micro- and meso-climate have interestingly been noted in the urban environment, as trees help to reduce the 'heat island' effects of cities; that they also contribute to the 'cool island' effects of forests has been largely ignored.

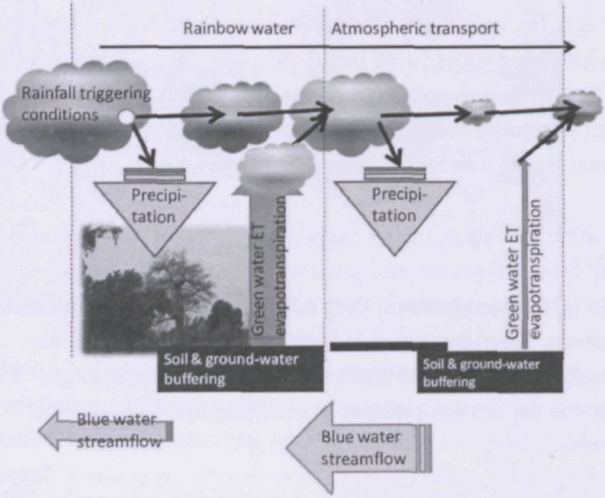


Figure 10. Interaction of small hydrological cycle, recycling 'green water', and the large ocean–land cycle with return flow through the 'blue water' of rivers[22]

The cooling effect of forests and trees is directly linked to their relatively high water use—with the fastest-growing trees transpiring the most—as the *Eucalyptus* debate has shown. This high use of 'green water' has a direct cost in terms of 'blue water': less stream flow is available for other uses, at least at the scale of a microcatchment. At larger scales, however, the 'small hydrological cycle' of evapotranspiration feeding rainfall complements the large cycle between oceans as the primary reservoir and land masses that feed rivers.

Staying in the tradition of colours of water, the precipitable water in the atmosphere is now termed 'rainbow water' and the costs to blue water are to be compared to benefits for rainbow water[23]. We can foresee that a new wave of 'hydroclimate' science will emerge beyond current carbo-climate science. It will change the appreciation for trees outside, as well as inside, forests.

That brings us to a third aspect of current science: the understanding of tree-cover transitions and the opportunities for leverage towards greater sustainability at societal scale[24].

B3. Tree cover transitions and 'sustainagility' science

The primary contribution that the 'forest transition curve' has made to science is its non-linearity. It hints at the existence of feedback loops that can be quantified, understood and influenced. Tree-cover transitions have major consequences for how food security is understood and achieved[25]. We now have a parallel discussion on soil-carbon transition curves[26]. It means that in both cases we shouldn't focus on reducing deforestation or loss of soil carbon as a rate constant because it is a symptom but on achieving the turnaround point from loss to gain at a higher stock level and reducing the lag time of the feedback loop, as dynamic properties of the socio-ecological system we are dealing with. The hierarchy of system leverage points that Donna Meadows provided is still of value[27].

Forest transition curves are largely an artefact of the way forest is defined, as the tree cover coming back to landscapes differs, often substantially, from what had been lost. Whether planted, tolerated or assisted natural regeneration, the 'new forests' respond to new demands and expectations. Under a very relaxed definition of 'forest', forests come back. Under a more stringent definition, the loss of natural forest is practically irreversible within policy-relevant time frames.

Perspectives on reversibility differ between albedo (directly responding to leaf area index and rapidly recoverable), carbon storage (large asymmetry in loss versus gain rates but not intrinsically different), soil conditions influencing infiltration (similar asymmetry), local-scale diversity and contributions to global biodiversity (largely irreversible for the most vulnerable biota, reversible for others). These differences mean that the 'sparing or sharing' debate has no single answer.

Are overall system goals better served by a segregation of intensive agriculture here and conservation focussed land use elsewhere or are integrated, multifunctional landscapes superior? System science, building on the analysis of intercropping, suggested 20 years ago that the answer depends on the shape of the trade-off curve, which itself varies between functions. However, the discussion between segregators and integrators became a watershed of values, intuition and belief systems among scientists, where both sides made selective use of evidence. Agroforestry tends to be in the 'integration' camp and aligns well with landscape services that need to be provided nearly everywhere—such as watershed services and agrodiversity—but less so with 'deep conservation' that can be achieved on a limited part of the area, provided it is the priority goal not diluted by too many compromises.

Interdisciplinary socio-ecological system science can help in the analysis and exploration of options but the language of land-use planning and decision support had to be replaced by support for messy, multistakeholder negotiations to acknowledge the complex realities on the ground. The way local perspectives and knowledge systems interact with public/policy knowledge proved to be at least as important as the value that scientific knowledge could add. A new science of comparative knowledge systems, or 'boundary work', is emerging, starting with typologies, classifications and comparative studies[28]. Agroforestry is part of the frontier in this new sustainability science or should we say 'sustainagility' science? The latter term is gradually gaining recognition[29].

C. Practice: systems that work for local livelihoods and as a basis for value chains

C1. Conditions for agroforestation

In discussions with farmers in all continents of the world (except Antarctica), a similar set of reasons comes up if we ask why they do or don't have trees on their farms. Farmers may be convinced that not having trees is better for them because trees have woody roots that make ploughing difficult, they provide too much shade, harbour birds that are pests to their crops, or block their view. If that is the case, so be it.

But many farmers tell a different story. They don't like trees on their farms because they don't want to be caught for illegal logging if they cut some of them for direct use, or for income if they have to capitalize their savings that grow with interest rates higher than banks. Or they don't like trees because they can't get the types and varieties of trees that would do well on their farms. Or they don't like trees because they live too far from the market to sell the fruit and no middlemen visit them at harvest season. Or they don't like trees because they fear their agroforest will be mistaken for a forest and be claimed by the forestry department, as has happened in parts of Indonesia. Or they respect local rules that forbid farmers to plant trees because those trees would establish private claims to land. Or they don't plant trees on the land they till because tree ownership is restricted to men.

We think that many of these reasons are valid in the current circumstances and that they can be part of 'theories of change': logical steps to remove bottlenecks to tree growing that can be removed for the benefit of both farmers and external stakeholders. But such theories of change must be framed within a theory of place, as locational specificity of constraints means that entry points for effective change differ along with local conditions. The revolutionary insight that scientists can have a meaningful two-way conversation with farmers is a breakthrough for many who have been trained in the primacy of science and the need for standardized, 'objective' survey methods. Further insights, for example, in gender differentiation of farmers' preferences come from the combination of role-play games and agent-based modelling[30].

C2. Incentives for landscape multifunctionality

There is, however, an additional rationale for farmers not to plant tree or remove the ones that grow there: the benefits of such trees are largely enjoyed by society at large while the opportunity costs for not growing cash crops are borne by the farmers. In the language of economists, the trees are 'externalities' and not taken into account in farm-level decision making. A possible solution for such cases is 'internalization of externalities'. This can take many forms. Many of these are usually discussed under the heading of 'payment for environmental services' or 'payment for ecosystem services' (in either case: PES)[31]. The idea is to provide economic incentives ('carrots') where regulation ('sticks') has not provided enough motivation. The third element of this triad ('sermons') is the most effective internalization if it aligns with social norms of behaviour that define identity. But it can backfire. The use of direct payments can even undermine existing social norms. To summarize in one sentence what took us more than a decade of action research to learn: approaches to PES that use a co-investment language and framing are more likely to work than those that simply follow the economists' belief in markets as the providers of all solutions.

C3. Agroforestry theories of place before theories of change

Agroforestry as a concept was framed more than 35 years ago[32] in the wake of a discussion on the Green Revolution. The caricature of that revolution was that scientists had discovered new technologies that farmers could apply, almost regardless of their circumstances, with benefits accruing to their families as well as society at large. This worked out in the relatively simple and uniform conditions of flooded rice paddies but it did not work in the more diverse and harsher upland conditions in many parts of Africa, Asia and Latin America. Existing use of trees in agrodiverse systems was seen as a major alternative and a council was set up to describe and promote these systems: the International Council for Research in Agroforestry (ICRAF). The initial discovery period brought many interesting examples to light but after a while it became clear that location-specific solutions were just that: if transferred elsewhere they didn't work so well. The need for a more critical research approach led to the change of ICRAF into a research centre and for it to join the family of international agricultural research centres, where it is now one of the largest of the member centres[33].

Agroforestry still doesn't have many silver bullets although advocates keep reinventing the wheel and declaring that trees with specific properties solve problems for many different farmers. Sometimes they do but usually not. What can be extrapolated are the basic concepts of how tree–soil–crop interactions relate crop and tree properties to local soil, climate, labour availability and market demands. What can be extrapolated is a way of local farmers' knowledge, the public/policy understanding and regulation of the world, and what scientists of various disciplines can bring to the negotiation table. We have many specific examples to share, many places and learning landscapes to visit for inspiration, but no standard recipes. Our theory of change is firmly connected to theories of place.

Anecdote 2: : One member of the generation further up my family tree was raised in open landscapes but lived the last 40 years of her life in a forest; she needed wide world views to feel really comfortable, without too many trees. My mother, trained as a biologist, focused on environmental education and the relevance of early experience to develop intuition and a value system, which, beyond knowledge, is needed to influences choices made later in life.
My own first research experience with trees was when I worked, 40 years ago, with the group of Herman Klomp at the Hoge Veluwe, exploring the diversity of spider webs in pine trees. On misty mornings this was easy. Later in the day I used a plant sprayer to get the same effect but many passersby did not fully appreciate the advanced scientific method I was using. I learned as much about tree canopy architecture as about spiders.

This brings me to theories of education as the last step in this lecture.

Theories of education

Wageningen University has an explicit 'theory of change' through which it educates students or helps students to educate themselves: it targets T-shape skills, meaning professionals who are both a specialist in at least one topic (the vertical axis) and a generalist who understands a broad range of topics. Looking at the WUR logo, an inverted U, it is even better if a student is a specialist in two widely different topics and covers all the space in between as a generalist.

There is a global need for people who are ***engineers*** (using theories of change, broad-based problem solvers), as well as ***academics*** (change of theory, depth and specialization), as well as ***boundary agents,*** able to support effective negotiations of change.

Agroforestry education, along the lines set out here, needs to go further than the T or inverted U. We need professionals who can be interlocutors of three complementary knowledge systems: science, farmers' knowledge and public/policy knowledge. We need Y-shaped skills!

The ICRAF logo of people-trees in a landscape configuration may symbolize these Y-shaped skills: combining the ***logos, ethos*** and ***pathos*** of classical rhetoric and the

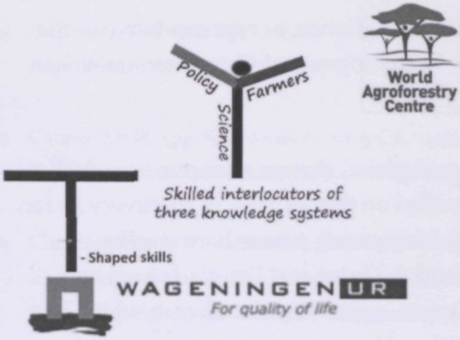


Figure 11. *Schematic relation between the T(or inverted U)-shaped skill articulation of the WUR to the Y-shaped skill perspective of this lecture and the people-tree logo of the World Agroforestry Centre*

credibility, legitimacy and ***salience*** of the more recent articulation of 'boundary work'. The three interpretations of what agroforestry is, ranging from technologies (logos, credibility), through trees in farmed landscapes (ethos, legitimacy) to the harmonization of agricultural and forestry policies (pathos, salience) relate to this triad.

Vote of thanks

Before closing it is time to express my thanks.

To the Rector and Board of Wageningen University for the trust given to me through this appointment.

To Tony Simons, Ravi Prabhu and the leadership of ICRAF for supporting the arrangement that allows me to spend ICRAF time in Wageningen.

To Ken Giller for taking the initiative and persisting in the process and to Ken, Martin, Maja, Peter, Peter, Peter, Lijbert, Jacques and all PPS, Plant and WUR colleagues and students who welcomed me warmly; also to the members of the Committee that advised the University in this matter.

To Freerk Wiersum, as early conversations with his father, who was my boss in my first job, helped us both in exploring what is now interdisciplinary agroforestry science.

To Piet Kuiper, who had hoped to be here in the audience, as representative of the generation of scientists in Utrecht, Arnhem, Wageningen and Groningen on whose shoulders I stand.

To all colleagues in the global agroforestry and global change science networks I'm part of, partners, students with whom I travelled on this journey of discovery so far, and with whom I hope to take further steps. Mentioning names here implies omissions but there is one with whom I shared the most and I'm glad she is here today, both as colleague and as part of the warm, supportive families to which I belong in the Netherlands as well as Indonesia.

Ik dank u voor uw aandacht, ik heb gezegd.

Notes and references

1 Agroforestry definitions and concepts have evolved from 1) a plot-level understanding of the interactions between trees, crops and livestock, via; 2) an understanding of the role of trees in production ecology (yield and efficiency gaps); to 3) that of multifunctional landscapes with trees; and 4) the reunification of forest and agriculture concepts in governance and sustainability debates.

2 Zomer RJ, Trabucco A, Coe R, Place F, van Noordwijk M, Xu JC. 2014. Trees on farms: an update and reanalysis of agroforestry's global extent and socio-ecological characteristics. Working Paper 179. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program. DOI:10.5716/WP14064.PDF.

3 Van Noordwijk M, Tomich TP, Verbist B. 2003. Negotiation support models for integrated natural resource management in tropical forest margins. Integrated natural resource management: linking productivity, the environment, and development. Cambridge, MA: CABI Publishing. p. 87–108.
Woldetsadik M. 2004. Population growth and environmental recovery: more people, more trees, lesson learned from West Gurageland. Ethiopian Journal of the Social Sciences and Humanities 1(1):1–33.
Critchley W. 2010. More people, more trees: environmental recovery in Africa. Practical Action Publishing.
Kabanza A, Dondeyne S, Tenga J, Kimaro D, Poesen J, Kafiriti E, Deckers J. 2013. More people, more trees in South Eastern Tanzania: local and global drivers of land-use/cover changes. African Geographical Review 32(1):44–58.

4 Dupraz C, Newman SM, Gordon AM. 1997. Temperate agroforestry: the European way. Temperate Agroforestry Systems. p. 181–236.

5 Cannell MGR, van Noordwijk M, Ong CK. 1996. The central agroforestry hypothesis: the trees must acquire resources that the crop would not otherwise acquire. Agroforestry Systems 33:1–5.

6 Chaplin-Kramer R, Dombeck E, Gerbert J, Knuth KA, Mueller ND, Mueller M, Ziv G, Klein AM. 2014. Global malnutrition overlaps with pollinator-dependent micronutrient production. Proceedings of the Royal Society B 281:20141799.

7 Van Noordwijk M, Cadisch G, Ong CK, eds. 2004. Belowground interactions in tropical agroecosystems. Wallingford, UK: CABI.

8 http://www.agroforestry.eu/node/287.

9 Miller FP. 2008. After 10,000 years of agriculture, whither agronomy? Agronomy Journal 100(1):22–34.

10 Evelyn J. 1664. Silva: or, a discourse of forest-trees, and the propagation of timber in his Majesty's dominions. London.

11 Dewi S, van Noordwijk M, Ekadinata A, Pfund JL. 2013. Protected areas in relation to landscape multifunctionality: squeezing out intermediate land use intensities in the tropics? Land Use Policy 30:38–56.

12 Van Noordwijk M, Villamor GB. 2014. Tree cover transitions in tropical landscapes: hypotheses and cross-continental synthesis. GLPnews 10:33–37.
Wiersum KF. 2014.Tropical forest transitions: structural changes in forest area, composition and landscape. CAB Reviews 2014 9, No. 018

13 Ordonez JC, Luedeling E, Kindt R, Tata HL, Harja D, Jamnadass R, van Noordwijk M. 2014. Tree diversity along the forest transition curve: drivers, consequences and entry points for multifunctional agriculture. Current Opinion in Environmental Sustainability 6:54–60.

14 Trees are a life form of plants rather than a taxonomic category; there may be about 100 000 different tree species in the world, spread over 250 plant families, representing about 25% of all plant species.

15 Van Noordwijk M, Agus F, Dewi S, Purnomo H. 2014. Reducing emissions from land use in Indonesia: motivation, policy instruments and expected funding streams. Mitigation and Adaptation Strategies for Global Change 19(6):677–692.

Van Noordwijk M, Matthews RB, Agus F, Farmer J, Verchot L, Hergoualc'h K, Persch S, Tata HL, Lusiana B, Widayati A, Dewi S. 2014. Mud, muddle and models in the knowledge value-chain to action on tropical peatland issues. Mitigation and Adaptation Strategies for Global Change 19(6):887–906.

16 JH von Thünen. 1842. Der isolierte Staat in Beziehung auf Landwirtschaft und Nationalökonomie. 3rd edn. Berlin.

17 Van Noordwijk M, Bayala J, Hairiah K, Lusiana B, Muthuri C, Khasanah N, Mulia R. 2014. Agroforestry solutions for buffering climate variability and adapting to change. In: Fuhrer J, Gregory PJ, eds. Climate change impact and adaptation in agricultural systems. Wallingford, UK: CABI.

Van Noordwijk M, Hoang MH, Neufeldt H, Öborn I, Yatich T, eds. 2011. How trees and people can co-adapt to climate change: reducing vulnerability through multifunctional agroforestry landscapes. Nairobi: World Agroforestry Centre (ICRAF).

Duguma L, Minang PA, van Noordwijk M. 2014. Climate change mitigation and adaptation in the land use sector: *from complementarity to synergy*. Environmental Management. DOI 10.1007/s00267-014-0331-x.

18 Mbow C, van Noordwijk M, Prabhu R, Simons AJ. 2014. Knowledge gaps and research needs concerning agroforestry's contribution to sustainable development goals in Africa. Current Opinion in Environmental Sustainability 6:162–170.

19 Various efforts have been made to capture the interactions between crops and trees in simple terms: $I_{tc} = F_{tc} + C_{tc} + M_{tc} + B_{tc}$ (I_{tc} = Tree-effect-on-crop, F_{tc} = fertility effect (short + long term), C_{tc} competitive effect (above- + belowground), M_{tc} = microclimatic effect, B_{tc} = biotic effect; all vice versa for crop effects on tree I_{ct}); Ong CK, Huxley PA, eds. 1996. Tree–crop interactions: a physiological approach. Wallingford, UK: CABI.

20 Van Noordwijk M. 2014. Climate change: agricultural mitigation. In: van Alfen N, ed. Encyclopedia of Agriculture and Food Systems. Vol. 2. San Diego: Elsevier. p. 220–231.

21 Van Noordwijk M, Brussaard L. 2014. Minimizing the ecological footprint of food: closing yield and efficiency gaps simultaneously? Current Opinion in Environmental Sustainability 8:62–70.

22 De Willigen, P, van Noordwijk M. 1987. Roots for plant production and nutrient use efficiency. PhD thesis. Wageningen, Netherlands: Agricultural University Wageningen.

23 Van Noordwijk M, Namirembe S, Catacutan DC, Williamson D, Gebrekirstos A. 2014. Pricing rainbow, green, blue and grey water: tree cover and geopolitics of climatic teleconnections. Current Opinion in Environmental Sustainability 6:41–47.

24 Bernard F, van Noordwijk M, Luedeling E, Villamor GB, Gudeta S, Namirembe S. 2014. Social actors and unsustainability of agriculture. Current Opinion in Environmental Sustainability 6:155–161.

25 Van Noordwijk M, Bizard V, Wangkapattanawong P, Tata HL, Villamor GB, Leimona B. 2014. Tree cover transitions and food security in Southeast Asia. Global Food Security. 3:200-208.

26 Van Noordwijk M, Goverse T, Ballabio C, Banwart S, Bhattacharyya T, Goldhaber M, Nikolaidis N, Noellemeyer E, Zhao Y. 2015. Soil organic carbon transition curves: reversal of land degradation through management of soil organic matter for multiple benefits. SCOPE review of multiple benefits of soil organic carbon. Wallingford, UK: CABI. pp 26-46.

27 Meadows D. 1999. Leverage points: places to intervene in a system. Hartland, VT: The Sustainability Institute.

28 Clark WC, Tomich TP, van Noordwijk M, Guston D, Catacutan D, Dickson NM, McNie E. 2011. Boundary work for sustainable development: natural resource management at the Consultative Group on International Agricultural Research (CGIAR). Proceedings of the National Academy of Sciences. DOI:10.1073/pnas.0900231108.

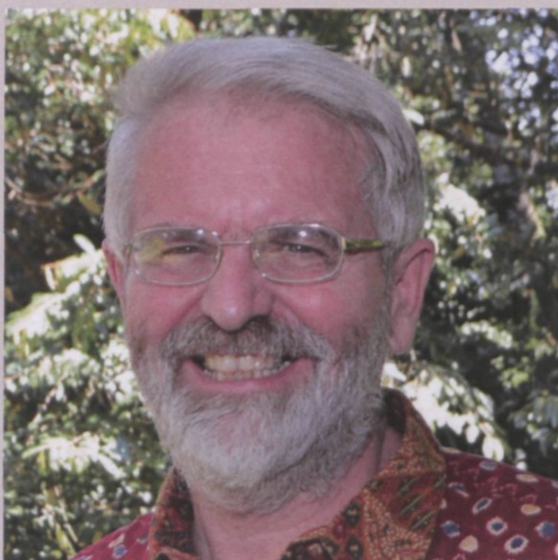
29 Sustainagility is defined and used, for example, in:
Verchot LV, van Noordwijk M, Kandji S, Tomich TP, Ong CK, Albrecht A, Mackensen J, Bantilan C, Anupama KV, Palm CA. 2007. Climate change: linking adaptation and mitigation through agroforestry. Mitigation and Adaptation Strategies for Global Change 12:901–918.
Jackson LE, van Noordwijk M, Bengtsson J, Foster W, Lipper L, Pulleman M, Said M, Snaddon J, Vodouhe R, 2010. Biodiversity and agricultural sustainagility: from assessment to adaptive management. Current Opinion in Environmental Sustainability 2:80–87.
Plus the publications referenced in notes 21 and 24.

30 Villamor GB, Desrianti F, Akiefnawati R, Amaruzaman S, van Noordwijk M. 2013. Gender influences decisions to change land use practices in the tropical forest margins of Jambi, Indonesia. Mitigation and Adaptation Strategies for Global Change 19(6):733–756.
Villamor GB, Chiong-Javier E, Djanibekov U, Catacutan DC, van Noordwijk M. 2014. Gender differences in land-use decisions: shaping multifunctional landscapes? Current Opinion in Environmental Sustainability 6:128–133.

31 Van Noordwijk M, Leimona B, Jindal R, Villamor G B, Vardhan M, Namirembe S, Catacutan D, Kerr J, Minang PA, Tomich TP. 2012. Payments for Environmental Services: evolution towards efficient and fair incentives for multifunctional landscapes. Annual Review of Environmental Resources 37:389–420.

32 Agroforestry as a formally institutionalized field of science and education celebrated 35 years in 2013 after the foundation of ICRAF in 1978 as a landmark (after an informal start in 1977 at the Koninlijk Instituut voor de Tropen in Amsterdam).
Wassink JT. 1977. Agroforestry: een samenspel van land- en bosbouw ten behoeve van de mens en zijn milieu. Amsterdam: Koninklijk Instituut voor de Tropen.
King KFS, Chandler MT. 1978. The wasted lands: the program of work of the International Council for Research in Agroforestry (ICRAF). Nairobi: International Council for Research in Agroforestry.

33 Agroforestry is the primary mandate of one of the 15 CGIAR centres (that is, ICRAF) and it is an explicit part of one of the overarching CGIAR research programs (on forests, trees and agroforestry: livelihoods, landscapes and governance) and implicit in a number of other programs aimed at integrated system approaches for intensification of drylands, humid tropics, water and soil management, as well as climate change and food systems.



Prof. dr Meine van Noordwijk

'Forests' and 'Agriculture' have long been handled as separate domains of policy, institutions and science. That 'theory of change' needs to change itself. Agroforestry refers to the (re)integration of agro- and forestry. It includes trees on farm, farmers in the forest and the manifold interactions between agriculture and forestry as basis of rural livelihoods, as components of landscapes and a economic sectors. Integration of local, public/policy and scie based knowledge is needed to achieve sustainable developm goals with and through trees.

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