DELIVERING ON THE PROMISE OF AGROFORESTRY

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Abstract. Agroforestry – the traditional practice of growing trees on farms for the benefit of the farm family and for the environment – was brought from the realm of indigenous knowledge into the forefront of agricultural research less than two decades ago. It was promoted widely as a sustainability-enhancing practice that combines the best attributes of forestry and agriculture. Based on principles of natural resource management and process-oriented research, agroforestry is now recognized as an applied science, that is instrumental in assuring food security, reducing poverty and enhancing ecosystem resilience at the scale of thousands of smallholder farmers in the tropics.

Trees on farms provide both products and services: they yield food, fuelwood, fodder, timber and medicines, which farm families can use at home or take to market to bring in much-needed cash; they replenish organic matter and nutrient levels in soils and they help control erosion and conserve water. The International Centre for Research in Agroforestry, and its partners, are working to integrate the functions of trees with policy and institutional improvements that aim at facilitating wide-scale adoption by farmers.

Two examples described in this paper are replenishing soil fertility in sub-Saharan Africa using short-term improved tree and shrub fallows and the results of agroforestry research to support significant land tenure policy in southeast Asia.

Although just one option in sustainable land-use, science-based agroforestry has the potential to produce economically, socially and environmentally sound results for the billions of people who depend on this ancient practice and modern science.

Key words: agroforestry, environmental protection, food security, improved fallows, land-use systems, soil fertility, sustainability, tree tenure.

From panacea to an applied science

Agroforestry – putting trees on farms for the benefit of farm families and the environment – is an ancient practice that was transferred from the realm of indigenous knowledge into agricultural research about 25 years ago (Bene et al., 1977). During the 1980s agroforestry was promoted widely as a sustainability-enhancing practice with great potential to increase crop yields, conserve soil and recycle nutrients while producing fuelwood, fodder, fruit and timber (Steppler and Nair, 1987; Nair, 1989). At that time agroforestry was regarded as almost a panacea for solving land-use problems in the tropics. Many development projects pushed agroforestry technologies without the backing of solid research. During the 1990s however, agroforestry research has gradually been transformed from a collection of largely descriptive and empirical studies into more scientific approaches, based on process-oriented research (Sanchez, 1995; Young, 1997; Buck et al., 1999).

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Agroforestry is now recognized as an applied science based on principles of natural resource management (TAC, 1999; Izac et al., 1999). The application of such principles includes the following research practices:

- Participatory, multidisciplinary and analytical approaches
- Technological and policy research
- Working at different spatial and temporal scales
- Beneficiaries at the community, national and global levels
- Working through the research–development continuum
- Working in partnership with governmental and non-governmental organizations
- Moving rapidly into on-farm research with a decreasing degree of researcher control
- Assessing impact in economic, social and environmental terms
- Being a credible partner in development

Agroforestry is a very extensive practice. It is found from the Arctic to the south temperate regions, but it is most extensive in the tropics. Approximately 1.2 billion people (24% of the world's population) depend directly on agroforestry products and services in rural and urban areas of developing countries (Leakey and Sanchez, 1997).

Agroforestry products include fuelwood, livestock fodder, food, fruits, poles, timber and medicines. Agroforestry services include erosion control, soil fertility replenishment, improved nutrient and hydrological cycles, boundary delineation, poverty reduction as well as enhanced food security, household nutrition, watershed stability, biodiversity, and carbon sequestration. Many agroforestry systems are superior to other land use systems at global, regional, watershed and farm scales because they optimize trade-offs between increased food production, poverty alleviation and environmental conservation (Izac et al., 1999).

Such developments are all well and good, but after 25 years has the promise of agroforestry been realized? The answer is increasingly yes. Some indigenous agroforestry systems have withstood rigorous scientific tests and now serve as examples that can be used across the tropics. The complex agroforests of Indonesia are one such example (Michon, 1997). Research based on the principles of competition for light, water and nutrients (Ong and Huxley, 1996), as well as on the complexity of interacting socioeconomic and biophysical factors (Sanchez, 1995), have led to new agroforestry components that indeed increase the sustainability and profitability of existing farming systems. Two such components are the domestication of indigenous trees (Leakey et al., 1996; Leakey and Tomich, 1999) and soil fertility replenishment (Buresh et al., 1997). In the process some widely promoted practices have not met the science-based tests and are no longer advocated at a large scale.

This paper describes two contrasting agroforestry developments that are working effectively to assure food security, reduce poverty and enhance ecosystem resilience at the scale of thousands of smallholder farmers. The first deals with the removal of a biophysical constraint, and the second the removal of a policy constraint. These examples come from the work of ICRAF and its partners because I am most familiar with them. Readers should recognize there are several other examples of successful agroforestry that have been produced by a wide variety of institutions across the world (Buck et al., 1999).

Soil fertility in Africa

The first example deals with a problem that was invariably identified by farmers in diagnosis and design exercises throughout the subhumid and semiarid tropics of sub-Saharan Africa (henceforth Africa). Soil fertility depletion in smallholder farms is now recognized as the fundamental biophysical root cause responsible for declining food security in this region (Sanchez et al., 1997a,b; Pieri, 1998). By fundamental root cause I mean that no matter how effectively other constraints are remedied, per capita food production in Africa will continue to decrease unless soil fertility depletion is effectively addressed.

During the 1960s, the fundamental root cause of declining per capita food production in Asia was the lack of short-statured, high-yielding varieties of rice and wheat. Food security was only effectively addressed with the advent of improved germplasm in this region. Then other key aspects that had been largely ineffective (enabling government policies, irrigation, seed production, fertilizer use, pest management, research and extension services) came into play in support of the new varieties.

The need for soil fertility replenishment in Africa now is analogous to the need for "Green Revolution-type" germplasm in Asia three decades ago. Two of the fathers of the Green Revolution, Norman Borlaug and M.S. Swaminathan certainly agree with this analogy (Borlaug and Dowswell, 1994; M.S. Swaminathan, personal communication, July 1998). A full description of the magnitude of nutrient depletion, its underlying socioeconomic causes, the consequences of soil fertility depletion and the various strategies for tackling this constraint have been described elsewhere (Buresh et al., 1997; Sanchez et al., 1997a,b; 1999). I will focus on an agroforestry approach, product of 10 years of research by ICRAF and collaborators.

Nitrogen and phosphorus are the most severely depleted nutrients in smallholder African farms. Although such constraints can be effectively addressed with imported mineral fertilizers, economic and policy constraints make mineral fertilizer use extremely limited in such farms. But Africa has ample nitrogen and phosphorus resources – nitrogen in the air and phosphorus in many rock phosphate deposits. The challenge is to transfer these natural resources to where they are needed in plant-available forms. For nitrogen this is achieved with biological nitrogen fixation by leguminous woody fallows, and for phosphorus with the direct application of reactive, indigenous rock phosphate in combination with biomass transfers of non-leguminous shrubs.

Two-year leguminous fallows accumulate about 200 kg N ha^{-1} in its leaves and roots which, upon incorporation into the soil and subsequent mineralization provide sufficient nitrogen for two or three subsequent maize crops, doubling to quadrupling maize yields (Kwesiga and Coe, 1994; Kwesiga et al., 1997; 1999). The greatest impact of this work is in southern Africa where about 10 000 farmers are now using *Sesbania sesban*, *Tephrosia vogelii*, *Gliricidia sepium* and *Cajanus cajan* in a 2-year fallow, 2–3-year maize rotation (Rao et al., 1998). Currently the equivalent amount of mineral fertilizer in the region would cost US$ 240 ha^{-1}, an unrealistic amount to farmers who make less than 1 US dollar per day.

The overall results were best summarized by one farmer, Sinoya Chumbe of Kampheta village near Chipata, Zambia when he stated:

> Agroforestry has restored my dignity. My family is no longer hungry; I can even help my neighbours now. (April 12, 1999)

In many high-potential areas of East Africa, smallholder farms are depleted of both nitrogen and phosphorus necessitating the combined use of organic and mineral sources of nutrients (Palm et al., 1997). Short-term improved fallows of 6–16 months duration of *T. vogelii, Crotalaria grahamiana* and *S. sesban* are an effective and profitable way of adding about 100 kg N ha^{-1} and recycling other nutrients in nitrogen-depleted soils of western Kenya. Fallows as short as six months have tripled maize yields in villages where farmers are now practicing a fallow-crop rotation every year in this bimodal rainfall environment (Niang et al., 1998; Rao et al., 1998).

In phosphorus-deficient soils Minjingu rock phosphate from northern Tanzania has proven to be as effective as imported triple super phosphate as well as more profitable (Sanchez et al., 1997a; 1999; Niang et al., 1998). Basal applications of 125–250 kg P ha^{-1} as a capital investment are beginning to be used by farmers with an expected residual effect of five years. In addition, biomass transfers from hedges of the wild sunflower tithonia *(Tithonia diversifolia)* have shown tremendous effects on yields of maize and high-value crops such as vegetables in western Kenya (Gachengo et al., 1998; Jama et al., 1999).

Tithonia biomass has high concentrations of N, P and K and decomposes very rapidly in the soil (Palm et al., 1997). Given the large additions of soluble carbon and nutrients to the soil when tithonia leaves decompose, we speculate that these processes may enhance phosphorus cycling and therefore the conversion of mineral forms of phosphorus into organic ones (Nziguheba et al., 1998).

Combinations of tithonia biomass with phosphorus fertilizers have shown to be very effective (Rao et al., 1998). The abundance of tithonia in roadsides and farm hedges at intermediate elevations in subhumid Africa makes it an additional natural resource that can be managed for soil fertility replenishment.

About 4 000 farmers are currently trying these techniques in western Kenya. Most of the dissemination work is done at the village scale as a pilot development project (Niang et al., 1998). Hosea Omollo, assistant chief Barsauri sublocation, Siaya District in Nyanza Province summarized the results as follows:

> For the first time there have been no hunger periods in this village. Only two ears of maize have been reported stolen this year. (July 7, 1998)

Many farmers adopting tithonia biomass transfers have shifted from maize to high-value vegetables, which are readily sold in nearby towns, effectively entering the cash economy. One farmer, Charles Ngolo of Ebuyango sublocation, Vihiga District, Western Province, reported that his annual cash income increased from US$100 to $1 000 with the sale of sukuma wiki (*Brassica oleracea* cv. *acephala*-kale) and commented:

> My wife and I are living the tithonia life. I built a new house with a tin roof and we are going to be able to send our children to school. (June 4, 1997)

These people now farming on replenished soils have achieved food security, and the last one mentioned is beginning to see his way out of poverty. The promise of agroforestry has been delivered to them. The question now is how to scale-up the delivery, from thousands to millions of farmers. This is the major challenge facing national governments which ICRAF's new Development Division intends to facilitate (ICRAF, 1998).

Enabling policies at the national, district and community levels are beginning to emerge in support of the technological breakthroughs (ICRAF, 1998). They include enhancing the availability of phosphorus fertilizer and high quality seeds, microcredit, and village chiefs fining farmers whose cattle eat their neighbor's sesbania fallows (Sanchez et al., 1997; 1997b). The Kenya Government established a pilot project on soil fertility recapitalization and replenishment for western Kenya and funded it. Furthermore the Kenya Government as a member of the CGIAR, is now providing considerable financial support for ICRAF to conduct the more strategic research underpinning the replenishment practices. Technological and policy research are therefore two sides of the same coin in agroforestry. Their joint impact will enable soil fertility replenishment to make a major contribution toward achieving food security in Africa.

Tree tenure in southeast Asia

In other instances, agroforestry research delivers improved policies, not technologies, but such policies must be backed by a sound biophysical base. The complex agroforests of Indonesia are indigenous systems invented by local peoples over generations living at the margins of tropical rainforests in Sumatra (Torquebiau, 1984). After Slash-and-Burn, food crops are planted along with coffee, pepper, fruit trees (*Lansium domesticum*-duku, *Durio zibethinus*-durian) and the resin-producing damar tree (*Shorea javanica*). The trees eventually shade out the crops, occupy different strata and produce high-value products such as fruits, resins, medicinals and high-grade timber (de Foresta and Michon, 1994).

Biophysical scientists have studied the productivity and ecological dimensions of these systems (Michon and de Foresta, 1996; Michon, 1997). The villagers in Krui, Lampung Province, who make a living from these complex agroforests, have an obviously higher standard of living than those who grow only crops (Bouamrane, 1996). Plant diversity in the mature complex agroforests is in the order of 300 species ha^{-1}, which approximates that of adjacent undisturbed forests (420 plant species ha^{-1}). The richness of bird species in mature damar agroforests is approximately 50% that of the original rainforest and almost all mammal species are present in the agroforest (de Foresta and Michon,1994). This is possible because such agroforests, composed of hundreds of small plots managed by individual families, occupy contiguous areas of several thousand hectares in Sumatra.

The problem was that farmers did not have land tenure, since their agroforests are classified as State Forest Lands by the Ministry of Forestry (Fay et al., 1998). In 1992, the government awarded a forestry company the right to harvest an estimated 3 million commercially valuable trees planted by these local people. This created a great deal of uncertainty among Krui agroforesters who adopted a 'wait and see' strategy and chose not to plant more trees until they would know for sure that they would be able to harvest the benefits of their work. In the words of Pak Hedrus, one of the Krui agroforesters, to a television crew:

> Up to now, the government does not know what to make of this land. We are trying to explain that it is a forest garden and not a virgin forest. (February, 1994)

The Indonesian Minister of Forestry invited ICRAF scientists, including seconded scientists from ORSTOM, France, two local NGOs and Ministry of Forestry counterparts to document the attributes of the complex agroforests and develop policy options for solving this problem. This effort benefited greatly from previous research on the ecological, social, and economic functions of the Krui agroforests conducted by ORSTOM scientists (Michon and de Foresta, 1996).

Policy research started in 1995 and culminated in January 1998, when Indonesia's Minister of Forestry signed a historic decree that established an official precedent for community-based natural resource management in Indonesia (Fay et al., 1998; ICRAF, 1998). Based on the Minister's concept for a distinctive forest-use classification, '*Kawasan dengan Tujuan Istimewa'* (KdTI), the decree recognizes the legitimacy of community-managed agroforests on a significant area of State Forest Land. This classification is unprecedented in that:

- it sanctions a community-based natural resource management system as the official management regime within an area of the State Forest Zone;
- it allows the harvesting of timber from within the State Forest Zone by local people;
- it allows the limited harvesting of timber from within a watershed;
- it devolves the management responsibility of State Forest Lands to a traditional community governing structure (Masyarakat Hukum Adat); and
- these rights are provided without a time limit.

The pilot area covers 29 000 ha and 7 000 families have benefited directly (Tomich et al., 1998). It is hoped that this prototype will be applied in numerous other locations in Indonesia to benefit the millions of farmers at the forest margins, in terms of income generation, improved resource management and reduction of social conflict. ICRAF and the other partners in the Krui research consortium now are undertaking consultations with villages and local government officials to discuss the rights and responsibilities of the KdTI concept in Krui (Fay et al., 1998).

The Krui experience has gained the attention of researchers working on similar problems as far away as Cameroon. African scientists visited the Krui agroforests as part of the activities of the Alternatives to Slash-and-Burn Programme (Ericksen and Fernandes, 1998). They now have expressed interest in the details of the new classification with the hope that lessons can be shared between Indonesia and Cameroon regarding implementation options (Tomich et al., 1998). Agroforestry research has certainly delivered.

Response to the core questions

1. What evidence is there that agroforestry approaches can produce increased yields and other benefits in the short run?

The evidence at the scale of tens of thousands of farmers in eastern and southern Africa is compelling. The main benefit is food security, with poverty reduction as the subsequent one. A key additional benefit of leguminous fallows is the provision of fuelwood on-farm. This eases the burden of women – a gender issue – and decreases the degradation of adjacent forests and woodlands – an environmental issue. This effect is evident in forest areas at risk such as the Bwindi impenetrable forest in Uganda and some Miombo woodlands in southern Africa. Soil fertility replenishment with agroforestry fits well with farmer priorities and preferences. After all farmers have been active participants in the design, execution and adoption of research since day one.

Agroforestry innovations suffer a time lag between tree planting and reaping the benefits. With the fallows the lag is between 1 and 2 years and farmers must sacrifice one rainy season crop. Farmers fully recognize this and since the yield increases are so high, they are willing to help.

2. What reasons are there to believe that agroforestry approaches will produce increased yields and other benefits in the medium to long run?

Farmers are consistently reporting doubling to quadrupling maize yields, both in eastern and southern Africa. Evidence to date shows that fallow–crop rotations can go for several years. Theory predicts they can go on indefinitely, provided farmers achieve good pest management and diversification of the fallow species. The benefits of tree tenure in Indonesia depend on the continuation of the policy as governments change.

3. What agroecological explanations can be given for the sustainability of these particular agroforestry systems?

Soil fertility replenishment is ecologically robust. It brings the natural resources (N in the air, P in the rock phosphate deposits and tithonia in roadsides and farm hedges) into the fields to replenish N and P. The case for tree tenure in Krui was based on a sound economic and ecological analysis. The sustainability of the policy will depend on political dynamics.

4. What are the requirements, costs and potential negative aspects?

The key requirements for fertility replenishment are the availability of quality seed and nursery production of seedlings of fallow species, and a microcredit scheme to purchase rock phosphate. Soil conservation structures are needed in sloping lands in order not to increase nutrient loading in rivers and lakes, which in Lake Victoria could exacerbate the water hyacinth epidemic. Lack of access to markets and unfair crop prices could be extremely detrimental and demoralizing. New pests and diseases could develop with higher biomass. Nutrients presently not deficient at low yield levels could become so at higher yield. This is already happening with potassium in western Kenya, but potassium fertilization so far has been avoided with the fallows. This is because fallow plants have all the essential nutrients, which they can recycle back to the soil. Costs have been described previously.

For Krui agroforests the requirement is continuity in government policies. Cash costs are very small for farmers, mainly meetings and visits. No major negative aspects.

5. How can these agroforestry approaches that are shown to be beneficial be extended on larger scales?

This is the key issue, how to scale-up from tens of thousands of farmers to millions in order to have a discernible impact on food security and environmental protection. For soil fertility, research is needed to find appropriate equivalent fallow species for other regions, particularly the Sahel. We also need the tithonia equivalent there. Managed tree fallows have tremendous potential in subhumid tropical areas outside of Africa, for example, in eastern Indonesia and Cuba. Playing a decisive advisory role to development agencies, – such as the national governments, international banks, bilateral donors, NGOs and farmer groups – is essential. ICRAF intends to be seen as a credible partner in the development process.

The KdTI decree should gradually expand to other forest margin areas of Indonesia and benefit millions of farmers. Specific policies such as these are difficult to extrapolate to other countries. Nevertheless, interest has been expressed to develop similar policies in Cameroon, as mentioned before. This is where international consortia such as Alternatives to Slash-and-Burn can play a major facilitating role in the transfer of such information.

Conclusion

The two examples represent extremes in the delivery of agroforestry research, one being technology-based and the other policy-based. The mutual dependency of both types of research in a multidisciplinary science is evident. Without enabling policies, the breakthroughs in soil fertility replenishment would not go far. Without the sound technical documentation, the Government of Indonesia would not have been as receptive to the suggested policy options.

It would be dangerous to generalize that all agroforestry interventions will have similar degrees of success. Agroforestry is certainly not the best land-use option for all tropical areas, and some have met with widespread failure when they were not solidly based on technological and policy research. Only science-based agroforestry is likely to produce economically, socially and environmentally sound results. These and many other science-based examples emerging throughout the world will assure that the delivery of the promise of agroforestry is felt by the billions of people who depend on this ancient practice and modern science.

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