Optimizing tree-crop interactions in agroforestry systems

Trees for Improving Sustainability, Resource Conservation, and Profitability on Farms and Ranches

Koror, Palau June 26, 2006

Guam, June 29, 2006

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Slide 1

Trees and crops have been grown together since ancient times, particularly in the Pacific Islands. In any system, the trees and the crops may compete for light, water, and nutrients or have complementary needs. When the interactions between the trees and crops are managed well, agroforestry systems, traditional or modern, can outperform sole cropping systems.

The photo shows an agroforestry system on Moloka‘i in Hawai‘i where shade tolerant ginger plants are grown under tree canopy of koa (Guam) or kalau (Palau) (*Cordia subcordata*).

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All agricultural systems must have a way to maintain soil fertility. Most systems through the years have relied on fallow periods. In the tropics, forest fallows allowed trees to reclaim a site. When trees were cut and burnt, nutrients were released that crops could use. In very wet climates such as in Samoa, the cut vegetation was allowed to rot in place. These systems were (and still are) seen as wasteful by authorities, and also they require a lot of land. From 3 to 20 acres of land are needed for the fallow for every acre of land that is cropped.

These traditional systems are sequential. Tree-crop interactions are not direct, as trees are cut before crops are planted. Any interaction is via changes in the soil during the tree phase.

The photo shows a farmer burning land in preparation for planting a maize field and a traditional rice and yam field in the Philippines.

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An alternative system was developed in eastern Indonesia in the 1930s and introduced to the world community by researchers in Nigeria in the 1970s. In this system, called “alley cropping” or “alley farming,” rows of nitrogen-fixing trees were planted in between the rows of crops (usually maize). The trees were pruned and the leaves were used as mulch. In this way it was hoped that the trees would serve as an on-site fallow and allow the farmers to cultivate the land continuously. *Leucaena leucocephala* was most frequently chosen as the intercrop tree because it grows rapidly, the leaves have a high nitrogen content, and it can withstand heavy, frequent pruning.

The photos show an alley cropping system and a multi-storey agroforestry garden in the Philippines in the 1980s.

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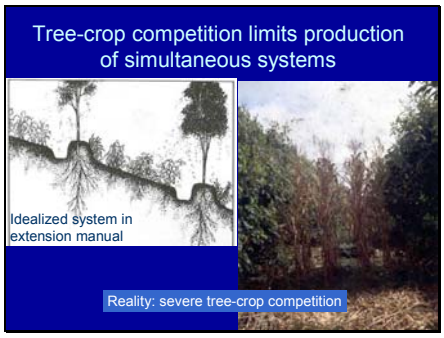

Early promoters of simultaneous systems, and in particular of alley cropping systems, underestimated the role of tree-crop competition on determining the success or failure of agroforestry systems. The picture on the left shows how an artist visualized an alley cropping system in an extension booklet. Note how the trees are small and the roots go straight down. In reality, tree-crop competition is in most cases severe. Farmers need to manage alley cropping systems closely so that the trees

don’t overwhelm the crops.

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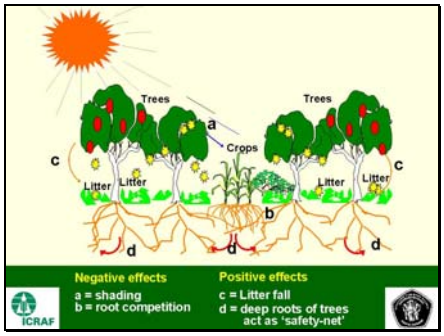

The key to whether simultaneous agroforestry systems work is whether the positive effects of adding nitrogen and other nutrients through mulching the leaves and improving the microclimate under the trees outweighs the negative effects of the trees competing with the crops for water and light.

This slide is courtesy of the World Agroforestry Center, formerly known as ICRAF (the International Center for Research in Agroforestry), www.worldagroforestrycentre.org/sea.

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Trees are particularly competitive with crops for several reasons. First, the are large and overshadow smaller plants. Trees grow rapidly, especially the multipurpose trees used in agroforestry systems. Usually trees are in place before crops are planted and thus have the advantage of having already developed crowns and root systems. Trees can weather temporary stresses such as drought or fire. Lastly, trees can satisfy many of their nutrient needs through re-translocation (absorbing the nutrients in the leaves before they drop) and recycling.

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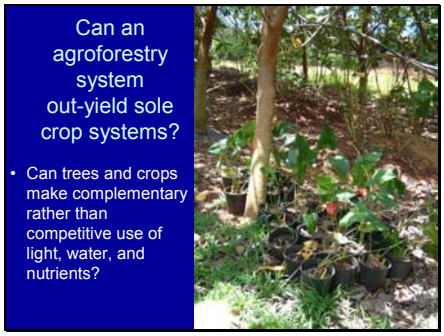

The central requirement for a successful agroforestry system is that the positive interactions in a system outweigh the negative ones and that the trees and crops together yield more than they would if grown separately.

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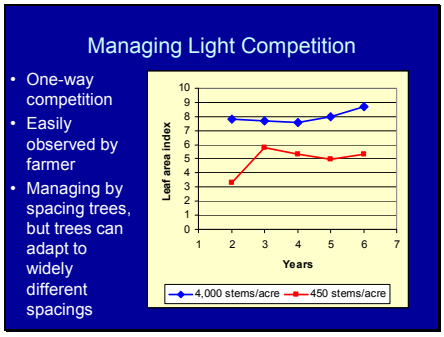

Light is the first resource to consider. Competition for light is usually one-sided: the taller trees shade the shorter crops. It is also easy for the farmer to observe when a plant is being shaded. Trees can be planted at wider spacings to allow more light to the understory, but stands of trees have the ability to maintain a constant leaf area index even at very different spacings. The wider spaced trees grow larger and produce more leaves, so the effect is for the ground underneath the tree canopy to be almost as highly shaded as if the trees were densely spaced. The graph shows the leaf area index (LAI) of two different stands of *Eucalyptus*; one planted at almost ten times the density of the other. Despite the different densities, after the second year the denser stand only has 30% more leaf area than the less dense stand.

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Overstory trees can be pruned, topped, or pollarded in order to decrease light competition. However, constant pruning is costly and likely to be uneconomic unless the trimmings have uses elsewhere on the farm.

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Thinning tree plantations will temporarily increase light to the forest floor and increase understory grass growth. If animals are grazed under the trees, the grass may be thought of as an extra crop.

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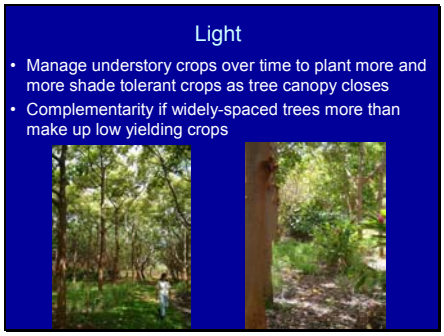

Light competition can be managed over time, though, by choosing more and more shade-tolerant intercrops as the trees close canopy. Eventually the overstory will be a pure stand of trees, while any yield at all from the understory crops will be a gain. Trees may grow exceptionally well in the first few years form being widely spaced. In this alley cropping system on Moloka‘i in Hawai‘i, alfalfa was originally planted between the rows of trees. As the trees grew and closed canopies, more shade-tolerant crops such as anthuriums, ginger, and kava (sakau) were planted.

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Trees compete very severely with crops for water. Trees usually have large root systems that can access reserves of soil water that crops can't, plus they have root systems in place at the beginning of the cropping system. With their relatively high biomass, trees can weather short dry spells that annuals cannot.

The photograph shows a row of *Sesbania grandiflora* trees used as a fodder bank adjacent to a village garden site in a dry area of East Timor. Note the ditch between the trees and the garden, dug to keep tree roots out of the garden.

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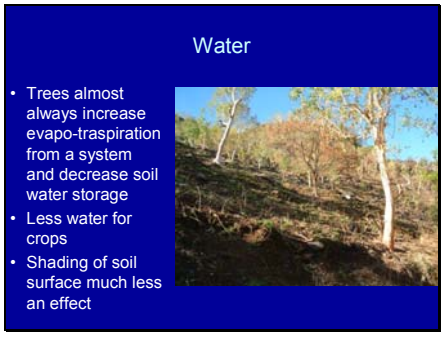

The interactions of trees, rainfall, and soils are complex. In most cases, trees increase transpiration and decrease soil water recharge and water available for crops. The effect of trees shading the soil, which decreases evaporation, is usually small relative to the increased transpiration.

The photo shows a dryland *Eucalyptus alba* forest in East Timor.

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While trees themselves use water, they may decrease crop water needs by shading understory crops and protecting crops from the drying effects of the wind.

The farmer on the left is growing vanilla in the shade *Gliricidia* and *Hibiscus* trees in a garden in East Timor. The photo on the right is of an *Erythrina* windbreak in Hawai‘i.

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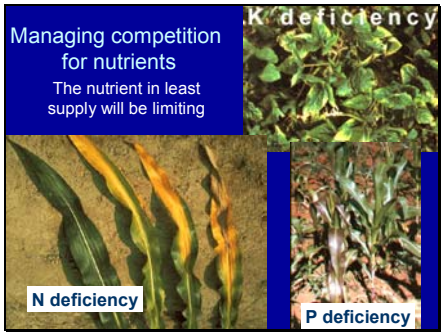

One role of agroforestry is to restore or maintain soil fertility. Soil fertility is largely the ability of the soil to supply the necessary nutrients for crop plants. The three main nutrients plants need are nitrogen (N), phosphorus (P), and potassium (K). Plant growth will be limited by whichever nutrient is most limited in relation to the amount the plant requires. Agricultural plants are most often limited by nitrogen. Plants need nitrogen to make chlorophyll in green leaves and to make proteins, which are especially important in the seeds or grain. That is why plants which lack N often have yellow leaves and bear little grain.

The photos of nutrient deficiencies are taken from the UH CTAHR website, Rx for Soils and Crops: http://www2.ctahr.hawaii.edu/tpss/research_extension/rxsoil/fair.htm

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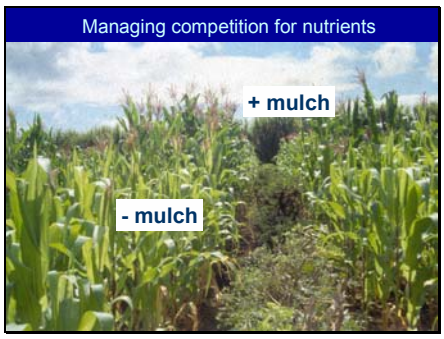

Alley cropping systems were originally designed with nitrogen-fixing trees, which when cut back supplied N to cereal crops. These systems increased crop yields in humid areas where water was not limiting and soils were low in N. Adding nitrogen will not help crops grow better if another nutrient, for example phosphorus, is limiting. For example, alley cropping successfully raised yields of corn grown between rows of *Leucaena* on an alfisol in Nigeria, since the corn was limited by lack of nitrogen. Alley cropping with nitrogen-fixing trees on an oxisols in Sitiung, Indonesia, did not increase harvests of rice, though, because in the very old, acid soil the crops were limited by phosphorus. Indeed, the alley-cropped plots in experiments did worse than the control plots, because the trees competed with the crops for what nutrients were in the soil. Plant growth may also be limited by water availability or soil acidity. Incorporating nitrogen-fixing trees into a farming system is not a cure-all; it only helps remedy certain problems, mainly lack of N as a nutrient.

This photo shows and alley-cropping experiment on Kaua‘i in Hawai‘i. The plot in the background has received mulch from hedgerows of *Leucaena* and is tall and green. The plot in the foreground has received no mulch or other nitrogen fertilizer and is yellow and stunted.

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Crops can only benefit from nitrogen in tree leaves, however, if the leaves are cut and applied as a mulch or made into compost. Even N-fixing trees do not leak nitrogen into an agro-ecosystem. Since it costs trees energy to produce nitrogen, the trees produce only what they need; they do not produce extra. If branches are cut and applied as mulch or made into compost, the nitrogen will be released from the leaves as they rot and the crop will be able to take some up. Cutting branches also forces the roots to die back, decreasing below ground competition. Since the trees continue to grow during the off season when no crops are in the ground, they form a “safety net” and accumulate nutrients which might otherwise be leached out of the soil. This is why even non-N-fixing trees are sometimes successfully used in alley cropping systems.

In this experiment on Kaua‘i, Hawai‘i, cut leaves from the hedgerows are applied as mulch

to some plots and not to others. Corn grown in the mulched plots yielded more and had significantly better N nutrition than corn grown in the no-mulch plots (data from Nancy Glover, 1994, PhD dissertation, Univ. of Hawaii.)

A limitation of alley-cropping systems is that while they are designed for cereal crops such as rice and corn, these crops are the most sensitive to shading and below ground competition from the trees.

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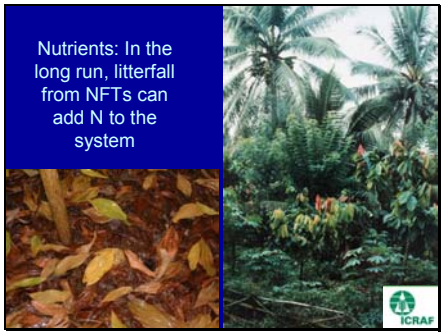

There will be some nitrogen released from litter beneath nitrogen-fixing trees, but much of the nitrogen in a green leaf is taken back into the tree before the leaf is allowed to drop. Leaves turn yellow before they fall because the chlorophyll is breaking down and the plant is reabsorbing the nitrogen. Most of the nutrients in litterfall are merely recycled in the system and do not represent an actual input. Still, over time the litter of a nitrogen-fixing tree can provide significant N to an understory crop. If leaves are cut elsewhere on a farm and brought to a garden to be applied as mulch or compost, they represent a nutrient input to the garden. Here a permanent agroforestry garden in Indonesia includes *Gliricidia sepium*, which is periodically pruned back to create mulch for the crop trees.

Over many years, trees can also build up soil organic matter and

increase the soil's water and nutrient holding capacity.

Gliricidia agroforest photo courtesy of the World Agroforestry Centre (www.worldagroforestrycentre.org/sea).

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The degree of competition between the trees and crops is the key to whether an agroforestry system will be successful. Managing competition is essential in simultaneous systems. Since trees are long-lived relative to crops, though, different strategies will be appropriate at different times as the agroforestry system develops. In the upper photo a young teak tree is shown growing next to sun-loving native Hawaiian grasses. The grasses are used to provide mulch to conserve soil water before the tree canopy closes. In the lower photo, 'ape (*Alocasia*, edible aroid) grows in the understory of a Pohnpeian agroforest. The agroforest is in a late stage of development and has a full tree canopy. Only shade tolerant plants can grow in the understory.

Bottom photo courtesy of Dr. James Fownes.

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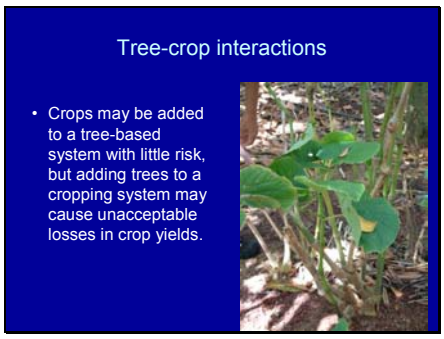

Since trees are usually much more competitive than crops, understory crops may be added to tree systems with little risk of increased competition and decreased tree growth. The reverse is not true. Adding trees to a cropping system requires careful planning so that the competition from the trees for light, water, or nutrients does not result in greatly decreased crop yields.

The photo shows a kava or sakau plant (*Piper methysticum*) growing in the shade of timber trees on Moloka‘i, Hawai‘i.

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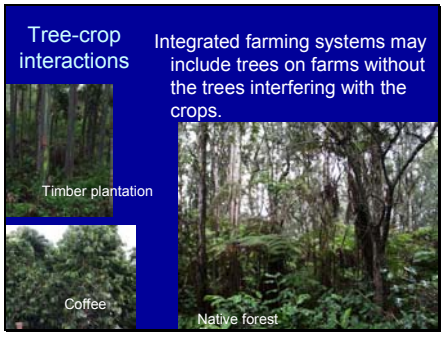

Lastly, trees may be used on farms in ways in which they do not compete with crops but are integrated into the overall farming system. There is always the option of planting trees and crops in different areas. Tree crops may serve as a source of future income while needing little day to day care.

The photos show a farm in Kona, Hawai‘i where coffee is grow at the lower elevations, timber trees at mid elevations, and native forest is preserved at the higher elevations. The farm is integrated economically and in a management sense, but the trees are grown separately from the coffee.