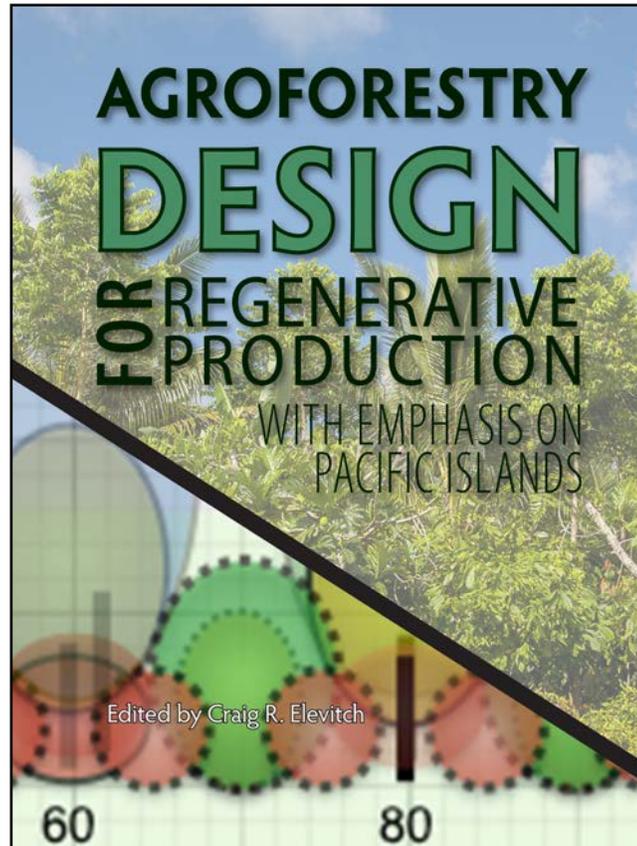


# Chapter 2

## Managing Tree-Crop Competition



By J. B. Friday



Agroforestry Net (<http://agroforestry.org>)

## *Agroforestry Design for Regenerative Production*

### Chapter 2. Managing Tree-Crop Competition

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AGROFORESTRY NET  
TREES OF LIFE, TREES FOR LIFE

# Chapter 2. Managing Tree-Crop Competition

by J. B. Friday

Traditional agroforestry systems, in the Pacific and beyond, have succeeded in providing food and forest products to local farmers for millennia. However, modern agroforestry systems designed on experimental stations have often failed when used by actual farmers. One very common reason for this lack of success is that the trees compete severely with the crops, reducing or eliminating crop yield. If instead of getting something extra from integrating trees into an agricultural system, the farmer finds she is losing her primary crop, she will quickly abandon the system. Successful agroforestry systems that are widely adopted by farmers manage tree-crop competition so that the integrated system yields more than either the trees or the crops would if grown alone.

## ABOVE- AND BELOW-GROUND COMPETITION

Agroforestry systems are based on key properties of trees including their large size and long lifespan, bark to protect trees against fires, pests, and diseases, and the ability of individual trees to store up enough energy to survive and flush out again after storms, fires, drought, or insect attack. Integrating trees into an agroforestry system can increase the resistance to change and the stability of the system. At the same time, trees' large size and perennial nature make them very competitive against annual crops. Not only can trees shade out crops, they can also outcompete crops belowground for water or nutrients. Trees have

extensive and perennial root systems that take up water and nutrients while crop's roots are just developing. Managing this competition is key to designing successful agroforestry systems.

Traditionally, Pacific Islanders created multi-story garden agroforestry systems built around fruit-bearing trees such as breadfruit and coconut. Understory plants such as taros and yams are planted either under the trees or in openings analogous to forest gaps. Although crops might yield less when grown in partial shade, the combination of trees plus crops can provide superior yields versus trees alone on one part of the farm and crops alone on another. Traditional agroforestry systems may not be designed to maximize yield of a single staple or cash crop but rather to minimize chances of crop failure and going hungry (Fownes and Raynor 1993). To that end, systems that are diverse and have some resistance to shock built in are often preferred to systems that maximize production but are prone to catastrophic failures.

Modern tropical agroforestry systems initially were developed on experimental farms as substitutes for shifting agriculture or swidden systems, which were seen as wasteful. Alley cropping systems were initially designed with hedgerows of nitrogen fixing trees grown between rows of cereal crops such as rice or corn (Kang et al. 1981). The hedgerow trees were frequently trimmed and the cuttings used to mulch the crops, supplying some additional nutrients. Initially, the on-sta-

tion results were promising, with alley crops out-yielding traditional crops in a seemingly sustainable manner. However, farmers found that if they were delayed in trimming their hedgerows the trees quickly grew tall enough to shade the crops, and in any case the hedgerows had roots that extended into the crop zone, competing for water and nutrients. In many areas, the negative effects of competition between the trees and the crops outweighed the positive effects produced by the added mulch (Sanchez 1995). Especially in dry zones such as in semi-arid India where farmers were growing cereals, alley cropping often failed because the trees outcompeted the crops for water (Rao et al. 1991).

Alley cropping and traditional multistory gardens are simultaneous agroforestry systems, where the trees are grown at the same time as the crops. Other simultaneous agroforestry systems are also vulnerable to excessive tree-crop competition. In acid soils of the humid tropics such as lowland Peru, trees can compete severely with crops for nutrients (Szott et al. 1991). Tree windbreaks can protect crops from desiccating winds and storm damage, but if the crops are too close to the trees they will suffer from shading and likely from belowground competition. Coffee, cacao, and some other crops are traditionally grown in light shade, but yield suffers if the canopy grows too dense. Another negative interaction between trees and crops can occur when the trees host pests or diseases that can affect the crops. Birds roosting in trees can be serious pests of grain crops and can also cause food safety issues due to their droppings. Coffee shade trees can be alternative hosts for the black twig borer (*Xylosandrus compactus*), a serious pest of coffee.

While competition for light is the most common factor that is managed to reduce tree-crop competition (Friday and Fownes 2002), belowground competition may be a more important factor in dry areas. Non-bearing or dwarfed crops growing next to low-cut hedgerows are signs that belowground competition is severe. Early draw-



**Figure 1:** Deep-rooted trees (*Acacia* spp.) are able to access water sources that grasses cannot and remain green through the dry season. These trees could be managed to produce fodder for livestock. Baucau, East Timor.

ings of agroforestry systems often depicted tree roots as growing straight below the trees, but in reality tree roots spread out and search for water and nutrients wherever they are available. Where the topsoil is well-watered or fertilized for crops, shallow tree roots will also proliferate there. In environments where soil water is not available in the topsoil, tree roots can also grow deep to reach water sources that annual crops are unable to access (van Noordwijk and Purnomosidhi 1995) (Figure 1). On rare occasions, trees are able to access nutrients that would be leached past the crop's rooting zone (acting as a "safety net") or uptake nutrients from mineral layers deep in the soil ("nutrient pumping"). In open parklands, tree roots will extend far beyond the drip zone of the trees' crowns.

Early designers of modern agroforestry systems enthusiastically embraced the use of nitrogen-fixing trees, with the idea that since these trees can obtain nitrogen from the air they would not require much from the soil and would enrich the soil rather than competing with crops (Domergues, 1990). Although nitrogen-fixing trees are able to access atmospheric nitrogen, they are dependent on the soil for phosphorus, potassium, calcium, and all the other mineral nutrients. Since fixing nitrogen costs the tree energy, if nitrogen is abundant in the soil, NFTs will also

take nitrogen from the soil in preference to fixing atmospheric nitrogen (Radovich et al. 2015, Singleton et al. 1990). In well-fertilized systems, NFTs may not fix much nitrogen but rather depend on the fertilizer. Although some writers blame harmful chemical exudates from the trees (allelopathy), usually competition from trees for light, water, and nutrients is enough to explain poor crop growth.

## MANAGEMENT OF TREE-CROP COMPETITION IN SIMULTANEOUS AGROFORESTRY SYSTEMS

Selecting the right overstory trees can minimize competition with crops. Coconut and breadfruit are the usual overstory species in traditional systems but other common Pacific Island species can be useful.

- Some multipurpose trees such as *Sesbania* and *Moringa* have thin canopies that allow sunlight to penetrate.
- Trees with a compact canopy structure will compete less with crops than trees with spreading crowns. In an alley cropping system in Indonesia, the native legume *Peltophorum dasyrhachis* had a more compact crown and competed less with crops than the other legume species in the trial (*Calliandra*, *Flemingia*, *Gliricidia*, or *Leucaena*) (van Noordwijk and Hairiah 2000).
- If the trees are going to be pollarded (all branches cut back to the main stem) or coppiced (cut back to a stump), trees that readily grow back after coppicing such as *Gliricidia* or *Leucaena* are frequently chosen.
- The unusual African dryland tree *Faidherbia albida* drops its leaves at the onset of the growing season, allowing newly planted crops to grow underneath (Vandenbeldt and Williams 1992). While most growers would like trees to grow quickly, fast-growing trees are by nature more competitive than slow-growing trees.

In windbreaks or other linear plantings, small or medium sized trees will be less competitive than larger trees. For windbreaks, a commonly used rule of thumb is that trees protect crops from the wind to a distance of ten times the tree height. Trees that are taller than needed to protect the crop area will interfere with crop growth without providing additional benefits. Trees with narrow crowns are usually preferred as windbreaks (Figure 2). The space just inside and to the lee of a windbreak can be used for a farm road to access the crop field, since crops planted close to the windbreak will usually suffer from competition from the trees (Figure 3). *Eucalyptus* species are the most common tropical hardwood plantation trees in the tropics but are much less frequently used in agroforestry systems than other trees primarily because their large size and rapid rate of growth makes them severely competitive with crops.

Slower growing, but well-adapted native trees, either in forest remnants or planted, may be important components of agroforestry systems. These may be less competitive than the non-native species usually used in agroforestry systems which have been selected for fast growth and are consequently highly competitive. On Hawai'i Island, remnant native *Metrosideros polymorpha* trees are sometimes retained to provide shade on coffee



Figure 2: Trees with compact crowns such as these *Araucaria columnaris* shade crops less than trees with broad, spreading crowns. Waimea, Hawai'i Island.

farms (Elevitch et al. 2009) (Figure 4). Nitrogen fixation is often useful but not always necessary in agroforestry trees; other useful species should not be discarded just because they do not fix N. Lastly, the properties such as fast growth, tolerance to pruning, and nitrogen fixation that make trees useful agroforestry species can also make them invasive (Hughes 1994). Where exotic tree species are to be introduced, good design involves selecting non-invasive species such as *Gliricidia* or *Sesbania grandiflora* instead of species that spread rapidly such as *Leucaena*.

A very useful tool to assess potential weediness of agroforestry species is the Hawaii-Pacific Weed Risk Database, found at [www.plantpono.org](http://www.plantpono.org).

Careful layout of the initial tree plantings can minimize tree-crop competition. The layout of alley cropping systems is complex and depends on the latitude and cropping season. On flat fields, hedgerows that are oriented east to west will allow the most sunlight to reach the alleys at noon in the tropics, but in the winter months in the northern hemisphere crops on the south side of the alley will be shaded. Shading during winter months, of course, will not matter if crops are grown only in the summer months. Conversely, crops on the north side of the alleys will be shaded by east-west hedgerows in the southern hemisphere in the winter. Running hedgerows north to south allows for more even distribution of sunlight throughout the year. For sloping fields, and in practice most of the time in the Pacific, hedgerows will be run on the contour of the slope to reduce erosion rather than along exact compass bearings.

Here soil conservation is more important than minimizing shading.

Managing tree-crop competition may involve pruning or cutting back trees to allow more light to reach crops. Frequency and height of cutting back affects shading. Cutting back tree branches may also result in some root dieback, especially of fine roots, alleviating belowground competition. Frequent pruning, however, is labor intensive, and if the farm is not mechanized farmers may not have the available labor to intensively man-

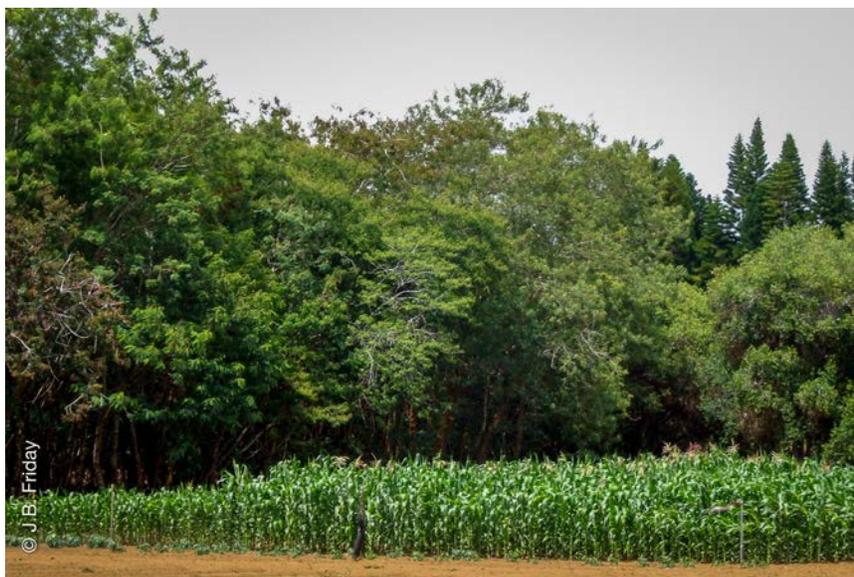


Figure 3: Windbreak trees to the left of the photo (*Eucalyptus* spp.) are competing severely with the corn crop. Shading is part of the reason but belowground competition probably plays a role as well. Waimea, Hawai'i Island.



Figure 4: Coffee grown under native 'ōhi'a lehua (*Metrosideros polymorpha*) forest in Kona, Hawai'i.

age their trees. If the tree prunings are valuable, for example for animal fodder or for fuelwood, farmers are more likely to dedicate the time to frequent pruning. On the other hand, if pruning trees is a chore with no immediate rewards, farmers are likely to delay management while they work at other farming tasks or take seasonal jobs elsewhere. If trees grow to the point that they overtop the crops, the entire system can fail. It is prudent to design systems that are stable and remain productive even if management lapses, especially if farmers are occasionally absent from the farm. Intensively managed systems work best in situations where farmers have relatively little access to land, need to maximize the yield per acre, and will be regularly present on the farm.

Tropical alley cropping systems rely on the quick release of nutrients from pruned branches and leaves to benefit adjacent crops. Except for the some of the nitrogen in nitrogen-fixing trees, all of the nutrients contained in the branches and leaves were taken up from the soil; trees do add any new nutrients to the system. Through their extensive root systems, trees take up nutrients gradually, and when the branches are pruned

and applied as mulch the nutrients are released for use of the crops relatively quickly. For cereals such as rice and corn, timing of pruning and application of mulch is critical, as most of the plant's nutrients are taken up within a period of a few weeks. Root crops, on the other hand, can be managed more flexibly. Taros and sweet potatoes take up the bulk of their nutrients over a period of several months.

Crop selection is perhaps more important than tree selection in designing agroforestry systems. Major global grain crops such as corn and rice are cereals that are very light demanding; even a little shade causes yields to drop precipitously. Traditional Pacific Island staple crops include taros (*Colocasia*, *Cyrtosperma*, *Alocasia*, and *Xanthosoma*), sweet potato, and yams (*Dioscorea* spp.). Each species and even cultivars within the same species are characterized by varying shade tolerances. In general, sweet taro (*Colocasia*) is either grown in full sun, as in Hawai'i (Figure 5), or in gaps in the agroforest where it receives full sun in the middle of the day (Figure 6). One study in Samoa, however, found that some cultivars could tolerate 50% shade without losing yield (Rogers



Figure 5: Sweet taro (*Colocasia*) and hard taro (*Cyrtosperma*) grown in full sun on Palau.



Figure 6: Sweet taro (*Colocasia*) and hard taro (*Cyrtosperma*) grown in partial sun at the edge of an agroforest on Palau.

and Iosefa 1993). Giant swamp taro (*Cyrtosperma*), ape (*Alocasia*), and cocoyam (*Xanthosoma*) are usually grown in gaps in the agroforest where they receive full sun at midday. They can also tolerate partial shade with some decrease in yield (Figures 7, 8).

In heavy shade, some plants will survive and produce leaves but not produce much in the way of edible corms (Figure 9). Yams (*Dioscorea* spp.) are commonly trained to grow up into the canopy of living trees such as breadfruit or noni (*Morinda citrifolia*) (Figure 10). The young plants are toler-



Figure 7 (left): Hard taro (*Cyrtosperma*) grown in a gap in an agroforest in Chuuk, Micronesia. Figure 8 (right): Hard taro (*Cyrtosperma*) grown under partial shade in a coastal agroforest on Yap, Micronesia.



Figure 9: Giant taro (*Alocasia*) grown under full shade of a *Terminalia* forest on Kosrae.

ant of shade as they grow up through the canopy of their host plant until they emerge into the sun. Other farmers manage yams by planting them under beach hibiscus (*Hibiscus tiliaceus*) trees, which are girdled to allow sunlight to reach the young yam vines (Balik 2009). Coffee, cacao, and ornamental ginger (Figure 11) are modern crops

that were developed from understory rainforest plants. All are suitable for agroforestry systems and can provide good yields in moderate shade. A study in Hawai'i found that shade grown coffee did not yield less than open-grown coffee as long as there was not more than 50% shade (Elevitch et al. 2009) (Figure 12).



Figure 10: Yams (*Dioscorea*) growing on a trellis in heavy shade on Pohnpei, Micronesia.



Figure 11: An experimental alley crop with ornamental ginger growing in the understory under *Thespesia* and candlenut (*Aleurites moluccana*), Moloka'i, Hawai'i.

Black pepper (*Piper nigrum*), betel nut pepper (*Piper betel*) (Figure 13), kava (*Piper methysticum*), and vanilla are more examples of commercial crops that are derived from rainforest understory plants and consequently are characterized by varying degrees of shade tolerance. Small gaps in the agroforest canopy can be used to grow pineapples and vegetable crops (Figure 14). Little light reaches the ground in a fully developed agroforest and the soil surface can be quite bare aside from leaf



Figure 12: Coffee grown under shade from monkeypod (*Samanea saman*) trees in Kona, Hawai'i.

litter from the overstory trees (Figure 15). Timber trees such as mahogany (*Swietenia macrophylla*) or tava (*Pometia pinnata*) are sometimes grown to provide shade for coffee or cacao (Figure 16). It is best to plan on harvesting the timber trees at the same time that the understory crops are replanted or heavily pruned so that felling the shade trees does not damage the crop.

As an alternative to pruning or pollarding, trenching has been suggested as a way to manage belowground competition. For small Pacific Island farms, however, this is seldom practical unless the farmer has access to a tractor or a backhoe. Irrigation may be used to offset belowground competition for water, but care should be taken to apply water so that it reaches the desired plants. Most crop plants have shallow, fibrous root systems and will need to be irrigated on a daily basis during drought conditions. If the goal is to get water to the trees in a system, they should be irrigated seldom (at most weekly but usually only a couple of times per month) but then heavily so that the water soaks deep into the soil (Meade and Hensley 1997). This will train the roots to grow deep. Completion for nutrients can be ameliorated by applying additional fertilizers, either organic or



Figure 13: Betel nut pepper (*Piper betel*) vine growing up under a canopy of breadfruit trees in Pohnpei, Micronesia.

chemical, to the crops, especially those adjacent to trees.

It can be difficult to discern the exact mechanism of competition. There are, of course, interactions among plants' uses of light, water, and nutrients. Management actions may also affect more than one mechanism. Pruning back tree branches, for example, may also cause roots to die back, alleviating water competition. With fewer leaves, trees

will also transpire less and will use less water. It may not be necessary to understand the exact mechanisms to be able to recommend management that will lessen competition. Management actions such as pruning that are observed to lessen competition between trees and crops can be adopted by farmers even if the reasons for the changes are not obvious.



Figure 14 (left): Pineapple is commonly grown in Pacific Island agroforestry gardens, but in gaps rather than in the understory. Figure 15 (right): Little light reaches the ground in a well-developed agroforest in Pohnpei, Micronesia.



Figure 16: A long-term trial of coffee shade systems in Costa Rica. Timber trees include *Chloroleucon eurycyclum* (casha in Spanish) and *Terminalia amazonia*. The shorter trees in the background are *Erythrina poeppigana*, pollarded regularly to produce mulch for the coffee trees.

## TREE-CROP COMPETITION IN SEQUENTIAL AGROFORESTRY SYSTEMS

Tree-crop competition is much less of a problem for sequential agroforestry systems, where trees are planted after crops are harvested, or where seedlings are interplanted into crop fields to grow into trees after the field is fallowed. In traditional shifting cultivation or swidden systems a patch of forest is cleared, crops are grown for a few years, and then the forest is allowed to return while the farmer opens up a new area. The return of the forest allows soil fertility to be restored, weeds to be shaded out, and crop pests to decrease. One way of improving swidden systems is by enriching the fallow forest with plants that will restore soil fertility quickly such as nitrogen-fixing legumes.

Another way of improving fallows is to plant useful trees in gardens before the last crops are harvested. These can be fruit trees or trees to be harvested for wood, posts, or non-forest products during the fallow period and then felled for timber at the beginning of the next cropping cycle. (Text box: local agroforestry adaptation in the Philippines). Tree plantations may be established by the taungya system, where farmers are given land to grow crops but also required to establish tree seedlings. After two or three years, when the tree seedlings have grown to a size that interferes with farming, the farmers are given new plots to farm. Taungya systems are historically employed in areas where farmers do not own much land and can be employed by large landowners to establish tree plantations. Taungya can also work for smallholder farmers to establish tree plantations where there is a market for plantation timber trees (Pasicolan et al. 1997). Interplanting tree seedlings into crop fields is an effective way to establish tree plantations in fire-prone grasslands, as the crop field will be mostly bare soil

after the crop is harvested and not conducive to wildfire. Pruning the trees can allow more sunlight to reach the ground and allow another crop to be grown.

Although simultaneous agroforestry systems and sequential systems are presented separately here, one can evolve into the other, and in reality farmers are constantly changing and adapting their systems. Land cleared for short-term crops such as sweet potato or cassava can be interplanted with bananas and papayas and ultimately breadfruit and become a full agroforest in time.

## CONCLUSIONS AND RECOMMENDATIONS

Trees in agroforestry systems can benefit crops but they can also limit crop production by being overly competitive. Managing tree-crop competition is key to designing successful agroforestry systems. Farmers can select trees that are inherently less competitive by virtue of being slower growing or having favorable architecture. They can also manage tree-crop competition by careful layout and spacing of plantings and pruning of the trees at critical times. Traditional Pacific Island crops such as yam, taro, and sweet potato are slightly more shade tolerant and adaptable to agroforestry systems than cereal crops such as corn and rice. Native trees that can be integrated into agroforestry systems deserve extra consideration and may be less competitive than fast-growing exotics. In any simultaneous agroforestry system where trees and crops are grown together, the farmer must take into account the lifecycle and needs of the crop and manage the tree component in order to limit competition at critical times. Sequential agroforestry systems, where trees are grown following food crops and are cut before the crops are planted again, have fewer problems with tree-crop competition than

**Table 1: Recommended crops for a sequential agroforestry system in Fiji (Ratukalou et al. 2000).**

First crop	9–12 months	Taro
Second crop	4 months	Cabbage, beans, peas, or peanuts
Third crop	9–12 months	Cassava
Fallow	1–3 years	Trees such as <i>Erythrina</i> or <i>Gliricidia</i> , pigeon pea ( <i>Cajanus</i> ), <i>Mucuna</i> sp., or lablab beans.

## LOCAL AGROFORESTRY ADAPTATION IN THE PHILIPPINES

Farmers in upland areas of Isabela Province in the Philippines experimented with contour hedgerow alley cropping systems in the 1980s and 1990s. Their main crop was corn, and hedgerows were composed of nitrogen-fixing multipurpose trees such as *Leucaena*, *Gliricidia*, and *Calliandra*. Because each family had relatively large areas under cultivation (up to several acres), labor was a limiting factor. Farmers found that they fell behind in trimming hedgerows, which grew tall enough to shade the corn and reduced yield. Crops in the alley cropping plots were abandoned, with the trees then being allowed to grow large enough to be harvested for fuelwood or charcoal production. Because there has been increased demand for locally-grown timber, farmers now have developed a new system of improved fallows. Farmers plant *Gmelina arborea*, a fast-growing, fire tolerant timber tree, into fields after the corn is harvested. Crops are planted for another year or two while the trees were getting established,

then the trees are allowed to grow for 6–8 years until harvest. This fallow period allows soils to recover some fertility and organic matter. After the trees are harvested, sprouts from the cut stumps are managed to produce another crop of timber trees. Agricultural crops such as corn, beans, and squash are grown between the stumps for a few years. By switching from a simultaneous agroforestry system such as alley cropping to a sequential system of improved fallows, farmers are able to minimize tree-crop competition and produce a tree crop with little labor on available land while concentrating their resources and labor on agricultural crops. These farmers have created an enriched fallow system in a situation where labor rather than land is the limiting factor and where there is a market for locally grown wood. Simultaneous alley-cropping systems might be preferred in areas where farmers are limited by access to land or where there is no market for timber crops.



Figures: In this locally-developed agroforestry system, farmers grow *Gmelina arborea* trees for 6–8 years for a local timber market, then harvest the trees and plant crops such as the squash shown here between the stumps. One sprout per stump is managed to replace the cut tree; after several years the crops are abandoned and the trees allowed to grow to maturity. In this photo a newly harvested field is shown planted with squash in the foreground of the photo with the coppice stumps growing between the vines. The trees in the background of the photo will be harvested in another year or two. Isabela Province, Philippines.

simultaneous systems. On any given farm, there is always the option of devoting some space to agroforestry systems with trees grown alongside of shade-tolerant crops, while some space is left for open gardens where sun-loving crops are grown in full sunlight.

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