Chapter 13

The Trillion Tree Project: Tree Crops and the Benefits of Agroforestry

Introduction

Though the phrase is catchy and alliterative, is planting a trillion trees possible? We need to start with the data about how much potential forest there is on the planet. The land mass of Earth is approximately 29% of the surface area of the planet, which equals 148.94 million kilometers squared (km^2). Of this, about 20% is extreme desert that grows little except in isolated and tiny oases, which are locally important but do not amount to much on a global scale. Another 11 million km^2 is ice, also unavailable for human use. Tundra, northern taiga, and taiga, 25.5 million km^2, really should be off-limits to human exploitation. After replanting the trees that have already been removed, humanity should leave these places alone. With these areas unavailable or off-limits, 83 million km^2 remain that could have trees. However, 25% of the global total is ecologically dominated by cool, warm, and savanna grassland. This leaves 45 million km^2—4.5 billion hectares, or 30% of the planet—dominated by some type of forest ecosystem.[1] A map of the global forest is given in figure 13.1. One trillion trees divided by 4.5 billion hectares gives you a total of 222 trees per hectare, or about 45 m^2 per tree, which is more space than most trees need in a closed canopy forest setting, except perhaps a giant sequoia or a baobab reaching maturity. There is room for one trillion more trees on the planet. The real question is how we grow and manage them.[2]

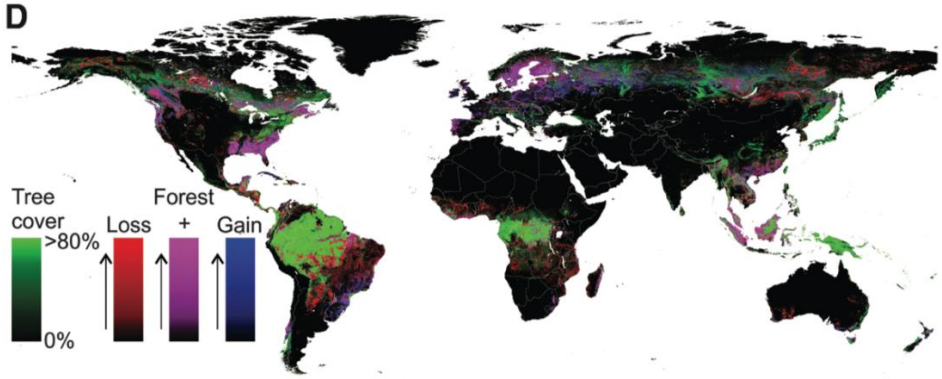

Figure 13.1: Global forests with changes in total covered between 2000 and 2012 based on satellite imagery.[3]

One method widely promoted to both increase trees in the ground and use them to benefit agriculture is called agroforestry. It is the integrated and intentional use of trees in association with crops that takes a variety

[1] These numbers are derived from table 6.1 in chapter 10, "Putting Carbon Where It Belongs: An Introduction to Soil."
[2] Since this was written, the journal *Nature* has published a new study, entitled "Mapping Tree Density at a Global Scale." The article's authors estimate that the global population of trees is now just above three trillion, and that this represents a decline of some 46% since the dawn of human civilization (Crowther et al. 2015).
[3] For a wonderful interactive map on the global forest, run by the University of Maryland and powered by Google Earth, go to http://earthenginepartners.appspot.com/google.com/science-2013-global-forest.

of forms globally. The most widely known institution promoted agroforestry is the International Center for Research in Agroforestry (ICRAF), headquartered in Nairobi, Kenya. ICRAF defines *agroforestry* this way:

> A dynamic, ecologically based, natural resources management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels.[4]

This chapter explains the nature of agroforestry in more detail in the larger context of planting more trees planet-wide as a response to climate change.

The Precursor to Agroforestry in North America

In the mid-1930s, the Midwest region of the United States went through an economic depression and a "Dust Bowl." The latter was caused by a severe drought following years of inappropriate farming on shortgrass prairies that left a barren landscape. It was less well-known that the eastern, northern, and far western parts of the United States had already suffered from landscape calamities. Shenandoah National Park, much of Appalachia, and a large part of the Piedmont actually consisted of a long stretch of partially abandoned farmland, deforested during the nineteenth century to grow oats and other small grains for feeding horses, the transportation system of that era. When the horses gave way to the automobile, these farms collapsed because they could not produce wheat and corn competitively with those further west. There are more trees in the Piedmont and Appalachian regions of the East now than there were between the Civil War (1860s) and World War II (1940s).

In the 1920s, one of the most forward-thinking and innovative foresters in the United States presented an idea that would have radically healed the American eastern forest and reduced much of the agricultural shift to the middle of the country. J. Russell Smith was a professor of economic geography at Columbia University and a professor of industry at the Wharton School, as well as being closely associated with the US Department of Agriculture and the Northern Nut Growers Association. He had a passion for using trees to provide more than just timber. In 1929, J. Russell Smith published a book called *Tree Crops*. His working thesis was simple: the agriculture that dominated much of the warm temperate belt from the subtropics to latitude 50° north was inappropriately practiced on steep hillsides in the foothills and mountains of Appalachia, the loess hills of China, and across much of the Middle East and the Mediterranean basin. The European farming systems exported to the United States were designed for light rains on relatively flat land. The Appalachians (analogous to hilly land everywhere) were subject to heavy thunderstorms that could rapidly strip barren land of its topsoil. Any agriculture that left the land uncovered was dangerous. Smith documented sheet erosion damage in Algeria, extreme gully erosion in China near the Great Wall, as well as deep loss of topsoil on gently sloping land in Illinois and steeper corn land in Alabama and Georgia in the southern Appalachian foothills. Agriculture could work in these areas only if they grew permanent crops. He pushed tree crops: fruit-, nut-, and fodder-producing trees.

This requires a change in mindset. Today, American agriculture is dominated by two energy-intensive crops, corn and soybeans, and much of our food production system is based on these two primary sources. When we eat beef, pork, chicken, turkey, and even farm-raised salmon, we are eating corn and soybeans. As Michael Pollan famously said, "You are what you eat eats."[5] Until recently, over half of all the corn in the United States, and an even higher percentage of soy, was fed to livestock.[6] These domestic animals did not live on corn and soybeans until the twentieth century. What if they ate what was normal for them? Cattle eat grass and herbaceous perennials. Pigs, turkeys, and goats gobble tree crops (acorns, chestnuts, fruits, and leaves). Chickens scratch for grubs, worms, bugs, fly larvae, and almost any seeds and greens they can find.

[4] http://www.worldagroforestry.org/

[5] Michael Pollan, *In Defense of Food* (New York: Penguin, 2009).

[6] Only recently has that percentage for corn dropped, though the amount fed to livestock has not. The recent rise in corn production goes to produce alcohol for fuel.

Smith documents a number of species that do well throughout the eastern part of the United States and beyond that could help change agriculture. His first example comes from the island of Corsica, a fiercely independent province of France, located in the Mediterranean Sea off the coast of Italy and Southern France. The island is mountainous, rugged, and rocky, but it is covered with trees and shows little sign of erosion. Most of the trees between 1,000 and 3,000 feet in elevation are the European chestnut (*Castanea sativa*). Americans have little knowledge of chestnuts except from a Christmas song that starts, "Chestnuts roasting on an open fire." We lost the American chestnut between 1904 and 1926 when a fungal disease was accidentally imported to the Brooklyn Botanical Garden on a Chinese chestnut and spread to the nonresistant American chestnut. The European and Chinese trees are resistant to the fungus. On Corsica, the European version thrives on the steep slopes, producing an annual bounty of chestnuts eaten directly by humans and fed to pigs, goats, and other animals. The agriculture of Corsica is based around this harvest, and it requires neither tillage nor fertilizer, and limited mechanization. For Smith, it became a model for a hill country agricultural revolution. While we lack a native chestnut at this time,[7] the European and Chinese (*Castanea mollissima*) varieties do well in the mid-Atlantic region. The number of chestnuts grown in the United States is presently very low. We have locked our agriculture into unsustainable crops with antiecological reasoning. It is time that we start looking at the details of Smith's 1929 proposal and implementing them.

Smith looked at the many resources within the eastern deciduous forest of the United States that qualify. Chestnuts are essentially equivalent to a grain crop. They are sweeter than grains when roasted, but the amount of oils and protein is similar. Grazing pigs in a chestnut woodland makes sense, because pigs will eat chestnuts from the forest floor without hesitation. They will also eat acorns. These seeds are mostly inedible for people, because, unlike pigs, we lack the proper bacteria and digestive system to deal with the acorn's high tannin content. Many ruminants, such as goats, deer, llamas, and camels, can handle acorns without a problem, whether from red or white oak groups. Red oak acorns are full of tannin and were seldom consumed as human food.[8] White oak acorns have less tannin, and they served as a major part of the diet for Native Americans in California and throughout the United States when available. In some cases, up to 25% of these people's calories came from acorns. The white oak acorn is quite nutritious and is higher in fat than grains are, about 18% dry weight. Before eating, the acorn needs to be ground and leached in water to get the tannins out.[9] Sometimes this takes three washings. Once washed, the acorn can be mixed with grain flour to make breads or can be eaten as porridge by itself. The high oil content, according to Smith, makes it taste like a bread-and-butter mix. Species potentially eaten in the United States include the swamp white oak (*Quercus bicolor*), white oak (*Q. alba*), chestnut oak (*Q. montana*), and bur oak (*Q. macrocarpa*), as well as a number of California species. In the Mediterranean, the evergreen holly oak (*Q. ilex*) produces an acorn that can be roasted like a chestnut, as it has low tannin content. The swamp chestnut oak (*Q. micheauxii*) is also edible without leaching the seed.[10]

The eastern deciduous forest has many fodder species other than oaks. Among them is the mulberry. Though we normally think of mulberries in association with silk (the silkworm caterpillars prefer mulberry leaves), the fruits and leaves are eaten by a number of farm animals. Ruminants go for the leaves, while pigs and chickens prefer the berries. These animals eat both from the ground, so there is no need for harvesting. Although the berries are not easily stored, apart from freezing, drying, or canning them, some varieties have a very long

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[7] The American Chestnut Foundation (ACF) is working on backcrossing American Chestnut (*Castanea dentata*) with Chinese Chestnut, which suffers only minor cosmetic damage from the blight. The ACF's work has progressed to the point that they are now testing a 15/16 American/Chinese cross that is intercrossed to eliminate genetic susceptibility to blight. Once these highly resistant crosses are confirmed, the ACF will begin to introduce them widely across the American chestnut's former range, which extended from Mississippi and Alabama to Maine and southern Ontario along Lake Erie. Regional adaptations will be required, but ACF has farms in many places working on genetic stock. See www.acf.org.

[8] This is not as definitive as originally thought. You can eat red oak acorns if you grind them up, soak them in water, discard the water and repeat. Two or three washing removes most of the tannin and the resulting flour is easily used in baking.

[9] Tannins were once used for treating leather to make it stiff for shoes. Because this is a difficult process, most leather shoes, especially the soles, use the toxic metal chromium as documented in McDonough and Brungart's book *Cradle to Cradle* (New York: North Point Press, 2002). The tannins extracted from acorns are useful for this task and far less toxic than chromium when floating in the environment.

[10] *The USDA Field Guide to Native Oak Species of Eastern North America*, by J. Stein, D. Binion, and R. Acciavatti (2003), is an excellent resource: http://www.fs.fed.us/foresthealth/technology/pdfs/fieldguide.pdf

fruiting season and will provide food for the animals over a two-month production period. This often happens in summer before acorns or chestnuts are ripe. When animals are allowed to forage for themselves, having a diet that produces food over time is critical. Depending on one species to supply all of an animal's needs is foolish. In Smith's day, when pigs were not factory-farmed but lived on pasture, mulberries were part of the food system. Mulberry plants were important for the mix; they are easily planted, they grow quickly, they fruit early, consistently, and heavily, and they provide timber, posts, and firewood. The mulberry on farms disappeared with the rush to industrialize agriculture. Ripe mulberries are also tasty food for people and can be dried and eaten later, but in the long term they are more important as animal food.

There are some exceptions to the use of mulberry. In Tajikistan and Afghanistan, among the Pamirs along the old China Silk Road, the white mulberry (*Morus alba*) holds a special place. Legend has it that the trees were smuggled out of China when a Pamir leader married a Chinese princess, who brought the mulberry and silk moth with her. Though the production of silk never took off in the region, the fruit became part of the diet. To the Pamir in the lowlands of that very elevated region, the mulberry is the single most important fruit. When the Soviet Union collapsed and Tajikistan went through a period of violence and instability with the absence of food imports, the mulberry became a major part of the diet. Dried fruit was used like a grain (van Oudenhoven and Haider 2017). Unfortunately, the red mulberry (*M. rubra*) of the eastern United States does not hold the same lofty place as the white mulberry of Asia.

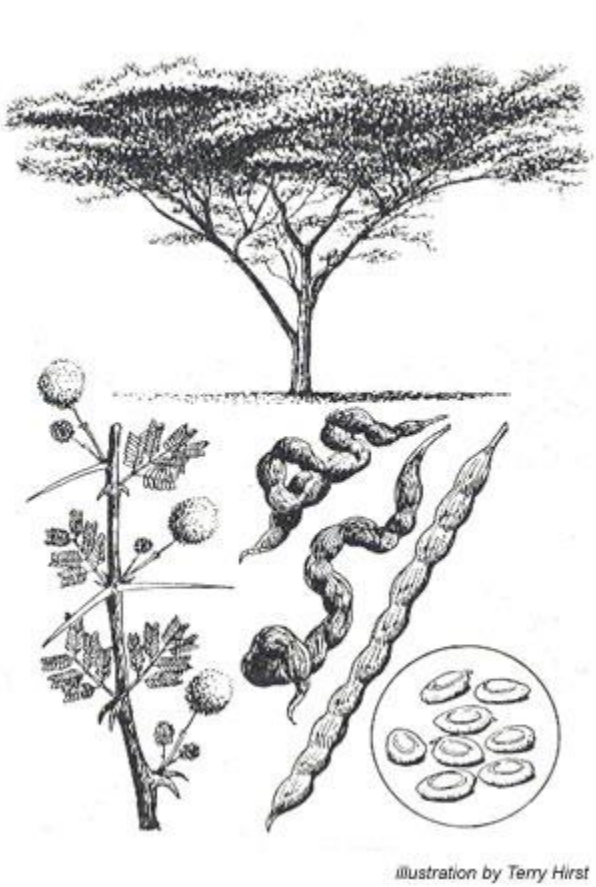
Another underappreciated tree is the American persimmon (*Diospyrus virginiana*), which produces an edible fruit. It is not the large flavorful yellow of the Asiatic persimmon (*D. kaka*) found in the supermarket. If an American persimmon is picked before the first frost, even though soft and ripe in appearance, it has a mouth-puckering astringency. With a bit of patience, a good frost, and a willingness to pick the fruit off the ground, these persimmons are as delicious as any purchased in the market—if the opossums, bears, and deer don't get them first. During the slave era and later, blacks in the US South often hunted possums at night in persimmon trees where the animals flocked to the fruit in season. Pigs, chickens, turkeys, and most other farm animals relish the fruit. Yet the tree has never gained a foothold in the United States. It grows over a broad range, on poor, eroded, or sandy soils. It also has a very long fruiting season, dropping ripe fruit from September to February. It is a perfect complement to the mulberry for foraging pigs, cattle, horses, turkeys, and chickens. The persimmon tree is harder to start than the mulberry or other fruit like apples, but because its leaves are basically inedible, once it starts growing, it requires less care and lives for a long time. Naturally occurring trees also support grafted stock of better varieties quite easily. Though they provide fairly dense shade, persimmons do well next to crops and do not seem to compete with them for nutrients and moisture. Smith pleaded for more research on the persimmon in 1929, and some research has gone into improving the American varieties and importing Asian types. Some new varieties have less astringent fruit and larger sizes. The market for persimmon has improved since Smith's day, but it remains limited.

The argument about the impact of eating meat assumes that the meat animals are fed corn and soybeans, slaughtered in centralized industrial plants, and shipped to stores around the country. Smith has pointed us to trees that provide food for pigs, chickens, turkeys, and goats. What about cattle? They are grazers and they belong on the prairie, but they like shade too. Smith identifies the honey locust (*Gleditsia triacanthos*) as the perfect tree for these animals in the eastern half of the United States. The honey locust thrives in moist lowland habitats but will grow on drier sites with deeper soils. It is a legume, producing prolific numbers of sweet pods that cattle and other animals like to eat either green or dry. The tree has an open canopy that allows some light through it and does not shade out or otherwise inhibit grass growth. It is a great pasture tree, with one notable exception. The honey locust evolved in the presence of now-departed megafauna like the mammoth and giant ground sloths, which loved the leaves and pods. In order to prevent an annual stripping of all photosynthesizing parts, the plant developed wickedly long thorns that stabbed anything larger than a squirrel attempting to grab its trunk or branches. The fiendish thorns allowed the honey locust to thrive, and the trees were spread by the same animals that eagerly ate fallen pods.[11] These animals are gone now, but the thorns remain on most wild trees. Humans have found some varieties without them and have propagated those varieties. Cattle can now take

[11] Whit Bronaugh, "The Trees That Miss the Mammoths," *American Forests* Magazine, http://www.americanforests.org/magazine/article/trees-that-miss-the-mammoths/.

over the duties formerly accomplished by sloths and put on weight at the same time. People are able to eat the honey locust pods, but the pods take a lot of time to prepare. The tree feeds us best via milk or meat of the cattle and goats that eat the pods.

The honey locust is a tree of the temperate deciduous forests, but other ecosystems have trees that serve a similar role. In the semiarid tropics, the acacia species provide both pods and foliage that make excellent fodder for goats and camels. *Acacia tortillis*[12] and *Faidherbia albida* (formerly *A. albida*) are excellent examples. In the Americas, the mesquite group accomplishes this job. *Prosopis glandulosa*, called honey mesquite, has sweet pods that are made into flour and eaten by native peoples in northwestern Mexico and the US Southwest. Cattle and horses can eat these pods directly, and the seed passes through their gut ready to germinate in the provided fertilizer. If the pods are ground, however, the nutritional value of the seed becomes available to the animals, making it nearly equivalent to feeding cattle grain mixed with a high fiber source. *Prosopis juliflora*, *P. chiliensis*, and *P. velutina* are excellent fodder producers, too. Acacias and mesquite are also thorny to protect their vegetation in dry landscapes. The trees do not become weedy in their natural habitat, but they do so with poor grazing management. The lessons Smith learned in the early twentieth century have been ignored in most of the United States. Mesquite is treated as a weed by ranchers in places such as western Texas, because these people tend to work against, rather than with, natural systems. However, Kenyan pastoralists will bag and sell *A. tortillis* pods in dry years to areas that do not have access to their own supply. For them, *A. tortillis* is the single most important tree for their cattle, sheep, and goats.



[12] The Acacia genus in Africa has been divided into two new genera. *Acacia tortillis* is now *Vachellia tortilis*.

Figure 13.2: Two trees in Africa widely used for agroforesty: *Faidherbia albida* is shown on the left and *Vachellia tortillis* on the right. The former is used in association with crops throughout its range, but perhaps most widely across the Sahel from Senegal to Sudan. *V. tortillis* is even more tolerant of arid conditions and is primarily used as a fodder tree for camels and goats, with pods sometimes collected and sold in the market.[13]

In the season of the black walnut (*Juglans nigra*) every fall, around early September, the wood's edge becomes a bit more dangerous, causing twisted ankles and bumps on the head. The tree grows on bottomland soils, usually well-drained and moist, throughout the eastern part of the United States. It has dark wood of excellent quality that is easy to work. It has edible nuts that are encased in a hard shell, sometimes used for industrial purposes as a grinding agent, and a soft outer covering that stains just about everything it touches a dark brown. Squirrels work hard to get at the nutmeat. It is rich, and very high in protein, oils, and calories. It makes good food for people, but is considered too strong to eat by itself, so it ends up mostly in ice cream and confectionaries. The squirrels commonly plant it for storage, then maybe forget about it or do not need it for food later, so it grows everywhere soils are suitable. The roots exude a chemical called juglone that has a strong allopathic effect on the Solanaceae family, including tomatoes, potatoes, eggplant, and peppers, and also other plants, like blueberries, blackberries, and apples. A number are unaffected by the black walnut, including most grasses and pasture species. In general, well-aerated compost over two months old made from black walnut leaves and seed husks will not harm any plants.[14] Smith felt that black walnut deserved a lot more attention from plant breeders than it had received in his day. The nuts are naturally better than most wild nuts, and improvements could make them superior to the English/Carpathian/Persian walnut, *J. regia*.

One of the themes that makes Smith's book stand out is his willingness to see things in a different way than Americans of his and our generations. His chapter on the Persian walnut is an excellent example. Americans tend to think in grand visions, like "amber waves of grain" stretching to the horizon, and we like monocultures. Smith did not. He wanted fields that produced but didn't erode. So he looked for ways to grow food that preserved the environment. When he considered Persian walnuts in Europe and Asia, he saw trees growing alone or scattered around fields in spots less useful for annual crops. He asked a farmer in France why he grew isolated walnuts and the farmer responded, "You see, monsieur, it is zis way. It is income wizout labor." Smith identified what we now call agroforestry: the deliberate management of trees in a diverse farming system.

Most of Smith's chapter on the Persian walnut is devoted to developing varieties suitable for the climate of the eastern United States. The varieties we imported from Europe are adapted to cool, moist winters and mild summers. This area of the United States is hotter in the summer, with powerful rains and higher humidity, and colder in the winter, with frequent killing frosts. We needed a variety suitable for this climate, but instead we grew the walnuts in California and Oregon in monoculture orchards and shipped them around the country. The idea of breeding a variety of walnut for the East Coast had not occurred to anyone, especially to people with enough money to support such a long-term enterprise. Smith also felt that we had not looked into developing commercially viable varieties of American native nut species, except for the pecan. Among these are black walnut, butternut, shagbark hickory, and shellbark hickory. According to Smith, if we made such an effort, perhaps nut crops could change the way we eat and could save the soil on sloping land at the same time.

There is another way to deal with black walnut and hickory nuts that is gaining interest now. Most of these nuts are characterized by hard, difficult shells that resist attempts to extract the whole nut. We can get the nutrient value of these nuts by breaking them into pieces and putting the entire nut, shell and all, into a boiling pot of water. This frees the oil, causing it to float to the surface, where it is easily decanted, filtered, and used as an edible oil. The remaining seed and shells can be fed to chickens, pigs, and turkeys, replacing the ubiquitous corn and soybeans with a more nutritious and local feed (Mudge and Gabriel 2014). The hickories that are best suited for this include shagbark hickory (*Carya ovata*), shellbark hickory (*C. laciniosa*), mockernut hickory (*C. tomentosa*), pignut hickory (*C. glabra*), and bitternut hickory (*C. cordiformus*).[15] The last of these, bitternut

[13] These illustrations were drawn by Terry Hirst for the website Agroforestry Trees of Kenya based on *A Pocket Directory of Trees and Seeds in Kenya* (Teel 1984). See http://agroforesttrees.cisat.jmu.edu/.

[14] https://www.hort.net/lists/perennials/jul03/msg00029.html.

[15] Steve Nix, "Identify Common Major Hickory Species in North America," ThoughtCo., January 29, 2019, https://www.thoughtco.com/identify-major-hickory-species-north-america-1341859.

hickory, is better used for nonedible purposes. The most well-known hickory is the pecan (*C. illinoiensis*), which has a thin shell and an easily extracted nut that has enabled widespread commercial development, especially in the state of Georgia.

Smith's ideas did not rise to the top of the American agricultural research agenda, which was hijacked by corporate agriculture, giant mechanization, and a collection of chemical companies. However, those ideas did not die in the 1930s, but survived in the quiet parts of university research and on the farms of mavericks who wanted to do things differently. One such maverick, named Philip Rutter, lives in southeastern Minnesota on Badgersett Research Farm, which he started in 1978. He is not connected to any university or to other nonprofit research-oriented groups like the American Chestnut Foundation® (ACF) or the Northern Nut Growers Association, though at one time he headed both groups and he maintains contact with them. He started working with American chestnut hybridization early on, but true to his maverick attitude, the relationship with ACF did not last. Rutter made the conscious decision to go with first-generation and second-generation hybrid chestnuts that are of blended American and Chinese chestnut heritage. The nuts are smaller and more flavorful, like the American nut, but their growth pattern and productivity are more like the Chinese chestnut. The ACF is attempting to get a timber tree back again, concentrating on combining the growth pattern of the American tree with the resistance to blight of the Chinese variety.[16]

If anything, Badgersett and Philip Rutter are more excited about hybrid hazelnuts than they are about chestnuts. The European hazelnut was perhaps the single most important plant source of nutrients for hunter-gatherer peoples from what is now Kazakhstan to the Balkan Peninsula. It remains one of the most important exports of Turkey, the world's largest producer. However, the European hazelnut, called the *filbert* in the United States, does not tolerate the climate of the northern Great Plains and can hardly tolerate the frosts of Virginia; further, it does not do well in the humidity of the Southeast, nor does it handle diseases native to that part of the world. The American hazelnut, on the other hand, thrives in these conditions and is very nutritious, but it produces smaller nuts that are not competitive on the market. Badgersett has had considerable success hybridizing these two species, working with American varieties from Wisconsin and Iowa as well as European varieties grown in Oregon. Badgersett breeders advocate planting hazelnuts in contour rows on farms. It is possible to grow row crops between the hedges of hazelnuts, but the nuts are shallow-rooted and could be damaged by tillage. They do well, though, when associated with pasture or other perennials like cane fruits or blueberries, depending on soil type. Rutter thinks that the hazelnut has the potential, with continued breeding, to replace soybeans on farms. This means a chemical-free perennial crop would replace an annual that requires frequent tillage or needs chemical treatment in no-till systems. The replacement would greatly please J. Russell Smith (Rutter, Wiegrefe, and Rutter-Daywater 2015).

Alley Cropping

Alley cropping is a method of agroforestry in which widely spaced rows of perennial trees are grown with crops between the rows. In the United States, this idea was developed best by H. E. Garrett, a research scientist at the University of Missouri's Center for Agroforestry (Garrett and Harper 1999). Garrett thinks the black walnut is really made up of two types of trees. To get the best timber with the least effort, the tree must grow densely in a closed forest system, keeping lateral branches to a minimum and straight vertical growth to a maximum. The tree in these settings produces a timber or veneer grade log in 50–80 years, depending on conditions. A nut tree requires a more open setting. It's grown at a 30 × 30-foot spacing, and then thinned slowly to 60 × 60-foot spacing, giving the tree adequate light and reduced nutrient competition in order to maximize seed production. While it is common practice to emphasize one production system or the other, agroforestry can work for both—using alley cropping with an emphasis on mixed production across a landscape. The walnut trees are planted in a row with relatively tight spacing, even as crowded as 15 feet between trees. These should be grafted trees, meant to provide commercial nuts from a known cultivar (Reid et al. 2009). The spacing between rows is based

[16] All the information from this paragraph comes from the Badgersett Research Corporation website (http://www.badgersett.com/) and the book *American Chestnut: The Life, Death, and Rebirth of a Perfect Tree* by Susan Freinkel (Berkeley: University of California Press, 2007).

on what is being farmed and the equipment used, but normally 60 feet is considered a good spacing. Crops are then grown between the rows of trees. In early years, corn, soybeans, and small grains are possible. As the walnuts grow, side branches are trimmed, reducing nut yield but keeping the trees growing straight. Nut production can start in as little as three to five years, depending on the cultivar chosen, but production does not peak until year 15 or later. Once trees reach this age, they usually cast too much shade for light-demanding crops like corn and soybeans. Small grains are grown, or the switch is made to pasture crops like alfalfa or mixed grass with legumes. Hay or pasture and nuts become the annual crops. Between 15 and 25 years, thinning of the black walnut trees occurs within the row. Trees are selected for form and length of the clear bole or trunk to maximize timber value when harvested. Often, about half the trees are thinned out. This also increases nut production on the thinned trees, though it never reaches the level of a true nut orchard. Full timber value is reached between 50 and 80 years. The amount earned on timber harvest can match the value of crops grown over the entire period of the agroforestry system if logs are of veneer quality. They are normally not as long as those found in a closed canopy forest, but they can still reach a high value. Agroforestry like this requires long-term, intergenerational planning and serves as a great example of a sustainable practice.

The National Agroforestry Center (NAC), based in Lincoln, Nebraska,[17] established in 1990 and expanded in 1995, serves as the American counterpart to the World Agroforestry Center, also called the International Center for Research in Agroforestry (ICRAF), based in Nairobi, Kenya.[18] Alley cropping was conceived by ICRAF as a way to increase nutrient availability for crops while reducing erosion; the idea is conceptually simple, but more difficult to implement. The plan is to grow a tree or a shrub that accumulates nutrients, like *Leucaena leucocephala* or the *Tephrosia* genus (both of which fix nitrogen on their roots), on contour lines or in straight rows within crop fields to provide nutrients as needed from trimmed leaves and stems. Contour lines of trees along a terrace riser are a good way to stabilize the steep banks and limit erosion. Complications arise in situations where the limiting factor in agriculture is light or water, since the rows of trees will compete for these. However, the technique can be successful on appropriate sites. It was also found that alley cropping was only one of a myriad of ways trees could integrate with overall farm productivity. Alley cropping is one of five agroforestry practices identified by the NAC and ICRAF.

[17] https://www.fs.usda.gov/nac/
[18] http://www.worldagroforestrycentre.org/

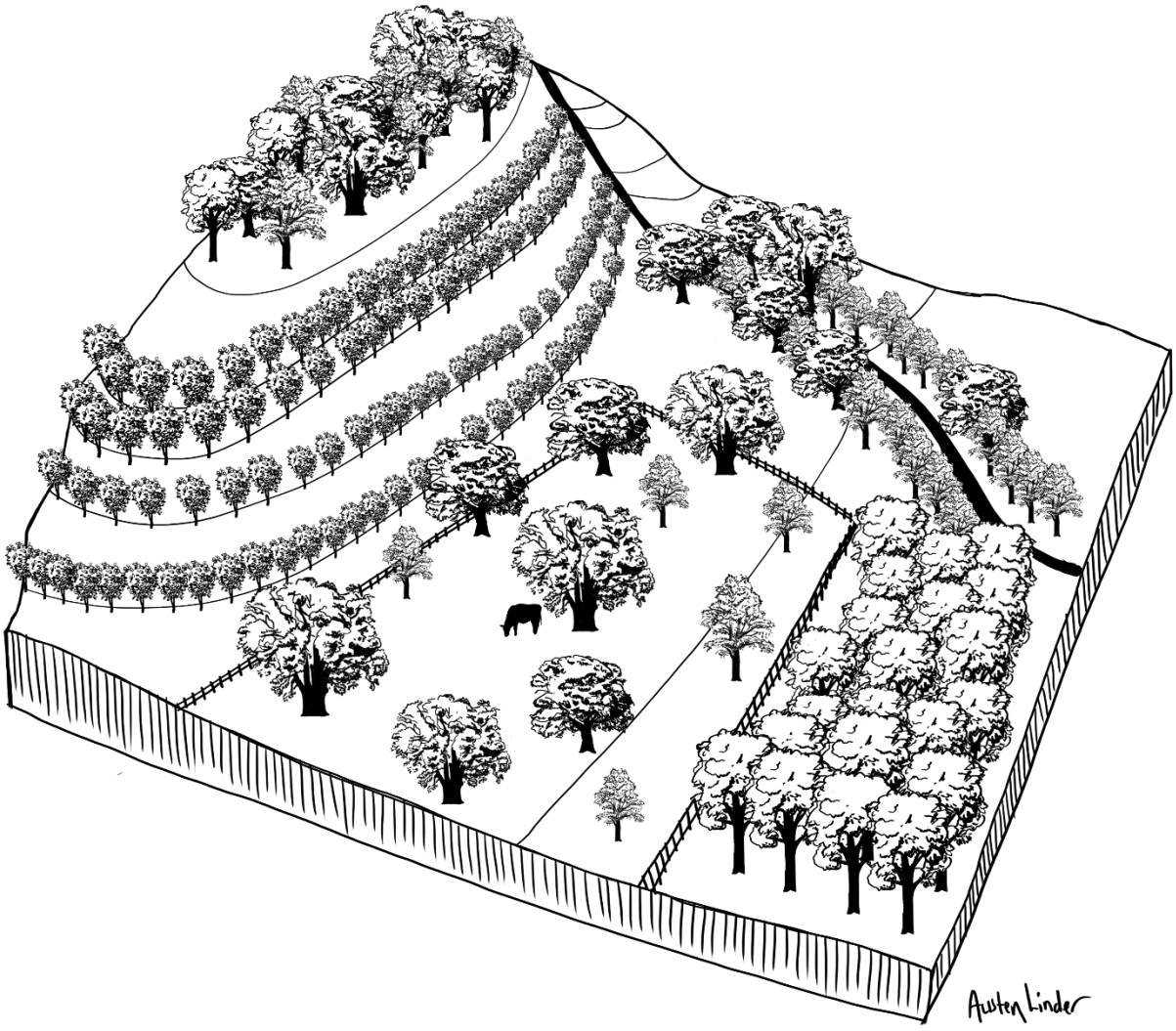


Figure 13.3: This illustration gives a glimpse at the places where agroforestry systems could occupy a landscape. The wooded areas shown in the top and bottom corners of the illustration act as shelterbelts and places for woodlot understory farming. In the upper right corner, a riparian area surrounds a stream. On the left side is an alley cropping system following the contour lines, in much the way as Badgersett Research Farm does with hazelnuts. In the bottom center is a silvopastoral system that can work in multiple climate types with differing tree species.

Windbreaks and Shelterbelts

Back in the Dust Bowl of the 1930s, it was very apparent that wind erosion was a major hazard. The newly formed Soil Conservation Service (now called the Natural Resources Conservation Service) focused on planting trees to act as windbreaks and shelterbelts throughout the Great Plains states. Windbreaks and shelterbelts work by slowing wind at field level and forcing it above the height of the tree. Their impact is usually effective to a horizontal distance 20 times the height of the tree, so a 30-foot tree would slow wind 600 feet away from the tree row. This impact is important both for protecting livestock and for reducing energy cost in heating homes. In October of 2013, a freak snowstorm in the western Dakotas killed thousands of cattle in areas where no protection was available.[19] In fields protected by windbreaks, the animals fared better, even though this storm

[19] Irina Zhorov, "Why Did South Dakota Snowstorm Kill So Many Cattle?" *National Geographic*, October 22, 2013, http://news.nationalgeographic.com/news/2013/10/131022-cattle-blizzard-south-dakota-winter-storm-atlas/.

arrived before the cattle had added their winter coats. Windbreaks around homes can reduce heating costs by 10% to 25%, depending on the aspect and quality of the house.

In the 1930s, the recommended windbreaks were wide. Today, the recommendation is for a narrower break of two to three rows of trees. Trees used in the windbreaks vary according to location. At least one row of evergreen trees is recommended to keep the effect through winter, and the short-needled spruce and fir species are commonly used. Pines are important in drier areas, but they commonly have a more open growth habit and the needles strongly inhibit growth under the trees by changing soil pH. A second or even third row of deciduous trees is recommended as well. These are commonly of a shorter species and could have additional uses. Serviceberries or saskatoon berries in Canada (*Amelanchier* genus) provide edible fruit for people and livestock. They taste a bit like blueberries and are about the same size but are harder to harvest. Osage orange (*Maclua pomifera*) has spiny branches, which can root if forced into the soil, forming a nearly impenetrable hedge that keeps even goats from passing through if done correctly.[20] There is an excellent guide for doing this in *Mother Earth News*.[21] Black locust (*Robinia pseudoacacia*) is another useful species in combination with evergreens in windbreaks; also, it provides highly durable wood for posts and makes excellent firewood. The National Agroforestry Center is an excellent source for more information on windbreaks and shelterbelts.

Riparian Buffers

Water erosion is the problem in the Appalachian region and more broadly in the East. While sheet erosion, the more or less even loss of soil from the surface through the action of rain drops and resultant runoff, has decreased due to implementation of best management practices pushed by the NRCS and others, erosion along stream banks persists in too many places. The best way to reduce this is to establish riparian buffers. A buffer is an exclusion zone on each side of a stream that prevents cattle entry and allows the growth of deeply rooted perennials, mainly trees. National and state programs like the Conservation Reserve Program and the Conservation Reserve Enhancement Program help farmers fence out cattle and other domestic animals, set up alternative watering systems, and plant trees. The recommended trees include many that Smith would have liked, such as swamp white oak, bitternut hickory, and black walnut. These are commonly called mast species, trees that produce seeds eaten by wildlife, including deer and turkeys. The trees evolutionary strategy is to overwhelm the seedeaters with food, so they are satiated, and leave some for reproduction, but they tend to do this in alternate years.[22] These buffers could be managed for human or domestic animal food production as long as the tree, shrub, or perennial grasses of the stream bank protection system remain intact. Other trees used in buffers include poplars, sycamores, willows, birch, honey locust, some dogwood, and red maple.

[20] Osage orange has a very large fruit, bigger than grapefruit, quite hard and heavy. It was found on a limited range in the Red River valley on the border between Texas and Oklahoma. It proved very useful for fencing and providing rot-resistant fence posts, so it spread all over the country. Evolutionary ecologists think that its limited range is a recent phenomenon caused by the extinction of mammoths and giant ground sloths, animals large enough to eat the fruit and spread the seed. Humans took over that role in the nineteenth century. Horses and cattle will eat the fruit in winter when fresh grass is not available (http://en.wikipedia.org/wiki/Maclura_pomifera).

[21] Harvey Ussery, "Living Fences: How-to, Advantages and Tips." *Mother Earth News*, October/November 2010. https://www.motherearthnews.com/homesteading-and-livestock/sustainable-farming/living-fences-zmaz10onzraw.

[22] https://www.britannica.com/science/mast-seeding

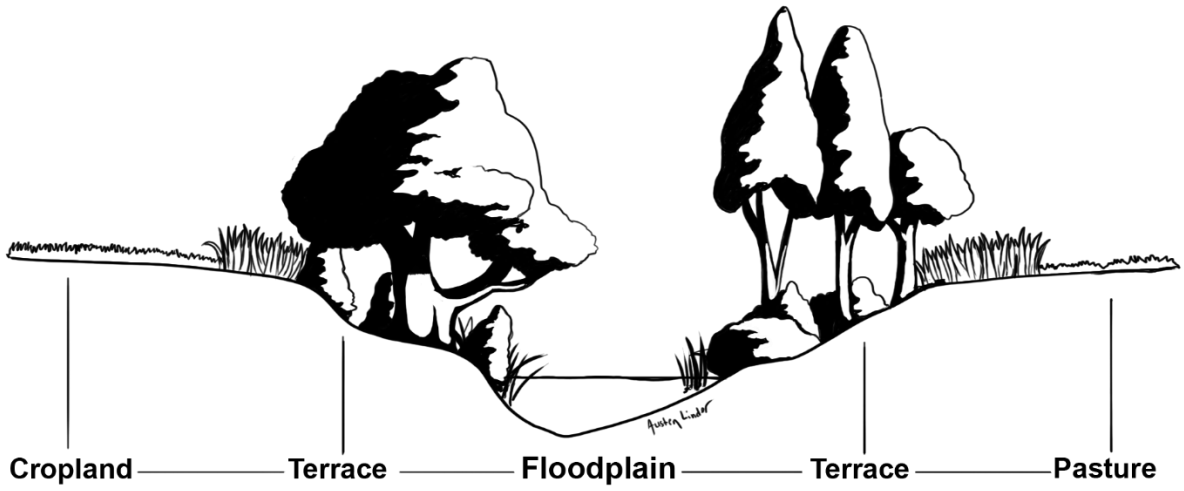


Figure 13.4: A cross section of a riparian buffer. Most of the time, the stream flows in a narrow channel, confined by non-erosive rock and a bank locked in place by the root system of plants. With heavy rains, the flow expands into the terrace area, reaching what is called "bank-full" flow. Extreme events may raise water levels into the broader floodplain. If the stream banks are well vegetated with deeply rooted perennials, this slows water, allowing sand and silt to settle out and add to the stream bank and floodplain. In the absence of these trees, shrubs, and deeply rooted grasses, the floods carry away soil, leaving behind a deeply scarred riparian zone.[23]

Silvopasture and the Importance of Shade

When working in East Africa, I visited a farm in the northwestern part of Tanzania on the east side of Lake Victoria, and west of the Serengeti. The area is high and relatively dry hill country, suitable for agriculture. People grow sorghum, millet, cowpeas, cassava, beans, and a mix of other crops. They also keep cattle, and since the area is elevated, there was some effort to bring in high-milk-producing breeds to improve local stock yields. A German government project used Brown Swiss cattle, a breed known for excellent milk production. Their pastures were good, and because it was a trial project they kept careful records of daily milk yields from individual fields. A pattern in daily yields was observed: when cattle grazed in certain fields, yields went up. Analysis showed that the only significant difference between fields was the amount of shade provided by remnant trees: the large fig (*Ficus thonningii*) and the umbrella thorn (*Acacia abyssinica*). Cattle have a highly predictable consumption pattern. They graze for about four hours, from dawn to mid-morning, then lie or stand around for four hours chewing the cud (which is rechewing the material eaten in the morning), grazing again in the afternoon to dusk, and spending the night sleeping and chewing more. Without shade in the heat of the day, cattle spend far less time chewing, reducing digestibility of their food and subsequently reducing yield. Adding shade increased yields by 20% or more. The project added a tree-planting component and asked for ideal shade trees. I recommended three additional species based on my work in Kenya: *Croton megalocarpus*, *Albizia gummifera*, and *Calodendrum capense*. These were suitable for the local elevation and rainfall, and all three were known locally by farmers.[24]

[23] For a detailed examination of riparian landscapes, see David Rosgen. *Applied River Morphology*, 2nd ed (Fort Collins, CO: Wildland Hydrology, 1996) and Luna Leopold, *Water, Rivers and Creeks* (Sausalito, CA: University Science Books, 1997).
[24] For more information on these trees and others in East Africa, see http://agroforesttrees.cisat.jmu.edu/.

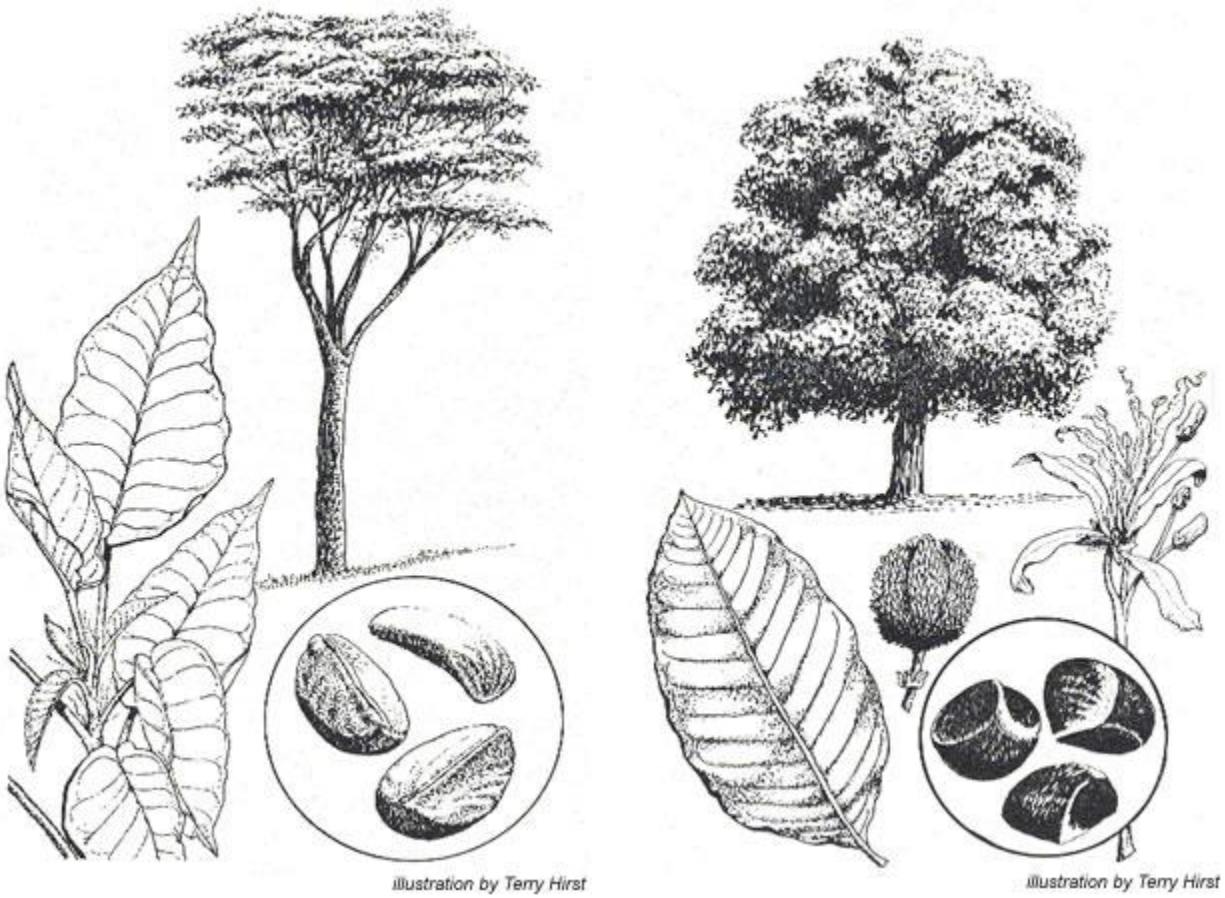


Figure 13.5: (a) *Croton megalocarpus* and (b) *Calodendron capense*, drawn by Terry Hirst for the website Agroforestry Trees of Kenya based on *A Pocket Directory of Trees and Seeds in Kenya* (Teel 1984) (http://agroforesttrees.cisat.jmu.edu/).

One of the harshest landscapes on the planet is found in the Sahel, the southern "shore" of the Sahara desert stretching from Senegal and Mauritania in the west to Sudan in the east. It is a land that receives only 200 to 600 millimeters of rain each year, most falling in one short rainy season when the intertropical convergence zone passes overhead between May and August. The Sahel experiences frequent droughts and at one point had a shortage of wood, the fuel used by most living in the region. This shortage is diminishing because a change of attitude and land use has slowly transformed the landscape. People are both planting trees and encouraging regrowth of those trees that survived the deforestation that dominated in the 1970s. The trees grown include many pod-producing species, such as the apple-ring acacia (*Faidherbia albida*), that are used to produce fodder and shade for the animals in the dry season. The animals, in turn, leave their droppings and urine behind for next season's production of crops.

In the tropics, trees give cattle more benefits than just shade. Some shrubs, notably *Calliandra calothyrsus*, provide fodder and increase the butterfat content of milk. *Harrisonia abyssinica* is another important fodder shrub, commonly found in hedgerows and a favorite of milk goats (Teel 1984). Hedgerow planting was

started on the smaller East African farms because of the multiple uses for the trees and shrubs. Hedgerows can be planted on contours and used for living fences, and the cuttings provide firewood and fodder use.[25]

Shade benefits cattle in the United States as well. Farmers in the southeastern United States grow widely spaced pines for this purpose. Pines have the advantage of being nonpalatable when young, so cattle do not browse them. Oak, hickory, maple, and black walnut are useful shade trees, but they require protection until they reach a size—usually at least four inches in diameter at the height of a cow's back—where cattle will not rub off their bark or eat any new growth. Cattle will congregate under the tree's shade during the heat of the day in almost every part of the country, and this will enhance their growth or milk production. If there are only small patches of shade, cattle will trample the areas, allowing little to grow in the understory and damaging the tree's root system.[26]

From 1987 to 1989, I worked on a master's thesis in Lewis County, New York, looking at dairy farms and their use of trees on the farm. The most enjoyable use of trees involved the making of maple syrup from sugar bushes. These are groves of trees dominated by sugar maple (*Acer saccharum*) that area codominant species with beech trees throughout much of New England, west to Minnesota, and into Ontario and Quebec. Maple syrup is made from the free-flowing spring sap of maples that begins when temperatures in spring rise above freezing during the day and fall back to below freezing at night. This period can last for up to a month. The sap contains between 1% and 4% sugar, though a few isolated trees can have even more. Usually, the trees having the highest percentage of sugar had full canopies and grew in open or widely spaced settings around the edges of farms. These same trees provided shade to cattle in the heat of summer and probably benefited from the increase in nutrients that the cattle deposited around the base. At least a few farmers I interviewed planted the trees deliberately for this dual purpose. Most of their sugar production was based in the woods.

Overstory and Understory Trees

This brings us to the fourth use of trees in agricultural systems: an overstory tree for understory crops. Here again ecology comes into sharp focus. Most ecosystems have a wide variety of niches for producers and consumers. The plants that humans use come naturally from a niche in their native ecosystems. Commonly, humans have pushed the plants into niches that differ from their natural ones in order to enhance production. Coffee and cocoa are two outstanding examples of this, as both are widely grown and economically valuable. Coffee as a commodity is exceeded only by petroleum in value on the world trade market. Cocoa is in the top ten of globally traded crops. They share the characteristic of originating as understory bushes to small trees in tropical forests. Arabica coffee, preferred by lovers of premium brews, is a native of Ethiopia's southwestern forests and grows as a small tree of variable habits in cool highland areas with a dry season of four to six months. Cocoa comes from the Caribbean region of South America and Central America, growing in dense lowland forests that also have a seasonal dry period. Both prefer partial to full shade. People did not keep them there, because shade reduces energy input to the plant and in turn reduces potential yield. To maximize yield, plantation owners took these two plants and grew them in monocultures. This came with a price. More inputs in the form of fertilizer, herbicides, fungicides, and insecticides were required to keep the plants healthy. There was also a heavy environmental cost in terms of biodiversity, erosion, water quality, and human health.

Coffee is the world's largest agricultural commodity. It grows in the tropics of places like the Atlantic forests of Brazil; the mountainous midlands and highlands of Colombia, Central America, Mexico, Kenya, and Ethiopia; and the hilly forests of Indonesia and Vietnam. These forests are some of the most diverse on the planet and also the most endangered. Conversion of these forests to coffee production is one of the key factors in this endangerment. Brazil and Vietnam produce primarily robusta coffee (*Coffea robusta*), which is tolerant of the warmer temperatures found in Uganda where it is a native understory tree. Colombia and Ethiopia focus on

[25] Regarding fodder trees and milk production in East Africa, see the World Agroforestry Centre 2009 Policy Brief, http://www.worldagroforestry.org/downloads/publications/PDFs/BR09326.PDF.

[26] These are personal observations of my own farm, and of farms in the Shenandoah Valley, in Lancaster, Pennsylvania, in Lewis County, New York, and in Western Washington.

Coffea arabica production. The relatively recent recognition that deforestation has had a profound effect on wildlife, especially birds and primates, has led some farmers to pursue shade-grown coffee. The results have proven to be very positive. An online article by the Smithsonian Migratory Bird Center that reviewed 50 academic studies of shade-grown or forest-grown coffee shows that the overstory forest has a strong positive impact on bird life, insect life, reduced insect damage because of increased predation, better pollination, lower erosion rates, higher income from noncoffee farm enterprises, and much more.[27] Agroforestry-grown coffee might reduce production, but the overall improvement of farmland ecology and farm income offsets this loss, and, in a less well-documented conclusion, consumers also think the coffee tastes better.[28]

There is an irony in the farming of coffee and cocoa. Coffee is a leading cause of deforestation in the Atlantic forest of Brazil and mid-elevation mountains of Colombia, while cocoa is a leading cause of deforestation in West Africa, especially the lowland forests of Cote d'Ivoire and Ghana. Why do these crops flip originating continents? The answer lies in colonial history and the presence of disease in their places of origin. Plants evolve in an ecological context, and in the tropics they are usually found in highly diverse ecosystems. When forced into monocultures, or at least more-intensive cultivation strategies, insects and diseases that coevolved with the plants gain an advantage. These organisms are not found on the new continent. While this was conventional wisdom for a long time, and holds true for some species like the rubber tree of the Amazon, it is not a universal truth. Sometimes, the problem is the loss of biodiversity associated with the intended crop. When you take an understory tree away from its ecological context, you lose the birds, insect predators, and other beneficial organisms as well as some of the problems. The plants, now in a context where environmental stimuli have changed, do not respond the same way, and more inputs are required. Agroforestry is an attempt to establish an ecosystem that simulates an original ecosystem context while still intensifying production on a given piece of land. The jury is still out for both crops when it comes to details (Asare 2006), but there is little doubt that bird populations, erosion control, and overall carbon capture are improved in an agroforestry setting, just not to the degree present in the original ecosystem of those places.

Like the Atlantic forest of Brazil, the West African forest that extends from Guinea to Cameroon is now highly fragmented and endangered. Cocoa, coffee, oil palm, and rubber are major contributors to this problem. All four are components of tropical forest ecosystems, but only oil palm is native to this part of Africa.[29] Ghana, Cote d'Ivoire, Nigeria, and Cameroon are the world's leading cocoa producers. After deforestation, the biggest problem now is child slavery. Cocoa as it is now grown requires thinning and pruning to maximize production. Since the trees have relatively fragile branches, it is best to use lightweight boys for the task. "Buying" or kidnapping young boys from poor families is an easy way to get the labor. A simple internet search of "chocolate child labor Africa" leads to numerous news stories and groups working to end the problem. Cote d'Ivoire is the center of this activity, but it extends to the other countries as well.

In Cameroon and Ghana, efforts are underway to change the nature of cocoa production, moving from monoculture to understory production. The latter was practiced during the introduction of cocoa, but monoculture became dominant from the 1950s through the 1970s. As the plantations aged, opportunities arose to adapt these systems. While growing canopy trees of fruits like avocado and mango is possible, both these trees have very dense shade, so they are probably best suited for the edges of cocoa groves. More success comes with growing open canopy timber species, though Asare's (2006) review indicates that no verdict has been reached on productivity and the reduction of inputs. He also provides a set of guidelines needed to assure the success of agroforestry-based cocoa production. Systems must be *ecologically possible* (appropriate for the best genetic expression of the tree), *socially acceptable* (plausible for local systems given available labor and conditions), and *economically viable* (people have to make a reasonable living). At present, even more than

[27] Robert Rice, with assistance from Mauricio Bedoya, *The Ecological Benefits of Shade-Grown Coffee*, September 2010, http://nationalzoo.si.edu/scbi/migratorybirds/coffee/bird_friendly/ecological-benefits-of-shade-grown-coffee.cfm

[28] All Ground Up: http://www.allgroundup.com/light_en/sustainability/

[29] Oil palm is a major factor in the deforestation of Borneo and Sumatra in Indonesia. See the Rainforest Action Network and the Nature Conservancy for their work on this issue. The rate of deforestation, as a percentage of total area, is the highest in the world in this region.

coffee, cocoa is subject to the needs of the corporations that control the market. Making a profit while being ecologically and socially appropriate has proven elusive—thus the problem with child slavery.

Montgomery (2017) adds another dimension relevant to both coffee production and cocoa production. He visited a farm in Ghana run by Kofi Boa, near Kumasi to the northwest of the capital city of Accra. Mr. Boa is an advocate of the soil-first paradigm. He emphasizes that mulch is the main ingredient of his success. He uses all dead organic material as a source for mulch, uses far fewer inputs like fertilizer and herbicides, and basically uses no insecticides. Birds and other predators, taking advantage of the overstory trees, remove most of the problem insects, which also reduces plant diseases where the insects are carriers. The thick mulch suppresses weed growth, so Mr. Boa is able to avoid the normal practice of burning crop residues in the area. In fact, Kofi Boa is a leading practitioner of Albert Howard's Law of Return, and his success promotes the spread of the ideas to the wider community (Montgomery 2017).

Cocoa is less problematic in Central America and South America. Even though less than a third of global supply comes from cocoa's native range, more efforts to grow it with agroforestry systems are underway. The "Fair Trade" and environmental movements have promoted these efforts. Just as for coffee, evidence acquired by the Smithsonian's Migratory Bird Center shows that cocoa planted with an overstory of native trees, the more species the better, has substantially increased the habitat for migratory birds. Cocoa yields underneath trees are somewhat less than in open plantations but require fewer inputs. The Smithsonian's article on the subject also indicates that cocoa trees have not had serious selection trials for yield when growing in these shade situations. Some trees do very well, while others bear very few fruits (Somarriba and Beer n.d.). Rolim and Chiarello (2004) caution that simply having an overstory of selected shade trees is not enough to save the Atlantic forest of Brazil, or by implication other tropical forests. Most of the trees that do well in this setting are early succession species, and later emerging canopy trees are not allowed to compete. The result is a slow degradation of the natural forest instead of a rapid deforestation. The end result for the ecosystem may be the same. It is important to recognize that agroforestry with cocoa and coffee is really in the early stages of development.

We are still learning about the agroforestry systems of cocoa, coffee, and other crops. We know they work, but it is unclear how they work best. The source for the best information is in the natural system that we are destroying. Even in agroforestry, the systems studied are often not a mimic of a natural ecosystem. There may be an attempt to overlay a natural ecosystem on a cocoa or coffee production system, even though done in a monoculture. Overall habitat is still reduced for natural inhabitants of an area. In addition, these are often relatively large plantation efforts, not mixed systems on a scale where a healthy natural system is adjacent to an agroforestry system and thereby allows genetic diversity and easy movement of insect, bird, and mammal species. The large-scale plantation model is part of the problem. On a smaller scale, more single-family-size operations interspersed with natural forest in a mosaic would prove better and more productive. Unfortunately, the human population pressure of the planet does not provide a lot of space to make the effort.

Forest Management: Farming the Woods[30]

This brings us to a final component of agroforestry that ties into the larger issue of how we manage and use forests on a broader scale. Historically, most farms had a woodlot or a woodland commons that every farm family could access. These woods provided a host of products: mulch and green manure, fodder, fruit and other food, fiber, timber and other construction materials, fuel wood, and medicine. These were things that were essential for the operation of the household economy but did not require collection every day, so it was fine to have the lot some distance away. Less well known, and certainly not well remembered, is that the plants of this ecosystem were managed. People needed certain items from their woods, so they tended and promoted the species that provided their needs and removed those species that they did not require. A weed in this system was not a waste; it was selected for use as green manure, mulch, firewood, or even biochar. A plant that provided

[30] This title is deliberately borrowed from the excellent book by Ken Mudge and Steve Gabriel: *Farming the Woods: An Integrated Permaculture Approach to Growing Food and Medicinals in Temperate Forests* (White River Junction, VT: Chelsea Green Publishing, 2014).

fiber or medicine was left to grow until needed for that use. Good straight timber trees were left to grow, while crooked, forked, or spindly trees of the same species would go on the wood pile. This is called low-grade management, with the removal of the poorest members first, while encouraging the growth and reproduction of the best-quality stock.

The United States had the dubious distinction of having destroyed native ecosystems faster than any other country on the planet—until Australia (and perhaps now China) broke our record. Before we Europeans destroyed the place, Native Americans had lived here for millennia. We do not know the role of the early Clovis people in destruction of megafauna, but since that period the native peoples, still called Indians even by themselves, managed the North American landscape in ways that looked so natural that the Europeans did not recognize management. It was not "natural" in the sense that there were no human fingerprints on the landscape. Indians did manipulate fire and promote some species and reduce others. What they did not do was change ecosystems in wholesale ways as the Europeans did. As just one example, starting in the 1830s, settlers began claiming land and clearing forest in the northern states of Michigan, Wisconsin, and Minnesota. This process sped up rapidly during the Civil War, supplying a substantial portion of the resources needed for the war effort, including railway ties and eventually supplying the ties and other timber materials for the transcontinental railway. The forests were stripped willy-nilly, giving rise to some of the most spectacular and destructive fires in US history, exceeding even the recent spate of fires in the American West. The native Indians of Wisconsin were confined to small tracts of land—reservations. One group, the Menominee, received a 235,000-acre piece northwest of Green Bay. Tribal elder and chief Oshkosh (yes, the one the clothing company is named after) introduced a style of sustainable management to this forest in 1865 amid the destruction of the rest of the state.[31] It takes people with a true vision to buck the prevailing paradigm of a dominant culture. Here is the mission statement of Menominee Tribal Enterprises:

> Menominee Tribal Enterprises is committed to excellence in the sustainable management of our forest, and the manufacturing of our lumber and forest products providing a consistently superior product while serving the needs of our forest, employees, wood products customers, tribal community, and future *generations.* (http://www.mtewood.com/)
>
> It is said of the Menominee that the sacredness of the land is their very body, the values of the culture are their very soul, the water is their very blood. It is obvious, then, that the forest and its living creatures can be viewed as food for their existence. (Marshall Pecore, MTE Forest Manager, *Journal of Forestry*, July 1992)

In the Pacific Northwest, and to a lesser extent everywhere, the forest is basically managed for timber. This leads to an even-age forest of one high-value species growing at the same rate. The Menominee turned this on its head. They manage for the full range of forest products and the full health of the forest with the active participation of the people. Trout, good walks, and mushrooms are all considered products that have value, even though they don't bring in money the same way that other products, like cabinets or molding, of the Menominee Tribal Enterprise (MTE) do. The key is managing for a healthy ecosystem. MTE wants a diverse ecosystem with mixed-age stands of every tree. The people monitor the trees closely on a regular basis, measuring 58,000 trees a year to track growth in a 15-year cycle. They remove trees that exhibit ill health or bad form, and they leave trees to form old-growth stands in places to maintain good genetics. They have harvested more wood than most single-product management systems, and they have more standing timber value now than when they began these practices 140 years ago.[32]

The same thing is true for the management of the Almanor Forest, owned and managed by the Collins Pine Company in northeastern California, just east of Lassen Volcanic National Park. The company has owned land in the area since 1902 and started managing it as an intact 94,000-acre forest on a sustained yield basis in 1941.[33] The forest is primarily coniferous, but species vary according to aspect, elevation, and soils: lodgepole

[31] http://www.mtemillwork.com/forest/index.php
[32] Christopher and Barbara Johnson, "Menominee Forest Keepers," *American Forests Magazine*, Spring 2012, http://www.americanforests.org/magazine/article/menominee-forest-keepers/.
[33] http://www.collinsco.com/almanor-fsc/

pine, ponderosa pine, other pine, Douglas fir, a variety of true firs, and incense cedar. The company was certified by the Forestry Stewardship Council® in 1992. Nattrass and Altomare (1999) cited the work of the company as an example of The Natural Step™ management practices in the book *The Natural Step for Business: Wealth, Ecology and the Evolutionary Corporation*. The result of the selective harvest management system is a forest with sustained yield, increasing wood content, an intact ecosystem (birds, mammals, and other wildlife), and healthy streams (where they are not impacted by preexisting dams). The Collins Pine website is highly transparent with respect to management systems, and the company is open to visitors. This contrasts greatly with the dominant model of private forests represented by Weyerhaeuser, Boise Cascade®, and Georgia Pacific that use square-mile clear-cuts and have "Keep Out" signs on their access roads.

While these forests are small in comparison to the total land found in major corporate forests or in the National Forest System, they represent a model much more in tune with how farmers or forest landowners could manage their personal land. Woodlots have a size range, from backyard trees to 500-acre forests. Most of them are ignored as a resource, with the possible exception of firewood, until they are turned over to a contract harvester to strip the woods of valuable trees. Unfortunately, they are still ignored after being stripped, and they come back with a combination of pioneer trees and weedy species of lower value. This degradation affects wildlife and soil and water quality. Using a woods well does not have to become an all-consuming exercise, but it does take planning and some ecological understanding. A few simple rules will suffice here to sum up the process of managing a sustainable woods with multiple products and a constant storage of carbon.

1. *Low-grade the woodlots.* Most woods almost everywhere in the United States are regenerated from forests heavily logged in the nineteenth and early twentieth centuries. Our wood products come from second- or third-generation forests farmed commercially. Most small woods came from what could easily and quickly recover. These woods are commonly a mix of weedy species, early succession species, and a few good-quality trees growing slowly in their midst. Low-grading means selective removal of trees that have little value as either timber, because of poor form or disease, or an alternative product like nuts, acorns, fruit, or medicine. When weeds like *Ailanthus altissima* (tree of heaven, which does make excellent firewood when larger), eastern red cedar, or autumn olive are removed, space is freed for higher-value species like white oak, shagbark hickory, or white pine.

2. *Plant species you want*. Many farm or family woodlots are disconnected from an extended region of forests, and there is no seed source available for high-value species that commonly have heavier seed that cannot be carried by the wind. Choosing and planting these trees is essential. Since they are not growing in an open situation, they do not need a lot of care, especially once they reach a height where deer cannot nip them, or a thickness of bark where rabbits or voles cannot girdle them. It may take some initial effort to protect what you plant, or you can simply overwhelm the pests by sowing a lot of seed and letting nature make the selection of the best new seedlings (Shepard 2013).

3. *Thin the growth*. Often, new growth comes in already very densely packed, since sunlight is not limiting at first. Once the canopy closes, growth of individual trees will slow if they are tightly packed. This can even slow overall carbon capture. Thinning to a spacing where the canopy is no longer closed will open the woods up and maximize growth. Selecting the trees to thin may involve cutting out a good tree. Do not be afraid to do this. Leaving two good trees could lead to growing two bad trees. It is best to thin to one good tree. Thinning to between 15 and 20 feet between trees in every direction is common in well-managed woods.

4. *Use the understory*. There are a lot of species that like limited light. The second highest value export in early America was ginseng. It was Daniel Boone's major source of financing for his exploration of Kentucky. Other high-value understory plants include goldenseal, black cohosh, and Virginia snakeroot in the East, Canadian and Pacific yew in the northern forests, Oregon grape and salal in the Pacific Northwest, and many more. Often, all these plants need is a space to grow and someone to plant them. Most are competitive native perennials that need only a chance to get started again in a formerly degraded habitat (Teel and Buck 1998).

5. *Think differently about management*. In the past, before fossil fuels and massive urbanization, people managed the woods for a variety of goods. Perhaps the most important part of the woods was the coppice woodlot. Most of us today do not know what coppicing is. Many tree species, when cut near the ground at between 15 and 50 cm, will sprout new stems. These will grow more rapidly than the original single stem, especially if thinned to two or three stems, and they will provide a continuous supply of poles and firewood on a rotational basis. Harvest of these stems was often every 7 to 10 years, yielding good volumes of easily harvested and cut firewood and above-ground construction poles. Many species, including oak, hickory, basswood, eucalyptus, redwood, willow, and poplar, coppice well. Mark Krawczyk and Dave Jacke are presently working on a book about coppice woodlots, hoping to reinvigorate the practice in the United States and elsewhere.[34]

Edible Forests in Your Backyard (or Front Yard)

For most of us, having land on which to plant an extensive number of trees is simply a dream. The best we can hope for is an area of maybe a quarter or half an acre, 10,000 to 20,000 square feet (930 to 1,860 m^2). For most Americans, this space is made into a manicured lawn with a few flower beds scattered around the edges. Lawns are basically green deserts. When you keep grass under four inches most of the time, you also keep the root system of grass approximately the same length. This is part of the reason why the lawn dries out so fast if we don't get a good weekly rain. What if the lawns, the largest area of managed land in the United States for a single crop (yes, larger than corn), were to transform into an edible perennial landscape?

This is the working premise behind Dave Jacke and Eric Toensmeier's two-volume work, *Edible Forest Gardens*. Their work is based on understanding the ecology of a forest as managed in a garden. Their premise is that humans need food, but have dissociated their food supply from their residence and need to put the two back together. The authors also recognize that most people do not have time for full-time gardening, but that perennials, once established in the correct arrangement, take care of themselves. People normally have problems figuring out the correct arrangement because they have lost touch with the ecology and genetic character of the species we use for food. So people plant six fruit trees in their backyard, too close together and in uncomplimentary arrangements. They fail to recognize that short sun-loving plants should go on the south side of taller species and a reasonable distance from the shade of the house. For Jacke and Toensmeier, less is often more. Yield is dependent on creating the right abiotic and biotic conditions of a yard. This is ecosystem thinking scaled to the backyard level.

In *Edible Forest Gardens*, they provide two excellent case studies of edible forest gardens. The first example is from Greensboro, North Carolina. The homeowner, Charlie Headington, has a standard quarter-acre lot with a driveway along the south side of the house, a front yard facing east, and a larger backyard of 50 ×100 feet. The front yard is filled with a small meadow, and flowering shrubs decorate the entrance to the house. The hot south side is now protected in summer by a trellis with muscadine grapes and three dwarf pear trees. The north side of the house has taller shade trees that rise above the roof. The roof serves as a water catchment, draining into 55-gallon drums, with the water used to irrigate the garden as needed. The backyard is a mix of fruit trees, including five plums, a grape, a kiwi, a persimmon, a fig, two apples, two peaches, a red bud, and a large mulberry in the south corner, with an ash, an elm, and a red maple along the north fence. In the middle of all this is a vegetable garden of annuals and perennials, like asparagus. The whole is a beautiful but very crowded space. The large trees prevent more productivity, and the crowding reduces the yield of some individual plants—yet the overall effect of the garden is stunning, even in the pictures. Charlie did not plan this space from the beginning. It was more ad hoc. The authors make a case for deliberate planning before planting, so the needs of each species are properly identified. When this is done, you get an aesthetically pleasing and productive yard with a relatively low-maintenance system. High maintenance is commonly a sign that the ecological conditions are wrong.

[34] More information is available on their website: http://www.coppiceagroforestry.com/index.html.

The second example comes from the home and garden of Martin Crawford in Devon in South West England. Martin developed his garden with a deeper understanding of the ecology of his place. His focus is on native species, and those plants are naturalized and developed for the cool, moist conditions of Devon. Though the garden is only two acres, Martin has 31 families of woody plants in the canopy and 550 total species growing on the property. Many of these he is simply testing both for individual plant yield and for interactions with other species. Even with this high diversity, Martin leaves a lot of space between the canopy trees. Around 40% of the canopy is open to allow light to reach the understory and ground plants. His original intent remains: to test species in relation to each other, measure yield, assess ideal growth conditions, and expose their usefulness to the wider public. He grows species like linden (*Tilia cordata*)—which has leaves that people do not know are edible—in a coppice that does not get above head height so the leaves are easy to harvest. The details of this garden are very complex and best explained by Martin himself.[35] He estimates that his garden can feed 10–12 people year-round.

The Trillion Tree Project: Reversing Climate Change One Local Planting at a Time

A trillion trees is a huge goal. It is not reachable with the mindset of our planet's inhabitants at present. We must recognize first that a problem exists and second that we are part of the problem. An interesting survey has been completed by Stanford University professors and students on the attitudes of US citizens about climate change and global warming. It found that even people in Texas and Mississippi were aware that global warming was a reality. Fewer people thought that regulation should induce business to lower carbon emissions. However, when the question turned to paying more for gasoline or electricity, the negatives outweighed the positives. Among survey respondents in Virginia, 81% were aware of global warming happening, 75% thought businesses should limit emissions, only 28% thought we should pay a consumption tax for electricity, and 41% thought the same for gasoline.[36] We are fine when it is someone else's problem, but we're not so interested in owning the problem ourselves. However, since the study was completed, the awareness of, and the need to act on, climate change has grown. The 2018 Congressional election and the climate strike actions of Greta Thunberg have made an impact even in the age of presidential climate denial.

It is not enough to stop putting carbon into the air. To reduce climate change, we have to get the carbon out—and tree planting is a major way of doing that. Yet tree planting is a very diffuse activity. It must be done over millions of square kilometers. No government is going to take on that responsibility unless its people model that behavior and push the government to participate. No person has modeled that dual effort more than Wangari Mathaii in Kenya. She planted trees with women in the Green Belt movement, focusing on land in and around cities, in public rights of way, and on barren or abandoned land. With her group, she planted 30 million trees and was aiming for a billion. Her vision continues though she has passed.

Another Kenyan, Patrick Musyimi of Makueni District (now called Makueni County), models this in a different way. Patrick owns a farm on the dry slopes of the Mbooni Hills, where less than 800 mm of rain fall in two annual rainy seasons, and the probability of rainfall failure is high. His area is limited by that availability of water. He heads a community self-help group called Nzaaya Muisya that came together to reduce the water problems by building a series of sand dams on the Mwea River, a seasonal stream that carries a lot of sand. The sand dams store water in a way that reduces evaporation and makes the water available throughout the year. Patrick uses this water to grow vegetables and fruit trees, but he does not stop there. Even before the sand dam, he planted trees, mostly eucalyptus and *Grevillea robusta* and some native species. With the help of his family, Patrick has planted over 10,000 trees, and the number continues to climb. He does not have a lot of land, his land is steep and dry, and the soils are not particularly good; yet he persists, and he now has an oasis of green that even shows up in satellite data (Ryan 2012).

[35] For a brief summary and videos see this site: http://permaculturenews.org/2011/06/08/martin-crawfords-forest-garden/. Crawford also has a book: *Creating a Forest Garden: Working with Nature to Grow Edible Crops* (Devon, UK: Green Books, 2010).
[36] For more information on Virginia and other states, see http://climatepublicopinion.stanford.edu/

These are examples of where we need to plant trees. We begin with our own yards, fencerows, and woodlots, and we grow to windbreaks on the prairie, riparian buffers on every stream, new woods along every highway, forest gardens in Europe, the deforested land of the Amazon, green belts in the Sahel, and terrace trees in the dry hills of Kenya.

Study Questions

1. How many trees and shrubs can you identify on your property? What are the trees in your area that have good value as shade trees, fruit and nut trees, and riparian trees?

2. Communities, college campuses, stream banks, and public commons often have spaces where trees would be appropriate. Take a walk around a selection of these areas and look. What trees can you find? How many can you identify? How many spaces are there where planting more would work? Add this up. How many trees could grow in the locations you identify?

3. As you move from city through suburbia to countryside, the space for trees expands. The number and type will change by region, climate, and soil conditions. The tools we have for identifying these areas geographically have improved greatly overtime. Google Earth is just one resource. Select an area and explore it. What agroforestry possibilities do you find in that area? How could you participate in making a tree-planting project in this region happen?

4. Do you have a favorite tree? What is it, and why is it your favorite? How does it fit, or how would it fit, in your yard, neighborhood, or region?

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