The Trillion Tree Project: Tree crops and the benefits of agroforestry

Catchy, alliterative, but is planting a trillion trees possible? We need to start with the broad data about how much forest there really is on the planet. The land mass of Earth is approximately 30% of the surface area of the planet or 148.94 million kilometers squared. Of this about 20% is extreme desert that will not grow much of anything except in isolated and tiny oases, which while locally important don't amount to much on a global scale. Another 11 million km^2 is ice, also unavailable for human use. Tundra, northern taiga, and taiga really should be off limits to human exploitation too. They have not been, it is true, but humanity should really let these places be after replanting the trees already removed. With these areas unavailable or off limits, that leaves 83 miliion km^2 that could have trees, but a substantial percentage, 25% of the global total is ecologically dominated by cool, warm and savanna grassland. This leaves 45 million km^2, or 30% of the planet dominated by some type of forest ecosystem.[1] A map of the global forest is given in figure 1. One trillion trees divided by 4.5 billion hectares, gives you a total of 222 trees per hectare, or about $45m^2$ 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 1 trillion more trees on the planet, the real question is how we grow and manage them.

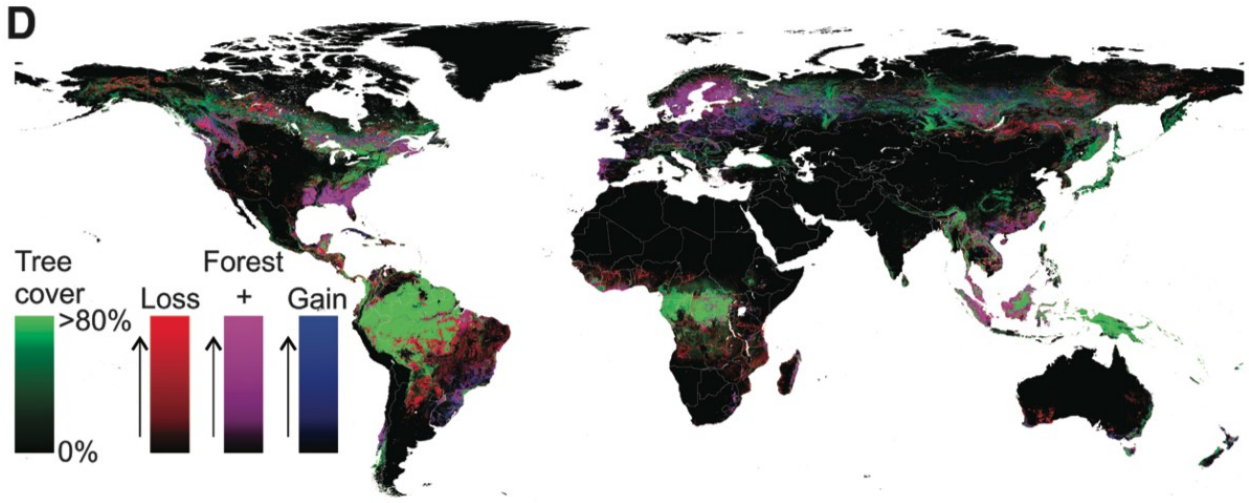

Figure 1: Global forests with changes in total covered between 2000 and 2012 based on satellite imagery.[2] Source: http://www.sciencemag.org/content/342/6160/850

In the mid 1930s in the United States we were going through a rough patch, the depression and a dust bowl. The latter was a combination of severe drought following years of inappropriate farming on short grass prairies that left the landscape barren. What was less known was that the eastern, northern and even far western US already suffered from landscape calamities. What we now call Shenandoah National Park was really a long stretch of partially abandoned farmland, deforested during the 19th century and farmed to grow small grains for feeding the transportation system of that era –

[1] These numbers are derived from Table 1 in "Putting carbon where it belongs, in the soil."

[2] For a wonderful interactive map on the global forest by the University of Maryland and powered by Google Earth go to: http://earthenginepartners.appspot.com/google.com/science-2013-global-forest

horses. When the horses gave way to the automobile, the farms collapsed because they could not produce wheat and corn competitively with farms from the west. There are more trees now in the piedmont and Appalachian region of the east than there were between the Civil War and WWII. In that era one of the most forward thinking and innovative foresters in the US presented an idea that if followed would have radically healed the eastern forest and prevented much of the shift of agricultural focus to middle of the US. J. Russell Smith was a professor of economic geography at Columbia University and professor of industry at the Wharton School, as well as closely associated with the US Department of Agriculture and the Northern Nut Growers Association. His passion was trees, especially trees that provided 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 50°N 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 Mediterranean basin. The European farming systems exported to the US were designed for light rains on relatively flat land. The Appalachians (analogous to hilly land everywhere) were subject to heavy thunderstorms that could strip barren land of its topsoil rapidly. Any agriculture that left the land uncovered was dangerous. He documented sheet erosion damage in Algeria, extreme gully erosion in China near the great wall, deep loss of topsoil on gently sloping land in Illinois, and worthless corn land in Alabama and Georgia in the southern Appalachian foot hills. The only way agriculture could work in these areas is to find and grow permanent crops. He pushed tree crops; fruit, nut and fodder producing trees.

His first example comes from the island of Corsica, a fiercely independent province of France that lies off the coast of Italy and Southern France in the Mediterranean. The island is highly mountainous, rugged and rocky. It is also covered with trees and shows little sign of erosion. Most of the trees between 1000 and 3000 feet in elevation are the European chestnut (*Castanea sativa*). Most Americans have little knowledge of chestnuts except from a Christmas song that starts, “Chestnuts roasting on an open fire”. We lost the American chestnut starting in 1904 when a fungal disease was accidentally imported to the Brooklyn Botanical Garden on a Chinese chestnut and spread to the American chestnut that had no resistance. By 1926 it was largely gone. 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 used directly for human food, but even more to feed pigs, goats and other animals. Their agriculture is based around this annual bounty, requiring no tillage, no fertilizer and hardly any mechanization. For Smith it became a model for a hill country agricultural revolution.

While we lack a native chestnut at this time[3], the European and Chinese (*Castanea mollissima*) varieties do well in the mid-Atlantic region. The number of chestnuts grown is very low. However,

[3] 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. Their work has progressed to the point that they are now testing a 15/16th American/Chinese cross that is intercrossed to eliminate genetic susceptibility to blight. Once these highly resistant crosses are confirmed they will begin to introduce them widely across the American chestnuts 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. www.acf.org

Smith documents a number of species that do well throughout the eastern US and beyond that could help change agriculture. They require a change in mindset. At this point in time American agriculture is dominated by two energy intensive crops, corn and soybeans, and much of our food production system derives from these two primary sources. When we eat beef, pork, chicken, turkey and even farm raised salmon, we are eating corn and soybeans. Until recently over half of all the corn in the US, and an even higher percentage of soy, was fed to livestock. Only recently has that percentage dropped, though the amount fed to livestock has not, because of the rise in alcohol production for fuel. These domestic animals did not live on corn and soybeans until the 20th century. In Corsica pigs live on chestnuts. Cattle eat grass. Chickens eat bugs, worms, grubs, fly larva and almost any seeds they can find as well as greens. Goats gobble acorns preferentially to almost any other food. We have locked our agriculture into unsustainable crops with anti-ecological reasoning. It is time that we start looking at the details of Smith's 1929 proposal and implement it.

Smith starts by looking at the resources within the eastern deciduous forest of the US. There are a number. Chestnuts are essentially equivalent to a grain crop. Roasted they are sweeter then grains, but the amount of oils and protein is similar. Pigs will pick them up in a forest without hesitation, so grazing pigs in woodland makes perfect sense. They will also eat acorns. This is a far less used food today than chestnuts. Most fresh acorns are inedible for humans. We lack the proper bacteria and digestive system to deal with the high tannin content of the seed. Many ruminants, including goats, deer, llamas and camels can handle acorns without a problem, whether from red or white oak groups. Red oaks are full of tannin and were seldom consumed as human food. White oaks on the other hand have less tannin and some served as a major part of the diet for Native Americans in California. In fact the Indians used acorns throughout the US where they were available. In some cases up to 25% of the calories were from acorns. The white oak acorn is quite nutritious and higher in fat than grains, about 18% dry weight. Before eating it needs to be ground and leached in water to get the tannins out.[4] Sometimes this takes three washings. Once done it can be mixed with grain flours to make breads or 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 US include the swamp white oak (*Quercus bicolor*), white oak (*Quercus alba*), chestnut oak (*Quercus montana*) and the bur oak as well as a number of California species. In the Mediterranean *Quercus ilex*, the evergreen holly oak 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.[5]

Fodder species are not limited to oaks. The eastern deciduous forest has many. Among them is the mulberry. Though we normally think of mulberries in association with silk, silk worm caterpillars prefer mulberry leaves, the fruits and leaves are edible by a number of farm animals. Ruminants go for the leaves. Pigs and chickens prefer the berries. They will eat these from the ground so there is no need for harvesting. Some varieties have a very long fruiting period, so although they are not easily stored

[4] 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 Cradle to Cradle. The tannins extracted from acorns are useful for this task and far less toxic than chromium when floating in the environment.
[5] The USDA Field Guide to Native Oak Species of Eastern North America is an excellent resource: http://www.fs.fed.us/foresthealth/technology/pdfs/fieldguide.pdf

apart from freezing or canning, they will provide food for the animals over a two month production season. This often happens in summer before acorns or chestnuts are ripe. In Smith's day, when pigs were not factory farmed but lived on pasture, mulberries were part of the food system. When you let animals forage for themselves having a diet that produces food through time is critical. Depending on one species to supply all the animal's needs was foolish at best. So having mulberries in the mix made perfect sense, plus it is easily planted, grows quickly, fruits early, consistently and heavily, and provides timber, posts and firewood. Yet we do not see mulberry on farms today. It disappeared with the rush to industrial agriculture. Mulberries are tasty food for people when ripe and can be dried and eaten, but this is not as important a use in the long term as animal food.

Another very under -appreciated tree is the American persimmon (*Diospyrus virginiana*). The American tree is not the large, flavorful yellow of the Asiatic persimmon (*Diospyrus kaka*) you can find in a supermarket. It you pick an American persimmon before the first frost, even when soft and ripe in appearance, it has a mouth-puckering astringency that rejects further trials. However, with a bit of patience, a good frost, and picking the fruit off the ground, the fruit becomes as delicious as any market purchase, if the opossums don't get them first. During the slave era and even after, blacks in the south used to hunt opossums at night in persimmon trees since they flock 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 US. It has a very broad range, grows on very poor, eroded or sandy soils, and has a very long fruiting season, dropping ripe fruit from September to February. This makes it a perfect complement to mulberry for woods foraging pigs, cattle, horses, turkeys and chickens. The persimmon is harder to start than mulberry and some other fruit like apples, but because its leaves are basically inedible once it starts growing it requires less care and it lives for a long time. Naturally occurring trees also support grafted stock of better varieties quite easily. Persimmons do well next to crops and they do not seem to compete with crops for nutrient and moisture, though they have fairly dense shade. Smith pleaded for more research on persimmon in 1929 and some research has gone into improving both the American varieties and on 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.

A great deal is made about the impact of eating meat on the planet. The argument makes a lot of sense but it makes a basic assumption that the meat we eat is fed corn and soybeans and slaughtered in centralized industrial plants and shipped to stores around the country. If this is the case then those making the argument are spot on. To this point Smith has pointed us to trees that provide food for pigs, chickens, turkeys and goats. What about cattle? Cattle are grazers. They belong on the prairie, yet they like shade too. Smith identifies the perfect tree for this animal in the eastern half of the US at least, honeylocust (*Gleditsia triacanthos*). Honeylocusts like moist lowland habitats, but will grow on drier sites with deeper soils. It is a legume, producing prolific amounts of sweet pods that cattle and many other animals like to eat green or dry. It has an open canopy that allows some light through and does not shade out or otherwise inhibit grass growth. In short it is a great pasture tree, with one notable exception. Evolution of honeylocust happened in the presence of now departed megafauna like mammoth and giant ground sloths, both of 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 attempting to grab trunk or branch larger than a squirrel. Fiendishly effective honeylocust thrived and was spread by these same animals that eagerly ate fallen pods. These animals are gone now but the thorns remain on most wild trees. Humans have found some varieties that are thornless and propagated them. Cattle can now take over the propagation duties formerly accomplished by sloths and put on weight at the same time. People can eat the honeylocust pods too, but it is a lot of work, so the tree feeds us best by feeding cattle and then us via milk or meat.

Honeylocust is a tree of the temperate deciduous forests. Other ecosystems have trees that serve a similar role. In the semi-arid tropics Acacia species provide pods and foliage and makes excellent fodder for goats and camels. *Acacia tortillis* 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 NW Mexico and SW US. If cattle and horses eat these pods directly they will thrive, but they do not damage the seed, which then passes through their gut ready to germinate in the provided fertilizer. However, if you grind the pods the nutrition 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 also excellent fodder producers. Along with the acacias these trees are all thorny to protect their vegetation in dry landscapes. They can also become highly weedy, but this problem stems from poor grazing management and is not a characteristic of the trees in their natural habitat. The lessons Smith learned in the early 20th century have remained ignored for the most part in the US. Mesquite is more likely treated as a weed than a benefit mostly because ranchers in places like west Texas tend to work against rather than with natural systems. Other places take more advantage of these resources. Kenyan pastoralists will even bag and sell *A. tortilis* pods in dry years to areas that do not have access to their own supply. For them *A. tortilis* is the single most important tree for their cattle, sheep and goats.

Every fall, sometime in early September, the woods edge gets just a bit more dangerous both for twisted ankles and bumps on the head. It is the season of black walnut. *Juglans nigra* grows on bottom land soils, usually well-drained but moist, throughout the eastern US. It is best known for excellent quality, easy to work dark timber and its edible nuts. These nuts 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, very high in protein, oils and calories. It makes good food, but is considered too strong to eat by itself, so ends up mostly in ice cream and confectionaries. Black walnut has characteristics that make it less welcome to some. The squirrels commonly plant it for storage, then forget 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 allelopathic affect on most plants in the solanaceae family that includes tomatoes, potatoes, egg plant and peppers, and others groups like blueberries, blackberries and apples. At the same time there are a number of plants unaffected by 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 plants.[6] Smith felt that black walnut deserved a lot more attention from plant breeders than it had

[6] http://tomclothier.hort.net/page43.html

received in his day. The nuts are naturally better than most wild nuts and improvements could make them superior to the English/Carpathanian/Persian walnut, *Juglans 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 generation and of our generation. His chapter on the Persian walnut is an excellent example. Americans tend to think in grand visions, amber waves of grain stretching to the horizon. In a word we like monocultures. Smith did not. What he wanted were fields that produced with no possibility of erosion. So he looked for ways to grow food that preserved the environment. When he looked at 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 Persian walnut is devoted to developing varieties suitable for the climate of the eastern US. The varieties we imported from Europe are adapted to cool moist winters and mild summers. The US is hotter in the summer, with powerful rains and higher humidity, and colder in winter with frequent killing frost. We need a variety suitable for this climate and no one was looking. Instead we grew the walnuts in California and Oregon in monocultural orchards and shipped them around the country. The idea of breeding a variety of walnut for the east coast had not occurred to anyone, or certainly to anyone with 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. Among these are black walnut, butternut, pecan, shagbark hickory and shellbark hickory. If we made such an effort, according to Smith, perhaps nut crops could change the way we eat and save the soil on sloping land at the same time.

The ideas of Smith did not die in the 1930s. Nor did they rise to the top of the American agricultural research agenda, which was hijacked by corporate agriculture, giant mechanization and a collection of chemical companies. Instead Smith ideas lived in the quiet parts of University research and on the farms of mavericks who wanted to do things differently. We are a large enough nation that these oddities can exist and thrive. Once such maverick lives in south eastern Minnesota on a farm he calls Badgersett Research Farm. Philip Rutter started the farm in 1978. He is not connected to any university or other non-profit research oriented group like the American Chestnut Foundation (ACF) or the Northern Nut Growers Association, though he one time headed both groups and maintains contact with both. He started working with American chestnut hybridization early on, but true to his maverick attitude that relationship did not last. Rutter made the conscious decision to go with first and second generation hybrid chestnut that are a blending of American and Chinese chestnut heritage. The nuts are smaller and more flavorful like the American nut, but the growth pattern and productivity are more like the Chinese chestnut. The ACF is attempting to get a forest tree back again, with much more concentration on the growth pattern of the American tree with the resistance to blight of the Chinese the only crucial characteristic from that parent.[7]

[7] All the information from this paragraph comes from the Badgersett Research Corporation website: http://www.badgersett.com/ and the book by Susan Freinkel, American Chestnut: The life, death and rebirth of a

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 nutrient for hunter gather 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 US, does not tolerate the climate of the northern great plains, in fact it can hardly tolerate the frosts of Virginia, yet at the same time it does not do well in the humidity of the southeast or handle the diseases native to this part of the world. American hazelnut thrives in these conditions, but it produces smaller nuts that are not competitive on the market. They are very nutritious. Badgersett has worked at hybridizing these two species with considerable success, working with American varieties from Wisconsin and Iowa and European varieties grown in Oregon. They advocate planting hazelnuts in contour rows on farms. It is possible to grow row crops between the hedges of hazelnuts, but hazels are shallow rooted and could be damaged by tillage. They do well when associated with pasture or other perennials though, like berries or blueberries, but this depends on soil type. Rutter thinks that hazelnut has potential, with continued breeding, to replace soybeans on farms. This would replace an annual requiring frequent tillage or chemical treatment in no-till systems with a chemical free perennial crop. Nothing would please J. Russell Smith more than seeing this.

Alley Cropping

Planting contour rows of a perennial is just one of the ideas in agroforestry. The concept is termed alley cropping, growing widely spaced rows of perennial trees with crops between these 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 1999). Black walnut is really two trees in one according to Garrett. 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 is grown at a 30 by 30 foot spacing at first, and then thinned slowly to sixty by sixty foot spacing, giving the tree adequate light and reduced nutrient competition to maximize seed production. While it is common practice to emphasize one production system or the other, agroforestry is a compromise using alley cropping and the emphasis is on mixed production across a landscape. The walnut trees are planted at relatively tight spacing in a row, perhaps as low 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 on what you are farming and the equipment used, but 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, which reduces nut yield, but helps keep 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 fifteen or more. Once trees reach this age they usually cast too much shade for light demanding crops like corn and soybeans, so either small grains are grown, or the switch is made to pasture crops like alfalfa, or mixed grass and legumes. Hay or pasture then becomes your annual crop along with nuts. Between 15 to 25 years in row thinning of the black walnut trees occurs. Trees are selected for form and length of

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Perfect Tree.

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 closed forest, but can still reach a high value. Agroforestry like this requires long term, intergenerational planning and serves as a great example of a sustainable practice.

Alley cropping is just one of five agroforestry practices defined by the National Agroforestry Center based in Lincoln, NE.[8] Established in 1990 and expanded in 1995, it serves as the American counterpart to the World Agroforestry Center, also called the International Center for Research in Agroforestry (ICRAF) based in Nairobi, Kenya.[9] Alley Cropping was conceived by ICRAF as a way to increase nutrient availability for crops while reducing erosion. The idea was conceptually simple, but more difficult in implementation. The ideas is to grow a tree or shrub that accumulates nutrients, like *Leucaena leucocephala* or *Tephrosia* species (both of which fix nitrogen on their roots) on contour lines or in straight rows within crop fields to provide nutrients as needed from cut back growth. 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 some success with the technique occurred on the appropriate sites. It was also found that alley cropping was only one of a myriad of ways trees could integrate with overall farm productivity.

Windbreaks and Shelterbelts

Back in the 1930s dust bowl 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 wind breaks throughout the plains states. Windbreaks work by slowing wind at field level and forcing the winds 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 for livestock and reducing energy cost for heating homes. In October of 2013 a freak snowstorm in the western Dakotas killed thousands of cattle in areas where no protection was available. In fields protected by windbreaks the animals fared much better. 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, 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 if appropriate. Pines are used in drier areas, but pines are commonly have a more open growth habit 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 shorter species and could have additional uses. Serviceberries or Saskatoon berries in

[8] http://nac.unl.edu/
[9] http://www.worldagroforestrycentre.org/

Canada (*Amelanchier* species) provide edible berries for people and livestock, tasting a bit like blueberries and are about the same size, though harder to harvest. Osage orange (*Maclua pomifera*) has spiny branches that can root if forced into the soil forming a nearly impenetrable hedge limiting the passage of even goats if done correctly[10]. There is excellent guide for doing this in Mother Earth News[11]. Black locust (*Robinia pseudoacacia*) is another useful species in combination with evergreens in windbreaks and it provides highly durable wood for posts and excellent firewood. The National Agroforestry Center is an excellent source for more information on wind breaks and shelter belts.

Riparian Buffers

Wind and wind erosion are not problems in the Appalachian region, but water erosion is. Though sheet erosion, the loss of soil from the surface of soil from the action of rain drops and the resultant runoff, has fallen 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 in the long term is to establish riparian buffers. A buffer is basically an exclusion zone on each side of a stream that prevents cattle entry and allows the growth of deeply rooted perennials, especially trees. National and state programs like the Conservation Reserve Program and the Conservation Reserve Enhanced Program help farmers fence out cattle and other domestic animals, set up alternative watering systems and plant trees. The recommended trees in these buffers include many that Smith would like, including oaks, hickory and black walnut. These are commonly called mast species, trees that produce seeds eaten by wildlife including deer and turkeys. There is no reason that these buffers cannot be managed for human or domestic animal food production as long as there is no removal of the tree, shrub or perennial grasses so the stream bank protection system stays intact.

Shade

Back in my days working in Africa I visited a farm in the NW part of Tanzania on the east side of Lake Victoria, but west of the Serengeti. The area is high hill country, relatively dry but suitable for agriculture. People there grow sorghum, millet, cowpeas, cassava , beans and a mix of other crops. They also keep cattle and since the area is high enough there was some effort to bring in high milk producing breeds to improve local stock yields. A German government project was working on this and they were using brown Swiss cattle, a breed known for excellent milk production. Their pastures were good, yet they had added an unanticipated component to the project. Since they were a trial and 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 of the fields showed that the only significant difference between fields was the amount of shade provided by remnant trees, *Ficus thonningii* and *Acaicia abyssinica*. Cattle have a grazing pattern that is highly predictable. They spend about 4 hours

[10] 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 Texas Oklahoma border, but 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 only in the 19th century. Horses and cattle will eat the fruit in winter when fresh grass is not available (http://en.wikipedia.org/wiki/Maclura_pomifera).

[11] Mother Earth News October/November 2010 by Harvey Ussery "Living Fences: How-to, Advantages and Tips."

from dawn to mid-morning grazing, then the lie or stand around for 4 hours chewing the cud, basically re-chewing the material eaten in the morning, before grazing again in the afternoon to dusk. The night is spent 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. So the project added a tree planting component and they were looking for ideal shade trees. I recommended three additional species based on my work in Kenya, *Croton megalocarpus*, *Albizzia gummifera* and *Calodendrum capense* as suitable for their elevation and rainfall and all three were known locally by farmers.

Shade is not the only benefit for cattle in the tropics. Some shrubs, notably *Calliandra calothyrsus*, provide fodder and increase the butterfat content of milk. This is not something practiced in the US and Europe probably because the smaller East African farms where this started have multiple uses for the trees. They are planted on contours, used for living fences and the cuttings provide firewood in addition to the fodder use. [12]

Shade benefits cattle in the US as well. Farmers in the south eastern US grown widely spaced pines for this purpose. Pines have the advantage of non-palatability when young so cattle do not browse them. Oak, hickory, maple and black walnut are useful shade trees but require protection until they reach a size where cattle will not rub their bark off or eat new growth. This usually means at least 4 inches in diameter at the height of a cow's back, about 5 feet. Cattle will congregate under the trees shade during the heat of the day in almost every part of the country and this will enhance their growth or milk production depending on the farm. If there are only small patches of shade, cattle will so trample those areas that little with grow in the understory and they may damage the tree's root system.[13]

During the period 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 single most enjoyable use of the trees was the making of maple syrup from sugar bushes. These are groves of trees dominated by sugar maple (*Acer saccharum*) that are co-dominant 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 below freezing at night. Depending on the year this period can last 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 nutrient deposited by the cattle around the trees base. At least a few farmers I interviewed deliberately planted the trees for this dual purpose. Most of their sugar production was based in the woods.

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[12] Fodder trees and milk production in East Africa, World Agroforestry Center 2009 Policy Brief. http://www.worldagroforestry.org/downloads/publications/PDFs/BR09326.PDF

[13] These are personal observations of my own farm, farms in the Shenandoah Valley, Lancaster, Pa, Lewis County, NY and western Washington State.

Overstory and understory trees

This brings us to the fourth use of trees in agricultural systems, an overstory tree for understory crops. Here ecology again 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 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 one characteristic, both originated as understory bushes to small trees in tropical forests. Coffee, at least the Arabica coffee preferred by lover's of premium brews, is a native of Ethiopia's south western forests and grows as a small tree of variable habits in cool highland areas with a 4-6 month dry season. Cocoa comes from the Caribbean region of South 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. 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. Though this had the intended effect, it came with a price; more inputs in the form of fertilizer, herbicides, fungicides and insecticides were required to keep the plants healthy. It also had 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 places like the Atlantic forest of Brazil, the mountainous midlands and highlands of Colombia, Central America, Mexico, Kenya, Ethiopia and the hilly forests of Indonesia and Viet Nam. 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. Brazil and Viet Nam produce primarily robusta coffee (*Coffea robusta*) a plant tolerant of warmer temperatures found in Uganda, also an understory tree. Colombia and Ethiopia focus on 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 very positive. An on-line article by the Smithsonian's Migratory Bird Center that reviews 50 academic studies of shade or forest grown coffee shows a strong positive impact of the overstory forest on bird life, insect life, reduced insect damage because of increased predation, better pollination, lower erosion rates, higher income from non-coffee farm enterprises and much more.[14] 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 think the coffee tastes better.

There is an irony in coffee and cocoa farming. 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

[14] The ecological benefits of shade grown coffee. By Robert Rice, with assistance from Mauricio Bedoya Published: September 2010
http://nationalzoo.si.edu/scbi/migratorybirds/coffee/bird_friendly/ecological-benefits-of-shade-grown-coffee.cfm

places of origin. Plants evolve in an ecological context and in the tropics are usually found in highly diverse ecosystems. When forced into monocultures or at least more intensive cultivation strategies insects and diseases that co-evolved with the plants gain an advantage. These organisms are not found on the other 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 verdict is still out overall 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.

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.[15] Ghana, Cote d'Ivoire, Nigeria and Cameroon are the world's leading cocoa producers. It is far from a guilt free crop. Aside from 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.

Meanwhile in Cameroon and Ghana some efforts are underway to change the nature of cocoa production, moving away from the monoculture to understory production. It has been practiced from the introduction of cocoa, but monoculture become dominant during the 50's through the 70's. 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 are probably best suited to the edges of cocoa groves. More success come with growing more open canopy timber species, though Asare's (2006) review indicates that the verdict is still out 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 coffee, cocoa is subject to the corporations that control the market. Making a profit while being ecologically and socially appropriate has proven extremely difficult, thus the problem with child slavery.

[15] 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.

Cocoa is less problematic in central and South America. Even though less than a third of global supply comes from its native range, more efforts to grow it with agroforestry systems are underway. The "Fair Trade" and environmental movements have promoted these efforts. Like 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, increases habitat for migratory birds substantially. At the same time cocoa yields underneath are somewhat less than in open plantations but require fewer inputs. The article also indicates that cocoa trees have not had serious selection trials for yield growing in these shade situation, so some trees do very well, while other bare very few fruits (Somarriba et. al. ND). 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 are really in their early stages of development.

Part of the problem with cocoa and coffee and many other agroforestry systems is that we are still in the early stages of the learning curve on many of these systems. We know they work but it is unclear how they work best. Again the source for the best information is 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, but the later are 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 allowing genetic diversity and easy movement of insect, bird and even mammal species. The plantation model, with its large scale, is part of the problem. Perhaps a smaller scale, more single family size operation interspersed with natural forest in a mosaic would prove better and more productive. This is speculative but worth trying, unfortunately the population pressure of the planet does not provide a lot of space to make the effort.

Woodland management: farming the forest

This brings us to a final component of agroforestry that ties into the broader 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 not things that required collection every day, so it was fine to have it some distance from the household, but they were things essential for the operation of the household economy. 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 or firewood. A plant that provided 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-grading management, 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 Europeans did not recognize and it looked perfectly natural. It was not "natural" in the sense that there were no human fingerprints on the landscape. Indians did manipulate fire, 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 speeded rapidly during the Civil War, supplying a substantial portion of the resources needed for the war effort, including railway ties – 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 on reservations. One small group, the Menominee, received a 235,000 acre piece NW 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, amidst the destruction of the rest of the state.[16] It takes a true visionary people to buck the prevailing paradigm of a dominant culture, but the Menominee did. 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 in the national forest everywhere, the forest is basically managed for just one thing, timber. This leads to even age forest stands of highest value species growing at the same rate. The Menominee have 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 are a product of the forest. Good walks are a product of the forest. Mushrooms are a product of the forest. You cannot get a price for these products they same way you get a price for cabinets or molding, also products of the Menominee Tribal Enterprise, but they have value. The key is managing for a healthy ecosystem. They want a diverse ecosystem with mixed aged stands of every tree. They monitor growth closely on a regular basis, measuring 58,000 trees a year to track growth in a 15 year

[16] http://www.mtemillwork.com/forest/index.php

cycle. They remove trees that exhibit ill health or bad form and leave trees to form old growth stands in places to maintain good genetics. The result: they have harvested more wood than most single product management systems and have more standing timber value now than when they began these practices 140 years ago.[17]

The same thing is true for the management of the Almanor Forest owned and managed by the Collins Pine Company in north eastern California, just east of Mt. Lassen 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.[18] The forest is primarily coniferous, but species vary according to aspect, elevation and soils. These include lodgepole pine, ponderosa pine, other pine, douglas fir, a variety of true firs and incense cedar. They were certified by the Forestry Stewardship Council in 1992. Nattrass and Altomare (1999) cited them as an example of The Natural Step management practices in their book, *The Natural Step for Business: Wealth, Ecology and the Evolutionary Corporation*. The result of their selective harvest management system is a forest with sustained yield, increasing wood content, an intact ecosystem for birds, mammals and other wildlife, healthy streams (where they are not impacted by pre-existing dams). Their website is highly transparent with respect to management systems and they are open to visitors. This contrasts greatly with the dominant model of private forests represented by Weyerhaeuser and Georgia Pacific Companies that use square mile clear cuts and keep out signs on their access roads.

While these forests are small in comparison to the total land found in major corporate forests or the National Forest System, they represent a model much more in tune with how a farmer or forest landowner could manage their personal land. Woodlots have a large size range, from backyard trees to 500 acre forests, yet most share one characteristic; they 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 come back with a combination of pioneer trees and weedy species of lower value. This degradation affects wildlife, soil and water quality. Really using a woods well does not have to become an all consuming exercise. 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 woods. Most woods we have now almost everywhere in the US are regenerated from forests heavily logged in the 19th and early 20th centuries. Most of our wood products come from second or third generation forests farmed commercially. Most small woods derived 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 or alternative product like nuts, acorns, fruit or medicine. By removing weeds like *Ailanthus altissima* (tree of

[17] Christopher and Barbara Johnson. Menominee Forest Keepers. American Forests Magazine Spring 2012. http://www.americanforests.org/magazine/article/menominee-forest-keepers/
[18] http://www.collinsco.com/almanor-fsc/

heaven), eastern red cedar or autumn olive, 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 come in with 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 can girdle them. This may take some initial effort at protecting what you plant, or you can simply overwhelm the pests by sowing a lot of seed and let nature make the selection of the best new seedlings.
3. Thin the growth. Often new growth comes in 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 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 PNW, and much more. Often all these plants need is a space to grow and someone to plant them. Most are competitive native perennials needing only a chance to get started again in a former degraded habitat.
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 trees species when cut near the ground, between 15cm and 50cm, will sprout new stems. These will grow more rapidly than the original single stem, especially if thinned to two or three stems, and 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 fire wood and above ground construction poles. Many species coppice well including oak, hickory, basswood, eucalyptus, redwood, willow, poplar and much more. Mark Krawczyk and Dave Jacke are presently working on a book about coppice woodlots hoping to reinvigorate the practice in the US and elsewhere. [19]

Edible forests in your back yard (or your front yard)

For most of us having land to plant an extensive number of trees is simply a dream. The best we can hope for is a yard with maybe a quarter or half an acre, 10,000 to 20,000 square feet (930 to

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

1860m^2). For most Americans this space is a manicured lawn with a few flower beds scattered around the edges. Lawns are basically green deserts. When you keep grass under 4 inches most of the time, as we are want to do, you also keep the root system of grass approximately the same length. This is part of the reason why it dries out so fast if we don't get a good weekly rain. What if lawns, the largest area of managed land in the United States for a single crop (yes, bigger than corn) were to transform into something quite different; an edible perennial landscape?

This is the working premise behind Dave Jacke and Eric Toensmeier's two volume book, 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 we have dissociated our food supply from our residence and we need to put the two back together. Yet they also recognize that most people do not have time for full time gardening and that perennials, once established in the correct arrangement basically take care of themselves. What people normally get wrong is the correct arrangement. The problem is that we have lost touch with the ecology and genetic character of the species we use for food. So we put in six fruit trees in our back yard too close together and in uncomplimentary arrangements, failing 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 conditions with the abiotic and biotic conditions of a yard. Ecosystem thinking scaled to the back yard level.

In their book 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, as small front yard facing east, and a larger back yard of 50 by 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 using 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 used to irrigate the garden as needed. The back yard is a mix of fruit trees including 5 plums, grapes, kiwi, persimmon, a fig, two apples, two peaches, a red bud, a large mulberry in the south corner and an ash, elm and 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 deliberately planning these spaces before planting so the needs of each species are properly identified. When this is done you get both an aesthetically pleasing and productive yard and a relatively low maintenance system. High maintenance is commonly a symptom that the ecological conditions are wrong.

The second example comes from SW England in Devon, the home and garden of Martin Crawford. Martin developed his garden with a deeper understanding of the ecology of his place. His focus is on native species and those plants 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 interactions with other species. Even with this high diversity Martin leaves 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*) that has edible leaves, which 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.[20] 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 at present. That is the core of the problem; we first must recognize that a problem exists and second that we are part of the problem. An interesting survey was just completed by Stanford University professors and students on the attitudes of US citizens about climate change and global warming. It found that people even in Texas and Mississippi were aware that global warming was a reality and that slightly 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. Virginia's numbers were 81% aware of global warming happening, 75% thought business should limit emissions, only 28% thought we should pay a consumption tax for electricity and 41% thought the same for gasoline.[21] We are fine when it is someone else's problem but not so interested in owning the problem ourselves.

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 getting 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 that responsibility on unless its people model that behavior and push them to participate. No person 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, public right of ways and barren or abandoned land. She did 30 million trees with her group and was aiming for a billion. Her vision still continues though she has passed.

Another Kenyan, Patrick Musyimi of Makueni District models this in a different way. Patrick owns a farm on the dry slopes of the Mbooni Hills where less than 800mm of rain falls 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 it 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 family members Patrick has planted over 10,000 trees and the number

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[20] For a brief summary and videos see this site: http://permaculturenews.org/2011/06/08/martin-crawfords-forest-garden/. Martin Crawford also has a book: Creating a Forest Garden: Working with Nature to Grow Edible Crops. UIT Cambridge Ltd. 2010

[21] For more information on Virginia and other states see http://climatepublicopinion.stanford.edu/

continues to climb. He does not have a lot of land. His land is steep and dry. The soils are not particularly good. Yet he persists and now has an oasis of green that even shows up in satellite data (Ryan 2012).

These are examples of where we need to plant trees. We start with yards, fencerows, woodlots and grow to windbreaks on the prairie, riparian buffers on every stream, new woods along every highway, forest gardens in Europe and the deforested land of the Amazon, green belts in the Sahel, terrace trees in the dry hills of Kenya, Ghana, Mali, China, or renewed forest in Siberia, Canada, Argentina and everywhere else we find a suitable space. If it is done right carbon in the atmosphere will begin to fall and the produce from the trees will change the way we eat. It will take a million projects, perhaps tens of millions of small projects, each one planned to meet the needs of the local ecological and social situation. At the same time each will contribute its small share to the global solution one newly planted seedling at a time.

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