Addressing the Problem not Just the Symptoms

Climate Stability with "Permanent Agriculture"

Eric Toensmeier

TREES ARE ONE OF OUR MOST POWERFUL TOOLS to pull carbon from the atmosphere and sequester it in the soil for long-term storage. This is why reforestation and the protection of intact forests are such an important part of plans to address climate change. Conventional thinking, however, suggests that the planet's capacity for reforestation is limited by the need to preserve land for agriculture. But we in permaculture know that farming and trees are not mutually exclusive. From tree crops to contour strips of nitrogen-fixing trees between alleys of annual crops, there is a wealth of techniques that can give us the best of both worlds. Should a global effort get behind their implementation, these could have a major impact on carbon levels in the atmosphere. They would also have numerous other benefits to the planet and its people.

Proper food forestry using mostly perennial crops could come much closer to matching the amounts of carbon sequestered per acre in natural forests.

A century ago, writer-farmer J. Russell Smith used the term "permanent agriculture" to describe food forestry and other farming practices that combatted a key issue of the day—the erosion and degradation of farmland. From Smith and his compatriots we have taken the name of our movement, though "permaculture" has grown to encompass much more than food forestry. Today these visionary ideas are more needed than ever to address an environmental crisis on a scale Smith and his contemporaries could not have imagined.

Potential climate impact

Trees are fundamentally more efficient than annual crops, with greater net primary productivity. In contrast to annual crops, they are larger, leaf out earlier, and start the growing season ready to do large-scale photosynthesis. There is a bigger carbon "pie" to be divided among wood, soil carbon, and food for people than annuals can provide. It makes intuitive sense that a forest-mimic agriculture would sequester carbon somewhat like a "real" forest. But what can science tell us about the carbon sequestering capacity of permanent agriculture strategies like agroforestry, silvopasture, and food forestry?

Broadly speaking, this appears to be the case. In their excellent 2004 review of the subject ("Carbon sequestration: An underexploited environmental benefit of agroforestry systems," in *Agroforestry Systems* 61:281-295), P.K. Nair and Francesca Montagnini state that generally agroforestry systems sequester somewhat less carbon than forests, though still much more than most annual systems (many of which are net releasers of soil carbon to the atmosphere, and they cause additional emissions from heavy fossil fuel use). I should note that most agroforestry systems integrate functional trees like nitrogen-fixing legumes for fertilizer with annual crops. Proper food forestry using mostly perennials could come much closer to matching the amounts of carbon sequestered per acre in natural forests.

Don Victoriano and Doña Corina of the community of El Matasano in Chiquimula, Guatemala use an A-frame level to mark contours for living terraces. In the background are steep mountainsides covered in cornfields. Photo courtesy Ripple of Hope.

Agroforestry systems sequester carbon both in biomass and in soil as humus, soil life, and undigested organic matter. The amount varies hugely, depending on several variables:

• Rainfall: Humid climates sequester more carbon than dry ones.

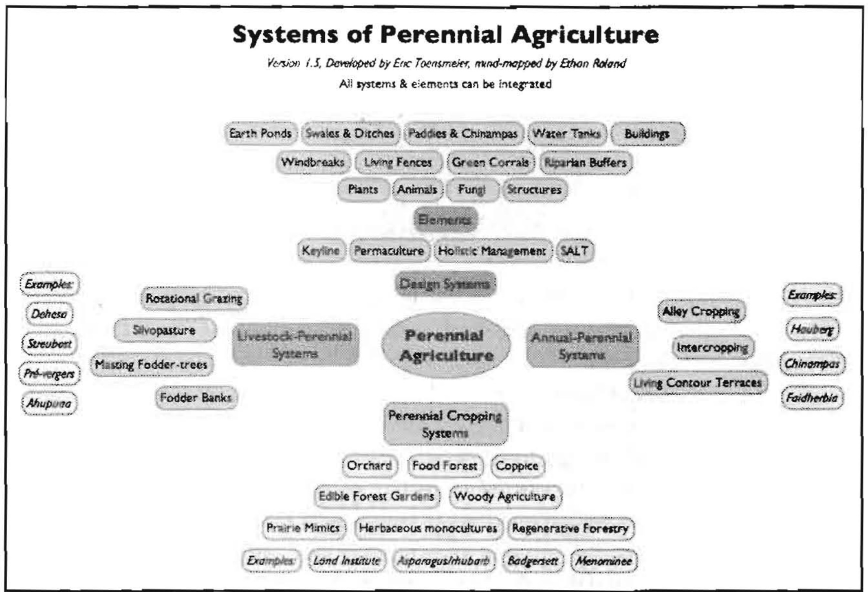
• Climate: Temperate ecosystems sequester more than tropical ones (where heat and moisture result in the rapid oxidation of soil carbon).

• Design: Polycultures sequester more carbon than monocultures in some studies.

• Species: Sequestration varies by species, with some standouts like mesquite (*Prosopis julibrissin*).

• Management: Layout and management practices have a huge impact.

Allowing for these factors, Nair and Montagnini report estimates of the world carbon storage potential of agroforestry ranging from 9 to 228 tons of carbon/hectare under different circumstances—tremendous variation. They report an estimate of current sequestration by agroforestry at 1 million tons/year. Their document estimates the amount of land that could be converted to agroforestry practices as roughly 585 million to 1.2 billion hectares (the US including Alaska is 770 million hectares). Even at a fairly conservative 25 ton/hectare average, that would sequester 14-20 billion tons—over its lifetime as much as 10% of the total 200 billion tons many experts estimate needs to be removed from the atmosphere even if we stop emissions tomorrow.



Sounds great—but that is a staggering amount of land. It works out to roughly 5-10% of the world's land surface (excluding Antarctica), or a whopping 40-80% of land in current use for arable crops.

Permanent agriculture doesn't just sequester carbon, however. It is also a fantastic way to restore degraded land to productivity. Much of the carbon we are pulling from the air becomes organic matter, the foundation of productive agricultural soils. The Global Assessment of Human-Induced Soil Degradation (concluded in 1990) found that vast amounts of the planetary surface have been degraded by human activity, through erosion of sloping land, desertification, salinization, and nutrient depletion.

Perennial farming systems are particularly suited to stabilizing slopes and preventing erosion on hillside farms. Roughly 45% of the world's farmland is classed as sloping at 8% or higher—regeneration of this quantity of farmland with permanent agriculture would sequester 16.8 billion tons of carbon (at 25t/ha).

About 135 million hectares of farmland have an unbelievable 30% slope or greater. I have seen miles of corn growing on mountainsides far steeper than this in Guatemala. These lands are eroding severely and are completely unsuitable for annual crops without extensive terracing, living contour hedgerows, or (preferably) replacement by tree crops. If a targeted international project began just focusing on these most vulnerable agricultural areas, 9% of total world farmland, we could (at 25 t/ha, towards the low end of agroforestry's potential) still sequester 3.3 billion tons of carbon—equal to a third of all human-caused carbon emissions released annually.

Of course perennial agriculture is only one element to incorporate in a larger effort to slow global warming. Reducing fossil fuel use, converting to clean energy sources, and reevaluating everything from transportation to economic policy are all necessary. But the carbon-sequestering capacity of food forestry and allied systems could and should be a major component of humanity's efforts to prevent runaway climate change.

So what exactly are the practices that have such great potential to stabilize the climate? The elements of perennial farming systems include perennial crop systems, perennial-annual integration strategies like agroforestry, and livestock-perennial combinations.

Perennial farming systems

This suite of practices, which I am collectively calling perennial farming systems, represents some of the best of today's "permanent agriculture." These methods improve the productive capacity of the soil over time, leading us to call them "regenerative agriculture." While permaculture did not invent these practices, we have worked hard to integrate, refine, and promote their adoption around the world.

Perennial crops

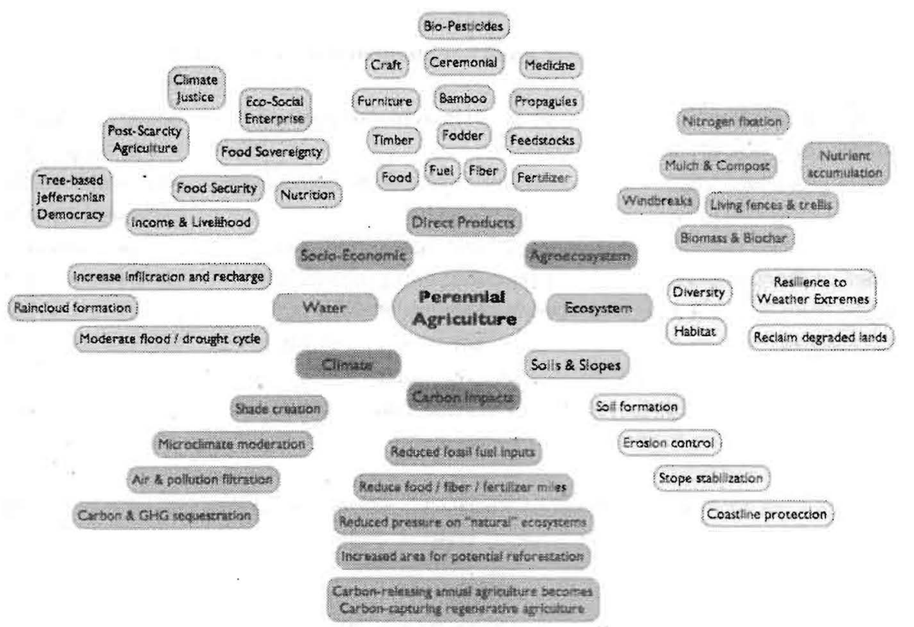
The first major category of carbon-sequestering permanent agriculture is perennial crops. These offer multiple benefits: once established they require no tillage and only minimal fossil fuel inputs, and they offer long-lived productivity. Systems using perennial crops include traditional orchards, multi-layer food forests and forest gardens, and herbaceous perennial farming from asparagus and globe artichokes to perennial grain polycultures. While some perennial fruit and nut crops are well known, perennial vegetables are still a fairly new concept for much of the world, and perennial staple crops to provide our daily carbohydrates and protein are sadly a rarity. I have been researching the many fascinating perennial staple crops of the world and am preparing an article on them for the winter issue of *Permaculture Activist*. Though getting people to adopt new foods can be challenging, these crops allow us to eat directly from carbon-sequestering plants.

Mesquite trees provide us a remarkable example. These nitrogen-fixing legumes are highly drought-resistant, with roots that can reach an astonishing 450 feet deep. Mesquite pods are edible and nutritionally comparable to wheat. However, mesquite trees can produce as much or more food per acre than wheat or other annual staples. Mesquite species are native to arid regions of Africa, Asia, and the Americas, and are under development as a new perennial crop. They can sequester up to eight tons of carbon per hectare annually on good soils as a monoculture. Though they are most productive with moderate levels of moisture, mesquites can crop on as little as 4" of rainfall annually! Check out Desert Harvesters' brand new *Eat Mesquite!*, a fantastic cookbook with lots of information about this important but neglected crop (www.desertharvesters.org).

Perennials provide much more than food. Most material human needs can be met by some form of perennial plant. Fuels are a great example, from coppiced nitrogen-fixing trees for firewood to castor oil biodiesel and milkweed gasoline. Timber and construction materials are a major perennial product, with bamboos as a standout plant group that sustains long-term harvests. Other products available from perennials include plastics, fibers, herbicides, medicines, mushroom substrates, crafts, and on and on.

Multiple Functions of Perennial Agriculture

Version 1.5, Developed by Eric Toensmeier, mind-mapped by Ethan Roland



Perennial polycultures

Of course, we are not advocating monocultures of any of these species. Vast corporate oil palm plantations are a perfect example of what can go wrong when promising ideas like perennial crops and biofuels are filtered through the corporate mindset. Rainforests growing on peat soils that are themselves immense carbon stores are being cleared for oil palm plantations on a massive scale, all in the name of "green" biofuels, and with a net loss of carbon to the atmosphere. That's not the win-win we are looking for. In the words of Dmitri Orlov, it's a boondoggle.

The best examples of perennial crop systems include progressive practices like intercropping, multistoried production with high-value shade crops beneath a productive canopy, and incorporation of robust nitrogen-fixing components. There are fine examples of these elegant farming systems to be found around the world. I hope to profile some in future articles for the *Activist.*

Growing perennials with annuals

There are many working models for combining annual and perennial elements. These are sometimes referred to as silvo-arable systems—those combining trees ("silvo-") with tilled crops. Most involve alternating annual and perennial strips on contour or along a keyline, with the perennial elements primarily serving to stabilize the slope and to fix and release nitrogen through coppicing. Sample systems include alleycropping and contour hedgerows. Annuals in these systems can yield some familiar foods, as well as high-protein crops like beans that can be difficult to grow as perennials in many regions.

Annuals can also provide a harvest in young perennial systems while we wait for the trees to mature. A final and less tightly integrated example for use in mixed terrain is the production of perennials on slopes with complementary production of annuals on flat land.

My current favorite example of annual-perennial integration is "evergreen agriculture." This system is a refinement of long-lived indigenous agroforestry practices in semi-arid regions of Africa. Well-mulched annual crops like grains and beans are grown under widely-spaced apple ring acacia trees (*Faidherbia albida*). The trees fix nitrogen and stabilize soil, with the unique characteristic that they leaf out in the dry season (when crops are not grown below) and drop their leaves to provide sun for productive annual understory crops in the rainy season.

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Integrating livestock with perennials

Livestock help solve many problems in perennial farming systems. For one, they are much more willing to try new perennial food plants than are humans, and can convert them into already familiar foods like meat, milk, and eggs. Livestock also circumvent the problem that some people are allergic to tree nut protein sources. Properly integrated, animals can provide benefits and reduce management labor. These contributions include soil fertility, pest control, harvesting, mowing, weeding, and site preparation. Particularly at larger scales of operation, livestock become a substitute for labor and fossil fuel-powered machinery.

Rotational grazing on pasture is a well-developed perennial farming system. Pasture is a perennial polyculture of grasses and forbs; it is a powerful carbon sequestering practice when managed intensively. High yields and soil improvement can go hand-in-hand. Though this article is primarily about food forestry, it is worth noting that rotational grazing can capture large amounts of carbon and stabilize it in soil as long-lived humus. Imagine the impact if the US took all the land we use to grow annual grain for confinement livestock feed and converted it to permanent pasture under rotational grazing.

Fodder banks are another strategy, useful on small scales and becoming popular in the tropics. These simple coppiced plantings of woody leaf crops are cut and carried to livestock in paddocks or pens. They represent a more efficient use of space, enable the farmer to collect the manure, and prevent livestock from damaging crops, particularly vulnerable young trees.

Silvopasture is the grazing of livestock under trees, typically timber trees, to provide a yield while waiting for timber harvest. This practice can be used under many kinds of trees, and can range from cattle under coconuts (common in the Pacific) to weeder geese under complex food forests. Silvopasture is one of the few agroforestry practices being implemented on a commercial scale in the US, particularly in the Southeast.

Masting fodder trees are a promising but underdeveloped livestock system. This silvopasture model, as popularized by J. Russell Smith in *Tree Crops: A Permanent Agriculture* back in 1927, involves trees in pasture. The difference from conventional grazing and pasture management is that the trees produce crops of seeds, pods, fruits, or nuts, which drop into the pasture and are consumed as fodder by livestock. These systems are very productive and include long-established models like the Portuguese cork-pork *dehesa* forests. Farmers are still actively managing these oak woodlands today and getting a high premium for acorn-fed pork.

It should be added that ruminant livestock (including sheep, cattle, and goats) produce methane, a potent greenhouse gas. It appears that as part of smart management (such as rotational grazing), the carbon they can help agroecosystems sequester outweighs their methane output. This factor is increased when we consider the fossil fuel-powered machinery they can replace, for example in mowing tree crop understory.

Fully integrated systems

All these systems can be combined, of course, and perhaps are at their best when this is done strategically to meet human needs. Permaculture design can unify productive elements with supporting practices such as living fences, green corrals, windbreaks, rainwater harvesting, aquaculture, and green structures. Permaculture farmers like Jerome Osentowski, Sepp Holzer, and Darrell Frey have shown us some examples of what this looks like in cold climates.

Unlike expensive, untested, and potentially very dangerous geoengineering approaches to slowing climate change, regenerative perennial agriculture uses biological solutions and human intelligence together with the vast surplus of labor presently available to address many of the other enormous challenges facing humanity today—soil degradation, food and energy shortages and dependency, poverty in agriculture—while sequestering large amounts of carbon. Were we to adopt this strategy as part of a program to stabilize the climate, we would reap many other benefits that would ensure that climate mitigation does not come about on the backs of the poor.

Carbon impacts

Sequestering carbon is not the only climate impact of permanent agriculture. Perennial agriculture practices use less fossil fuel, both from mechanization and in the form of chemical fertilizers. Food forestry provides a sustainable basis for increasing local production by stacking yields vertically on the same acreage. It could therefore help to reduce fossil fuel use in transport by suppressing the demand for imported food.

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Interestingly, at least in tropical regions, the most powerful climate impact of agroforestry is not in the carbon sequestered on-farm (which is significant), but in the reduction of pressure on wild trees and forests. Because agroforestry provides fuelwood and reduces or eliminates the need for shifting cultivation, every hectare of agroforestry prevents the deforestation of 2.5-10 hectares of wild forest. (Nair & Montagnini 2004).

Improving soils and slopes

Perennial farming systems can stabilize eroding farmland, especially sloping lands, with dramatic results. Nitrogen-fixing perennials provide mulch and fodder while fertilizing adjacent crops; keyline subsoil plowing greatly increases soil humus and moisture-holding capacity as it provides greater levels of forage; and intensive livestock rotations increase pasture diversity, mineral accumulation, and stored soil carbon while potentially returning a good profit to the farmer.

Plantings of useful trees can also protect coastlines from damage caused by increased storm activity.

Ecosystem benefits

On the farm, trees and perennials can dramatically improve rainwater infiltration and groundwater recharge. At both the farm and regional scale, permanent agriculture can break the flood-drought cycle by soaking up and slowly releasing water like a sponge, providing a longer season of moderate water flow in streams and rivers. Less erosion means less siltation and nutrient runoff in streams, with cascading effects from local waters all the way to coral reefs along the coast. Finally, at the regional scale agroforests can transpire sufficient water to create rainclouds and also seed them with organic particles, allowing rain to fall farther inland, helping to fight drought and desertification.

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Food forests provide many of the same ecosystem services that "natural" forests do. In addition to the water, soil, and climate benefits mentioned above, cultivated forests can serve as critical habitat for many kinds of wildlife, and their diversity is much higher than that of annual agriculture.

Perhaps most interestingly, permanent agriculture not only helps to ameliorate and even reverse global heating, but it is also resilient in the face of the increased intensity and frequency of droughts, floods, storms, and other extreme weather that climate change is bringing. Trees and perennials typically have stronger and deeper root systems than annuals and can survive and continue to yield in conditions that would ruin many annual crops. By offering multiple alternatives to conventional crops, polycultures act as a form of insurance against crop failure due to pests, diseases, or adverse weather, so that there is always a yield of one kind or another.

At the farm scale, shade can be essential for livestock and certain crops, particularly in the tropics, but increasingly in temperate zones. We owe coffee, vanilla, chocolate, ginseng, wasabi, ramps, and many other important products to the shady canopies beneath which they grow. Trees in particular are important for filtering air pollution and particulates, and help to create a protected and nourishing microclimate in most places they are planted.

Opportunities to improve productivity

Many perennial farming practices are already in common use due to their positive effect on yields. In many parts of the world, windbreaks, living fences, and living trellises are standard farming practices. Agroforestry frequently incorporates nitrogen-fixing plants, and growing plants for compost and mulching purposes is common in many sustainable agricultural systems. But all of these practices could be much more widespread.

Biochar, a farm-made charcoal soil amendment, is a practice with tremendous potential to sequester carbon and build soil. It is currently controversial due to concern over its being used in connection with large-scale monocultures, thus taking land away from food production in the developing world, much as has already happened with corn- and palm-based biofuels. It appears to me that as an integrated farm practice, not as a vast monoculture, biochar can have a positive effect on farm productivity while sequestering substantial carbon without impacting food security. Any of these perennial farming systems, if practiced by large corporations in vast plantations, could lose carbon efficiency as well as have negative social and ecological impacts.

Permanent agriculture can meet most of our material needs. Foods, biofuels, construction materials, fiber products, plant-based plastics, medicine, ceremonial plants, and more can all be produced. Some perennials can continue to yield for hundreds of years once established.

Socio-economic benefits

The human benefits of regenerative agriculture are the primary reason it is so much more desirable than pumping sulfur into the atmosphere or liquidized carbon dioxide into empty oil wells. A global investment in perennial farming systems would address climate justice by sending funds from the developed countries, which have caused most of the damage from global heating, to the developing countries which did the least to cause it but are, perversely, most affected by it.

Beyond improved nutrition and food security, transforming degraded land to tree-based farming provides income and regenerative enterprise opportunities for rural people, and could support a return to the land for former rural dwellers who were driven into cities in search of income. Permaculture is a system designed to serve large numbers of people on small parcels of land, and some research suggests that carbon sequestration is actually higher on small, intensively managed parcels. This matches the profile of area productivity: small holdings yield more calories per square foot than do large farms mostly due to more careful management and lower negative impacts from mechanization. Thus we might imagine that rural economic revitalization would be another impact of permanent and carbon-sequestering agriculture.

The supply of fossil fuels used for the transportation and production of crops today is imperilled by global conflict, declining geologic resources, and competition from a growing number of consumers, and their continued use not only aggravates carbon heating of the atmosphere and oceans, but more importantly degrades the resource base on which a still-growing human population utterly depends. Relocalizing agriculture everywhere is therefore inevitable, whether perennial crops are grown or not. Food sovereignty takes the notions of local food and food security and unites them with broader human rights concerns.

The food sovereignty platform includes the right to food and the land to grow it on, regional self-sufficiency, giving precedence to nutrition and natural resources over international trade, and democratic control rather than corporate dominance of the food system. The broadscale establishment of perennial farming systems would support food sovereignty by providing a regenerative farming toolkit for community self-determination. A permanent agriculture supports popular food sovereignty against the multinational interests whose drive for short-term profit is the cause of so many social and ecological maladies. I also see permanent agriculture as greatly supporting the development of communities of prosperous smallholders around the world. This would give all societies a more resilient basis, buffer the world against autocracy, and improve the quality of life for the vast majority of people. I like to call this key element of perennial food sovereignty "tree-based, Jeffersonian democracy."

A permanent agriculture system in action at Badgersett.

No single strategy will be sufficient to accomplish what is required. But the large-scale conversion of degraded land to regenerative perennial agriculture is deserving of the world's resources.

Stepping up

Obviously, to convert land use on such a scale would entail a massive undertaking, one perhaps unprecedented in history. It would also have to take place rapidly—probably within 30 years at most. But addressing climate change requires us to rethink every aspect of our civilization, and agriculture is no exception. Arguably, if we do not come to grips with global heating, then agriculture as we know it is certain to fail.

Food forestry has always been a great idea, but in this time of climate crisis it has become an essential one. For many years in permaculture we have focused on our own backyards and farms. While that has been essential for the demonstration of our ideas, its carbon sequestration impact is barely noticeable on the global scale. Permanent agriculture needs to be spread much more widely if it is to have a significant impact. To prevent runaway climate change we need to change our civilization's infrastructure—and many, many more of us need to be engaged in our food systems to make that transformation happen.

My emphasis on perennial farming systems is not to discount the many other important contributions that permaculture has made and can make to address climate change. Reducing household level energy consumption and changing consumptive behavior patterns in the society at large can have a very large collective impact. Everything we do, and everything that the transition and climate change movements are doing, will be critical to this struggle. No single strategy will be sufficient to accomplish what is required. But the large-scale conversion of degraded land to regenerative perennial agriculture is a project that we can put forward to the broader climate change movement, one which is deserving of the world's resources.

We need as well to be honest about what is and isn't known about permanent agriculture, particularly in cold climates. Examples are still too few. Let's target more testing on systems that can be replicated at farm-scale in our own regions and beyond. And what better way to demonstrate permanent agriculture than developing regenerative enterprises that allow people to prosper while charting a new course for agriculture.

It seems to me that this is a critical moment in history for permaculture. Terraforming the planet into a perennial food-producing paradise may be the only way to avert climate disaster. Let's step up and show the world what we have to offer. Δ

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