A CARBON SEQUESTRATION PROPOSAL FOR THE WORLD: Based on Reforestation, Improved Ecosystem Management & Increasing Soil Carbon Levels in Farm Soils

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About the author:
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I have been following the climate-change and carbon storage debates for over 30 years and still have not heard of any proposals that make as much sense as the one outlined herein. The recent Copenhagen Climate Conference was a lot of business-as-usual power plays. I have yet to read a single report that said anything meaningful was agreed upon. There have been a lot of high-tech ways proposed to tie up the atmosphere's excess carbon dioxide, but it seems that hardly anyone talks about the down-to-earth, achievable methods of carbon sequestering outlined here.

One good thing that did come out of the Copenhagen conference is that 50,000 people from civil society, small farmers, indigenous people, NGO's, etc attended the alternative Klimaforum09 in Copenhagen. A lot of real things were accomplished there and people will go home and make real changes that count. It is interesting to note that Klimaforum09 was conceived of by a long-time Danish permaculturist, Tony Anderson.[1]

The following proposals are needed global investments whether you believe in climate change or not. These proposals make financial sense, are doable without inventing any new technology and will be net gains for society and biodiversity at large.

There are four main themes in this proposal:

I. Reforestation/Afforestation of 5 billion acres worldwide = 150 billion tons of carbon sequestration.

II. Earth repair and improved ecosystem management of existing forests and all other terrestrial ecosystems = 100 billion tons of carbon sequestration. This includes cities, forests, marshes, savannas, grasslands, steppes, and deserts. (I haven't tackled this equation yet, but this is a conservative estimate.)

III. Increasing the soil organic matter content by 1% on arable farmland worldwide = 43.86 billion tons of carbon sequestration
(75.62 billions tons of soil organic matter which is 58% carbon). These figures are for the top one foot of the soil. Most farm soils in the world currently have between 1% and 3% organic matter levels.

IV. Mobilizing the people and resources to accomplish these goals.

This adds up to a total of 293.86 billion tons of carbon sequestered. A billion tons is a gigaton. There is currently 780 billion tons of carbon in the atmosphere. There are estimated to be 575 gigatons of carbon in the world's biomass. This proposal calls for increasing the amount of biomass-carbon on earth by another 50%. From 575 gigatons to 865 gigatons. This level of carbon sequestration would bring atmospheric carbon dioxide levels down to where they were in the early 1800s, if done in tandem with lowering human-caused carbon emissions.

"Although the figure is frequently being revised upwards with new discoveries, over 2700 Gt of carbon is stored in soils worldwide, which is well above the combined total of atmosphere (780 Gt) or biomass (575 Gt), most of which is wood. Carbon is taken out of the atmosphere by plant photosynthesis; about 60 Gt annually becomes various types of soil organic matter including surface litter; about 60 Gt annually is respired or oxidized from soil."
http://en.wikipedia.org/wiki/Soil_carbon

How I obtained the carbon sequestration figures given here are explained in the text following. Undoubtedly some figures will need to be revised as more information becomes available, but not enough to dismiss the general validity of this proposal.

I. Reforestation/Afforestation
Increasing the world's forest cover by 5 billion acres (from 10 billion to 15 billion acres) = 150 billion tons of carbon sequestration

1 hectare = 2.47 acres
1 square kilometer = 247.10 acres

In this proposal I have chosen to use measurements familiar with US readers. Acres instead of hectares and square miles instead of square kilometers. In future editions I plan to supply all the figures in metric as well.

Reforestation is the practice of planting trees on land which has just been clear-cut harvested or had been forested within the last 50 years. Afforestation is the practice of planting forests on land which were once forested but have been de-forested for more than 50 years, sometimes hundreds of years, and in some cases did not historically support forest.

Depending on which expert's figures you go with, the world has only 30% to 40% left of its forest cover prior to the development of agriculture. "Eighty percent of the forests that originally covered the earth have been cleared, fragmented, or otherwise degraded". World Resources Institute.

Adding 5 billion acres to the current 10 billion acres of the world's forest cover would go a long ways toward the desired carbon sequestration. It takes awhile as new forests' capacity to tie up carbon increases over time. It is slow the first few years to a decade but then it accelerates. Each forest has a maximum amount of carbon it can store. It isn't infinite, but generally it takes hundreds of years to reach its maximum carbon store. This of course depends on the forest not being unduly, negatively impacted by humans or natural disturbances such as fire, wind-storms, hurricanes, insects and disease epidemics. Every forest is subjected to natural disturbance regimes which damage growth. Forests have adapted to this. The disturbance regime in some forests is mainly small-scale disturbances but some forests have disturbance regimes include

large, high-intensity disturbances such as hurricanes, ice-storms and forest fires. Forest fires burn at many intensities but hot, stand-replacing fires can drastically reduce forest carbon levels. In the natural scheme of things even though parts of a forested region may suffer high carbon losses to fire, a region's overall forests will attain greater carbon storage over time (barring large-scale climate shifts). Human forest management can be used to assist this carbon storage process, to mitigate and reduce natural disturbances and to extract timber and other natural resources at the same time. This does mean that I advocate intensive management of all forests. However I do advocate intensive management of most new afforestation projects to assist these new forests to succeed. I discuss management of existing, natural forests in the 2nd part of this 4-part proposal.

In Friends of the Trees 1988 International Green Front Report, I wrote a long article on a 5 billion acre, world-wide, afforestation plan. How many trees would it take, how many tree planters would be needed and how much would it cost. The following afforestation discussion is an abridged version of that article.[2] The full article should be up on my website by February, 2010.[3]

Here is a synopsis of my 1988 calculations:
The FAO 1978 figure for total world forest area was 10 billion acres (this means it was actually less).
My calculations are for adding 5 billion acres to the world forest cover. From 10 billion acres to 15 billion acres.

If we take an average of 300 trees to the acre to reforest 5 billion acres that would be 1,500 billion trees. The world's population going into 2010 is estimated to be 6.79 billion which means we only need to plant 220 trees per person over 10 years to reach the goal.

How many tree planters would be needed? I go into this in some detail in my 1988 article and ended up estimating an average of 400 trees planted per day per tree planter and a planting season of 60 days a year which is a total of 24,000 trees per tree-planter per year. A ten-year plan to plant 5 billion acres would take 62.5 million tree planters for two months of the year. It would make sense that many of them would work in tree nursery production, or other earth repair work during the rest of the year. Bear in mind that these are full-time job equivalents. Part of the work can be done as part-time jobs so people have time to grow food and do things for their family and community. Bear in mind that many individuals already grow and plant trees on their own and the upscaling of movements like Wangari Maathai's Green Belt Movement in Kenya could accomplish a lot at the grass roots level.

How many nurseries are needed? These figures are per year for a ten year program. It would take 150,000 nurseries growing a million trees each. Or 1.5 million nurseries producing 100,000 trees each. Or 15 million nurseries producing 10,000 trees each or 150 million people producing 100 trees each. Undoubtedly there would be a wide range of sizes of tree nurseries, but small to medium size are best. These nurseries would require a labor force of perhaps 20 million. Part of this work force coming from the tree planters in the off season.

How much would it cost to plant the trees? I go into this in some detail in my 1988 article and ended up estimating an average of $1.00 a tree as an average cost for tree raising, planting out, protection, and tending for several years. In the current economic paradigm, tree planting/tending costs in the US are much higher per tree than places like Africa or Asia. This $1 a tree is a global

average. At which rate it would cost $1500 billion to reforest our proposed 5 billion acres.

The industrial inputs to accomplish this are surprisingly few. Food for the workers is the main input. Shovels, rakes, hoedads and hand tools are important. People could walk to work if they needed to, but when available, transportation vehicles are desired. When I was in back country Nepal a days walk from the nearest road, I could find nurseries producing tens of thousands of trees each with the only industrial input being some thin plastic sheeting for seedling tubes. They showed me tree tubes made out of local leaves, for when plastic was in short supply.

Let's put this in perspective. Global military expenditure stands at over $1.46 trillion in annual expenditure at current prices for 2008, and has been rising in recent years. In other words about two years of the world's military budget would cover the costs of this 10-year afforestation plan. The total US bank bailouts in the latest crisis is estimated to be as high as $4 trillion which is more than double the cost of this 5 billion-acre afforestation budget!

Thankfully we don't need to pry the money out of the military or the banks to get the job done, as I outline in the social section of this proposal.

Where to plant the trees? This would vary from country to country and region to region as there is a lot of variation in current land ownership and various degrees of land concentration. As far as deciding where to site those 5 billion acres of new trees, that would be decided at a decentralized local level. These do not all have to be contiguous, closed-canopy forests. This initiative includes tree planting in cities, towns and farmland as well as on degraded lands. Farmland tree planting would include a combination of windbreaks, agroforestry, orchards and converting some marginal farmland to timber crops. Good agroforestry systems on 10% of the arable farmland would improve the yields on the remaining 90% so that crop production would not drop, plus there is now all the products of the agroforestry systems. Agroforestry is highly productive in its own right. [4]

Who owns the trees? Here are some possibilities which will be done in various combinations depending on the country and situation:

- Farmers plant trees on their own land. They retain full ownership of the land and all the products of the planting. Society subsidizes them to do this.
- Government land is used. City, town, county, state, federal. Plantings are totally native species and designed for native habitat restoration.
- Landowners can sell land to individuals, groups, or communities for forest establishment.
- Individuals or cooperatives can lease government land to put in plantings for future harvest. Subsidized at the beginning and paying tax on harvest later.
- Landowners can plant totally native plants and be subsidized. Native Plant Conservancy, conservation trust lands, etc.
- Land can be purchased from land-owners by cooperatives who plant, tend and harvest.
- Tribes and cultures with common land can plant some of their common lands upon agreement of the community. Future products can be for common good or leased to families
- Abandoned land can be planted by local community or possibly homesteaded.
- Indigenous peoples can do plantings of what they want where they want on their territories and be subsidized.

- Restoration communities.
- Private landowners can give long-term leases on parts of their land for planting and harvest.
- Land reform. We all know that land reform is needed in many countries where people have had their land ripped off.
- The goal is to enfranchise people, not disenfranchise them.
- In all cases, care should be taken to protect and augment any healthy native ecosystems.
- The trees (forests) can be owned by the local community who support the people to plant them and tend them. The initial investment costs can be borne at the local community level. In some cases the people who do the planting/tending get harvest rights from the trees they plant/tend. If these planting are well planned and executed there can start being some payback in only a few years with gradually increasing productivity over time. Tree plantations by outside corporate interests in lesser-developed countries for export to developed countries should be made illegal. Forests should be owned/controlled/stewarded by local people and communities and should be used to meet their needs first before export. Exports after meeting local needs should be given a fair price. The "Fair Trade" movement is providing some experience in these regards.
- In places with high tree failure due to grazing, subsidize the planting and give a payment to the tender for every year that the plant lives. Once harvests start, the payment stops. This is one way of giving people incentive to protect trees in development projects.

For the sake of simplicity I have chosen to focus on the number of trees planted. A good permaculture or restoration design is going to call for planting ground-cover plants, shrubs, and vines, as well as trees. On many sites, you have to start out with erosion control plants, soil building plants and tough pioneer plants to create the conditions for later plantings of late successional species. Trees alone do not make a forest. Fungi, soil microorganisms, insects, birds, mammals, etc all have to be factored in. In some cases this calls for inoculation or re-introducing species. However, it has been demonstrated all over the world, that if you plant the trees, many other species will show up on their own.

How much carbon would 5 billion acres of new forest sequester? Obviously it would increase every year with significant increases starting in years 10 to 20 depending on the climate, soils, etc.

How much carbon does a forest usually contain? Obviously this is going to vary widely, depending on the climate, how old the forest is, management, etc. The heaviest forests in the world are the temperate rainforests of the Pacific Northwest with up to 400 tons per acre of biomass.

The US Forest Service gives the total carbon content of a maple-beech-birch forest from the US at 65 years of age (after clearcutting) as 206.7 tons/hectare which is 83.68 tons/acre.

Here is their breakdown in tons of carbon/hectare. Live tree 101.1, standing dead tree 7.0, understory 1.7, down dead wood 7.2, forest floor 25.3, and soil organic 64.4. In other words, 31% of this forest's carbon is held below the soil. Mind you, this is a north temperate forest so it will have a higher amount of biomass on the floor and in the soil, as compared to a tropical forest with its much higher rates of decomposition. To me, the most surprising parts of this study was that the soil organic matter (SOM) was a very high % of the total and that SOM did not decrease

upon clearcutting but actually kept increasing slowly through the 2nd rotation. [5]

For the sake of our purposes here I propose looking at how much carbon would be tied up in new forests at age 50 years. This exercise could be done for carbon amounts at 10 years, 20 years, etc. But in most places in the world trees are starting to get pretty big by age 50. An acre of forest of widely-spaced trees in Africa's dry sahel of Africa is obviously going to weigh a lot less than an acre of forest in the wet tropics vs. in temperate rainforests, vs. tall-grass prairies, etc. If we estimate an average carbon amount of 30 tons an acre in our 5 billion acre of new forests at age 50 would contain 150 billion tons of carbon. I believe this is a conservative estimate.

It has come to my attention that some people in the world are proposing cutting down existing forests so they can plant new forests and claim carbon credits. This is obviously an insane and obscene proposal. Current forests need protection and better management to maximize carbon sequestration. You don't increase carbon sequestration by cutting big trees down to plant baby trees!

Planting 5 billion acres of trees is feasible, desirable and doable. This becomes a huge carbon sink as well as greatly increasing natural resources available for human use and having many beneficial affects on world climate such as increasing rainfall and slowing winds.

II. Earth repair and improved ecosystem management of existing forests, marshes, grasslands, shrub-steppes, deserts and cities
= 100 billion tons of carbon sequestration

This following chart is incomplete and has multiple sources, but it is what I could find at the moment of going to press with this first draft.

World land surface 36.48 billion acres
Arable land: 10.57%.
    Permanent crops: 1.04%.
    Irrigated land: 2,770,980 sq km (1,721,886 sq mi).
Forest 9.8 billion acres
    Closed forests
Woody savanna and savanna; 13.8%
Open and closed shrub 12.7%
Non-woody grassland 8.3%
Tundra 5.7%
Marshes
Peatlands (4,000,000 square kilometers) [6]
Desert
Cities, towns, roads, human environment 3% plus [7]

Forests contain the largest amounts of carbon per acre, but almost all land surfaces store carbon in the form of organic matter. Grasslands, marshes, shrub-steppes, deserts, farmland, cities. A sensible human goal would be to assist nature to create biologically rich, resilient ecosystems that store carbon to the highest extent possible, EVERYWHERE. Ecological land-use practices can achieve habitat restoration and at the same time increase food, livestock forage, medicine, fiber and resources for humans. Well-managed, restored ecosystems grow in biological

productivity, biodiversity and carbon storage over time.

There are many different kinds of earth repair work such as erosion control, refilling aquifers, cleansing air, building soils, stabilizing riparian systems, reducing flooding, reversing desertification, planting forests, restoring native plants, animals and ecosystems, etc

Note that I use a number of terms to describe the wide range of work needed to carry out this carbon sequestration plan. Earth repair, earth-healing, and ecosystem restoration are terms I use interchangeably. A term being used in Australia is "land care". The Land Care movement in Australia [8] is one of the world's best examples of a nation-wide, land care effort which involves government funding as well as a significant labor force of volunteers and paid workers. Of course, it is a drop in the bucket compared to the huge environmental problems Australia faces at this time, but it has given some very good experience to ramp up and for other parts of the world to study.

FORESTS:

Applying restoration forestry management to the current existing world forests would increase the amount of carbon held in the world's forests by a large factor, plus there would be a steadier supply of higher quality woods than under current, short-rotation forestry methods. Plus there would be less stand-destroying forest fires. This is outlined in my 1994 book "*Restoration Forestry: An International Guide to Sustainable Forestry Practices*".[9]

"Globally forest vegetation and soils contain about 1146 billion tons of carbon, with approximately 37% of this carbon in low latitude forests, 14% in mid-latitude, and 49% at high latitudes. Over 2/3 of the carbon in forest ecosystems is contained in soils and associated peat deposits." They estimate that total forest carbon (aboveground) to be 359 billion tons and 787 billion tons in soils (and peat).

"Forests are important in the global carbon cycle because they store more than 55% of the global carbon stored in vegetation and more than 45% of that stored in soils." The study concludes that 60 to 87 billion tons of carbon could be sequestered by improved forestry practices in the 55 years between the years of 1995 and 2050. *The Terrestrial Carbon Cycle: Managing Forest Ecosystems*. [10]

Effective carbon sequestration via forests is not necessarily dependent on the number of trees, nor necessarily on the number of acres of trees. Certainly both are part of the equation, but the most important part of the equation is how many pounds of biomass are there on each acre of forest. We need forests which have big trees, big snags, big down logs and woody debris, plus healthy litter layers, soil organic matter and lots of big roots (both dead and alive) in the ground. All these things added up are the biomass along with all the soil life, insects, birds, mammals, etc.

In other words, we need forests that weigh a lot.

A forest with thousands of spindly dog-hair trees does not have much carbon. A forest with a diffuse cover of small trees does not have much carbon. Forests need to be managed for a goodly amount of old growth. Thinnings can provide lots of wood of all diameters, while maintaining a "heavy" forest. We can have our lumber (and better quality lumber), and have good carbon tie-up at the same time.

Here in the Okanogan and in the interior Pacific Northwest in general, there are a lot of overstocked young forests and abnormally high rates of hot, stand-replacing fires which burn out most of the carbon. To get long term carbon storage in these forests, we need much better forest management. This includes cool burns and thinning so that we reduce our frequency of stand replacing fires. Once our dryer site forests get reasonably large trees than they are much more resistant to fire. Thus fire can have a place in a landscape that still manages to achieve a high carbon storage overall. All we have to do is look at the historical records of what was here a short 200 years ago. Gorgeous forests with heavy carbon storage being managed by the indigenous peoples.

By my reckoning we need to dramatically increase the world's forest cover AND we need to increase the weight of most forests by a large factor, depending on the current level of forest health or degradation. Only a small percentage of the world's forests have not been degraded and are operating at natural weight levels.

All forests cannot achieve equal weights. Limiting factors include light, growing season, water, temperatures, and soils. The heaviest forests in the world are in the Hoh valley rainforest on Washington State's Olympic peninsula with weights of up to 400 tons of biomass per acre. This is due to big trees plus slow decomposition rates. Big logs pile up. In the tropics, decomposition rates are fast and so almost all the biomass is in the live tree mass. Tropical forests can never get as heavy as temperate rainforests. It would be interesting to see a chart on the average biomass weights of old-growth forests from climates all around the world.

Heavy forests are what we need to aim for. Helping forests gain weight is the primary single way that can draw down atmospheric carbon dioxide. The add on benefits are immense including oxygen production, ozone layer strengthening (this from stronger oxygen columns extending up into the atmosphere), a large increase in the production of timber and forest products, flood amelioration, soil building, healthier fresh water ecosystems, better ocean fisheries, etc, etc.

Every area needs a team of forest weight-watchers.

SHRUB-STEPPES AND GRASSLANDS:
"Approximately 13.8 percent of the global land area (excluding Greenland and Antarctica) is woody savanna and savanna; 12.7 percent is open and closed shrub; 8.3 percent is non-woody grassland; and 5.7 percent is tundra. Thus, approximately 40.5 percent of terrestrial area is grassland. This estimate of 52.5 million km² (12.97 billion acres) for total grassland area falls within the range of previous estimates: 40.5 to 55.5 million km²." World Resources Institute. [11]

The vast majority of grassland and steppe is used for domestic livestock grazing. The biomass/carbon weight of these ecosystems is held largely below ground as root mass and soil organic matter. Restoration activities and improved grazing management could likely double the amounts of carbon held in these ecosystems.

FRESHWATER AND SALTWATER MARSHES occupy what percentage of the earth's land area? What were their extents historically? I am looking for this data if someone can send it. Marshes are one of the most biologically productive ecosystems on earth. They have a high carbon content and a high carbon turnover. Marsh restoration and improved management has

many benefits including carbon sequestration, improved fisheries, biodiversity and protection of land from storm surges.

CITIES, TOWNS, VILLAGES:
Urban cities cover 3% of the world's land surface. Towns and villages occupy what percentage of the earth's land area? I am looking for this data is someone can send it. Most cities, towns and villages will be more livable places with a healthy addition of trees, shrubs, vines, gardens, parks, etc. The concrete jungles of the world need to be turned into places like the fabled "Hanging Gardens of Babylon". Home gardens for food production in cities, suburbs, and towns is already a big deal in many parts of the world and is rapidly becoming more popular. This all results in increased vegetation, biomass, soil organic matter and carbon sequestration. Permaculture offers one of the best wholistic design systems to design productivity, livability and carbon into urban and settled landscapes.

III. Increasing soil carbon levels in farm soils worldwide
= 43.86 billion tons of carbon sequestration

This proposal calls for increasing the soil organic matter content by 1% on arable farmland worldwide.

3.98 billion acres of arable cropland x 19 tons (weight of 1% organic matter in an acre of soil) = 75.62 billions tons of soil organic matter x .58 (soil organic matter is 58% carbon ^{12} = 43.86 billion tons of carbon sequestration.

Arable land is that capable of being used for crop growing and, thus, has qualities including a fresh water supply and a richness in nutrients, and is located where the prevailing climate is suitable (not too hot or too cold).

The total area of arable land in the world today, according to the CIA World Factbook, is 3.98 billion acres. 10.57% of the land surface. The definition used is land that is under cultivation, or temporarily fallow (for less than five years) -- but it excludes abandoned land resulting from shifting cultivation. There is .61 acre of arable land per capita in the world.

About 10% of the world's arable land is in perennial crops such as fruits, nuts, rubber, palm oil, berries, herbs, asparagus and other crops produced by woody-stemmed plants and herbaceous perennials.

This is only one of a range of estimates for world arable land. One difficulty is that different people have different definitions of arable land. Many parts of the world have imperfect surveys, and every year large amounts of land are lost to degradation and abandonment. Permaculture does not have such a black and white view of arable and non-arable lands. Permaculture has taught me to recognize the productive potentials of every acre of land. In a sense, all land becomes productive land even though we may not till or cultivate. For instance we may enhance and manage for valuable species for wildcrafting. The yields we aim for or not only in the form of crops, but also in the form of functions, biological productivity, stability, resilience, and biodiversity.

The average organic matter in world arable soils at present is somewhere around 2%. A 3%

organic matter content is considered good soil and 1% is not uncommon. Best farming practices could likely double the amount of organic matter content held in the world's farm soils. This would store a huge amount of carbon, increase crop yields, reduce erosion and reduce floods, all at the same time. Let's look at the current situation and what is possible.

20% of arable land is irrigated. 2,770,980 sq km (2003) irrigated. CIA Factbook.
"During the past 40 years nearly one-third of the world's cropland (1.5 billion hectares) [3.7 billion acres] has been abandoned because of soil erosion and degradation."
"About 2 million hectares [4.94 million acres] of rainfed and irrigated agricultural lands are lost to production every year due to severe land degradation, among other factors."
"Approximately 40% of the world's agricultural land is seriously degraded." [13]
For the sake of our purposes here, let us define an acre-foot as the top one foot of soil from an acre of land. 43,560 square feet.

Different kinds of soils have different weights of their acre-foot. It is easiest to grasp by looking at how much a square foot of soil weighs.
Silicious sand ……110 pounds
Half sand and half clay……..…..96
Common arable soil……...80 to 90
Heavy clay……..75
Garden mold rich in vegetable matter.....70
Peat soil……..30 to 50
Source: *Farm & Garden Rule-Book* by L.H. Bailey.

For this proposal we have chosen 87 pounds as our average square foot of soil weight so our world average for an acre-foot would weigh 1900 tons. Increasing the proportion of soil organic matter in an acre of soil by 1% is a 19 ton (38,000 pounds) gain in soil organic matter. Each 1% of soil organic matter in an acre-foot weighs 19 tons.

Here are some methods to increase soil organic matter in farm soils. There are many books written on each of these topics.

Reduce or halt water and wind erosion.

- Use of multi-year, sod crops of grasses/legumes/forbs to build organic matter. Typically 4 to 7 years. Mostly these are used for livestock pasture and/or hay.
- Growing green manure crops for incorporation into the soil. One, two or even more crops a year depending on length of growing season and its place in the crop rotation.
- Careful recycling of farm manures and crop wastes back to the fields. Better results are had if these are composted first.
- Judicious use of fertilizers (preferably natural) to get good crop growth. These can be added when making composts to good affect.
- The judicious use of the Keyline system of soil and water management developed by PA Yeoman in Australia. [14]
- Addition of tree biomass to the soil, ideally through a composting process. Sawdust, chips, bark, ramial chipped wood (chipped green branches) [15] leaves, leaf litter.
- Conversion of some cropland from annual to perennial crops, particularly tree crops. Soils devoted to annual cropping have little organic matter in the 2nd or 3rd foot.

Agricultural tree crops such as fruit orchards will obviously increase organic matter in all levels of the soil that the tree's roots reach.

- Long term fallowing of degraded farmland. Take land out of cultivation for a decade or more. Manage for tough pioneers that can stop erosion, build soil and provide wildcrafting income. A prime area for planting some of the needed 5 billion acres of new forest.
- Terra Preta and Biochar. [16]
- Soil inoculation with mycorrhizal fungi, blue green algae, EM effective microorganisms, Biodynamic preparations, earthworms, etc.

There are many more soil building methods.

Terra Preta soils are a recent discovery in the Amazon Basin which have been receiving increasing interest in the last decade. Terra Preta soils were created centuries ago by indigenous people and contain high amounts of charcoal and organic matter and oftentimes, unfired pottery shards. Charcoal is a form of carbon that can exist in the soil for thousands of years. Charcoal functions as apartment houses for soil microorganisms and has a high cation exchange capacity (storage spots for fertility elements in the soil such as calcium, magnesium, nitrogen). Pottery shards perform similar functions in the soil. In the last several years the term biochar has been used as a name for charcoal produced for agricultural use. What climates that biochar is useful in as an agricultural amendment is still being worked out. We can say for sure that it is an excellent addition to wet, tropical soils. It is most likely also useful in temperate wet climates where nutrients and minerals are easily leached from farm soils. Biochar charcoal added to soils has the potential to substantially increase soil organic matter, crop production and long-term carbon sequestration.

Prairie soils hold their organic matter in a different form than forest soils. Soil organic matter in prairie soils is held primarily as humus. Organic matter in forest soils is held in the form of live and dead root material as well as varying amounts of humus. Some forests have a significant amount of humus, but many forest soils have little humus.

It is important to realize that there are two types of soil organic matter.

- One type includes stable humus compounds which are very long lived in the soil, decades to hundreds or even thousands of years. These long-lived humus elements are very important for soil health as they provide structure, permeability, water holding capacity, resistance to wind and water erosion and cation exchange capacity.
- Another part of the soil organic matter is transitory with a shelf life of weeks, months or a few years. It provides the food base for the soil food web pyramid and releases nutrients for plant growth.

Managing farm soils for carbon sequestration and crop productivity means balancing and encouraging both of these types of soil organic matter. Short-lived and long-lived.

Even with the best practices some soils may not be able to have their ogm increased by 1%. By far the majority of soils can achieve this and many soils can actually be increased by 2%, 3% or even more. Farm soils that are currently in good health and have a good organic matter content will have a relatively easy time adding 1% more soil organic matter. Most farm soils

in the world are getting worse, not better, at this time in history. How long would it take to achieve an average of 1% globally? As a general average I would say it takes 4 years to increase a soil's organic matter by 1% if you do the right things and have the resources. Few farmers have the resources to tackle this effort on all their acres at once plus there will be early adopters and late adopters. If this becomes the goal of farmers worldwide we could see significant progress in the first ten years of effort and possible achievement of this goal (1 % average raise globally) in 20 years.

I have established five agroforestry systems of my own over the last 23 years. In my more recent plantings I would estimate I have been able to add 1% soil organic matter every 3 years. The result of gradually reducing cultivation and gradually increasing trees, shrubs and perennial crops as well as managing live ground covers. My system uses labor-intensive practices on a small acreage with organic fertilizer inputs.

We are usually taught in school that it takes 500 years to create an inch of soil. This might be true if you think of how long it takes to weather rock into soil, but it is certainly not true about creating topsoil out of subsoil. Changing poor soils into rich soils can be accomplished in a matter of years or decades. Keyline practitioners claim that they can usually double the depth of the topsoil in four years.

The Keyline system of soil and water management was developed by PA Yeoman in Australia. It has many facets, but some of the most important are: it is integrated systems design, includes contour farming, reforestation of steep slopes, capture and storage of runoff for flood-flow irrigation and subsoiling with special implements in specific patterns across the landscape to aerate the soil, build topsoil, and stop erosion. Livestock are integrated into the system. [17]

Erosion

Accelerated erosion is estimated to affect a large portion of the world's farmland. 40% of the world's farmland is considered seriously degraded. Erosion carries off soil organic matter as well as nutrients. Keyline subsoiling is a technique that can greatly reduce erosion on sloping farmland under tractor tillage.

"On-going soil erosion and expanding urbanization contribute to the continuous loss of cropland in the U.S. Annually, more than two million acres of prime cropland are lost to erosion, salinization, and waterlogging. In addition, more than one million acres are removed from cultivation as America's limited arable land is overwhelmed by the demands of urbanization, transportation networks, and industry." David Pimental and Mario Giampietro.[18]

"Environmental Costs of Agriculture. The use of inappropriate agricultural practices, like large monocultures and removal of shelterbelts, contributes to serious wind and water erosion. Soil and water losses are responsible for significant economic and environmental on-site costs in U.S. agriculture. Each year the estimated 4 billion tons of soil and 130 billion tons of water lost from 400 million acres of U.S. cropland translate into an on-site economic loss of more than $27 billion. The most significant component of this cost is the loss of valuable soil nutrients, which must be replaced by increased applications of fossil-based

fertilizers in order to maintain and augment yields." Pimental.[19]

"Around the world, deforestation and desertification result from peasants pushing into sub-marginal land while high-quality farmland is either held out of use entirely, or used to grow export crops. The situation is so acute in Brazil, for example, that squatters have been massacred simply for occupying remote, unused areas of privately-held ranches. A large, organized movement has grown around the peasants' demand simply to be allowed to use land that others have no (current) use for."[20]

An important point that isn't understood on the world stage is that small-scale, intensive farming is just as good, or better, at producing high yields as industrial agriculture. If appropriate LEISA (low external input sustainable agriculture)[21] and permaculture methods[22] were used worldwide, there would be no starvation and everyone would eat well (even with today's population).

Given today's economic paradigm it is impossible to see how enough labor could be paid out of farm receipts to do the needed soil restoration work. Some countries pay farmers or cost-share to build soil. I believe it can be accomplished by a multitude of new small farmers. People with small enough land bases that more individual attention can be given to each acre. Currently existing family farmers and subsistence farmers around the world should be assisted in staying on the land. Farmers need access to fertilizers and other inputs. All existing arable farmland should be protected from degradation and from loss to development.

Restoration communities could be given long-term leases for degraded land to do earth repair work in exchange for a place to grow food and build houses (inexpensive houses, local materials). The restoration work and plantings eventually provide wildcrafting opportunities to make the communities self-supporting. In the early stages they can be given outside support if available.

What is the size of the total workforce it would take to achieve these three goals? We calculated it would take 62.5 million tree planters and perhaps 20 million people to run all the nurseries. These are overlapping labor forces. Quantifying labor requirements for objective two is much harder to calculate. What I would suggest is that earth repair is something that almost everyone would do to one extent or another. It should be a career path for many, but a full flowering of humanity would certainly include a universality of kind and loving actions for the Earth.

For the sake of a round number how about 100 million people's efforts employed in Earth repair work. This is one worker out of every 32 people in the world labor force or about 3%. Bear in mind that many of these people are only employed for part of the year and that as tree planting goals, etc become completed that they can go on to other work. One generation of earth repair on the world level should suffice to get a great deal of the job done. There is less work (and more resources and time for enjoyment) for ensuing generations.

Implementing these practices will cost in terms of money, labor and resources. These proposals are not public giveaways or money out the door. They are wise investments that will pay off for generations to come. As well as the economic benefits of higher crop yields and more nutrient-dense foods, there is also savings from reduced losses to floods, decreased

costs of purifying water for metro water systems, improved fisheries, reduced health care costs from less air and water pollution and so on.

The question is not “Can we afford this?” The question is “Can we afford not to?”

IV. Mobilizing the people and resources to accomplish these goals

The knowledge of how to sequester the carbon in the atmosphere to a comfortable level already exists. We know how to afforest lands, and put carbon back into farmland soils. Ecological ecosystem management is still evolving, but we know a lot already and have the methodologies to figure it out. The labor, the knowledge and the resources are easily at hand.

What is lacking is that the energies of the people are not being directed this way. The financial powers seem hell bent on destroying the natural environment and maximizing human misery. A miniscule percentage of government and corporate budgets go towards earth repair work. Most people in the world are busy trying to make a living or are living in slums or are landless peasants. People often have no sense of ownership of their local environment or a feeling of having a voice. People who work with their hands with the land are often looked down upon.

But, if the current governmental and economic system breaks down, it opens the door for some new evolution of local control/governance. If local people have to rely on their own environment for sustenance, it might inspire them to do local, earth repair work. There has to be some system of rewards. This can include future harvesting rights, management positions, community subsidy credits in the local currency and public prestige.

There actually are hundreds and thousands of real world examples to look at and draw upon. If the best are identified and multiplied across the globe we could have a global earth repair movement directed, and funded at the local community level. No need to wait for permission and funding from upstairs.

Let’s take a few minutes to examine the world’s labor force. The US as of November 2009 has an official unemployment rate of 10.0%. This is actually only one category of the unemployed they measure. With a little research into the other categories we find that the actual unemployment rate is 15.8% of the so-called workforce, which means it is certainly higher than that, depending on where you want to draw the line at who is employable.

Some other official unemployment rates are: Zimbabwe 90%, Turkmenistan 70%, Mozambique 60%, Nepal 42%, Kenya 40%, Spain 19.3%, Ireland 13%, France 10%, Russia 9.9%, Canada 9.3%, China 9%, Argentina 8.8%, United Kingdom 7.8%, India 7.2%, Japan 5.5%, Denmark 4.2%, Bhutan 2.5%, Thailand 2.1%, Cuba 1.8%, Liechtenstein 1.5%, I read the other day that unemployment was 70% in Afghanistan, but I see the Wikipedia source cites 40%. If you want to know more you can see all the world’s countries unemployment rates at: "http://en.wikipedia.org/wiki/List_of_countries_by_unemployment_rate" These figures are the most current rates available as of November 2009. Most of the countries of the developed world currently have between 7% and 15% rates. What is the average unemployment rate in the world? Realize now that different governments have different ways of calculating this. Ecuador for instance has an official jobless rate of 8.3%, but it also has an

official underemployment rate of a whopping 51.6 %.

Here is a credible information source that puts a lot of money into research. The CIA World Factbook tells us that the "World Unemployment rate is 30% (2007 est.) note: combined unemployment and underemployment in many non-industrialized countries; developed countries typically 4%-12% unemployment. Definition: This entry contains the percent of the labor force that is without jobs. Substantial underemployment might be noted. The information in this page is accurate as of September 17, 2009." [23]

As of 28 December 2009, the Earth's population is estimated by the United States Census Bureau to be 6,792,800,000. What % of these are in the workforce?

Index Mundi gives us a figure for the Earth's total labor force of 3.232 billion (2008 est.) [24]

If we take a conservative figure of 20% world unemployment and Index Mundi's labor force figure, we theoretically have a 1.616 billion labor force in the world who could divert their energies into earth-healing and other useful activities. It is interesting that a lot of the countries with the highest unemployment rates are also the most in need of ecological services to repair damaged environments. Here in the US with a labor force of 154,300,000, the official unemployment figure of 10% gives us 15.4 million people with time on their hands. At the 15.8% rate it is 24.3 million people. During the Great Depression, US unemployment was said to have gone up to 30%. One more big economic downturn and the US could reach 30% again which would equal 46.2 million people. There is no problem with labor power to do the needed earth repair work.

One of the permaculture principles is to turn problems into opportunities. This is certainly the case with the unemployed. Society needs to figure out how to unleash the human potential in these huge numbers of unemployed people. Another permaculture principle is to turn wastes into resources. This applies to humans as well as things. Society needs to learn how to make every person count. The profession of "horticultural therapy" has clearly shown that many disturbed people obtain benefit from working with plants. The carbon sequestration workforce outlined here would require millions of people with a wide range of capabilities. A lot of the work is skilled, however some of the work is capable of being done by people with marginal job skills or various handicaps. Everyone deserves a chance to have meaningful work that is within their capacity. Good training and supervision are necessary to optimize results.

One goal of a rational society is to encourage each of its citizens to be all that they can be. Utilize the talents and passions of every person. Current societal norms mean that a large number of people's talents and energies are not being utilized. This includes the unemployed, under-employed, multi-generation welfare cases, disenfranchised, cast out, homeless etc. This is probably between one fourth and one third of the population at this time. And if we looked closely at all the people who have jobs and pull down salaries, we could debate how many of them are actually doing useful work. The point I am trying to make is that there is a huge amount of latent energy in our under-utilized (and mis-utilized) people in our society. Permaculture is not only about how to make symbiotic relationships between flora and fauna; permaculture is also about making symbiotic relationships between people. How can people cooperate to their mutual benefit? How can true democracy and freedom be implemented to

unleash peoples' creativity?

I would like it to be clear that I am not proposing that we bring all of the world's unemployed into the formal work force. Rather it is that they create space in a new economic paradigm which has a lot to do with the world's informal economy. Indeed my proposal is to take large numbers of people out of the formal employment sector and bring more of their energies into aspects of the informal economy such as home food growing, barter, volunteerism, gift-economies, etc. True democracy and freedom is about decentralization and self-reliance. It is opposite to globalization and specialization.

It is unlikely that the carbon sequestration measures outlined in this proposal would ever be fully implemented from the top down. Even so, we should recognize, and applaud, that there already is some government funding, government agencies, non-profit organizations and lots of volunteer groups (from local to international) who are doing useful earth repair work of all kinds. Most people are sympathetic to the concept of earth repair. There are tree planting and soil building projects happening in many places. They are providing the knowledge base for larger efforts such as envisioned here.

How can these changes happen? Here is one possible scenario. A collapse of the value of the dollar throws the economy of the US and the world into shambles. Unemployment skyrockets. Production of real goods plummets. Globalized shipping shrinks. Government services are drastically curtailed. Many countries and regions are forced to rely more on their own resources.

Citizens of countries that are affected will be unhappy with the governments and powers that caused the mess. Here would be an opportunity to elect populist governments that favor things like freedom, justice, ecological development, local governance, protecting the environment and reversing the world's carbon flows. There is no doubt that there are plenty of would-be dictators and wolves in sheep's clothing that would also be vying for political power.

With unemployment so high, a good chunk of the unemployed decide to go to work fixing up the ecosystems around them and making them more productive and habitable for life. How is everyone going to get paid? This is going to call for a lot of innovative thinking and development of local economic systems. This is not likely to be a top-down outside funding process. It looks to me like there will shortly be a world-wide economic crisis that will dwarf the 2008/2009 recession. This could have any number of outcomes but the emergence of local currency and exchange systems are likely to be one outcome. This is an entry point to come up with systems that will reward people for doing land care work in local environments. Everyone in the locality benefits and so they recognize this by rewarding the people doing the work for the whole community. Volunteer work could also be a big factor in how the work gets done.

A new economic paradigm is beginning to be articulated. Economic systems are not my specialty. Planting trees and building soil are my specialties. Nonetheless here are some of my ideas of what a new economic paradigm might look like.

- Barter of goods and services at the local level becomes a major means of exchange.
- Local currencies spring up around the globe. Neighboring currencies develop means of reciprocity.
- Stock markets, commodities exchanges and money speculating are made illegal.
- Loans are made by local savings institutions and revolving loan funds embedded in local communities.
- An internationally recognized medium of exchange enables things like travel, imports and exports. Gold and silver look pretty ideal to me. Universally recognized and easy to travel with.
- Abolish the World Bank, International Money Fund (IMF) and similar organizations. They are just too compromised in the old paradigm to be reformed. Allow new international organizations to evolve based on equal rights and whose roles are to facilitate international exchange, but not to have control of any money.
- Encourage local production for local consumption to the fullest possible extent. Most communities have the capability to produce almost all of their food locally and many of their other needs.
- Manufacturing is done at the smallest scale feasible.
- Self-employment, small businesses and worker-owned cooperatives are the norm. The Mondragon Cooperative in Spain has demonstrated how to scale up worker-owned cooperatives into large manufacturing industries.
- A much smaller % of people work for someone else as an employee.
- There would be few chain stores, coast to coast fast-food joints, big-box chains, etc. The marketing of goods is done by locally-owned stores.
- A higher percentage of people are employed in the informal sector as compared to the formal sector.
- Farmland is owned by farmers. No big outside ownership of plantations. No speculating in farmland. Limits on farmland ownership
- Most taxes are collected locally and are allocated by local democratic decision-making. Regional, state and national governments need some tax money but a fraction of today's.

The ideas listed above will be resisted by the current people at the top, but it will obviously benefit the farmers, the workers and the vast majority of people in the world today. And even for the people at the top, just imagine what it would be like for your children and grandchildren to live in a world without fear, hunger, desperation, crime, violence, terrorism, war, repression, etc. Really, it is in the best interests of everyone to come up with a new economic paradigm.

The seeds of a new economic paradigm are sprouting and growing in many places. My personal belief is that the changeover will happen. I do not think it will come about because of armed revolution. I believe that a world-wide economic collapse will force willy-nilly the development of local systems to replace the collapse of big institutions. A forced decentralization. It won't be pretty. I believe that the powers at the top already know the collapse is coming and are positioning themselves to gain even greater control of the world. My hope is that when the dust settles, the new economic paradigm will have replaced the old.

In the current economic paradigm a car mechanic in India gets paid ten times less than a car

mechanic in the US for the same amount of work. A tree planter in China might get paid 20 times less than a tree planter in Switzerland for the same amount of work. Why is it that there is such a disparity in what is paid for the same amounts of work in different parts of the world? Everyone knows that the countries of "The North" rip off the countries of "The South", also referred to as The "Developed World" and the "Developing World". It could also be referred to as "The Siphoning Countries" and the "Siphoned-from Countries". What would the world look like if these North/South inequities were resolved so that fair trade becomes a reality?

The relevance of these economic and social comments to my carbon proposal is that local economic systems with local taxation can fund the needed earth repair work outlined in this proposal. Local people will act in their own best interests when given the power to do so. Fixing the local environment, building farm soils, having healthy forests, etc is obviously in the local's best interests.

It takes an extremely optimistic outlook to see how the world is going to get from its present condition to a world which has accomplished the proposals outlined here. Obviously vast changes would be needed in economic systems, land distribution and governance. The world's human population is straining the planet; the hungry and oppressed number in the billions; nature (and laboratories) are creating new diseases every day; climate perturbations are increasing worldwide; a collapse of the current economic system looks imminent; and the worldwide information network is enabling faster dissemination of information, knowledge and ideas.

These are some of the factors affecting the future we will soon be inhabiting. Humans have shown great adaptability in the past and the knowledge of how to make a transition to a just and sustainable future is taking clearer outline. Will humanity choose this path?

The nice thing about this proposal is that it doesn't require any international agreements or money from the big financial actors of the world. It doesn't even need a functioning world economy or world communication infrastructure. The solution is in a decentralized approach whereby local populations act in their own best interest. The impetus is from below rather than from above.

Michael Pilarski – January 1, 2010

This proposal is dedicated to Richard St. Barbe Baker, known as the Man-of-the-Trees, 1889-1982. Throughout much of the 20th century Richard St. Barbe Baker was a tireless advocate for doubling the world's forest cover. St. Barbe Baker inspired me to start Friends of the Trees Society in 1978 to help carry on his life's work. [25]

This proposal is the first draft of a work in progress. Send feedback.
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About the author: Michael Pilarski combines hands-on experience in agriculture, horticulture, forestry, tree planting, agroforestry, plant propagation, ethnobotany, wildcrafting, ecosystem restoration and permaculture; along with extensive research, writing, networking and teaching in all of these fields. He started farming in 1972 and has planted 80,000 trees so far.

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Understanding Economics
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WiserEarth helps the global movement of people and organizations working toward social justice, indigenous rights, and environmental stewardship to connect.
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