The Animal Improved Dung (AID) plus seeds treatment.

Managing livestock, dung beetles and earthworms to disperse rock dusts, fertilizers, beneficial micro-organisms, biochar and seeds to grow forests and food, improve soils and fix carbon and climate.

Summary

The AID plus seeds treatment is a system of innovations which hastens and enhances succession, increases soil carbon and fertility and grows high biomass vegetation. Soil improvers such as rock dusts, spores of beneficial micro-organisms, mineral fertilizers, biochar and burnt bone (from home-made fuel-efficient stoves) and seeds of fast-growing, deep-rooted plants can be fed to livestock to disperse in their manure. Dung beetles, earthworms and termites further disperse and incorporate the improved dung into the soil and increase the availability of nutrients, while their tunnels improve soil structure including air and water infiltration and root growth. Livestock in a planned grazing system can be used to treat/seed areas such as pastures, orchards, plantations, vegetable garden fallows and to reafforest degraded land. The resulting vegetation produces food and fodder, timber (carbon stored for hundreds of years), and fuel wood which produces charcoal (carbon stored in soil for possibly thousands of years), improves soil by promoting the growth of soil life and adding carbon, reduces erosion, as well as increasing transpiration, cloud formation and precipitation.

"...increasing agricultural productivity would not only reduce conversion of wild land to new cropland, but it could return existing cropland back to nature. Increasing agricultural productivity is the single most effective method of preventing habitat loss and fragmentation, and conserving global forests, terrestrial biodiversity and carbon stocks and sinks".
Indur M. Gocklany, 2003.

"Science commits suicide when it adopts a creed". T. H. Huxley.

"...and he gave it for his opinion, that whosoever would make two ears of corn or two blades of grass to grow where only one grew before would deserve better of mankind, and do more essential service to his country, than the whole race of politicians put together...".
Jonathan Swift, Gulliver's Travels, 1726.

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Introduction

The problems are everywhere: deforestation, poverty and hunger, the fuel wood crisis, droughts, floods, landslides, overgrazing and erosion, desertification, soil salinity/degradation, water shortages, possible climate change etc. Many of these problems are linked to deforestation and low soil organic matter. According to Gore (2009), we now only have half of the forest cover we had 300 years ago and 40% of the excess CO2 that has accumulated in the atmosphere has come from deforestation in past centuries. The World Resources Institute states that some 80% of the earth's natural forests have been destroyed (Walters 2010), with a tragic loss of biodiversity.

Most of these problems can be at least partially solved by the prudent and creative management of soils and vegetation. There is a great and pressing need for achievable, inexpensive and practical solutions. We need to become much better stewards of the environment: we need to tend the garden, not trash it. The AID treatment is an integrated, cost-effective and synergistic system, which can help to restore or even enhance forests, grasslands and soils, and positively influence climate, providing a buffer against extremes.

The carbon fraction of soils is called organic matter. Fertile, productive topsoil, unlike sterile subsoil, contains organic matter and an abundance of life. The best single thing that can be done to improve most soils is to add organic matter. "Organic matter has long been recognised as the key component to soil health as it feeds the soil biology and impacts on soil structure, water holding capacity and nutrient cycling". Organic matter in the form of compost has been demonstrated to increase plant productivity across a wide range of crops, soils and climates in Australia (Benjamin 2009). "The impoverishment of agricultural soils through depleted levels of biological activity and reduced carbon flow poses a greater threat to human existence than climate change" (Jones 2010). Carbon is the stuff of life. The carbon in soils comes mostly from plants and soil life such as mycorrhizal fungi, which comes from carbon dioxide in the atmosphere. Fast-growing or high biomass plants fix more carbon, so that more carbon is added to soils, thereby further enhancing plant growth, which adds more carbon to soils, and so on. Poor land management, including deforestation, does the opposite.

Ancient Egyptian civilisation was founded on high agricultural productivity based on fertile soil rich in organic matter which was formed by the flooding of the Nile. The river brought new inputs of organic matter, mineral particles (rock dust) and water every year. Nearly 80% of this came from Ethiopia, much of which was densely forested then, with fertile topsoils, mostly derived from volcanic rock. Ethiopia once had 75% forest cover, but by 1980 it was 4% (Troeh et al. 1980). Since 1957, more than three quarters of the land has come under cultivation, and 99% of the forest cover in the country's north-west region has been lost (Borchert 2009). In modern times, a few dams have been built on the Nile which interfere with annual flooding, and are filling up with sediment and compounding the disaster. The fisheries at the delta collapsed in 1965, after the construction of the Aswan Dam (Borchert 2009, Tudge 2003). Once a breadbasket, Ethiopia is now known for its famines - "The desert spreads not because of irreversible climatic change, but because of abuse" (Troeh et al. 1980). A cautionary tale. Similar tales of land degradation and desertification could be told of Roman wheat fields in Libya, the other end of the Fertile Crescent, and Australia today.

Not surprisingly, enriching the atmosphere with carbon dioxide can make plants grow faster and bigger, and not just in greenhouses (Atwell et al. 1999, Wittwer 1992, see "Do plants like more CO2?" at www.CO2science.org). Higher CO2 concentration results in more efficient use of light, nutrients and water, as well as increasing nitrogen fixation (Azam et al. 2005). In a free-air carbon enrichment experiment in North Carolina (as reported by Kunzig and Broecker 2008), with CO2 increased to 580 ppm, *Pinus taeda*, which is known for being particularly unresponsive to enrichment (Nambiar and Brown 1997), which is not mentioned, and not nitrogen-fixing, grew between 13 and 27% faster, and the understorey grew 77% faster. We could surmise from this that an average plant response might be close to 50% faster growth, at 580 ppm. However, the choice of relatively old *Pinus taeda* in a relatively cool climate does not provide a fair representation of the potential growth/carbon fixation responses of forests to an increase in atmospheric CO2, yet it is presented as if it were the best case scenario - "one of the fastest-growing trees on Earth" pg. 115. In fact, these trees in this climate might grow at best 1-2m a year, whereas a nitrogen-fixing *Falcataria moluccana* tree in Sabah grew 10.74m in the first 13 months, and bamboo, to 0.91m per day! (Guinness World Records). We are not given the truth, the whole truth and nothing but the truth. This gives a very misleading impression that CO2 enrichment has a minimal positive effect on forest growth, that reafforestation is not a viable way to reduce CO2, and that emission cuts are needed. Significantly greater responses and a more honest appraisal of CO2 enrichment potential could have been achieved with much faster growing nitrogen-fixing trees, grasses and herbs, in a warmer climate. Even in a cool temperate climate, younger hybrid poplars and nitrogen-fixing *Robinia pseudoacacia* over shade-tolerant grasses (e.g. *Miscanthus*) would have given a much better indication of the potential of forests to fix carbon. Assessment of carbon fixation should also take into account the roots and the carbon stored in soils as associated soil life, such as mycorrhizal fungi. The world's soils hold around three times as much carbon as the atmosphere and over four times as much carbon as the vegetation (Jones 2007). The abundance of soil life is directly linked to plant abundance and physiological activity (Archer and Pyke 1991), so fast-growing, high biomass grassy woodlands or grassy forests will have very high levels of carbon stored as soil life and humus.

While it may be unwise to recklessly add CO2 to the atmosphere, increased atmospheric CO2 may incidentally represent a short-term windfall, an opportunity to increase plant productivity and improve soils, and therefore be able to restore forests, produce more food, timber, increase cloud formation (which reflects incoming solar radiation), increase precipitation, and in turn fix more CO2. Fortunately, there are systems and processes that already exist in nature that fix carbon, including photosynthesis of course, but also succession, livestock and other animals including soil life (they are all a carbon sink – see Mason-Jones 2010) and charring organic matter.

The AID treatment works with livestock, dung beetles and earthworms to disperse beneficial micro-organisms, nutrients and seeds, to improve soils and aid in reafforestation. It is a matter of creatively, sympathetically and efficiently managing these processes to maximise the benefits to humanity and the environment. This is challenging, as it requires a combination of knowledge, common sense, wisdom, moral integrity and physical resources.

Forests and some of their functions

Forests transpire water from the soil to the air. Transpiration and evaporation have a locally cooling effect. It has been estimated that if the forests of Amazonia were converted to grassland, that this would decrease evapo-transpiration by about 20%, considerably decrease cloud cover, and increase temperatures by 2-5 degrees C. Eroded land causes warm updrafts, and reduces rainfall (White 2003). Bacteria grow in the stomata of leaves, and as these rise into the air (over 1 billion tonnes annually), they provide nuclei for cloud formation and rain condensation (enough to nucleate 50% of global rainfall), increasing reflective cloud cover and rainfall, particularly in tropical areas. The combined cooling effects of cloud albedo (reflectance) and transpiration have been measured to reduce temperatures over forested equatorial regions (compared to cleared areas) by as much as 15 degrees C (Jehne 2007). A revegetation program in Indonesia resulted in a 3-5 degree C reduction in average air temperature, an 11 % increase in cloud cover and a 20 % increase in rainfall (Gore 2009). The range of temperature extremes within forests are also around two thirds less than cleared land (Buchanan 1989), which also shelters animals (and people) from heat stress and wind chill, improving growth rates and reducing mortality. Soil which is cooler releases less CO_2 from soil carbon. Vegetation above soil has a cooling effect through shading, transpiration, and photosynthesis which is an endothermic (cooling) reaction.

Forests also increase precipitation when the trees are in contact with moisture from low level clouds or fogs, particularly on mountains. Research in North Queensland indicates that this may be as much as 30% of total precipitation (White 2003). Cape Town's Table Mountain receives an extra 3290 mm per year from fog drip from its "tablecloth" cloud (Chang 1969, in Mollison 1988). Trees have an enormous surface area on which water can condense, and the higher humidity within forests also results in condensation at night as the air cools, and trees may drip water all night (Buchanan 1989). Deforestation, especially on hill and mountain tops, also reduces stream and river flow. Lack of forest cover results in landslides, and more runoff, causing flash floods.

As forests grow, the soil is improved as organic matter from the vegetation accumulates, increasing plant growth and therefore the surface area available for condensation, and presumably the production of bacterial nuclei, increasing precipitation and growth, and so on.

Jehne (2007) suggests that reafforestation could enhance global cloud densities by 3%, reflecting 1% of incoming solar radiation (for more information on solar activity/radiation and global warming see Svensmark and Calder 2007). This would theoretically have an equivalent global cooling effect to reducing CO_2 levels back to pre-industrial levels (see also Engelhaupt 2010). He calculates that to date we have released some 300 GTC (billion tonnes of carbon) from burning fossil fuel. By comparison, we may have released over 2000 GTC (more than six times as much) due to past deforestation and soil degradation. Historically these forests may have absorbed some 300 GTC per year. He states that restoring just 5% of this prior bio-sequestration capacity (i.e. 15 GTC per year) should enable us to balance the 7 GTC per year we are currently emitting plus sequester some past emissions to re-balance the global climate.

It appears that CO2 emissions from burning fossil fuels are of secondary and relatively minor importance compared to the problem of deforestation and soil degradation (not to mention solar activity). If deforestation is the problem, then reafforestation is the solution. Reafforestation would increase cloud formation, thereby reflecting incoming solar radiation, increase precipitation, and reinstate cooler conditions, and so should function as a resilient buffer against possible anthropogenically induced climate change, or other unpredictable disturbances such as wildcard volcanic eruptions. These could at any time change climate through the addition of sulphurous gases, particles (which could cool the Earth for years, especially if the volcano is near the equator, such as in Indonesia) or perhaps add more CO2 in days than humanity produces in years. Reafforestation appears to be one of the quickest and best solutions to many of the world's actual or potential problems. The AID treatment is a cost-effective method of restoring grasslands, grassy open woodlands, and forests.

Succession – nothing succeeds like success

Succession is a natural phenomenon, which proceeds after a disturbance such as a landslide, fire, flood, glaciation, cyclone/hurricane, or abuse by people. Certain plants colonise the disturbed area, which in turn are succeeded by another group of plants, in an on-going sequence until the next disturbance. Each stage tends to increase soil organic matter from increased plant growth (tops and roots), as well as soil life such as mycorrhizal fungi (which live on carbohydrates exuded by roots and form a major, long-term carbon sink), soil fertility (for example, through nitrogen-fixing bacteria/plants, but also other nutrients from mycorrhizal plants, plants with proteoid roots, and root exudates acting on mineral particles), water-holding capacity, sometimes species diversity, and usually complexity of inter-relationships. As overstorey plants establish, light to understorey plants tends to decrease. Generally, the plants in the early stages of succession tend to be short-lived herbs (often nitrogen-fixing) and grasses, called pioneers or colonisers, followed by woody shrubs, and then long-lived woody trees and understorey species, culminating in what is known as a climax vegetation for that climate (Lichter 1998, in Krohne 2001, Raven 1986). In the tropics, early succession forest is often called regrowth or secondary forest, and late stage succession forests are called old-growth, climax or primary forest. Primary forest may exist for hundreds of years or more, eventually ageing, followed by secondary succession.

In the process of succession, organic matter, nutrients and plant growth increase in nature's equivalent of compound interest. Thus, in a temperate climate, bare sand dunes can become a deciduous forest, (Krohne 2001), and in the wet tropics, clay subsoil exposed by a landslide can return to lush tropical rainforest. The process may take hundreds of years, although grasses, *Casuarinas* and now a mixed rain forest has established in seventy years on Anak Krakatau.

Carefully and creatively managed succession can be bulked up and speeded up, constituting a "super succession". This could be achieved by utilising and sympathetically managing the best complementary mixtures of the best plant species, cultivars, seeds from "plus trees", hybrids or outstanding provenances, sourced locally, and/or from around the world plus appropriate beneficial micro-organisms and nutrients. It should be possible, through increasing water infiltration and holding capacity, organic matter and nutrients, and even increasing precipitation, to progress beyond the expected climax vegetation for the region/climate, and maintain it. In nature, the process eventually levels off, with plants in the climax vegetation competing for light, water and nutrients, but it should be possible to manipulate succession into continued growth, at least until the next disturbance, though perhaps not indefinitely. Presumably no land-based ecosystem can progress to a climax beyond a lush rainforest. To achieve this in a low-impact, energy-efficient way would require high biomass, deep-rooted plants, canopy/shade management, the addition and dispersal of seeds, nutrients, and other soil improvers which could be achieved utilising livestock, dung beetles and earthworms, as well as controlling future disturbances such as fire. Ideally, degraded land would be revegetated, with the ultimate aim of re-instating, as near as practically possible, the original forest, perhaps with a grassy understorey or clearings, or at least a grassy open woodland.

Plants that are early succession species tend to be tough, easy to grow and fast-growing. Plant groups that are commonly associated with the early stages of succession include: grasses and herbaceous or woody nitrogen-fixing plants, particularly legumes, and for example, commonly plants in the Asteraceae, Malvaceae, Chenopodiaceae, Solanaceae (most are poisonous), Moraceae, Euphorbiaceae (many have poisonous sap), Urticaceae, and Brassicaceae families. Many of our agricultural grains, pulses and vegetables are "weedy" early succession species, in these plant families, and this is one reason why many are easy to grow, and grow well in disturbed soil (cultivated soil) (Low 1989). However, many of the plants in these families, and some of the plants mentioned in this article, are, or may be, invasive environmental weeds. Wherever possible, it is best to use indigenous plants, or at least plants that are not likely to be invasive weeds. In some cases the plants are already established weeds, so they might be used, but managed to reduce their invasiveness (by cutting to prevent seed set for example), or only temporarily as part of an early successional stage. Overall, it would be better to err on the side of caution.

Plant root systems – retrieving water and nutrients, and storing carbon at depth

Different types of plants have different root systems. Some have fleshy root systems or tubers, which can increase macroporosity (open up the soil), such as Daikon radish, fodder beet, sweet potatoes, papaya, *Vigna vexillata* and cassava. Some have fine, fibrous root systems, including most grasses, with an <u>enormous</u> surface area (Raven 1986), which support mycorrhizal fungi and promote the production of glomalin, quickly improving soil structure and massively increasing long-term carbon levels.

Tree roots go down the deepest, and perhaps the Mimosoideae (mimosa family) in particular. In Egypt, *Acacia* and tamarisk roots have been found at 30 metres, and in Arizona, *Prosopis* *juliflora* roots at 53.3m. Surprisingly for an herbaceous plant, the roots of lucerne/alfalfa *Medicago sativa*, may grow 9m deep, and corn, *Zea mays*, to 1.5m. (Raven 1986, Troeh 1980). The roots of *Faidherbia albida* (syn. *Acacia albida*), "can reach aquifers up to 80m below the surface" (Le Houerou, F.A.O). So far, the world record goes to a wild fig tree in South Africa, with roots down to 120m!

Roots deposit carbon in the soil, and the deeper the deposition, the longer it lasts. This may be due to low oxygen, temperature and reduced microbial decomposition. Carbon at one metre or deeper, may be sequestered for several thousand years (Ladd and Foster 1996, in White, 2003). Deep-rooted trees and grasses therefore constitute a practical means for beneficial long-term carbon sequestration.

Deep root systems can tap into underground water, with cooling transpiration in the hot or dry season, and the provision of fresh green fodder in the dry season. Deep roots can also bring nutrients to the surface. This may not be much (Faradah Hanum and van der Maesen 1997), but would still be a net increase in nutrients to the system. *Faidherbia albida* is probably the best example of this. In a cover crop trial in Zambia, a small percentage of *Sesbania sesban* (a small, very fast-growing tree) roots reached the water table at 7.5 metres after two year's growth (Kwesiga and Baxter). In high precipitation areas, nutrients tend to leach away, and deep-rooted plants can retrieve at least some of these, as well as gain access to underground water.

The percentage of shoots to roots also varies considerably. The roots of tropical trees are usually about 20% or so of the total biomass. In most cases, more than half of a grass plant is roots, usually more than 60%; and with desert grasses and plants, the roots may be more than 85% of the plant (Ehrenfeld 2001). Regarding perennial prairie grasses in North America, approximately 20% of the standing crop is above ground in stems and leaves; 80% is below ground in root tissue (Krohne 2001). In wetter, more fertile sites, roots may be less, perhaps 50% down to 20% of the plant. Thus, if the tops of plants are harvested, grasses are likely to leave behind more biomass (carbon) in the soil than trees.

Maximising biomass – two blades of grass

The plants that produce the greatest biomass are algae (from slime through Sargassum weed to giant kelp, but also bacteria), and other water plants such as water hyacinth, salvinia, and papyrus, as well as grasses. Figures for water plants often seem comparatively high, but it should be remembered that they include the roots, which is often not the case with figures given for grasses and trees, and water plants have unlimited access to water, and often have access to high levels of nutrients. Grasses such as *Pennisetum purpureum* hybrids, *Arundo donax, Sorghum, Miscanthus* x 'giganteus', sugarcane and bamboos, come closer to water plants if roots are included, and they have access to ample water and nutrients, which is usually not the case. Some of these grasses, e.g. *Pennisetum purpureum* hybrids, can grow taller than 4m, and under optimal conditions, might reach 10m, and are reputed to be able to produce more than 60 metric tonnes of dry matter per hectare per year, plus the root system which could be perhaps 60 - 120 t, giving a total of 120 t/ha/yr DM or more! In North

Queensland, nitrogen-fixing *Sesbania cannabina* and sugarcane sometimes grow together, apparently with minimal adverse effects and mostly complementary effects, so a combination of *Pennisetum* and either annual or perennial *Sesbania* species, or bamboo and *Falcataria*, should produce even more biomass.

For high biomass forests, trees should be selected that are preferably not allelopathic. For example, pines acidify the soil and drop leaves that contain resins and terpenes; eucalypt leaves contain polyphenols, oils, and waxes that can cause water-repellency in soils, and the leaves and bark of some *Acacia* species are high in tannins. Allelopathic, or otherwise highly competitive trees should either be avoided, or perhaps constitute half or less of the overstorey. Eucalypts and pines are also fire-prone, and promote fire.

Careful selection of combinations of the highest possible biomass plants, maximising any beneficial relationships, and minimising competition and allelopathic effects, will result in much more organic matter in much less time (see Cardinale et al. 2007). This organic matter, in the form of timber, can be used for construction and fuel wood. Houses, bridges, furniture etc. fix carbon for decades and potentially hundreds of years. As fuel, wood forms charcoal which can last in the soil for thousands of years. One way or another, if the organic matter ultimately ends up in the soil, the soil is built up and improved, and so is plant growth, producing even more biomass.

Grass under trees can grow better, or at least some grasses under some trees. Shade, but usually not deep shade, can enhance grass productivity, especially if this is combined with nitrogen- and mineral-rich litter fall from deep-rooted nitrogen-fixing trees. If the tree canopy is naturally relatively open, or it allows more light through at some time in the year, or it is maintained that way through thinning, coppicing and pollarding, there will be much greater total biomass production (from the combination of grass and coppice growth– for more information on coppicing see Evans and Turnbull, 2004). In a trial in Sri Lanka, the grass *Panicum maximum* cv. Guinea VRI 435, grew better under the shade of *Gliricidia sepium* and *Erythrina lithosperma* (syn. *E. subumbrans*). The researchers concluded that growing leguminous trees and grass in mixed forage systems enhances the yield and quality of the understorey grass and total output of the system (Seresinhe and Pathirina 2000). There are also shade-tolerant Guinea grass cultivars, see www.tropicalforages.info. Yields of millet were doubled under *Prosopis cineraria* in Rajasthan, India (Mann and Saxena, Mann and Shankaranaya, in FAO public. "*Faidherbia albida*"). Increased productivity has also been recorded with *Faidherbia albida* and *Albizia* spp. Multiple citations by Lowry and Seebeck (1997), suggest a minimum "canopy effect" of 33% growth increase in understorey grasses or crops, through to more than doubling grass productivity. They also point out that the quality of grasses under trees may increase, remaining green for longer into the dry season, and fallen tree leaves provide fodder. It should also be factored in that some trees provide additional leafy fodder, and some provide significant quantities of nutritious seedpods, e.g. *Albizia saman, Gleditsia, Prosopis, Faidherbia, Parkia, Inga,* carob and *Leucaena*, and some provide both. Fodder and pod production allows a higher stocking rate to be maintained, forming an even larger carbon sink.

Since grasses are some of the most productive plants, and much of their biomass is in the roots (plus associated soil life), and since their productivity increases under nitrogen-fixing trees with a light canopy, it is therefore possible to quickly and greatly increase the biomass/organic matter of a system with complementary plant associations.

Single storey pine plantations (monocultures) in cooler temperate climates are often used to suggest that growing trees will not make any significant impact on fixing anthropogenically produced CO2. However, such forests are likely to produce approx. 5-10 tonnes per hectare per year of dry matter (t/ha/yr DM), above-ground material, plus roots at 1.25-2.5t with a maximum total of 12.5t. Including roots, an exceptional best case scenario in a warm temperate climate might be 22t. By contrast, in the tropics, with higher temperatures and light levels, a well-managed and sited plantation with a complementary combination of a shade-tolerant cultivar of Guinea grass at a conservative above-ground 20 t (could be 60t), plus a middle storey of *Sesbania, Erythrina* or *Gliricida* at probably 15t (could be 25t) plus an overstorey of perhaps *Falcataria*, at probably 15 t (could be 20t or more) might give a total above ground biomass of 50t/ha/yr DM. At 20t/ha of top growth for the grass, and a probable worst case scenario of 10t of root mass would give a total of 30t (but the roots could be up to 80% of the plant, which would mean a total of 100t). The trees with roots included would be about 18.75t each, with a grand total of around 67.5t/ha/yr DM, which is 5 times as much as the pine forest at12.5t. Adding a conservative 33% to the grass for the canopy effect, the grass would be 40t, and the grand total 77.5t, 6 x the pine plantation.

In fact, there are Eucalyptus clones that produce over 30t by themselves (with roots = 37.5t or more). Moreover, a trial in Hawaii found that Eucalyptus growth increased 2.5 fold when grown with the light-foliaged, N-fixing tree, *Falcataria moluccana* (syn. *Paraserianthes falcataria, Albizia falcata*) (DeBell et al 1985).Thus the overstorey figures could be much higher. Climbers/lianas and epiphytes such as *Ficus pumila, Philodendron* or *Scindapsis* spp. growing on the trees would add a few more tonnes.

In one exceptional case in Thailand, a monoculture plantation of *Acacia crassicarpa* (seed from Woroi Wipim in New Guinea), “produced a total above-ground dry biomass of 207t/ha in 3 years” An oversimplification, but that would give an average of 69t/ha/yr DM (Faridah Hanum and van der Maesen 1997). The total with roots would be about 86t. This tree is allelopathic, so an understorey of *Panicum maximum* might produce a low total of 20t, with a grand total of perhaps106t, 8.5 x the cool temperate pine trees.

If the resources are available for planting “quickstick” or “liveset” cuttings (large stems placed straight in the ground, or rooted cuttings from a nursery bed), an ultimate combination of *Pennisetum purpureum* hybrids, or high biomass sugarcane clones, (top growth up to 70t, plus roots of probably 30t or more) plus a middlestorey (e.g. *Sesbania* sp.), and with an overstorey of *Falcataria* or *Acacia crassicarpa* combined with superior *Eucalyptus* clones or hybrids might produce staggering figures over 150t (12 x the pine trees). The biomass of soil life should be added to this. Such high growth rates could significantly reduce ground water, and so if such a forest were grown it would need to be a horizontal strip or strips, perhaps not more than half the hill slope, or water tables and stream flow are likely to be negatively affected. Equally, such forests could largely solve problems of flash flooding and landslides, where these occur. Alternatively, trees could be spaced more widely.

Such multi-storey grassy forests in the wet tropics, with their high biomass and deep root systems, are an extremely effective and beneficial means of increasing transpiration, as well as fixing carbon and storing it in soils (including associated soil life and humus) and above ground, and more so if they are combined with animals dispersing decay-resistant biochar from fuel-efficient stoves (see Appendix 4).

Combinations of (preferably indigenous) trees such as *Acacia, Albizia/Samanea, Faidherbia, Pithecellobium, Falcataria, Erythrina, Parkia, Enterolobium, Prosopis,* etc. as overstorey spp., with the number of trees first thinned, then coppiced, then pollarded, and with the coppice and pollarding thinned to as much as half the canopy (to allow light in), with middlestorey species such as *Calliandra, Sesbania grandiflora, S. sesban, Gliricidia, Leucaena* (arboreal forms), *Pithecellobium,* and *Adenanthera* also thinned and coppiced, and shade-tolerant cultivars of grasses such as *Panicum maximum* and *Pennisetum purpureum* hybrids are just begging to be tested.

Even a simple, little-or-no-maintenance two storey forest of trees over grass (a silvo-pastoral system) would be a great environmental improvement across huge tracts of degraded land worldwide. Trees could be chosen that are nitrogen fixing, and drop pods for livestock. There are extensive areas of cleared, degraded land, either barren or infested with weeds such as blady grass or lantana, and cattle ranches that could be restored and improved by reafforestation in parts of Brazil, Africa, South-East Asia and Australia, where there is already tree-growing expertise. In tropical America for example, raintrees, *Enterolobium* and a middlestorey of *Calliandra* could be grown over pasture on cattle ranches. According to Jehne (2008), natural forests and agro-systems could be expanded in inland Australia to potentially bio-sequester over a billion tonnes of additional carbon per annum. This could theoretically generate over $50 billion AUD annually in carbon credits for many years. The grassy, multi-storey forests in wetter climates described here should do much better than that, largely or entirely solving the C02 build-up, for decades at least. This would buy time for research and development into alternative or more efficient energy sources.

There are also opportunities using algae and other water plants, but there are also problems including weediness, methane production and breeding disease-carrying mosquitoes. In Uganda for example, experiments are being carried out to turn papyrus into briquettes for fuel (Finlayson and Moser 1991). The highest possible biomass production in ponds might be achieved by growing *Cyperus papyrus* (cut frequently to let light in) over water hyacinth (or *Salvinia* or *Pistia stratiotes*) with *Azolla* (nitrogen-fixing), perhaps fed with manure/sewage/urine/rock dusts (to produce fodder, briquettes, renewable potting mix/peat substitute, compost or mulch). *Pistia* and *Azolla* should combine well to produce fodder (Kamalasanana 2005). Ponds could be built above-ground using heavy duty plastic sheets with supporting walls made of wooden planks or bamboo. Productivity should be greatly increased if these were within polythene covered greenhouses, and even more with CO2 enriched air, which could come from the composting process. Algae can be used to capture carbon in coal power stations and produce stockfeed or food for humans (Woodward 2009). *Spirulina*, *Chlorella* and many seaweeds are already used for human food. Algae also produce oil which can be used for food or biodiesel. Warm, humid, CO2 rich air from coal power stations could be pumped into tall, multi-span greenhouses to grow crops, or pastures or hay for livestock, which would sequester carbon in the soil. Biomass (e.g. grasses) could be grown to feed the power station, and the ash used as fertilizer.

In parts of some oceans, adding deficient nutrients, usually iron, results in algal blooms, which sequester carbon (Lomborg 2010). Ocean nourishment may also include adding calcium, phosphorus and nitrogen, for example. Whale dung is high in iron and causes phytoplankton blooms. Adding iron to Antarctic waters, including under the ice caps where algae grow, could make up for the reduction in whale manure, at least until whale and krill populations return to pre-whaling numbers. In this system, carbon and iron are cycled between phytoplankton, krill, whales, and back to phytoplankton, forming a carbon sink (with some losses of course). Marine animals called salps also concentrate carbon as they consume algae, so there may be opportunities to add nutrients to "farm" salps. Rather than losing the carbon to the sea bed, it might be possible to harvest the salps, compost them with other organic materials, and then add the compost to crop soils, to increase food production. CO2 given off during composting would be an advantage if crops are grown in greenhouses. Floating marine plants such as Sargassum weed could also be farmed. Seaweed has been used in agriculture for hundreds of years, in Ireland for example. Regarding the lowering of sea water pH, see www.CO2science.org, and www.cquestrate.com.

Biomass figures for many plants can be found at www.tropicalforages.info., Duke handbook of energy crops (unpublished, on the internet, see references) and Faridah Hanum and van der Maesen 1997 (Prosea no. 11 auxiliary plants.), for example.

Animals in the system – livestock, dung beetles, earthworms and termites

"Ideas are the root of creation". Ernest Dimnet.

Domestic livestock production systems occupy 45% of Earth's land surface excluding Antarctica, and are worth at least US$1.4 trillion. The industry employs 1.3 billion people globally, including 600 million poor livestock keepers (Haskins 2010). Rangeland (land that can be used for grazing animals) vastly exceeds arable land (land good enough to grow crops). For example, about 83% of Kenya is considered rangeland (Troeh1980), and about 80% of Australia is rangeland, with only 6% arable land (including cropland and sown pasture) (White 2001). World hunger and the lack of arable land for crops means that animal systems must be as productive as possible, and preferably as environmentally friendly as possible.

Livestock can play a major role in improving soils, fixing carbon and restoring vegetation through their grazing and their manure. Planned grazing can facilitate/boost succession in an energy- and cost-effective way. Soil improvers such as powdered biochar (charcoal), clay, rock dusts, fertilizers and beneficial micro-organisms can be fed to animals, as well as seeds of fast-growing, deep-rooted plants, which are then dispersed by the animals in their manure, and further dispersed and incorporated into the soil by dung beetles, earthworms and termites.

This dispersal system will not provide a perfectly even distribution, but it is not essential for nutrients and water to be evenly distributed throughout the soil profile – plant roots will proliferate where the nutrient and moisture status is optimal – and still grow well, as demonstrated by drip irrigation and micro-dosing or band applications of fertilizer (Haskins 2009, Troeh et al. 1980, Smith 2009). Drip irrigation for example, has been shown to cut water use by 30 – 40% while increasing yields 20 – 90% (Lomborg 2007). Regarding drip irrigation, an intriguing result occurred in Australian research with grapevines. Instead of using a single pipe with drippers, two drip lines were used, one on each side of the vine row, watering one side at a time, while allowing the other side to dry out. The net result was the same fruit production, applying half the water (Einspruch 2003). More research could determine whether this would work with crops and orchards/plantations, either with drip or flood irrigation of alternate rows/furrows. Liquid fertilizer could be included in the water, or a spot application of fertilizer, such as a tablet, could be buried beneath each dripper, for maximum water and fertilizer efficiency.

If the aim is to end up with a climax vegetation which is as close to a rainforest as possible, rather than the typical treeless grassland, then livestock will be needed that preferably browse (eat leaves), as well as graze (eat grass), and also eat fallen seedpods, fruits, and perhaps roots and tubers. In the forested tropics, probably one of the best domestic animals would be Bali cattle, also called Banteng. They are non selective feeders, that is they browse and graze a wide variety of plants, are adapted to the tropics (they have gone wild in the monsoon forest of the Cobourg Peninsula in Australia), and are relatively small, reducing the problem of soil compaction (this can be a problem with large animals on wet soil, especially with set stocking). Canadian research found Galloway cattle to be the most feed-efficient breed, and Danish research found that they eat a wide range of plants. They are also tough and suited to colder climates (see www.gallowaysaustralia.com.au). Perhaps a cross between Galloway and Bali cattle would suit Mediterranean and subtropical climates.

Depending on climate and vegetation, there are many other possibilities including deer, goats, sheep, rabbits, chickens, pigs etc. Some less obvious possibilities include African eland antelope, Addax, South American capybara, African cane rats, guinea fowl, ratites etc. What a shame that dodos and moas are gone. Goats, deer and eland browse as well as graze, and pigs and chickens are adapted to forests. Pigs and eland eat roots and underground tubers as well, so that plants in the ginger family (and perhaps *Plectranthus esculentus, Pueraria phaseoloides, Cordyline* spp.) could be part of the understorey as shade increases. Eland are very efficient in both feed and water usage. “Eland can go for months without water” (Mayhew and Penny 1988). An eland eating the leaves of *Acacia* (at night when there is condensation) can derive 5.3 liters of water per 100kg of metabolic body weight, meeting its needs to maintain a constant body weight. Growth rates of eland are .33 kg/day, compared with cattle at .14 kg/day, and sheep at .05 kg/day. (Kyle 1972, in Bolen and Robinson, 1999). Eland have been farmed and semi-domesticated in Southern Africa and Russia, and can successfully co-exist with other stock (Ucko and Dimbleby 1969). Deer also have feed conversion rates which are much superior to cattle.

It would be better to move away from the wasteful and inefficient feeding of grain that is fit for human consumption to livestock. Grass-fed beef is twice as energy efficient, and healthier to eat than grain-fed beef (Jones 2010). We could instead change to stock that have more efficient feed conversion rates and that can utilise leaves, pods, fruits, tubers etc. as well as grass, in a grassy open woodland or grassy forest setting. These are mostly plants that we can't eat, and can be grown on land which is not good enough to grow crops, and yet produce nutritious milk, eggs, and meat, as well as wool and a host of other useful products.

A particular area can be "treated" with soil improvers, within a system of holistic planned grazing. Planned grazing allows plants to recuperate after grazing/browsing, and maintains a permanent vegetation cover, unlike set stocking which leads to plant exhaustion and bare soil. Grazing low to the ground is generally avoided, with some farmers not allowing stock to graze grass to less than 30 cm (12 inches) in height. Grazing might be for a few days (or even hours) followed by a few weeks to many months or even years of rest/regrowth. To gain some appreciation of the enormous potential of holistic planned grazing, see Allan Savory's inspiring work in Zimbabwe (winner of the 2010 Buckminster Fuller Challenge) – http://seedmagazine.com/content/article/greener_pastures. See also www.savoryinstitute.com, www.achmonline.squarespace.com, and www.holisticmanagement.org. David Mason-Jones describes Allan Savory's insight as "possibly the most significant environmental insight of the 20th century". The AID plus seeds treatment builds on his work.

Planned grazing normally allows a much greater stocking rate (and therefore a larger carbon sink), and reduces problems with worms, parasites and weeds. Intensive, planned grazing systems usually require a minimum of 4 separate fenced or hedged areas, but 12 or more is better (Mollison 1988). Some farmers in Australia have 70 or more. Sheep or goats following or with cattle will graze vegetation down to lower levels (if desired), and their hooves will spread and trample their dung, and seeds and soil improvers into the soil. Chickens and pigs following the previous animals would scratch and dig even more (Mason-Jones 2009). Dung beetles make tunnels, burying "improved" manure down to 30 or even 50 centimetres deep (Marshall 2009). Their outward circle of influence may be about 90cm in diameter, therefore dung piles that are an average of about 1 metre apart or less, should give a reasonable distribution (see Appendix 1). Earthworms will also spread the "improved" manure in their tunnels, and make nutrients more available to the growing seedlings (see Appendix 2). Tunnels, lined with manure which includes decay resistant charcoal, should last for years, holding nutrients and increasing aeration and water infiltration into the soil. Some of the roots of grass and tree seedlings are likely to grow down the tunnels, hastening establishment and growth. Equally, earthworms may burrow where roots have died. Manure which is quickly buried will experience very little in the way of losses due to volatilisation (e.g. nitrous oxide, methane - methanotrophic bacteria in aerated soils quickly oxidise methane), leaching, or surface run-off of nutrients (Taylor 2010), into rivers and lakes.

Dung is also eaten and spread by termites (126 species, utilising the dung of 18 wild and domestic mammal species, discovered so far), improving soil fertility and structure. They may remove one third of a dung pile in one month in the dry season in the tropics (Olff et al. 2008).

Livestock could be manually herded, or confined cheaply with portable, solar-powered electric fencing, or permanent fencing, which could be multi-purpose living fences (cheaper and longer lasting - see Appendix 5). Solar fences should become cheaper in the near future due to the invention of nearly five times cheaper collectors by Professor Vivian Alberts (see more about his invention at www.scienceinafrica.co.za/2006/april/solar-panel.htm). See also the work of Professor Paul Dastoor at Newcastle University (Australia), and the possibility of "solar paint" in a few years time. Another approach is to use moveable pens, which may need to be predator proof (Savory 2010). Alternatively, stock can be tethered. A running tether would result in a rectangular grazed area, which is more useful on the contour, on sloping land. A running tether consists of two stout pegs hammered into the ground, with strong wire between the pegs, and a running, light-weight chain, attached to a comfortable collar (Mayhew and Penny 1988). Following treatment, stock will need to be excluded for as long as it takes for the plants to establish, and possibly long enough to produce seed. Rabbits or other pests and fire may need to be controlled.

Livestock will produce "improved" manure at night as well, and if they are penned, the manure and urine can be collected and used to make compost, for vegetable gardens for example. Compost could include *Tithonia* leaves, water plants, burnt bone, rock dusts, clay etc. Human urine is sterile, and can also be recycled to grow vegetables, potted seedlings, fuel wood or fodder plants. Alternatively, manure could be dried, charred and spread on gardens or orchards (Miller 2009).

Dispersing soil improvers using animals

Cattle, sheep, goats, poultry etc. can be fed with supplements that improve the soil. The first rule would be to "do no harm" (to the animals, or the environment), so local veterinary advice should be sought before you act on any of these recommendations. Some of these supplements are likely to be neutral, while others should be beneficial. To entice stock to eat supplements, it may be necessary to add molasses or some other syrup, or sea salt, mixed together with warm water to fodder. Sea salt will probably not combine well with beneficial micro-organisms, and would not be suitable in saline soil areas. Molasses is "highly palatable and high in potassium" (Kahn 2005). Both molasses and sea salt contain a wide range of trace elements (molasses may also feed soil micro-organisms and thus help with mineralisation of nutrients in the soil – some Western Australian wheat farmers are maintaining yields while reducing their fertilizer requirement by adding molasses with fertilizer to the soil).

As an example, for cattle, Pat Colby (2002) recommends:

"A base lick for free take of bail feeding is:

25kg dolomite

4kg of copper sulphate

4kg of yellow *dusting* sulphur

4kg of urea free seaweed meal

Other trace minerals would depend on the soil analysis, zinc, boron or cobalt might have to be added if their absence is causing trouble". In this example, the seaweed would provide trace elements; the dolomite should raise pH and is likely to be good for earthworms, providing calcium and magnesium, while too much copper sulphate can kill earthworms. Where affordable, a soil test will provide information as to which supplements are needed, for both the stock and the soil, and in what quantities/proportions. Advice should be sought from local soil experts. Supplemented fodder may need to be placed in different areas or troughs, and feeding supervised to ensure the feed is evenly distributed between individual animals.

A fodder production area could be grown in a convenient location (near the home, stock pen, water supply), so that especially palatable feed can be mixed with soil improvers/seeds, and fed to animals (a cut-and-carry system). The fodder area could have extra water from a roof, and nutrients from manure and human urine. It could also produce seeds, mulch, wood, and grow medicinal and insecticidal plants.

Plants could be grown in complementary mixtures on a swale (contour ditch that catches water) or an arborloo (a composting pit toilet - for more information on arborloos see http:// aquamortripod.com/Arborloo2.HTM, www.ecosanres.org/factsheets. htm - fact sheet 13 "toilets that make compost" and fact sheet 6 "guidelines on the use of urine and faeces on crop production", and www.kernowrat.co.uk which shows a "deckchair toilet" using biodegradable plastic bags).

Alternatively, fodder plants could be grown using the Tumbukiza method/Zai holes (animal manure mixed into planting holes, with manure further distributed by termites and/or earthworms) - see www.fao.org/ag/AGP/AGPC/doc/Newpub/napier/tumbukiza_method.htm, and www.echonet.org/content/article/1374/DRYLAND%20TECHNIQUES%20AN...).

Some suitable fodder species, depending on climate, include Napier or Guinea grass, *Miscanthus*, sugar cane (crushed, with the juice fed to animals), *Phalaris, Azolla, Moringa, Sesbania*, *Calliandra*, *Tithonia*, *Montanoa leucantha ssp. arborescens, Chamaecytisus, Populus,* comfrey, *Acacia* spp., *Caragana* and *Leucaena*. A combination that should be productive (in the tropics), nutritious and largely complementary, could include *Sesbania sesban* or *S. grandiflora*, (or *Leucaena* or *Calliandra*) with *Tithonia/Montanoa* and one of the above grasses. See also www.foddersolutions.org.

Dung production should be about 80% of feed consumed, with improved dung production starting perhaps 18 hours later, and most passed through in perhaps 24-48 hours, but up to 96 hours. The quantity of dung produced could be as high as 10 tonnes per year fresh weight, (about 2 tonnes dry matter) for a stabled or yarded, 500 kg horse (Myers 2005), but is more likely to be 1 tonne DM or less, per year, for cattle in less ideal conditions. In Australia for example, the cattle herd is about 27 million, producing around 25 million tonnes of dung per year (Marshall 2009). Adult goats with supplementary feed in Nigeria produce 138 kg dry manure per year, containing 3.4 kg N, 0.5 kg P and 1.1 kg K, plus Mn, Zn, and Cu (Osuhor et al. 2002). Defecation is likely to be 5 to 12 times per 24 hours, per animal.

Soil improvers

Some of these materials are untested, and some dosages suggested are speculative. Seek veterinary advice. More information on some of these materials can be found in Peter Bennet's "Organic Gardening", especially pages 96-109.

Clay. A tried-and-tested positive addition to animal diets, and may be good for humans too. Bentonite clay fed to cattle improves feed intake, conversion and absorption by 10 – 20%, resulting in superior growth rates (Engel 2002). It could be that continual feeding of clay to animals, or an overdose, may hinder absorption of nutrients in the gastro-intestinal tract, so it would be best to use it intermittently. The same may apply to charcoal. Perhaps five days on, two days off, or similar.

The names of clays can be confusing. The volcanic smectites are probably the best, including bentonite, where montmorillonite is a major constituent of bentonite, or the names are sometimes used interchangeably (see www. eyton's earth.org/drinking-clay-internal-use.php.) Sodium bentonite is suggested for horses up to 700 grams a day ((Kahn 2005, the Merck veterinary manual), although some farmers provide clay so that stock can eat as much as they want. Kaolin, another type of clay, is used with pectin for diarrhoea in people and animals at 1-2 ml per kg of bodyweight (Kahn 2005). Montmorillonite, a clay derived from basalt, should have a wide range of trace elements, and is likely to be good for animals, soil and plants. Clay, sometimes from termite mounds, is commonly eaten by animals to deal with plant toxins, with the most well-known example being macaws in South America. Animals recorded eating clay include monkeys, gorillas, chimps, giraffes, elephants, rhinos, tapirs, peccaries, deer, birds etc., ...and humans - "Clay is an extremely useful medicine" (Engel 2002).

Clay is very effective in sandy soils to increase water holding capacity and cation exchange capacity, and generally, the more the better. It may still be useful in clay soils if you use a different type of clay, which may have different trace elements, or physical or chemical properties. Clay could also be mixed with drinking water, but usually clean water is best.

Biochar. Charcoal or biochar in soils is resistant to decay (sometimes called recalcitrant), and can be considered a long-lasting form of organic matter. This can be very helpful, especially in the warm, wet tropics where organic matter disappears quickly. Charcoal in soil is reputed to last hundreds or even thousands of years, while charcoal rock art, such as Chauvet cave in France has been carbon dated, and could be as much as 35 000 years old.

It has been suggested that the porous surface area of biochar promotes the growth of soil life by providing safe niches for micro-organisms to occupy. Biochar also holds water and nutrients, with decreased losses of nutrients due to leaching and volatilisation (Lehmann

2007). Since fast-growing plants produce more organic matter, some of it could form a long-term bank of decay-resistant organic matter, while still leaving sufficient non-charred organic matter to feed soil life. Biochar in this system would ideally be produced on a relatively small, domestic scale, utilising homemade fuel-efficient stoves for example, which could be designed to leave more charcoal and less ash (see Appendix 4). The charcoal and ash could be crushed into powder, mixed with palatable feed, and then fed to livestock to disperse in their manure.

Higher quality biochar could of course be produced on a bulk industrial scale, and mechanically incorporated, but at a much higher energy cost. For compacted, infertile soils, using a tractor, diesel fuel etc. initially to cultivate and incorporate bulk quantities of biochar and other soil improvers may well be a worthwhile investment, to kick start the system. Alternatively, soil improvers could be injected as a slurry. Improvers could also be ploughed in with draught animals. By comparison, using stock, dung beetles and earthworms as dispersal agents is extremely energy-efficient, but involves smaller quantities over more time.

Activated charcoal is used for the treatment of humans and livestock in cases of poisoning (Beers 2003). For people, 60-100 grams is administered orally (McPhee). "Activated charcoal is not absorbed, so overdose is not a problem" (Kahn 2005), however long-term continuous use may interfere with absorption of nutrients. The dose recommended in Kahn is 2-8 g per kg of bodyweight. Activated charcoal is likely to be much more absorptive than charcoal from a fire or fuel-efficient stove, and so higher doses should be safe. Since charcoal is not absorbed, all of it will pass through animals to the soil.

Charcoal can reduce livestock methane production, as can higher quality legume forages, and garlic. The CSIRO in Australia is working on specific, methane-reducing gut flora to inoculate domestic livestock (Coffey 2000). However, it should be remembered that greenhouse gases produced by animals (and humans) are derived from the environment, and are recycled back to the environment, with no net increase, and so are not the big problem they are made out to be (Mason-Jones 2010). As long as numbers are maintained, animals form a carbon sink.

Burnt bone. This is reported to have a very high phosphorus content of up to 35% phosphoric acid equivalent, compared with unburnt bone at 21%, and unburnt bone may not decompose and release its phosphorus for hundreds of years (Bennet 1995). Burnt bone from mammals, fish, poultry etc. (produced in fuel-efficient stoves – see appendix 4) could be crushed into a powder and fed to livestock, and would be sterile and disease-free, although it is illegal to feed bone to livestock that will be eaten by humans in some countries (it can spread anthrax, botulism and mad cow disease). A suitable dose might be 1g per kg of bodyweight of the animal (seek veterinary advice). Alternatively, if there is any risk involved, burnt bone could instead be added to compost heaps, worm farms, home-made fertilizer pellets/spikes, seedballs, zai holes/tumbukiza or arborloos.

Home-made compressed fertilizer pellets (tablets, spikes) could be made with burnt bone and other needed nutrients, and placed underground in the root zone of crops such as maize and vegetables. Burnt bone fed to earth worms in a "worm farm" might further increase phosphorus availability (see Appendix 2) and be cost-effective. Fertilizer pellets/spikes could be made using vermicompost from worms that have been fed small quantities of burnt bone (and possibly rock phosphate or superphosphate, ash, powdered charcoal, rock dusts and beneficial micro-organisms). These could be made in ice cube trays and could be a business opportunity.

Ash. There have been dramatic plant growth responses to applying ash to soils. Ash usually has high levels of potassium and calcium. Ash should normally be helpful to make acid soils more alkaline and is freely available, which may not be the case with lime and dolomite. In Brazil, adding 5 tonnes per hectare of ash from burnt bark (4.7% Ca and 1.4% Mg) to a 6 year old *Eucalyptus grandis* plantation growing in a sandy soil, increased stem volume from 38 to 86 cubic metres! In another plantation of *E. grandis*, 5 tonnes of ash per hectare resulted in a 71% increase in wood volume, and 20 t/ha resulted in a 102 % increase (Nambiar and Brown 1997). Elephants, chimpanzees and domestic stock have all been observed eating ash (Engel 2002). Ash from fuel-efficient stoves could be fed to stock to spread in their dung, and could also be used in arborloos and fertilizer pellets. A suitable dose for animals might be 1-3g per kg of bodyweight.

Beneficial micro-organisms – mycorrhizal fungi and nitrogen-fixing bacteria. Mycorrhizal fungi grow in a symbiotic relationship with plants, nourished by carbohydrate from plant roots, and their spreading hyphae represent a major proportion of the carbon in soils. It has been estimated that in perennial grassland, the hyphae in the top 10 cm of four square metres, if joined end to end, would stretch all around the equator of the earth (Jones 2009). They also produce long-lasting carbon in the form of humus. Mycorrhizal fungi generally increase the surface area of contact between roots and soil and change the root architecture, thus improving nutrient (especially phosphorus) and water uptake, resulting in improved growth and drought tolerance. The absorptive area of mycorrhizal hyphae is approximately 10 times more efficient than that of root hairs and about 100 times more efficient than that of roots, and plants may grow 10-20% faster (Jones 2009, see www.amazingcarbon.com).

Eucalyptus spp. inoculated with ectomycorrhizal fungus may improve growth rates by 50 – 100%. Acacias show much improved growth rates with VA mycorrhizal fungi, especially in infertile soils: 50% for *A. holosericea*, 300% for *A. auriculiformis*, 400% for *A. saligna* and a stunning 1240% for *A. mangium*, (shoot dry weight). This last example is particularly significant, as *Acacia mangium* is a major tropical plantation species. *Albizia* and *Leucaena* also respond positively (Jasper 1990). Asteraceae species, such as *Tithonia diversifolia* (*Glomus* spp.) also benefit, which may account for the high levels of nitrogen and phosphorus in its leaves. Thus mycorrhizal fungi increase plant growth, and the increased photosynthesis provides more carbohydrate to feed the fungi, and the growth of the fungi in turn enormously increases the living soil carbon, and ultimately humus.

Mammals appear to be effective dispersal agents, although distribution will be patchy. Research in North Queensland found spores of mycorrhizal fungi in 57% of dung samples from 12 out of 17 small mammal species. Inoculation experiments showed that spores retained some viability and colonised the roots of host-plant seedlings (Reddel et al. 1995).

It is a common practice to coat seeds of legumes with peat or clay and nitrogen-fixing *Rhizobium* bacteria, with major economic benefits - "In 2005 the value of nitrogen fixed by Australia's pasture and pulse legumes was estimated to be around $4 billion a year, with 85% of the protein in meat and wool derived from legume pasture nitrogen fixation" (Benjamin 2010). Regarding nitrogen fixation, Tudge (2003), states that no process is more important to the survival of the human species, and the ecology of the world as a whole. The cost of using inoculants is two to three dollars per hectare, compared to the expense of over $100 AUD to get the same results, using nitrogen fertilizer for example (White 2003). This is amazingly cost-effective, especially if you also take into account the use of fossil fuels in the manufacture of fertilizers.

The spores of beneficial micro-organisms, (measured in milligrams) such as free-living nitrogen-fixing bacteria, *Rhizobia, Glomus* spp. and mycorrhizal fungi, could be "brewed", mixed into supplementary feed and fed to livestock, along with appropriate seeds (and possibly deficient trace elements and molasses), to disperse the organisms. If inoculants are not available, roots nodulated with *Rhizobia* and roots infected with mycorrhizal fungi could be dug up and fed to livestock with seeds. Spores might find refuge in or on coal dust, clay or biochar, and survive better in manure piles, and possibly provide more successful inoculation of seeds and soils. Earthworms are known to disperse micro-organisms (White 2003), which would occur as they feed on manure. Presumably dung beetles and termites also spread micro-organisms. Spores could also be effectively distributed if mixed in with seedballs made of clay (see follow-up treatments), compost, perhaps powdered charcoal, and seeds.

Dispersing beneficial micro-organisms utilising animals should be extremely cost-effective, with enormous worldwide potential. Developed nations could provide improved strains of beneficial micro-organisms (and appropriate seeds, fertilizers and even livestock and dung beetles) to developing countries, effectively donating perhaps billions of dollars worth of aid, for the cost of millions or even hundreds of thousands of dollars. This may be difficult, as the spores of these micro-organisms are alive, and may therefore require care (against overheating for example) during transport. However, if the political will exists, it could be done, in the same way that the World Health Organisation managed to distribute smallpox vaccinations worldwide in the seventies. The money to do this could legitimately come from the budgets of climate change government departments and aid organisations. Such an opportunity should not be neglected.

Another possibility would be to feed spores of probiotics to stock (in the same way that people take *Lactobacillus acidophilus* supplements for example). This may improve digestion and growth rates, and some probiotics may also be beneficial in soils (*Lactobacillus subtilis* and brewer's yeast for example), providing a dual benefit for a single cost. Various probiotics have been successfully given to cats, cows, dogs, horses, bears, chickens and rodents (Elmer et al. 2007).

More information on beneficial micro-organisms and their use in agriculture can be found in Rai (2006), Kennedy and Choudhury (2002), www.amazingcarbon.com, www.yladlivingsoils.com.au., and www.fungi.com, for example.

Rock dusts. These are finely ground/crushed rocks, also referred to as rock powders or rock flours. They include the commonly used powders of limestone (providing calcium), dolomite (calcium and magnesium), calcium phosphate, gypsum (calcium sulphate), sulphur and rock phosphate, which are routinely fed to livestock or applied to soils. Others include powders from basalt, scoria, zeolite, granite, and glacial deposits. Since glacial deposits are likely to be made up of a variety of rocks, containing a wide range of minerals, they may often be the best, followed by volcanic basalt and then granite dusts. Sedimentary rocks are likely to be lower in minerals. In a trial by James Cook University in North Queensland Australia, volcanic basalt dust was applied to seven tropical coastal soils (a high rainfall area, and therefore likely to be acidic, leached and mostly infertile). The basalt dust increased pH, cation exchange capacity, available P, and exchangeable Ca, Mg, and K., with the effects expected to last for a considerable length of time (Gillman et al. 2002, Coventry et al. 2001). Some of the more fertile soils in the world are derived from volcanic rocks and ash from recent volcanic activity. These soils are usually capable of supporting a high biomass of animals, for example the Ngorongoro crater in Tanzania. In Tanzania, wildebeest time their migration to feed on rich pastures growing on volcanic soils, high in calcium and phosphorus, needed for lactation (Engel 2002).Volcanic dusts are also eaten by mountain gorillas (Engel 2002). Birds require grit in their crops. Some rock dusts are even claimed to be good for human health (Tompkins and Bird 1989). In my own experience papaya and some other plants seem to respond well to basalt dust dug into the soil, even just using sieved "crusher dust" normally used in road construction, or scoria dust. Rock dusts could be fed at perhaps 1-3g per kg bodyweight.

Instead of waiting for natural weathering processes to act on rocks, adding rock dusts to soil could be viewed as a way of fast-tracking soil formation. They should work even better if combined with coal dust, and passed through an animal, with the attendant addition of micro-organisms.

Sulphur, or lime/dolomite could be fed to stock to adjust pH over time, and trace elements as needed. Trace elements are only needed in trace quantities, perhaps tens of milligrams fed per kg of animal bodyweight. Some rock phosphates, depending on the source, may contain toxic levels of fluoride and cadmium, and so may not be suitable for stock or soils - use defluorinated phosphate. If sulphur is fed along with rock phosphate, the phosphate may be more available for plant use. If phosphate is fed with clays such as kaolin, the phosphorus may become unavailable.

Rock dusts could be produced domestically with a mill/grinder powered by draught animals. A concrete mill grinder is described in Twohig (1986), and a human pedal-powered grinder is illustrated in McKenzie and Lemos (2008).

Diatomaceous earth may be given internally and may reduce parasites (Mason 2003), but it is unknown whether this would have a negative impact on earthworms.

Brown Coal dusts/powder. Powdered brown coal, with various names such as lignite, lignapeat, leonardite etc. Stock ingest soil and humus when they graze, and coal dusts (organic matter, like humus) in small quantities will probably not do any harm. Coal dusts should contain a wide range of trace elements and are likely to be high in sulphur. Farmers in South Australia and Victoria have spread coal dust on their pastures, and one farmer in Victoria reports an increase in earthworms and dung beetles, and an improvement in the health of dairy cattle (Mason-Jones 2009). Coal dust/powder fed to stock (at around 1-3g/kg) could provide a quick input of organic matter to soils, which should quickly form humus, and improve water holding capacity and cation exchange capacity, and perhaps an improved medium for beneficial micro-organism establishment. Coal dusts may improve saline/sodic soils. Government researchers in North Dakota U.S.A. showed that humic acid improved sodic soils through chelation of sodium, or breaking the bond between sodium and magnesium, allowing the sodium to leach from the soil profile. They also found that humic extracts from lignite increased the population of nitrogen-fixing bacteria (Clemson 2010).

Water plants and seaweeds. Algae, kelp/seaweed and other water plants such as *Azolla, Pistia, Eichhornia* and *Salvinia*, may be abundantly available (often weeds), and most can be fed to stock. *Azolla* in particular, can be used as a green manure, grown for animals to eat, and fixes nitrogen, and so has good levels of protein (Kamalasanana et al. 2005). Nutrients lost from higher altitudes end up in water bodies, and therefore plants. Water plants are usually high in nutrients, but may also be high in pollutants. Feeding water plants and/or seaweed to stock which could then deposit manure at higher altitudes, would be an efficient recycling of the nutrients. These plants could constitute a major part of an animal's diet. Seaweeds contain a wide range of mineral nutrients, and so food produced from soils to which seaweed has been added should be good for human nutrition.

Chemical fertilizers. Low rates of some fertilizers have been found to be useful as supplements for stock. Urea is commonly used, and mono and diammonium phosphate provide both nitrogen and phosphorus to stock, and then to soils. It is likely to be beneficial to the establishment of legume plants and effective nitrogen fixation if small quantities of molybdenum, cobalt, iron, calcium and superphosphate are added to the supplementary feed along with *Rhizobium* inoculants and seeds (or to seedballs). Since some chemical fertilizers, or at least high applications of some fertilizers may be detrimental to beneficial micro-organisms such as mycorrhizal fungi it would be better to feed them separately to different animals, or at different times and at low rates. In circumstances where chemical fertilizers are available and affordable, they can be very cost-effective if used judiciously, in spite of their high embedded energy cost and possible damaging effects on beneficial micro-organisms. Relatively high application rates could be restricted to initial treatments and reduced later. Dosage could be .1-1g per kg of bodyweight.

Combinations of soil improvers. Implementing the AID treatment to add appropriate supplements and seeds should improve almost any soil. Improvers should be tailored to the needs of a particular soil. Manure, combined with soil-improvers such as charcoal, clay, beneficial micro-organisms, rock dusts, brown coal and any nutrients that are deficient in the soil, plus seeds of high-biomass plants should produce synergistic soil improvements. Combined with dispersal by dung beetles, and the action of earthworms making nutrients more available, treated soils should have greatly increased carbon storage, increased fertility, reduced nutrient losses from volatilisation and leaching, increased cation exchange capacity, improved structure with better water infiltration and water holding capacity, improved aeration and drainage, reduced bulk density with easier root penetrability, greater microbial populations and activity, faster nutrient cycling, and reduced erosion problems. All this combines to increase plant growth with still more carbon fixation and storage. Outstanding benefits for minimal costs.

Dispersing seeds using animals

"In Tanzania, an elephant stool weighing 8 kg was found to contain 12000 *Acacia tortilis* seeds." (Lamprey et al 1974, in Fenner 1985).

Feeding seeds to livestock is a method which has been used successfully to increase species diversity in pasture, and is called interseeding. "A passive way to interseed fields is to add the seeds to the grain mix and allow them to be eaten by your sheep (or other stock). These seeds will pass through their digestive system, pass out in the manure, and be deposited on the ground as they move about the pastures, and trample them into the soil."(Hasheider 2009). Vita fed seeds of *Faidherbia albida* to livestock to disperse them in their manure (1977, in Duke 1983). Mayhew and Penny (1988), recommend feeding legume seeds to cattle to distribute the seeds in the manure. Weed seeds can also be effectively and problematically spread by domestic stock and wild or feral animals, such as *Acacia nilotica* and *Prosopis* spp. in Australia. The effective establishment of *Acacia* and *Prosopis* by ungulate dung dispersal has been observed on four continents (Archer and Pyke 1991). Another approach is to sow seed by hand or machine and allow the stock to trample the seed into the ground (Mason-Jones 2009). Seedlings may establish better if grazing is down to ground level, especially if weed control is part of the program. While seed germination in dung piles after ingestion by animals can be spectacularly successful, direct-seeding by any means tends to be a hit-and-miss affair. Many seeds may be destroyed while passing through, but larger animals particularly, are still useful dispersal agents. In a West African trial, 46-87% of *Acacia* and *Prosopis africana* seeds survived passage through cows, while 2.3-74% survived passage through sheep. *Prosopis* had the highest passage rate. Seeds required acid scarification before feeding to livestock, and they found that germination capacity was higher for cattle than for sheep, and the speed of germination was higher for seeds that had passed through animals (Razanamandranto et al. 2005).

In Spain seeds of Cistaceae spp. that passed through sheep had a 40% survival rate, and a seven-fold increase in germination survival, and establishment of seedlings was not hampered in the deposited dung. 90% of seeds passed through in 48 hours, with some taking up to 96 hours (Ramos et al. 2006). Experiments with seeds of *Faidherbia*, *Acacia tortilis* and *A. nilotica*, and their passage through cattle, sheep and goats in Tanzania found that more seeds passed through cattle. Germination was not improved. Generally, using smaller seeds and larger animals was most successful (Shayo and Uden 1998). It seems that dispersing seeds utilising animals will probably work best with large numbers of small seeds, perhaps particularly hard-seeded legumes from clover to rain trees, through large animals such as cattle and horses. The seeds may or may not germinate better, but they may establish better in a pile of "improved" dung (due to higher nutrient status, beneficial micro-organisms, and higher water holding capacity with clay, coal dust and/or charcoal). Burial by dung beetles may reduce seed predation by small mammals, ants and other insects, and may favour germination and establishment of some species (Andresen and Levey 2004), while others might be too deep for successful germination. Some seeds may also be collected from dung, dispersed and cached (scatter hoarding) by ants and small mammals, with high losses but perhaps a low percentage of germination.

Nutrients tend to be concentrated in seeds compared with leaves. An analysis of Western Australian proteaceous plants found that, compared with leaves, seeds had 30 to 500 times as much phosphorus, 8 to 100 times as much nitrogen, 15 to 64% more protein (dry weight), and 14 to 31% more oil (Buchanan 1989). Seeds fed to livestock that are chewed and digested should therefore be nutritious, especially if they come from plants that are deep-rooted, and have a rhizobial or mycorrhizal association - and the manure can be expected to be high in nutrients for growth of seeds that do pass through. In addition, earthworms that feed on this manure should make the nutrients more available for plant growth (see appendix 2).

Depending on circumstances, there may be advantages to feeding different seeds and different soil improvers to different groups of livestock (that is, different individuals of the same species, or different species). For example, grasses tend to out-compete tree seedlings when they grow in close proximity, so grass seed could be fed to one group, and tree seed to another, so that manure piles would be separated spatially, minimising competition in the critical early phase of growth. Another possibility would be different seeds and improvers at different times. Tree seeds could be distributed first, with grasses later. Trees and climbers could also be separated so that trees have time to grow before the climbers grow on to them. Beneficial micro-organisms and chemical fertilizers might be separated. A variety of strategies are possible.

Legume seeds commonly have a hard seed coat which prevents the entry of water, and thus germination. There are various scarification treatments, including using a blade to nick larger seeds individually (which works very well but is labour-intensive), abrasion, hot water and acid treatments. Acid treatments are normally effective, and from personal experience a compromise hot water treatment that should work well for many species is as follows:

Place seeds into a sieve.

Dip them into near-boiling water for ten seconds.

Immediately place seeds under cold, flowing water for ten seconds.

Repeat

Dry seeds and store, or soak for 8 – 24 hours in tepid water, (prolonged exposure to hot water may cook them) then sow or feed to stock as soon as possible. In theory, the hot and cold water causes expansion and contraction of the seed coat, causing cracks which allow water to enter, aiding germination. A small percentage of untreated seed could also be fed, to germinate later and sporadically, through slower microbial decomposition or fire. Acid treatment may be better for many species, and in colder climates, some seeds may require cold stratification treatment. See www.winrock.org/fnrm/factnet/factnet.htm.

Seeds could be added to feed, up to perhaps 50% of the feed, by volume, with molasses. Some seed could be fed as whole fruit or pods, for example, guavas and *Opuntia* (where they are not weeds) figs, *Prosopis, Acacia, Albizia, Faidherbia, Leucaena* etc.

Follow-up treatments

Since the deposition of dung piles and seedling establishment is likely to be patchy, it may be necessary to fill in the gaps with follow-up treatments. It may also be desirable to hasten results by adding a larger quantity of soil improvers/seeds, thrown onto dung piles by hand, at least in small-scale projects if labour is available.

Seedballs. These can be thrown into gaps between piles of manure. Seedballs are usually made by mixing seeds (one part) into moist clay (five parts) and compost (three parts), or similar. Seedballs could include appropriate soil improvers/inoculants. The mixed ingredients are rolled together into balls (around golf ball size or less), or rolled into rod shapes, and preferably sown as soon as possible. Alternatively, a hole could be pressed into a piece of clay using your thumb, with seeds and improvers pressed into the hole and squeezed closed, or clay could be rolled into flat sheets, with seeds and improvers packaged like ravioli pasta. Seedballs also provide an opportunity to use larger seeds, soft seeds and seeds which are poisonous to eat, but not to touch, and thus unsuited to livestock dispersal. Some examples include *Gliricidia, Erythrina, Adenanthera, Crotalaria*, (poisonous seeds), sunflowers, *Carica papaya*, *Mucuna* (large or soft seeds). Seeds of grasses and herbs particularly, tend to be eaten by seed-predators if they are simply scattered on the ground. Seeds enclosed in an uninteresting ball of clay are less likely to attract attention. If predation is a problem, seedballs could also be coated in a repellent such as a smelly rotten egg/water mixture (use disposable gloves). Seedballs are likely to be more successful on a bare, heavily grazed, cultivated or herbicide sprayed surface. Normally seedballs would be used at the beginning or in the middle of the wet season. They can be useful for throwing into inaccessible areas, or a catapult or sling could be used.

Where funds are available, direct seeding using aircraft could revegetate extensive areas, especially places which are remote and inaccessible – in this case they might be called seedbombs. Incorporating pith in some form into the seedballs (from kenaf or *Sesbania* for example), would cushion the fall, which may be helpful, or may just be an unnecessary complication.

Large, direct-struck cuttings (and root cuttings/tubers). Also known as liveset, quickstick, stake, or truncheon cuttings, pushed straight into the ground. These could be tried later, in areas that have failed, and to add species diversity. These cuttings can be up to two metres long and fifteen cm. in diameter in some plants. Temperate climate species include willows, poplars, *Tetrapannax, Helianthus tuberosus, Arundo, Miscanthus* and many succulents. In the wet tropics, some possibilities include: *Erythrina, Morus, Gliricidia, Tithonia, Bursera, Montanoa, Samanea (Albizia), Moringa, Hibiscus tiliaceus, Milletia, Plectranthus, Odontonema, Cordyline, Dracaena, Heliconia, Zingiber, Alpinia*, *Musa*, sugar cane, Napier grass, *Cymbopogon citratus*, vetiver grass, some bamboos, cassava, *Dahlia imperialis, Ipomoea, Aloes, Euphorbias* and many other succulents (including cacti such as *Opuntia, Cereus* and closely related genera).

Potted trees/tube stock. These can also be planted in gaps. Trees grown in pots beforehand provide flexibility for planting in the exact spot that is desired with a high success rate, which could be important for species that are especially valuable, otherwise difficult, or perhaps for those that will ultimately be emergent giants. The potting mix could include beneficial micro-organisms and soil improvers. Some plants can be grown in friable soil/compost/potting mix in raised, sheltered nursery beds, gently dug up, and planted as bare-rooted plants before they dry out. Inoculating the bed with appropriate micro-organisms should be successful. If not, inoculation might work better after the bed has been covered and sealed with two sheets of clear plastic and solarised for a month or more (Bundrett et al. 1996), or treated with hot water or fire. For many Mediterranean climate plants, smoke enhances germination. This system should suit *Sesbania, Gliricidia, Tithonia*, *Montanoa, Pinus*, *Macaranga*, *Leucaena, Hibiscus* and *Albizia*, and in colder, temperate climates, many conifers, and deciduous shrubs and trees, in the *Rosaceae* family for example.

If funds and labour are sufficient, plants should establish better if they are watered in, mulched and kept free of weeds for about a metre around the plant, for the first year or two. If spot spraying of herbicide using a knapsack or hand-held sprayer is acceptable/affordable, plants can be protected from spray drift by a hand-held sheet of corflute, cardboard or similar. Plants can be protected from browsing by thorny branches, wire mesh or a clear plastic (polythene) sleave with three stakes.

Practical application of the system – some scenarios. For more information, see Mollison (1988) and Faridah Hanum and van der Maesen (1997).

Wet tropical environments

Mixed, improved fallows (leys, cover crops) for small-hold farms and vegetable gardens

There is a desperate need to improve the fertility of soils in small-scale farms in developing countries. For example, it is estimated that 75% of African farmlands are degraded (Haskins 2009). Growing a nitrogen-fixing legume between crops has been a successful strategy for increasing organic matter and fertility in soils for hundreds of years. A combination of berseem clover grown as a green manure crop followed by rice has been successful in the Nile delta for over 700 years (Murray 2003). Azolla in rice has probably been beneficial for thousands of years, whether by accident or by design.

Mixed, improved fallows (leys, cover, or green manure crops) have great potential to improve fertility/productivity, especially if they are combined with the AID treatment. Prior to a fallow, the AID treatment could add suitable soil improvers and possibly seeds of some species to establish the cover crop. The AID treatment could be applied again before the food crop. Even with unimproved dung, there can be great improvements in crop production due to faster recycling of organic matter and nutrients, see http://seedmagazine.com/content/article/greener_pastures.

Where weeds are a problem, the nitrogen-fixing, groundcover/climber *Mucuna pruriens* var. *utilis* has proved itself in many countries, smothering weeds as well as adding organic matter and nitrogen. Other groundcovers such as *Lablab purpureus* and *Canavalia ensiformis* have also proven useful. See "Green manures and covercrops" in the references. The effect of *Calopogonium mucuniodes* and associated legumes in improving soil fertility may last for 14 - 16 years (Faridah Hanum and van der Maesen 1997). The cover crop would normally be grown for five months or more. The N-fixing small tree, *Sesbania sesban,* however, generally adds more organic matter and nitrogen (Wortmann and Kaizzi 2000) and has a deep root system which can retrieve nutrients from 50cm. deep or more. In a trial in south-east Queensland (subtropical Australia), *Sesbania sesban* was the most productive species in the first 18 months, compared with 71 other trees and shrubs. The variety 'nubica' grew better than the variety 'sesban' (see tropicalforages.info). It also responds well to cutting, at around 50-100cm height (Gutteridge). *Sesbania sesban* was reported to grow to a height of 4-5 metres in 6 months in India. Research in Kenya has shown that *Sesbania* can be beneficially paired with *Crotalaria grahamiana, Tephrosia vogelii,* siratro and peanuts (groundnuts), to add more nitrogen, or organic matter, or to provide food or fodder. The fallow mixtures were tested for six to fifteen months with better results for a longer fallow. Crops such as maize following improved fallows can be double or more, continuing for a few years later (Kamiri et al). Generally, it seems that the poorer the soil, the better the response of the crop following the fallow. Once the fallow is slashed, animals could feed on the residues and add improved dung, with dung beetles and earthworms incorporating the improved dung, before the next crops. *Sesbania* also provides fuel wood.

Fallows can be sequential between crops, but can also be relay planted. *Sesbania sesban, Gliricidia* or *Mucuna* for example, can be sown or planted within the crop, usually about half way through the growing season. *Desmodium heterocarpon* ssp. *ovalifolium* could also be relay planted and grown as an understorey, as it is shade-tolerant, provides fodder, and helps control *Striga* (see www.push-pull.net). The cover crop grows with the food crop, with minimal competition, and then continues growing after the food crop. The cover crop might then be slashed at the end of the dry season, when fodder is in demand. Stock could then feed on residues, and add improved dung before the next food crop, and fuel wood collected.

Annual *Sesbania* spp. (e.g. *S. cannabina*, *rostrata, sericea, javanica*) may add even more organic matter in a shorter time, and may produce much more biomass if cut at around 10 – 100 cm to induce branching. This does seem to be the case from personal experience growing *S. cannabina*. For maize, if a fast-maturing variety is available, a quick cover crop of *Sesbania sericea* or similar could be grown for about 4 - 6 wks, then cut to remove the apical bud for more branching/biomass, and then finally cut at or below ground level (to provide mulch). It could also be ploughed in, after perhaps a total of 8 - 12 weeks (similar to the use of *Sesbania rostrata* in wet rice culture, see Becker et al. 1988). Combining *Cosmos sulphureus/bipinnatus* or sunflowers with *Sesbania* may prove beneficial. In small plots, if labour is available, annual *Sesbania* could also be grown between maize plants and then cut to form mulch. The *Sesbania* plants could be cut at or below ground level about half way through the crop to kill the plants (before they compete too much with the maize), followed by a relay planting of *Sesbania sesban* or *Gliricidia* which would continue growing after the crop.

To bring new land into productivity, or to improve very poor soils, it may be necessary to have a succession of cover crops, starting with exceptionally tough and adaptable species, with the AID treatment interspersed between food crops and fallows. For example, a first treatment might be made up of the following species: *Acacia holosericea, Canavalia ensiformis, Pennisetum glaucum,* siratro, which could be distributed by animals in their dung with beneficial micro-organisms and other improvers as necessary. This might need to grow for 12 to 36 months, with cutting to increase branching. After the fallow, apply the AID treatment, and food cropping e.g. *Pennisetum glaucum* may then be possible, with a relay planting of *Sesbania*. Otherwise the next fallow might include: *Sesbania sesban, Crotalaria* spp. and sorghum for example, and then the first crop. In harsh conditions, planting in zai holes may be the best option, but is labour intensive. In dry shady places, *Sansevieria* could be useful for fibre and possibly cut-and-carry mulch and fodder.

A compromise combination, to provide food or other useful products, but not necessarily the highest biomass or fertility, could be *Cajanus cajun* (edible seeds, N-fixing, fodder) or *Sesbania* (fuel wood, N-fixing, biomass, fodder), plus sorghum or *Pennisetum glaucum* (seeds, biomass, fodder), plus sunflowers (seeds, biomass, fodder), and an understorey of groundnuts (nuts, N-fixing, fodder), or *Vigna vexillata* (edible tubers, N-fixing, fodder), or *Vigna subterranea* (nuts, N-fixing, fodder), or shade tolerant *Desmodium heterocarpon* spp. *ovalifolium* (N-fixing, fodder, Striga weed suppressant).

If maximum biomass is desired, and if spraying with glyphosate afterwards is an option, a combination of *Pennisetum purpureum* hybrid e.g. 'Pusa' giant Napier, plus *Sesbania sesban* and *Tithonia/Montanoa* with frequent cutting (about every 6-10 weeks, and cutting high – 50cm. or higher) should work. Irrigation and fertilization should improve results.

Nematodes may be a problem for crops and some cover crop species such as *Sesbania* and *Mucuna*. Some species of *Tagetes* and some *Crotalaria* species, perhaps *Crotalaria juncea, C. spectabilis, C. agatiflora* (syn. *C. laburnifolia*) may help to control them. Using grasses or legumes in a fallow might carry over pests and diseases to another grass or legume crop, so rotation would be advisable.

Improved slash-and-burn agriculture in the wet tropics

Slash-and-burn or swidden agriculture works where there are few people and large tracts of land, because the natural fallow can be long enough to restore nutrients and biomass.

Nevertheless, by 1993, shifting agriculture was responsible for 70% of deforestation in tropical Africa. Typically, once the forest is cleared and burnt, crops are grown for one to three years, with decreasing productivity, followed by a natural fallow of around ten years or so. Increasing population pressure demands shorter fallows, which must still somehow restore sufficient nutrients and biomass (Ooi 1993). In spite of the damage to natural vegetation, this form of agriculture is likely to increase, therefore any improvements could save significant tracts of undisturbed natural forest.

Utilising the AID plus seeds treatment should result in a mixture of high biomass, deep-rooted plants, which should bring land back into production within six months to three or more years, instead of the usual ten or more. Alternatively, a fallow of around ten years, with AID treatments and using complementary associations of the best plants will result in more organic matter and more fertile soil than random natural regeneration of indigenous plants. This should extend the length of time crops can be grown, increase productivity and reduce the need to clear more forest. In newly cleared areas, and after fallows, wood could be collected and used in fuel-efficient stoves to produce charcoal and ash, which could be returned through AID treatments.

A possible fallow mix could include some or all of the following, which could be established by the AID plus seeds treatment:

For a short fallow, around six months;

Annual or perennial *Sesbania* spp., plus annual sorghum, siratro or *Centrosema*, *Cosmos sulphureus/bipinnatus* or a tall, branching variety of sunflower, or use *Mucuna* if weeds are a problem. Perhaps also Malvaceae spp. such as kenaf, okra, roselle, *Abelmoschus manihot. Crotalaria* seeds, broadcast by hand or in seedballs.

For a longer fallow, around one to three years:

Preferably all suitable indigenous plants to avoid introducing weeds, possibly *Trema* spp., *Musanga* spp., *Macaranga* spp., *Cecropia* spp., *Ceiba* spp., *Homolanthus*, plus indigenous nitrogen-fixers.

For probably better results with a one to three year fallow:

Sesbania sesban, plus *Acacia crassicarpa* (Woroi wipim, New Guinea provenance), or *A. mangium*, or *Leucaena leucocephala* and *Calliandra* spp., and possibly *Inga* spp., *Gliricidia, Cajanus, Tephrosia* (overstorey),

and one or more of the following: perennial sorghum, *Desmodium heterocarpon* ssp. *ovalifolium,* and/or siratro, *Centrosema pubescens/molle, Macrotyloma axillare, Canavalia ensiformis, Vigna vexillata, Stylosanthes* (shade-tolerant understorey)

Seedballs: possibly add giant, branching varieties of sunflowers, *Crotalaria* spp., *Papaya*

Cuttings: perhaps add *Tithonia* or possibly *Montanoa* sp., sugarcane, or Napier grass/hybrids, or *Panicum maximum* from broadcast seed, but these species would require glyphosate to spray regrowth after slashing.

In many places, wind-blown Asteraceae species, such as *Chromolaena odorata* will establish by themselves and may dominate. Many are considered weeds, but they will add valuable organic matter, and could be cut before seeding. Long-term fallows could have repeated AID treatments, long enough to add soil improvers, but not long enough for stock to cause significant damage to plants. Cropping after the fallow should be sustainable for more than three years, possibly to around 15 years, especially if *Sesbania*, *Gliricidia, Mucuna*, or *Lablab purpureus* for example, are relay planted/sown with each crop. There may still be situations where a rare burn is helpful, possibly to control soil pathogens, nematodes or some weed spp.

Degraded hill slopes in the wet tropics

There are extensive deforested and degraded areas, including cattle ranches, in this climatic region that would benefit from reafforestation using the AID plus seeds treatment.

If fire is a problem, then the first step would be to try to establish fire-retardant hedges, (see appendix 5) with grazed strips/tethered stock initially. Intensive grazing could be carried out in horizontal strips to form firebreaks, before the fire season.

In some places frequent fires may be an insoluble problem. If fire cannot be controlled, browsing/grazing/timber would still be possible, with fire-resistant plants, which survive fire or grow back. Some possibilities include: *Panicum maximum, Tectona grandis, Gliricidia sepium, Acacia mangium, Adenanthera microsperma (pavonina), Sesbania grandiflora, Leucaena leucocephala*, *Eucalyptus e.g. E. tereticornis*, *Erythrina poeppigiana* and possibly *Erythrina altissima.*

The second priority should be to reafforest hilltops with indigenous vegetation. The top 20-33% of hills should be revegetated. This should improve the fertility of lower slopes, increase precipitation, increase recharge and minimise runoff, reducing floods and landslides.

This might need a succession of treatments.

If the there is a severe weed problem, use *Mucuna* (seedballs or hand buried*), Calopogonium, Pueraria phaseoloides, Canavalia* or similar for an initial smothering cover. If land is severely degraded but not weedy: use the AID plus seeds treatment and perhaps seedballs, large cuttings and planting as needed to establish a pioneer forest with for example, some or most of the following: *Canavalia ensiformis, Macrotyloma axillare*, plus *Sorghum* or *Pennisetum glaucum, Sesbania sesban*, or other appropriate *Sesbania* spp., *Gliricidia*, Siratro, *Centrosema, Acacia auriculiformis, A. holosericea, A. crassicarpa, A. mangium, A. celsa, A. simsii, A. flavescens, Erythrina* spp., *Cecropia* spp., *Macaranga* spp., *Musanga* spp., *Trema* spp., *Terminalia* spp., *Ficus* spp., *Khaya* spp., *Muntingia calabura, Casuarina junghuhniana, Alphitonia* spp., *Peltophorum, Homolanthus, Spathodea campanulata* - (seedballs) or other tough, preferably indigenous, nitrogen-fixing plants. The Caesalpinioideae do not nodulate with *Rhizobia*, but are still useful – *Cassia siamea* (syn. *Senna*), *Senna* spp., *Bauhinia* spp., *Delonix regia* - (seedballs or hand buried).

Once soil is improved, or if the land is not severely degraded, then indigenous climax forest should be restored on hilltops, plus corridors (preferably 50 m or more wide) down ridges and drainage lines (and eroded gullies), connecting to forests along rivers. Re-establishing indigenous forest should still initially focus on tough, fast-growing N-fixing trees with a wide canopy, and plants that have habitat value and attract wildlife. Useful plants include those that provide nectar as well as fruit, (e.g. papaya, passionfruit, *Psidium* spp., *Schefflera, Buchanania, Leea* spp., *Syzigium* spp., *Muntingia calabura, Alphitonia, Pittosporum, Cordyline Spp.* – used where they are native), nuts or pods (e.g. Mimosoideae species, *Moringa*), and plants that grow tall quickly to provide perches. Also, dense, lower-growing plants/grasses. *Ficus* spp. are especially useful, and there are "rock figs" nearly everywhere in the tropics that can grow in thin soils or even in cracks in rocks. If there are remnant forests nearby, and safe perches, tree hollows, fruit and nectar are provided in the "new" forest, then birds, fruit bats and other animals will be attracted from the remnant forest and bring in a wide range of seeds and greatly increase the biodiversity. Unfortunately, weed seeds may also be dispersed. Plants that provide hollows for nesting or homes are good for birds, small mammals such as fruit bats, as well as amphibians and reptiles. *Eucalyptus* stand out in this regard, particularly *E. camaldulensis, E. tereticornis, E. platyphylla* (syn. *E. alba*), *E. grandis, E. saligna, E. torelliana,* perhaps *E. deglupta,* or hybrids of these. *E. platyphylla* is most likely to succeed on hilltops with degraded soils, or even in cracks in rocks.

Perches and wooden boxes (providing roosting or nesting hollows), placed high on poles bring in fruit bats and birds (Kelm et al. 2008), and based on personal experience, if homes are in short supply, then wildlife from snakes to birds will take minutes to weeks to move into newly provided shelter. Seed rain under perches should increase by an order of magnitude (Archer and Pyke 1991) or more. Seeds may also arrive stuck to fur or feathers. Poles should be as tall and smooth as possible, since safety from predators is a major consideration for most wildlife. Perches may attract birds of prey (Archer and Pyke 1991) such as owls and hawks, which reduce the population of small mammals which eat seeds. Poles and boxes could be made from long, <u>large</u> diameter bamboo culms (stems). Holes could be cut into segments of the culms making two diagonal cuts with a machete, forming "V" shaped holes, towards the upper end of each segment. Hollows should be towards the top of the pole to reduce predation. Holes should vary from 3cm to over 10cm in diameter, with mostly larger holes and hollows as these are able to accommodate both large and small animals (Gibbons 2002). Tree branches should be attached high up on poles, pointing in all directions. Culms with holes in every segment could also be placed just off the ground (to avoid rotting), providing homes for lizards and snakes, possibly reducing the number of seed-eating insects and mammals. All holes should point downward so they do not collect water and breed mosquitoes.

The ground beneath the perches should be grazed beforehand to bare soil by livestock (which have previously been fed seeds of tall, fast-growing plants, and soil improvers), or otherwise sprayed, or cultivated. Two or more hollow-forming *Eucalyptus* trees could be planted near the perimeter, plus plants that provide fruit and nectar, and plants that have large seeds which are otherwise unlikely to be dispersed. Perches should initially be placed near remnant forest (perhaps 50 metres or closer, although fruit bats may fly up to 40 kilometres between roosts and feeding areas – Ramsey 2008, or even hundreds of kilometres – Shilton et al. 1999), and new ones placed a similar distance further away as plants establish beneath the first ones. Perches could be placed on hilltops and next to streams, so that seeds spread downhill. Perches should result in "island" or "satellite" forests, between which animals move, depositing seeds on the way, steadily connecting the islands and ultimately re-establishing forests. A better option may be to place perches in lines connecting remnant forests, to form corridors, which would also encourage seed dispersal by non-flying animals. Later corridors could connect existing corridors, and still later work could make the corridors wider. If perches are close enough to each other, ropes could be tied between them for more perches, preferably with AID plus seeds treated (or at least sprayed) strips of ground beneath. The AID plus seeds treatment should also be used to extend and protect the edges of remnant forest.

Perhaps the simplest and cheapest way to construct perches would be to hammer a steel bar/post (or sturdy, durable wooden stake) into the ground. This could also be used for tethering an animal. The pole would be tied on to the stake with three lengths of strong wire, with the ends twisted tight with pliers. Before raising the pole, tree branches and nesting boxes could be attached with wire to the top of the pole, and in the case of bamboo, holes cut into the top segments. Bats and birds often perch together in large groups (safety in numbers), so three poles could be erected in a triangle pattern, and bamboo culms with cut holes could be tied horizontally to the top of the posts, connecting the posts, providing more perches and hollows as well as improving structural stability. Branches and ropes should be added high up for more perches. Another option would be a "tepee" shape, tied in place at the base with tent pegs/stakes.

There should be an ongoing program of increasing biodiversity, using indigenous plants and adding climax spp. as soils and habitat are improved. Repeat treatments of various sorts will probably be required. These forests should be protected, though they should be able to sustain well-managed poultry, bee-keeping and occasional browsing without too much damage.

The third priority would ideally be the hill slopes:

Start with AID treatment and seedballs to establish cover crop if necessary (in badly degraded or weed-infested land), e.g. *Sesbania, Acacia crassicarpa, A. auriculiformis, Gliricidia, Peltophorum, Mucuna*.

When the soil is improved, multiple options become available, and a possible sequence could be:

browsing/grazing- for example, Guinea grass and a middlestorey of *Sesbania, Calliandra, Leucaena* and an overstorey of *Samanea/Albizia, Parkia, Prosopis, Enterolobium,* around 10 - 80yrs, with cropping in the early stages cropping – a few years. The first one or two stages should result in soil good enough for some crops

possibly timber plantation, coffee, cocoa or orchard: around 6 - 100yrs, with initial cropping between tree rows and later grazing

possibly cropping again, or straight on to the final recreated rain forest

finally:

Recreated rain forest (or as close as possible) with a high percentage of plants and animals that are useful for people – plants for browsing, producing fallen fruit, pods, edible roots, possibly Bali cattle, deer, eland, chickens, guinea fowl, pigs, honey bees. Almost indefinite, or clear some for temporary vegetables/staple crops/grassy patches/timber and go through succession again in the cleared patches back to forest (improved slash-and-burn treatments), maintaining a mosaic of vegetation of different ages and species composition.

Some potentially useful supplements to stockfeed for the AID treatment in the wet tropics include:

Beneficial micro-organisms.

Lime, dolomite or ash for acid soils.

Gypsum for heavy clay soils, brown coal and clay for sandy soils.

Charcoal for decay-resistant organic matter.

Deficient nutrients.

Customised combinations of soil improvers and seeds should produce synergistic results.

Semi-arid environments

In this environment, water catchment, infiltration and storage are critical. This could include plants grown on contours, swales, terraces and limans (ponds fed by runoff from flooding creeks, with overflows back to creeks - an Israeli invention). The AID treatment and rotational grazing can be used to increase the organic matter and clay content of sandy soils, to increase infiltration and storage. Mulching and drip irrigation are also helpful. See the Sahelian ecofarm at www.worldwidewattle.com.

Some potentially useful plants include:

Prosopis spp., *Atriplex nummularia, A. halimus, A. lentiformis, A. cinerea, Einadia (*syn. *Rhagodia)* spp., *Enchylaena, Maireana, Haloxylon aphyllum, Ceratonia, Jatropha curcas, Faidherbia albida, Canavalia ensiformis,* siratro, *Casuarina decaisneana, Azadirachta indica, Ricinodendron rautenenii, Sclerocarya spp., Boswellia spp., Acacia tortilis, A. cambagei, A,. brachystachya, A. aneura, A. leucophloea, A. tumida, A. seyal, A. saligna, A. salicina, A. nilotica, A. holosericea, A. saligna, A. torulosa, A. victoriae, A. peuce, A.*

pendula, A. oswaldii, A. estropholiata, A. coriaceae, A. bidwillii, A. argyrodendron, etc., *Pennisetum glaucum, Digitaria exilis,* teff and some *Panicum* spp. e.g. *P. phragmitoides, P. turgidum, P. milliaceum* and other millets. Many species of cacti and other succulents, e.g. *Opuntia, Portulaca* spp., *Portulacaria afra, Aloe* spp., *Sansevieria.*

Some potentially useful plants for soils which are somewhat saline or sodic:

Tall wheat grass (*Agropyron repens),* saltwater couch, *Atriplex* spp., *Einadia (*syn. *Rhagodia)* spp., *Salicornia* spp., *Acacia longifolia var. sophorae, A. salicina, A. saligna, Prosopis cineraria, P. tamarugo, Prosopis* spp., *Sesbania rostrata, S. aculeata/bispinosa, Sesbania* spp., *Myoporum insulare, Albizia lebbeck, Casuarina equisetifolia, C. glauca* and some *Alocasuarina* spp., *Melaleuca halmaturorum, M. lanceolata, Melilotus alba,* some *Tamarix* spp., mangroves.

Some potentially useful animals include:

Addax (a spiral-horned antelope) can survive in deserts, and virtually never drink. They obtain water from vegetation and from condensation on plants at night. They were semi-domesticated by the Ancient Egyptians, with art from 2500 years ago showing them collared and tethered. They were, like cattle in much of Africa today, an indication of wealth and position. (Tate 1971). Goats, if well managed in a rotational system, otherwise they tend to be destructive, ostriches, emus, donkeys and camels.

Some potentially useful supplements to fodder include:

Coal dust, charcoal, clay to increase water holding capacity, especially in sandy soils

Sulphur and sulphate fertilizers to lower pH in alkaline soils.

Gypsum and brown coal for saline or sodic soils, with seeds of plants suggested above.

Gypsum for clay soils with poor structure.

Beneficial micro-organisms, especially mycorrhizal fungi, to improve drought tolerance and possibly performance in saline soils.

Deficient nutrients.

Mediterranean climate environments

This is a difficult climate where it is often too dry when it is warm enough for plants to grow, and too cold when it is wet enough for plants to grow. Dung beetles are important or may be introduced (e.g. *Bubas bison* and *Geotruper spiniger*), and earthworms may be dormant in the dry season, or repopulate from eggs after drought. See semi-arid above regarding water.

This climate is the most prone to fire. Fire retardant windbreaks, hedges, climbers and groundcovers can be useful e.g. *Aloe arborescens,* (see www.debraleebaldwin.com, regarding A. arborescens stopping a fire), *Opuntia* spp., *Portulacaria afra*, *Portulaca spp., Carpobrotus* spp., *Senecio angulatus* (syn. *Senecio tamoides*), and other succulent spp. Also, *Atriplex* spp., *Einadia* spp., *Myoporum insulare*, *Lagunaria patersonia*, *Brachychiton populneus*, *Casuarina cunninghamiana*, some *Quercus* spp., *Coprosma repens*. Many of these are, or could be, weeds. For some suggestions on planting for protection from fire, see Clode (2009).

David Crespo in Portugal, (Watson 2010) has demonstrated that pastures with a great diversity of species can be very productive. Crespo's pasture mix includes:

Dactylus glomerata, Phalaris aquatica, Festuca arundinaceae, Lolium spp., Trifolium subterraneum, T. vesiculosum, T. resupinatum, Ornithopus compressus, Biserula pelecinus, Medicago sativa and other *Medicago spp., Onobrychis viciifolia, Hedysarum coronarium, Cichorium intybus* and *Plantago lanceolata.*

It is worth adding a tree or shrub component, successfully done with tagasaste (tree lucerne, *Cytisus palmensis,* syn. *Chamaecytisus proliferus*), in Western Australia, with rows of tagasaste on the contour, or at right angles to the wind in windy places, or at right angles to where a fire might come from. Tagasaste is a nitrogen-fixing long-lived shrub or small tree, providing year-round fodder for a range of livestock, with roots down to 11 metres (Mason-Jones 2009). One farm in Western Australia, with infertile, sandy soil, changed from annual pastures to perennial pastures and tagasaste, and was able to increase the stocking rate from 1.4 dry sheep equivalent per hectare to 4.0 Dse/Ha (Barret-Lennard 2010). Other possibilities, perhaps in combinations: *Acacia saligna, A. salicina, A. aneura, A. implexa, A. doratoxylon, Quercus spp.*

Acacia saligna or *A. aneura* over the low fodder shrub, *Einadia nutans* (syn. *Rhagodia nutans*) should work, since *Einadia nutans* is tolerant of dry soil and shade, and would be provided with nitrogen.

Atriplex nummularia, A. halimus, A. cinerea (or other *Chenopodiaceae*), *Portulacaria afra* may be useful as fodder hedges on contour, and *Opuntia* cv. 'Burbank's spineless' may be useful where it is not a weed, perhaps combined with N-fixing *Acacia saligna*.

Faidherbia albida from Israel might succeed in other Mediterranean climate regions with access to underground water, assuming that it drops its leaves at an appropriate time for crops/pasture beneath.

Dipogon lignosus might work as an equivalent to the tropical *Mucuna*, as a sequential fallow or relay planted within crops.

The following could be weeds plus problems with tannins in the soil, but could be grown for around three to ten years, coppiced once or twice a year to prevent seed set, and finally killed with herbicide (possibly painting cut stumps). They would all add nitrogen and increase soil organic matter, and could produce biochar: *Acacia longifolia, A. sophorae, A. saligna, A. retinodes, A. decurrens, A. mearnsii, A. dealbata, Albizia (Paraserianthes) lophantha ssp. lophantha, Virgilia, Psoralea pinnata, Lupinus arboreus.* More organic matter could be produced with an understorey of *Einadia nutans* or *Cortaderia selloana*. The foliage of *A. saligna* can be used as goat and sheep fodder.

With irrigation, and to achieve high biomass, possibly: *Sorghum, Miscanthus, Arundo, Virgilia oroboides* or *V. divaricata,* sunflowers, *Cosmos bipinnatus, Montanoa spp.,* hemp, and perhaps *Sesbania cannabina/bispinosa/aculeata* obtained from as high a latitude as possible.

Some other potentially useful plants include (some are or could be weeds):

Brooms: *Genista, Retama, Spartium, Cytisus, Ulex;*

Crotalaria, Colutea, Melilotus, Ceratonia, Olea, Cercis, Albizia julibrizzin, Coronilla valentina, Solanum aviculare, Raphanus spp., Podalyria spp., Brassica spp., Alyogyne huegelii, Lavatera cachemiriana, Polygala myrtifolia, Alnus spp., Echium candicans, Chenopodium bonus-henricus, various *Pinus* and *Eucalyptus* spp. but most are allelopathic and promote fire.

A wide range of livestock is available. Supplements - see semi-arid above.

Cool, temperate climate environments

Earthworms are likely to be most important in this climate but dung beetles may still play a part in warmer temperate climates.

Some potentially useful plants include some listed under Mediterranean climate, plus:

Trifolium spp., Robinia, Salix, Populus, especially hybrids, *Paulownia, Ailanthus altissima, Helianthus tuberosus* and *H. anuus, Beta spp., Raphanus spp., Brassica spp., Lavatera spp., Lespedeza (Kummerowia) bicolour, Hordeum, Piptanthus, Cosmos bipinnatus, Betula, Alnus, Prunus, Caragana arborescens, Elaeagnus, Miscanthus,* brooms, lupins, vetches, *Lotus pedunculatus, Lotus spp., Melilotus spp., Desmanthus, Coronilla varia, Quercus spp., Polygonum spp., Lolium, Phalaris, Miscanthus, Avena, Hordeum.* Some of these could be weeds. Various conifers, but most are allelopathic.

Poplars drop protein-rich leaves providing additional feed for livestock and earthworms, and *Gleditsia* drops edible pods.

A wide range of livestock is available for colder climates including Galloway cattle, which would probably thrive under oak species that produce edible acorns, *Gleditsia triacanthos,* poplars and *Albizia julibrizzin*.

Some potentially useful supplements to stockfeed include:

Beneficial micro-organisms

Ash, dolomite or lime where soils are acidic.

Rock dusts such as basalt and glacial dusts.

Clay in sandy soils

Gypsum in heavy clay soils

Sulphur in alkaline soils

Brown coal dust and biochar where organic matter levels are low.

Deficient nutrients.

Conclusion

"Whenever you find yourself on the side of the majority, it is time to pause and reflect".

Mark Twain.

The demand for fertilizers, water, food, fuel wood, compost and biomass for biofuels and biochar, is likely to increase. It is therefore critically important to implement systems that quickly maximise biomass/organic matter production, and do so in an energy- and cost-effective way. Degraded environments worldwide can be restored or even enhanced with rotationally grazed livestock, soil improvers and seeds for reafforestation – utilising the AID system, to maximise biomass production and improve soils.

On a cost/benefit basis, proactive revegetation and soil improvement by this system (including using fuel-efficient stoves) has minimal costs and many more benefits than cutting greenhouse gas emissions. It helps the poor in less developed countries through more fertile soils, more food and food security, improved nutrition, more fodder and fuel wood production (and reducing the need for fuel wood), with multiple social, health, economic and environmental benefits. It also fixes carbon, increases reflective cloud cover and rain fall, and has a cooling effect, which helps those in industrialising and industrialised countries, without the costs of unduly compromising jobs and prosperity as extreme emission controls would. To date, attempts to control emissions have been largely ineffectual anyway, costly, too little too late, and do nothing to deal with CO2 that has built up from the past.

To avert possible climate change will require a proactive manipulation of greenhouse gases, especially water vapour (by far the dominant green house gas, responsible for at least 75% of the greenhouse effect – White 2003, other estimates range from 60% to 98%). It will need responsible and relatively risk- and pain-free management and manipulation of vegetation, soils, water vapour, clouds and rainfall. It would be wise to avoid experimental solutions that may have unpredictable consequences, (such as adding sulphurous gases to the atmosphere, which might then be unpredictably added to by volcanoes) whereas restoring or improving forests, grasslands and soils has multiple known benefits, and little or no risk.

If emission controls are pursued, they should focus on cutting greenhouse gas emissions that do little or no harm to Western civilisation. For example, stopping fires in Indonesia that are intended to speed up the drying of deep, peaty soils, before the establishment of oil palm plantations, (more CO2 emissions than deforestation in Brazil, the world's largest deforester – Gore 2010) and putting out permanently burning coal seams in China, which produce nearly as much CO_2 as all the cars and smaller trucks in the U.S.A. This is also a problem in India (White 2003). Exposed coal seams also emit methane.

A worst case scenario, and a very likely one, is that emphasising emission controls will hobble Western industrialised societies (which in all likelihood is the real agenda of some - consider the burden of the growing worldwide bureaucracy, public funds involved and increased costs so far, and continuing *ad nauseam*), will cause (or has already caused) a loss of jobs, overall price increases, starvation through food shortages and multiple other negative, painful consequences - there are already indications of this. Many of those stridently demanding emission cuts are at the top of Maslow's pyramid and may be willing and able to pay, but many in this privileged, sheltered segment of the world's population do not appreciate that the poor in the West cannot afford any price increases for electricity or food for example, and that some of the desperately poor in less developed countries are so poor that they die of starvation. Few people in developed countries are aware or have any understanding that close to 75% of Africans languish on less than U.S.$2.00 a day, while in Europe U.S.$2.00 is the daily subsidy for each cow (Wu 2007, see also Driessen 2003). It is a tragic re-enactment of "Let them eat cake". On the other hand, the AID plus seeds treatment is one practical way of making the cake bigger for everybody.

After all these negative consequences, this scenario (of reducing emissions/carbon trading) will not solve the problem of C02 build-up from worldwide past deforestation and industrialisation. Meanwhile, carbon becomes a commodity, and its business-as-usual, which usually means the powerful profit, with ever-increasing exploitation of the poor, and deforestation continues in freefall. To persist in concentrating on reducing emissions, which will directly or indirectly drive the poor even deeper into poverty and harm Western society, to the exclusion of vastly superior alternatives with multiple potential benefits such as reafforestation and soil improvement, would not be in the best interests of humanity. It could even be described as a crime against humanity. It would also squander an environmental opportunity and indicate another agenda.

There is an opportunity cost to focusing on emissions, diverting limited resources from unquestionable and genuinely pressing priorities such as saving lives, feeding the hungry and reducing poverty. Reducing emissions provides a very poor return on investment, with major, certain costs now, and minimal, uncertain returns in the distant future (Lomborg 2010). Plimer (2009) states that since the inception of the Kyoto Protocol, some $10 billion a month has been spent to avert a speculated 0.5 degree centigrade temperature rise by 2050 – an enormous investment for a woeful return. By comparison, reafforestation and soil improvement provides multiple and much better returns, including at the very least partial solutions to many immediate and certain problems, as well as possible future climate change, for much less money. Imagine the results if we spent $10 billion a month on worldwide reafforestation, soil improvement, human health, and reducing poverty.

The solutions to the multiple problems faced by humanity are most likely to come from Western democratic countries because of greater literacy, education, a culture of learning, Judeo-Christian values such as the work ethic, and access to technology and information. An environment conducive to creative innovation is fostered by economic prosperity, democratic freedoms (as opposed to overt tyranny or despotic rule, as well as the intrusive, oppressive pettiness of the "nanny state"), and a relative lack of civil unrest. This is demonstrated, for example, by the fact that Nobel Prize winners mostly come from these countries. The top five countries are the U.S.A. (320 winners), followed by the U.K. (117), Germany (103), France (57), and Sweden (28).

Another example which proves this assertion is Israel, which has a 97.5% literacy rate, with 100% literacy among the Jewish population. Israel also has the highest number of university degrees and the highest number of personal computers per capita in the world. The result is that Israel produces the highest number of scientific publications and the highest number of patents filed for inventions per capita in the world (see www.imninalu.net/israel-arabs.htm). Israel is also world famous for being a leader in forestry and agricultural innovations.

Another country that is likely to produce solutions is Australia. Australia is a world leader in creative inventions and innovations in agriculture, including the Ridley stripper, the H. V. McKay grain harvester, the stump-jump plough, the fertilizer spinner, the corrugated iron water tank (Smith 2009), the rotary hoe, 'Federation' wheat (William James Farrer) and salt-tolerant wheat right now, the sugarcane harvester (Toft brothers), clever clover (Richard Stirzaker), the Wallace/Yeomans plough, keyline farming (P. A. Yeomans), natural sequence farming (Peter Andrews), evergreen farming (Christine Jones) and of course, permaculture (Bill Mollison and David Holmgren).

It should be self-evident that if Western democratic societies are harmed or undermined in any way, by a more expensive or unpredictable power supply for example, then the chance of people coming up with solutions is reduced accordingly. In Australia, anthropogenic GHG emissions have been estimated to be about 1.5% of global emissions, which means that if Australia had zero emissions, starting tomorrow, it would not make any statistically significant difference to possible worldwide climate change. On the other hand, to jeopardise in any way the possible solutions that might emanate from Australia due to misguided ideological zeal would be counter-productive.

The problem-solving inventiveness of people is consistently underestimated, down-played or ignored by the media. Some in the media have created a pervasive climate of morbid Malthusianism, with their constant negative spin, media hype, disinformation and repetitive brainwashing. Goebbels would be proud of them. There is always an Hegelian style crisis/conflict, preferably global, designed to make it easier to impose global change. The exaggeration of global problems creates an artificial need for worldwide solutions, empowering global authorities, while undermining the democratically elected governments of independent nations, thus incrementally disenfranchising the people. The crisis in the seventies was global cooling with an impending ice age, followed by global warming, and then climate change/disruption/volatility (a bet each way). The media tend to talk-up topics like "peak oil" without balancing the doom-and-gloom by discussing alternative views (see Mills 2008), and the positive implications of the many marvellous innovations/solutions being worked on by a multitude of people all around the world.

The AID plus seeds treatment is an innovation which could help solve many of the world's problems. However, the rare qualities of wisdom and moral integrity are also essential to manage both agriculture and the natural environment, in order to provide a solid foundation for long-term social, economic, environmental and political stability...

"*Without permanent agriculture there is no possibility of a stable social order*". (Mollison 1988).

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Appendices

Appendix 1 Dung beetles

Dung beetles are common in warm climates in most countries, particularly in Africa. There are also species suited to Mediterranean and cooler climates, such as the winter-active *Bubas bison* and *Geotruper spiniger*. They can also be successfully introduced, amply demonstrated in Australia, where around half the species introduced established themselves.

Dung beetles make tunnels which they line with manure, and bury manure down and outward to 30-50cm, or even 100cm. They lay their eggs at the end of their tunnels. The young feed on the manure, but leave some behind, as well as their faeces, forming a humus-like substance. Their tunnels are likely to last more than 10 years and form channels for root growth, and water and air infiltration. In one experiment, where 10 pairs of beetles were added to cow pads, one litre of water infiltrated the soil in 4 minutes, compared to 90 minutes for nearby pasture (in a cool temperate part of Australia). They also mix subsoils and topsoils and increase the permeability of subsoils, encouraging deeper biological activity and root growth.

Dr. Bernard Doube, a world authority on dung beetles, has run multiple trials, since 1975, and concludes that "dung beetles, plus deep-rooted perennials, plus managed sporadic heavy grazing is good for farm profitability and good for storing carbon deep in the soil profile". He also estimates that introducing dung beetles results in 20-40% more roots (in this case deep-rooted pasture species, including tall wheatgrass, phalaris, perennial ryegrass and cocksfoot), and at least a 20% increase in dry matter production in almost any soil, with an equivalent increase in stock carrying capacity (Marshall 2009).

U.S. researchers estimate that dung beetles save their cattle industry around U.S. $70 million a year (Taylor 2010).

Dung beetles could be introduced to developing countries, where necessary, by aid organisations or agricultural institutions.

Appendix 2 Earthworms

Increasing plant growth from high-biomass plants produces more mulch from increased litter fall. This surface mulch holds moisture in the soil and provides food for earthworms, increasing their numbers and activity, which promotes more plant growth... and so on.

“Earthworms can enhance the incorporation and decomposition of organic matter in the soil, assist the incorporation of lime and fertilizers, increase the number of water stable aggregates, improve soil porosity, aeration, water infiltration and water holding capacity, increase microbial activity and encourage deeper root growth.” (Baker 1991). In a cool temperate part of Australia (Fleurieu Peninsula), earthworms commonly live in the top 5-10cm of soil, but under cow pads, they consumed the dung and burrowed down to 50 cm (Marshall 2009). It is possible that the earthworms took advantage of all the hard burrowing work done by dung beetles, and also increased the nutrient availability of the dung. In Britain, earthworms have caused soil disturbance to a depth of 2-5 metres (White 2003).

Earthworms can dramatically improve the physical structure of soils. At Tatura, Victoria, S.E. Australia (inland, Mediterranean climate), three years of heavy mulching of a peach orchard with straw and sheep manure, providing food and moisture, plus annual applications of 1500kg/ha of ammonium nitrate, 150kg/ha of superphosphate and 100kg/ha of lime, resulted in earthworm numbers rising from 151 to 2000 per square metre, air-filled porosity from 5 to 19 volume %, and the infiltration rate from 63 to an amazing 3000mm/hour. In a trial in New Zealand pasture soil, available water nearly doubled, from 1.8 to 3.1mm/cm of soil (Handreck and Black 2007).

Earthworms can improve nutrient availability to plants and thus plant productivity. Through the action of grinding and bacteria in their digestive tract, earthworms produce casts in which nutrients are more available. In addition, and contrary to popular opinion, low to moderate rates of chemical fertilizers can increase earthworm populations (more fertilizer equals more plant growth providing more food and mulch), and increase the nutrient status of casts. For example, growth responses of *Amaranthus tricolor* (a leafy vegetable) in Bangladesh, increased with higher applications of vermicompost (up to 10 tonnes/ha), with vermicompost superior to NPKS fertilizer, and better again when NPKS fertilizer was added to the vermicompost. The combination spectacularly increased growth by about 305% (13.25 t/ha), compared with the control (Alam et al. 2007).

Some figures for increased nutrient availability given in some sources are likely to be unachievably high, however work in New Zealand has shown a threefold increase in plant-available phosphorus in soil that has passed through earthworms (White 2003). A more likely result comes from Ibadan, Nigeria, (Lal et al. 1982) where increasing amounts of N and P chemical fertilizer resulted in increasing nutrients in casts, and nutrient status of casts in no-till plots was generally superior.

Worm casts, compared to the top 10cm of soil, contained:

Organic matter: 1.5 – 2.3 times more than the top 10cm of soil

C.E.C.: 2.1-3.1 times higher

N: 1.2-1.8 times more N

P: 1.3-1.6 times more Bray-P

K: 2.2-3.1 times more exchangeable K

Ca: 2.1-3.2 times more exchangeable Ca

Mg: 2.5-3.8 times more exchangeable Mg.

Thus small additions of fertilizer to soils with high numbers of earthworms are likely to significantly increase the availability of nutrients to plants.

Seeds contain high concentrations of nutrients and protein, so seeds that are crushed and soaked, or sprouted and fed to worms should produce vermicompost that is high in available nutrients. Low rates of burnt bone, rock phosphate, superphosphate, rock dusts, pigeon manure (high in a range of nutrients because they eat seeds from far and wide), guano and chemical fertilizers could be fed to worms, giving similar results. Vermicompost could be side-dressed onto crops, or compressed into pellets/spikes and placed in the root zone, possibly beneath drippers. Vermicompost can also be applied as a liquid feed.

Worms tend to proliferate if they can be kept moist, cool, well fed (mulching helps with all these) and if the soil pH can be kept or modified to 6 through to slightly alkaline. Avoid most insecticides and vermicides, frequent cultivation and high rates of acidic (such as sulphate of ammonia) or salty fertilizers (Handreck and Black 2007). They also appear to thrive under certain plants. More worms were found under *Acacia auriculiformis* than *Pinus kesiya* in the Philippines. In Hawaii, leaf litter under *Falcataria moluccana* contained more nitrogen and lower polyphenol concentration than *Eucalyptus saligna* and *E. grandis*, and soil under *Falcataria* had 470 worms per square metre, compared with 90 for *Eucalyptus* (Nambiar and Brown 1997).

From personal observation, it appears that earthworms thrive under the leaf litter of *Ficus* spp., *Acacia mangium*, *Inga* spp., *Pennisetum purpureum*, as well as *Panicum maximum* that has recently been killed with glyphosate. Mulching with these grasses, or the leaves/pods of nitrogen-fixing deep-rooted plants, should increase earthworm numbers and their activity, and improve the growth of most plants in most situations. The mass of earthworms in well managed soils may be a few tonnes per hectare, often more than the aboveground animal biomass, and more earthworms equals a larger carbon sink. Finally, earthworms provide excellent feed for poultry, pigs and aquatic animals.

Appendix 3 Fuel wood

Fuel wood is the primary source of energy in many developing countries and while this is less than ideal, it is unlikely to change in the short-term. In most places demand is increasing, and deforestation/land degradation results. In India, cooking is the largest use of energy for 75% of households, with 70% of cooking using traditional biomass, wood and dung (with indoor pollution prematurely killing more than 1.5 million people each year, Lomborg 2010). In Burma (Myanmar) about 85% of energy comes from firewood and charcoal, and in Vietnam, about 75% of energy comes from biomass, with the domestic sector using nearly 100% (Faridah Hanum and van der Maesen 1997). In Africa, about 90% of the population use fuel wood for cooking (Nambiar and Brown 1997). Any method which either provides more fuel wood and/or reduces the need for fuel wood, is obviously helpful. Fuel wood could be produced from plantations established using the AID plus seeds treatment. Alternatively fuel wood/fodder could be grown in zai holes (tumbukiza). Fuel wood should ideally be produced close to where it is needed for easy collection and could be fertilized with human urine. Plants should be inoculated with appropriate micro-organisms.

Some potentially useful plants include:

Acacia - many species, *Eucalyptus* – many species, *Adhatoda vasica*, *Sesbania sesban* and annual *Sesbania* spp., *Gliricidia, Calliandra, Prosopis spp., Leucaena, Senna siamea, Zyziphus mauritiana, Lespedeza bicolour, Alnus spp., Gmelina arborea, Trema spp.,* bamboos, stalks from *Pennisetum purpureum* and other fast-growing grasses. *Tithonia* stalks are used in Java (Faridah Hanum and van der Maesen 1997). If *Eucalyptus* trees are grown, they should produce more wood if grown together with N-fixing trees/plants.

Appendix 4 Fuel-efficient stoves

"If we could turn official and popular interest away from the grandiose projects and to the real needs of the poor, the battle could be won". E. F. Schumacher, small is beautiful.

These stoves use significantly less wood (or other wastes), with more heat and less smoke than the traditional, ubiquitous three stone fire. The ash and charcoal produced by these stoves can be crushed into powder and fed to livestock to disperse in their manure. These stoves (perhaps larger versions) could also be used to burn bones, for use as a fertilizer.

There are multiple different designs, with many people worldwide constantly working on improvements e.g. Mbaula simple mud stove: www.rippleafrica.org/ripple_charity_environ3.htm, www.terrapretapot.net, and a wealth of information and different designs can be found at www.bioenergylists.org/. The permaculture guide book from East Timor has a design using a bucket (outer mould) and a large tin can (inner mould) for cement, plus wire mesh (Mckenzie and Lemos 2008). This design could be modified so that it is upside down, i.e. providing a broad base and narrower top. A hole dug in the ground can also form an outer mould and a larger stove could be made using a ten litre plastic bucket as an inner mould. Insulation could be incorporated using scoria, pumice or perlite in the cement mix. If a door is placed across the fuel entry hole, less oxygen would get in, which should produce more charcoal and less ash, if so desired.

There are numerous, not immediately obvious benefits to fuel-efficient stoves. The need to collect less wood means that women in India and Africa particularly, don't need to walk as often or as far (to 10 kilometres, or more, taking around 2 hours a day), and so reduce the risk of being attacked or raped, possibly getting HIV/AIDS, and passing it on to their families (see www.worldvision.org.uk/server.php?show=nav.2695). Smoke inhalation in homes is a major worldwide health hazard. Smoke from biomass fires also causes outdoor air pollution. Stove design should therefore prioritise smoke reduction. Three-stone fires and kerosene stoves are also responsible for many people being burnt, and for starting house fires. All of these problems should be reduced with stable, enclosed, clay, cement or mud stoves. More efficient stoves that need less wood increase the likelihood of disease-ridden water being boiled, thus avoiding many diseases and deaths, especially among children. According to the WHO, one million people die each year from malaria. Disease-carrying mosquitoes may be repelled by burning the leaves of Neem trees, *Azadirachta indica*, lemon grass, *Cymbopogon citratus*, *Vitex trifoliata var. trifoliata* or *Croton arnhemicus* in fuel-efficient stoves. Just planting *Vitex* close to houses is reputed to have greatly reduced dengue fever in Bali (Beasley 2009). Another advantage is that fuel-efficient stoves can be made at home by individuals, or as a small business, using locally available free or cheap materials, without the need for outside help.

Appendix 5 Living fences/hedgerows

Planned grazing requires efficient control of the movement of livestock, which may include herding, tethering and fencing. Electric fences are cheaper than standard post and wire, and living fences are cheaper again, and last longer. They do however, require time to grow, and require access to plentiful propagation material. Many can be grown as 1-2 metre cuttings stuck straight into the ground. Living fences/hedges have been the source of introduction of weeds in the past, for example, *Lycium ferocissimum* in Australia and *Hakea sericea* in South Africa, so plants should be selected with care. Nevertheless, living fences provide a great opportunity to add wildlife habitat and increase the biodiversity in the system. According to Arthus-Bertrand (2008), in Europe many species of mammals, butterflies, reptiles and amphibians live in hedges, with an average of 50 birds from 20-40 species per half-mile of hedge. A hedge made up of many plant species can have multiple uses, including attracting beneficial insects such as parasitic wasps and pollinating bees, and birds which may eat insect pests. Some birds which eat insects also require nectar. Aloes and grevilleas are good for birds and bees, and *Erythrinas* are good for birds. Sometimes crops can be grown mixed in with the fence, such as *Piper nigrum* (pepper) and vanilla. Living fences also act as a windbreak. See the article, “The living fence: its role on the small farm”, by Franklin W. Martin 1991, at www.echonet.org.

Some plants which should be useful include:

Erythrina spp. - perhaps the most popular genus, and in most tropical areas there is likely to be an indigenous *Erythrina* species suited to growing a living fence. In tropical America, *E. berteroana* may be one of the best, along with *E. poeppigiana*, while *E. latissima*, *E. haerdii* and *E. humeana* should work well in Africa. *E. latissima* has thick bark and is likely to be fire-resistant. *E. variegata* is popular in Asia. Monocultures of *Erythrina* may be susceptible to diseases and pests. Hybrids could be bred that are better again, and may be sterile, preventing weed problems. There are at least two in existence already, E. x ‘Sykesii’, E. x ‘Bidwillii’. *Erythrina* spp. are N-fixing, provide fodder, attract birds and are usually thorny. Grown from large cuttings placed directly into the soil (liveset cuttings), or seed.

Gliricidia sepium - one of the best and most popular. N-fixing, fodder, timber, fuel wood, seeds used as a rat poison. Liveset cuttings or seed.

Moringa oleifera - one of the best. Fodder, edible "beans" and nutritious leaves, nectar for bees and small birds, water clarification. Liveset cuttings or seed.

Leucaena leucocephala – one of the best. N-fixing, fodder, fuel wood, mulch. Grown from seed.

Morus spp. – one of the best. Fruit, fodder. Liveset cuttings.

Sesbania sesban and *S. grandiflora* – N-fixing, fodder, food, but short-lived. Seed.

Aloe arborescens, A. kedongensis, A. ferox, A. striatula. – medicinal, nectar for birds and bees. Hedges of thorny succulents can stop or reduce fire and protect stock from fire and predators. *Aloe arborescens* would be one of the best, and is found in a range of climates and altitudes in Africa. Because of its usefulness, mass production by tissue culture would be helpful. Hybrids could be bred which may be even better. *Euphorbia lactea, neriifolia, tirucalli etc.* - many are thorny and have poisonous sap. Cacti, for e.g. Mexican fence cactus – various genera (which keep changing): *Cereus, Stenocereus, Pachycereus, Trichocereus, Opuntia* – bees, some attract bats. *Opuntia* 'Burbank's spineless' for fodder, or burn off thorns. Liveset cuttings, "leaf pads", seed.

Tithonia diversifolia - flowers for insects and birds, fodder, leaves make a high-phosphorus and nitrogen mulch or compost, and liquid fertilizer. *Montanoa hibiscifolia, M. leucantha ssp. arborescens, M. grandiflora, Montanoa* spp. are related to *Tithonia*, and so may have similar benefits, but also likely to be weeds outside of their natural range. *M. leucantha* has been used successfully as sheep fodder in Mexico. They could be added between woody species or may be strong enough by themselves. Liveset cuttings, or cuttings rooted in a nursery bed.

Acacia flavescens, A. holosericea, A. saligna, A. longifolia, A. farnesiana, A. paradoxa and others. Many provide fuel wood, N-fixation. Some have storable, edible, high protein seeds and some are useful fodder. See www. worldwidewattle.com. From acid or hot water treated seed.

Grevillea banksii cv. 'Fosteri' (likely to be a weed), *G. pteridiifolia, G. parallela*, G. 'Honey Gem' and similar hybrids (possibly sterile) - Grevilleas are exceptionally good for birds and bees, fodder for goats. From seed, or cuttings in a propagation facility.

Caesalpinia echinata, C. sappan - Honey, dye. Seed.

Heliconia spp. and hybrids, gingers – birds, cut flowers. Could be added between woody species for increased biodiversity. Liveset divisions.

Odontonema strictum – could be added for small nectar-eating birds, such as sunbirds and humming birds, but weedy. Liveset small cuttings.

Cordyline and *Dracaena* spp. – between woody species for biodiversity, berries for birds, nectar for insects. Liveset cuttings.

Calliandra thyrsiflorus and *C. surinamensis* – good hedge, N-fixing, fodder, fuel wood and nectar for birds or bats. Some species may be relatively slow-growing. From seed.

Premna serratifolia – untested, attracts beneficial insects especially bees and wasps. Fuel wood. May be good where it is native. Seed.

Leea spp. – untested, fruit and nectar for wildlife, between woody spp. Seed.

Crataegus spp. and some plants in the *Rosaceae* family – a cold climate favourite, nectar and fruit for wildlife. Can be weedy. From seed or bare-rooted plants.

Dovyalis spp.- Fruit, thorny. Seed, cuttings.

Flacourtia spp. – Fruit. Seed.

Busera simaruba – honey, birds. Liveset cuttings, seed.

Jatropha curcas – poisonous, source of biodiesel. Seed, cuttings.

Oncoba spinosa – bees, thorny. Seed.

Pithecellobium dulce – N-fixing, thorny, fodder pods. Seed.

Alphitonia spp. - insects, birds, timber, fodder, soap substitute. Fast-growing. Seed.

Grasses – mixed with woody plants e.g. *Pennisetum purpureum* hybrids, *Cymbopogon* spp., and vetiver, grown on contour can catch water, soil and nutrients. Some may also provide grain and fodder. Liveset divisions, cuttings or seed.

Bamboos - some species – multiple uses. Liveset divisions.

Zyziphus spp. – fruit, fuel wood. Seed.

Some plants that are grown in gardens or farms that may possibly work as living fences, or provide more variety (some of these could be weeds):

Espaliered fruit trees, *Escallonia, Inga, Murraya,* privet, *Coprosma, Pittosporum, Pyracantha, Cotoneaster, Duranta, Prunus, Ceanothus, Laurus, Photinia, Tecomaria capensis, Hakea, Buxus, Clerodendrum, Citrus,* palms – possibly *Chrysalidocarpus lutescens, Ptychosperma, Hibiscus,* tagasaste, *Ixora,* feijoa, bougainvillea, *Cupressus, Thuja, Chamaecyparis, Acmena, Syzigium, Eugenia, Psidium, Kunzea, Melaleuca* (including the former *Callistemon*), *Leptospermum, Sorbus, Yucca, Viburnum, Cassia/Senna, Vitex, Salix, Rhamnus, Malvaviscus, Banksia, Bixa, Mahonia, Greyia, Berberis, Hamamelis, Hamelia, Cordia, Buddleja, Ilex, Myrtus, Halimodendron, Schefflera arboricola, Cercidium/Parkinsonia, Phillyrea, Malus, Codiaeum, Griselinia, Corylus, Euonymus, Ulex, Genista, Polyscias, Myoporum, Polygala, Rhaphiolepis, Rosa, Rubus, Weigela, Eupatorium.*

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Some internet resources:

www.winrock.org/fnrm/factnet/factnet.htm

www.amazingcarbon.com

www.holisticmanagement.org

www.ilri.org

www.savoryinstitute.com

www.permaculture.org.au

www.permaculture.org.uk

www.hortpurdue.edu/newcrop/default.html

www.agroforester.com/overstorey

www.agroforestry.net

www.worldagroforestry.org

www.fao.org

www.proseanet.org

www.prota.co.ke

www.worldwidewattle.com

www.tropicalforages.info

www.cabi.org

www.foreststreesandlivelihoods.co.uk

www.pfaf.org.

www.rirdc.gov.au

www.idrc.ca

www.naturalsequencefarming.com

www.sarep.ucdavis.edu/ccrop/

www.icrisat.org

www.igfri.ernet.in/

www.ciat.cgiar.org

www.gatesfoundation.org

www.rockefellerfoundation.org/

www.aciar.gov.au

www.echonet.org

www.acresaustralia.com.au

www.acresusa.com/

www.journeytoforever.org

http://desertification.wordpress.com

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