Vision for food security, water shortages, and climate change

16 Dec 2011 Colin Austin

Summary

This report presents a technology designed to improve food security and offset climate change by taking carbon from the atmosphere and embedding in the soil. There is considerable saving in water as the soil is maintained moist not wet, with minimal loss by evaporation or soaking into the ground.

While plants absorb many times man-made emissions most of the carbon is returned to the atmosphere by degradation and decomposition so there is only marginal benefit in reducing atmospheric carbon. This technology diverts this stream of returning carbon back into the soil to regenerate top soil to simultaneously enhance food production and reduce atmospheric carbon.

Soil Degradation

Around the world our soils are being degraded by excessive tillage and the use of chemical fertilisers which destroy the soil structure.

Ammonium nitrate, one of the early fertilisers, was first used during the Second World War in making runways for aircraft in war zones. Planes could not take off and land on the soft soil, but the application of ammonium nitrate killed off the microbiology, which gives soil its structure, making it hard like concrete.

Soil biology creates soil structure: It creates a porous microstructure, which holds water and nutrients, making them readily available to the plants while giving the soil its structure or mechanical strength.

Without this mechanical structure, there is nothing to hold the soil together. It can easily be blown away, creating dust storms

Or, the soil can be washed away in floods.

Loss of topsoil reduces food security.

The increased severity of floods and droughts from climate change make this one of the biggest threats to humanity

Solving two of the world's great problems

Plants are largely made from carbon extracted from the atmosphere; plants extract some thirty times man-made emissions. Photosynthesis creates complex organic materials, such as sugars, containing a great deal of energy (again, many times that used by man). This powers the earth's life cycle and provides our food. In addition to the carbon extracted from the atmosphere, the plants also need a range of chemicals and minerals, which they extract from the soil.

Nitrogen, phosphorus and potassium are required in bulk; calcium and magnesium are needed in moderate quantities while trace amounts of boron, iron, manganese, copper, zinc, aluminium, cobalt, molybdenum, selenium and silicon are also essential.

There is no global shortage of these nutrients (with the possible exception of phosphorous), but not in a soluble form. The great symbiotic relationship between the plants and soil is that the plants provide carbon and energy, while the soil biology transforms the insoluble nutrients into soluble nutrients, which are then readily available to the plants.

The practice of excess tillage and application of fertilisers in simple chemical form has been slowly killing soil biology, which destroys the soil structure, and makes the nutrients less available to the plants. In the short term, this is resolved by simply adding more fertilisers, which has led to major pollution impacts on rivers and aquifers.

Soil and water are linked together: Good soil can hold large amount of water, which is readily accessible to plants. Therefore, strategies to resolve water shortages must include improvement to the soil structure. In short, solutions to the destruction of topsoil are intimately linked to the solution of climate change.

In other words, we can resolve both problems by diverting carbon flow to regenerate topsoil, instead of simply allowing it to return to the atmosphere, as happens now.

We know how to do this; it is simply a question of the political will to do it on a large enough scale.

Regenerating top soil

Topsoil is regenerated naturally; the problem is that is takes hundreds of years. The question is: once it is lost, how do we regenerate topsoil? This is the critical question for humanity. We need a way to regenerate topsoil within a few years.

This is possible now! And, it is not that difficult to achieve, if a defined process is followed.

Topsoil is generated by the microbiological action of decaying vegetation. The soil formed has an open structure with considerable pore space held together, to form a sponge like structure, by the hyphae of fungi. These small pores hold considerable quantities of water and nutrients, which are readily available to the plants. Healthy soil biology turns topsoil into an open and spongy nutrient-rich topsoil, which is the key to food production. But, soil biology must to be cultured and cared for, just like a farmer cares for his crops.

There are four essentials to this process:

Firstly, we must grow something. Plants offer us the only way to capture both energy from the sun and carbon from the atmosphere to produce the basic ingredients of soil. Without plants, there is no energy or carbon to drive the process.

Secondly, we must have the right type of soil biology; if it is not already there we have to add it by using inoculants to start the process.

Thirdly, we must feed the soil biology; without food it will just die.

Fourthly, we must have water—enough to make a moist environment. Too little water and the soil biology will not be able to make soil. Too much, and we will have a stinking anaerobic mess —not soil.

Plants the source of energy and carbon

To restore soil it is necessary to grow something, virtually any plant will help the restoration.

Many of the plants that we grow for food or ornamentation are relatively delicate and will not grow in poor soil.

Certain plants, generally described as 'pioneer plants' are capable of growing in extremely poor soils. These are often thought of as weeds because of the ability to spread rapidly and their resilience.

If the existing soil is badly degraded, we may have to start the process of regeneration with these pioneering species.

Some plants are incredibly tough; first on the left is a Gidgee tree (Acacia Georginae), which can grow in the tough conditions of the Simpson desert.

As the soil improves these pioneering species are usually outgrown by more vigorous pants.

Australia has many particularly effective pioneer species. On the left is Easter Cacia (Senna pendula var. glabrata). They grew very fast, are a legume so can capture nitrogen and they have deep roots, which are very effective at capturing phosphorous from deep in the soil. They provide two of the three critical nutrients (N,K,P) for plant growth. They make excellent soil regeneration plants

Soil biology

The second component is soil biology. If the soil is reasonably healthy, there may already be enough soil biology to continue to improve the soil's health.

There are an immense number of organisms living in healthy soil, but two critical ones are mycorrhizal fungi and worms. The hyphae of fungi give the soil mechanical properties so it is resistant to wind and water erosion. The fungi also helps to create small pores in the soil, which hold both water and nutrients, making them readily available to the plants**.**

Worms play a crucial role by creating 'passages' so that water and air can flow through the soil, but they have in role in transporting fungi throughout the soil.

Inoculants or starter kits are used to initiate the soil biologial action, these are mixes of bacteria, fungi and worm eggs in small boxes which are simply placed upside down on the soil.

Inoculants

These are mixes of various biologies, typically Mycorrhyzal fungi, bacteria, and worm eggs. Mycorrhyzal fungi (described at http://en.wikipedia.org/wiki/Mycorrhiza) are symbiotic with plants, with a far higher ability to extract nutrients from the soil than plant roots, which exchange nutrients for sugars within the plants. Fungi, in general, are important in providing the soil structure: they excrete enzymes which have the power to attack and dissolve rocks, make available locked-up nutrients, and decompose organic material with less carbon dioxide emissions than bacteria.

Worm eggs (eggs are far more transportable than live worms) soon hatch out to fully-grown worms, which have a dual function: they create pores through the soil, which aids movement of water, but they also appear to act as carriers of the fungal spores, spreading them throughout the soil.

Inoculants are a complete waste of time if the basic requirements of moisture and food for the biology are not in place.

Food for the biology

There is no value in just putting the inoculant directly onto impoverished soil, because it won't survive. The more we feed it, the faster it will grow, circulating food as some creatures die, feeding others organisms or providing nutrients for the plants.

Every organic material will be attacked by some member of the body of soil biology.

Bacteria consume soft fleshy material, but unfortunately, this releases some carbon dioxide back into the atmosphere. But, bacteria are short lived, so, as they die, they provide a valuable resource for the soil. Fungi exude enzymes from their hyphae, which allows them to attack many hard materials, particularly lignin, the hard component of wood, but also rocks, providing a source of minerals for the soil.

Fungi still release some carbon dioxide but much is retained. Fungi can become huge subsurface structures that live for a long time, but they are somewhat delicate and need moist conditions protected from the sunlight.

Some organic material will be available locally as a waste product from agriculture.

A load of mill mud being delivered. This is a by-product of the sugar cane industry, but most agricultural crops produce significant amounts of waste.

Plants can be deliberately grown for carbon capture and to improve the soil. We are growing these Easter Cacias as part of the process of soil regeneration. They are nicknamed ‘soil trees’ as they are deliberately grown to improve soil quality. They also have another use in providing safe havens for mycrorrhyzal fungi when growing crop where some soil tillage cannot be avoided.

They are pruned regularly to provide feed for the soil biology.

To supply the large volume needed for a major soil regeneration project and to reduce atmospheric carbon we need to look outside the farm.

Parks and urban waste can provide a significant source of organic material. Forests, natural or plantations, are another source. With the advent of carbon trading, some forests are deliberately being established to generate revenue. It is a far more efficient to grow trees to generate green waste and capture the carbon in the soil to help food production, rather than simply locking the carbon up in timber.

Bush fires

Bush fires are increasing with climate change due to the increased flood and drought cycle. They cause enormous damage to life and property. They also put huge amounts of carbon back into the atmosphere, aggravating climate change.

Controlled burning is often used as a somewhat hazardous way of minimising bush fire. Many bush fires actually start from a controlled burn.

At best controlled burning puts large amounts of carbon back into the atmosphere.

Yet, the fuel load can be reduced by using a mulcher, and the organic material collected to regenerate topsoil. This is also a simple way of taking carbon from the atmosphere and embedding in the soil.

There are many different types of mulcher on the market.

This is a commercial scale mulcher, which can rapidly clear ground debry. Other are fitted with automatic rakes to collect the green waste.

This is a small-scale petrol mulcher, for home or small farm use.

Electric mulchers are available at low cost.

If no mulcher is available, a slasher or mower can be used to make coarse mulch.

Sewage and waste water

We waste huge quantities of a very valuable resource, sewage, which is a combination of water and nutrients, simply dumping this into the sea. Of course, there are health, odour and physiological barriers to using sewage for food production, but sewage can be safely used to grow 'soil trees' as part of the process of regenerating soil.

Water – the big challenge

Many problems of soil generation are easily solved. There is no shortage of suitable plants to grow. Soil biology grows very rapdily and can be produced on a large enough scale to satisfy global demand. There is a large amount of organic waste, currently being throwing away, which can be used for soil regeneration, and there is still plenty of second grade land, not really suitable for agriculture, which can be used to provide green waste.

But water is the biggest challenge. Without water the soil biology will simply die and the degraded soil will remain degraded.

We are simply running out of suitable supplies of fresh water. It is not so much that there is an absolute shortage of water, it is a question of availablity. There is either too much or too little and it is often in the wrong place at the wrong time. The demand for usefull water is greater than the supply.

There is intense competition for water from cities, industry and mining, with far bigger budgets than farmers to devote to soil regeneration.

Global agribusiness is the biggest user of water, so it is a question of using it more effectively.

It is wrong to think of water as a separate problem: Soil and water are linked together. Good soil can hold large amount of water, making it readily accessible to plants. Strategies to resolve a water shortage must include improving soil.

In Australia, the Liverpool planes region, for example, has naturally good soil structure, consistently producing high yields, without irrigation, in a low rainfall area, while nearby areas with poorer soils struggle to grow crops, even with irrigation.

The majority of water (as high as 95%) of water, particulalry in developing countries, is applied by flood irrigation. But flood is instrinsically inefficient. At the start of the field, where water is applied for longest, there is a large loss of water through soaking into the ground.

Unless a recyling system is used (which is very rare), the end of the field can also be over irrigated by water flowing down the field at the end of irrigation. There are also major losses from evaporation.

Soil biology prefers a steady moist condition. Flood irrigation swings from an excess of water to too dry. This is not good for the soil.

This could be solved by using drip irrigation, but practical experience with farmers show that up to 50% of the water can still be lost by poor scheduling. This can be solved by sophisticated technology, such as computer controlled irrigation, using soil moisture and weather sensors, but this is a technology beyond the reach of most farmers.

The sad fact is that we waste trillions of litres, around the world, wastefully irrigating poor quality soil, when greater production could be achieved by applying a smaller quantity of water to good quality soil.

Good quality soil needs less water because water and nutrients are more available to the plants. The water saved, coupled with wastewater and sewage, can be safely used to generate top quality soil by growing 'soil trees'.

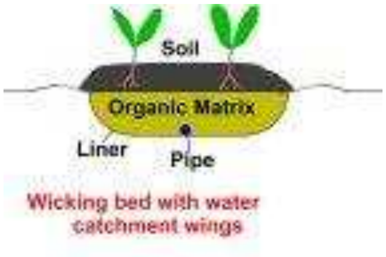
Separating water management from soil management is a grave mistake, because they are totally linked; water can be used to create good soil and good soil is more productive with less water.

Not just quantity

It is not just quantity of water that is an issue. Soil biology thrives under moist, not wet, not dry conditions. Take a walk through any forest; it is generally teaming with microbiological activity. The trees create a moist microclimate, trapping much of the water, and the water is continuously recirculating. In the Amazon basin some 70% of the rain is just recycled water. This continuous moisture establishes the ideal conditions for the soil biology, particularly the fungi, to survive.

Now, contrast this with the wide-open fields typical of many irrigation areas. After irrigation the soil is saturated but slowly dries out, —a totally different scene to the humid rainforest. Soil is created by microbiological action, which only flourishes if the soil maintains continuous moisture, which requires some water. Conventional irrigation technologies tend to cycle, first saturating the soil, and then allowing it to slowly dry out until the next irrigation.

The purpose of the wicking bed, where the water travels by surface tension, is to avoid saturating the soil while maintaining moisture—the conditions needed for biological action.



A wicking bed is essentially an underground water reservoir, which can be topped up by external water or rainfall, allowing the water to wick up by surface tension to the roots above.

It is like a perched water table, often found in nature with different types of soils layers.

Wicking boxes

Our experiments on wicking beds began using plastics boxes like this. They were used to investigate types of soils and combinations of organic materials, as well as determine how high the water level should be in the bed and what is the best frequency of applying the water.

The aim was to find out how to regenerate soil on a large scale.

Now there are thousands of wicking boxes in use. Many of these wicking boxes are incredibly simple; just a scrap box, like the polystyrene vegetables boxes collected from the local supermarket. A plastic pipe is used to deliver water to the base of the bed and there is a drainage hole about half way down the box.

It is a very simple and practical way of growing vegetables because there is virtually no water loss, so all that needs to be done is occasional look down the pipe, to see if is empty; then fill up to just below the drain hole.

Boxes like this are very cheap and convenient and easily fit onto a patio.

However, it appears the big attraction is that people are looking for more healthy food. They feel supermarket food comes from 'forced' growth with chemicals, and treated with herbicides and insectaries.

These boxes can be filled with rich organic material, like mill mud (a waste product from sugar production), with extra nutrients added. In particular, the addition of minerals is believed to be very important for human health, as they are beneficial for fighting such diseases as diabetes and cancers.

Wicking beds are filled with good soil or organic material such as mill mud or green chips. Organic material, fertilisers and particularly minerals can be added to the wicking beds, often using a worm farm.

Above ground outdoor beds

While the small boxes are very convenient for growing on a patio many people have built larger boxes in their garden.

A wide variety of beds have been made for outdoor use: dimensions vary widely, even for depth, which is determined by the root depth of the plant.

The beds can be dug into the ground, but most people prefer to place them on a level piece of ground.

Above ground beds are easy to construct and practical as they raise the level of the plants so there is less need to bend.

They are also much less prone to water logging from flooding

Drainage is an essential feature of wicking beds. The plants do not grow in the water; they grow in the soil above the water, which is maintained moist by the wicking action.

There is no loss of water to seepage into the topsoil and evaporation is virtually eliminated, as the surface should be dry.

The beds must be level so that the depth of the water is the same throughout the bed.

Large beds on a slope can be split into a number of smaller beds by internal terracing.

Overwatering has been a problem with some users who have been used to frequent watering. Beds can go for much longer without watering; all that needs to be done is to look at the water level in the filling and inspection pipes and refill when necessary.

With the deeper beds it may be necessary to add surface water to germinate the seeds but as soon as the plants have put down roots they only need watering from below.

Multiple beds, rather than one large bed, are generally preferred as this allows specific water treatments to suit the different type of crops.

Some beds are built quite high, to make access easy, (higher beds have been installed in homes for the handicapped and aged).

The bottom reservoir should not be too deep as the water will not wick up, the bottom is simply filled with waste material, and the plastics put on top of this.

Some people have constructed their beds as engineering masterpieces so they look very neat and tidy.

Other people prefer a more rustic approach using scrap material such as old railway sleepers.

It is common to incorporate a worm bed into the wicking bed, this is used to recycle organic scrap and add nutrients to the bed.

There are many designs to suit personal preferences.

Insects and excessive sun can be a problem in some areas, like Queensland, so the beds are built in a shade house.

Here, shade cloth is used to hold the soil: the sides of the beds are formed by hammering stakes into the ground. This is an excellent system as the shade cloth ensures that there is no water logging.

This is an interesting project at a school. The ground was not level but, although the beds look like one long bed, they are a number of small individual beds in the long wooden frame, which was made from railway sleepers.

These types of wicking beds, built on the ground, using a pipe to distribute the water, have now been used for many years and can be regarded as a mature technology. A big advantage of building on the ground is that the surface is higher; this means it is easier to work, pick the vegetables or view the flowers. (Some beds raised even higher have been installed in retirement villages so the elderly citizen can easily care for their own garden, without bending.)

In-ground beds

These box-style beds constructed on the ground are great for small projects. Thousands, of all shapes and sizes and designs have been made (even from old bath tubs). For some people there is a little learning experience, such as avoiding overwatering, not making the beds too deep and providing adequate drainage. Apart from these issues, the method can be regarded as a mature and successful technology.

There is little doubt that urban agriculture will play an important role in food security as cities get bigger and there is a demand for local of home grown food. However, these box-style beds are not going to resolve the coming food or climate change crises.

Solutions to emerging food, water and climate change problems requires an approach which can be used on a much larger scale and that means constructing much larger wicking beds in the ground.

This has been the focus of research, which has been going on for many years and hopefully will increase in the future as these major worldwide problems are recognised.

Early experimental in-ground beds were made by digging a hole, lining with plastic for about half the depth then filling with organic material and soil. It was thought that adequate drainage would be provided by water moving into the adjacent soil.

These in-ground beds were installed during the middle of the drought in Australia; the surrounding soil was dry and the beds produced well.

The Queensland floods were quite a learning experience and a portent of what the world has to expect with climate change.

The Queensland floods were not a single heavy rain but a prolonged period of rain, so the soil in the entire region was water logged. When the really big rains came, the soil was already so wet that the water could not soak into the ground and it literally formed a wall of water (it has been described as an inland tsunami). There is little that can be done to protect against a wall of water.

Plants can survive a short period of submersion in water, the problem was the whole area was so saturated that there was simply nowhere for the water to drain to. The flood showed that the level design in heavy clay was prone to water logging. In a sandy soil, there may have been adequate drainage.

This is another early example of an in-ground bed, much large than previous beds, but prone to flooding in the heavy clay soil. Of course, conventional flat areas were also flooded.

The flood and drought cycle

The Queensland floods were a traumatic experience, forcing a major rethink about what living with climate change will be like. After a twelve-year drought it is natural to focus on water shortages and how to grow crops with limited water. Experience has taught us we have to also worry about flooding.

The dramatic events of the flooding, and, more particularly, the weeks of water logging and saturation that followed, caused a major re-think of how to develop technology to cope with flood and drought cycles.

Hindsight is wonderful!

Warmer air holds more water and, therefore, there will be less tendency for rain to occur, but when it does rain it is going to be much heavier rainfall. There is nothing like a wall of water rushing under your house to show the dangers from climate change that lie ahead. It would be a good lesson for the remaining climate change sceptics to experience.

To avoid water logging, the system was changed to a raised bed design. The ground is first dug down to the depth of the organic layer (about 300mm).

The hole for the bed is now much shallower, after putting in the plastic and filling with green chips the soil will be used to form the raised bed.

These second generation beds still used pipes for transferring water. They are simply slotted using an angle grinder.

The third generation beds, currently under development, have eliminated the pipes and use an automated water supply system.

The aim is to make them more suitable for large scale application by reducing costs and labour.

The plastic and pipes are then laid in place.

The bed is then filled to the natural soil level using organic material.

The original soil is then laid back on top of the organic material so the plants are growing in a raised bed.

Below is another bed showing the final raised bed

Other raised beds, designed to avoid damage from flooding

Open beds

Shallow rooted plants can be readily grown in the beds as shown above, but large trees cannot be grown inside the bed so they are grown alongside the bed with water wicking up and outside the bed

In this case, the channels were formed using 1 set of blades in a rotary hoe. Naturally, the beds are much narrower than the 'closed' style beds.

The bed is then lined with a polythene film and filled with organic material. To help reduce costs for large-scale application, no pipes are used in these beds. In this example, the lower layer is built up with coarse wood chips and sticks to allow water to flow through the mix.

Mill mud is then placed on top to act as the wicking medium to transfer the water to the trees.

This is a much longer bed, testing just how far the water will flow without a pipe. A low flow rate is used to give time for the water to flow.

Other trials use a micro furrow to transport the water.

Sloping beds




Wicking beds are normally constructed flat to give a uniform water depth. If the ground is not level, the beds are run along a contour line. However many existing orchards are on sloping ground with the rows of trees running down a slope, as in this case.

Wicking beds can still be applied by building each bed in a series of terraces.

In this bed, a deeper hole was created next to each tree, so that each tree had its own reservoir.

The plastic is laid so that the edge is virtually at the surface between the trees, so there is no loss of water in the areas that do not need irrigating. This part of the trench acts purely to transport water.

The edge of the plastic is lower around the hole, so when filled with organic material there is a wicking path through to the tree roots. In this case, the areas between the trees are filled with coarse wood chips and the holes near the tree with mill mud.

This method of using wicking beds on a slope is particularly exciting as there must be millions of kilometres of furrow irrigation, which could be readily converted to wicking beds.

This would have a major impact on water use efficiency with minimal change. Furrow irrigation is inefficient because of the loss of water, both from soaking into the ground and from evaporation. Wicking beds eliminate the losses from water soaking into the ground and evaporation.

Replacing floods irrigation

There is another factor to consider: The way to make flood irrigation efficient is to have a very high delivery rate.

This is normally achieved by having large open channels to deliver the water. These channels are often provided by a Government controlled organisation. Due to costs, channels often are not large enough and do not have a high enough water flow rate, further increasing water losses. Although, in theory, it would be highly desirable to replace these open channels with pipes, the costs of large pipes needed are prohibitive.

Wicking bed do not need a high flow rate, quite the opposite; the only way for the water to move along the wicking bed through the organic material is to apply the water slowly. By using wicking bed technology, the entire infrastructure of large open channels, which are used intermittently, could be replaced at a low cost by small pipes running continuously.

Replacing inefficient flood irrigation with a system which is efficient yet simpler and lower cost than drip is a technical breakthrough with great social benefits.

Costs and practicality

The overriding obstacle to the wide-spread adoption of wicking beds is the cost to the farmer.
Two strategies are in place to overcome this hurdle:

Automation

The first is to automate the entire process of creating wicking beds.

This is a specially developed tyne which can lays the plastics directly into the ground without the need to dig a trench.

It is simply towed behind a tractor.

The soil has been excavated to show the film lying under the ground.

Another approach to automation is an automatic compost or organic material layer. This picture shows a large machine in which the organic material fills a trailer.

The material is then augured down under the surface.

Carbon capture

The second approach is carbon capture, which is now looking much more promising after COP17 in Durban.

Plants absorb large amounts of carbon; reports indicate up to thirty times man-made emissions. Unfortunately, this carbon largely returns to the atmosphere. Converting this carbon to improve soils would go a long way to resolving the global climate crisis.

Before this can be a reality, a methodology to account for the carbon being sequestered must be developed. This needs to be simple, and practical, to enable it to be used on millions of farms around the world. Fortunately, the amount of carbon added to the soil is easily measured. This may provide the basis of a simple scheme, which is approved for international trading.

The grand vision

The grand vision is to use a proven, simple, and inexpensive technology to alleviate threats of food security, resolve the water crisis, and manage climate change.

There are social aspects as well: Farmers around the world are generally poor. If this technology is accepted internationally, it will provide a way for poor farmers to raise their living standards by being paid to capture carbon on behalf of the rich polluters.

To turn this vision into reality will require a number of development stages:
Firstly, it requires selling the concept to top decision makers so they can allocate the funding for further research and to approve the international trading.

Secondly, it requires training and support for the farmers so they can adopt the technology.

Thirdly, it requires turning the technology from a research activity into a mature system for practical application.

Fourthly, it requires commercial companies to provide the services, such as the supply of material and inoculants.

These are major challenges. A start has already been made at the Farmland Irrigation Research Institute where a test bed has already been installed.

Test site at the Farmland Irrigation Research Institute in Henan province, China.

Further information: http://www.waterright.net.au