Wicking beds and Global warming

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Abstract

Global warming is a race between carbon emissions and the plants' ability to absorb carbon. This race is unlikely to be won solely by reducing emissions – we have to transform agriculture from being a major emitter of carbon to becoming a major absorber of carbon. This requires changing our agricultural practices with systems so farmers are paid to absorb carbon as well as grow our food. This requires a major rethink of how agriculture operates with power stations becoming just as important a source of revenue as supermarkets.

Wicking worm beds, by controlled composting of plant material, can absorb large volumes of carbon which is captured in the soil (also improving soil quality). Water supply, already under threat from global warming, is a critical component of the process, but wicking beds can incorporate water harvesting technology developed from understanding and imitating natural process which enable plants to grow in regions of low rainfall and high evaporation.

Restating the problem of global warming and the water crisis

Solutions often start by restating the problem in a slightly different way and so I start by looking at the causes of the twin problems of global warming and the water crisis

The process of global warming has been well documented in many publications, one of the most readable is 'An Ocean of Air by Gabrielle Walker' [1] and I follow closely her theme.

Over the millennia there has been a continuous carbon dioxide race between plants and animals. Plants were first of the starting block taking in carbon dioxide and releasing oxygen into the atmosphere. Animals, by which I mean all non plant creatures including the microbes, were not even on the starting block. Lap one to the plants.

But as the plants created oxygen and food the animals were in the race running neck and neck. Plants used the energy from the sun to create organic material as an energy source while expelling oxygen as a waste product. The animals would consume the plants using their energy and expelling carbon dioxide as a waste product back into the atmosphere. These early plants were soft and easily broken down ready for use by the animals. It was an even race, call lap two a draw.

But then plants developed lignin, the hardy woody stuff that animals cannot eat, and plants took the lead again. Fungi were the only organism that could decompose the hard lignin of trees but only in wet and sunless areas. Lap three to the plants.

Animals countered with the development of ants and termites. They still could not digest lignin but were smart enough to chew it up, take it back to their mounds or nest, where in the damp sunless conditions fungi get to work and produce digestible food.

Smart work by the termites, clearly deserving a Nobel prize, but the plants had won lap four, capturing vast tonnages of carbon which was stored in coal, oil and particularly in the soil, where the increased fertility consolidated the plants as leaders.

But although they had victory it was a well fought race with over a hundred billion tonnes of carbon being captured each year by the plants and then largely consumed by the animals, the small balance ending up as stored carbon (coal, oil and soil carbon).

It looked as though plants had won the race.

Then along came man, not making much difference for the first million years or so but the development of machinery soon swung the balance - using up the stores of carbon in the ground to push animals into the lead. Even so the total energy produced by the plants was still thirty times the total energy used by mans machines, but the balance had been tipped to put animals marginally ahead. By no means a disaster at this point!

But man also played dirty, undermining the plants ability to capture carbon. Some areas occupied by plants were replaced by his cities but the biggest damage was done by the vast area of agriculture, replacing the hard lignin based trees by the soft plants man (and his animals) and the ubiquitous micro organisms could readily eat.

Not only had man increased the output of carbon dioxide he had hobbled plants ability to absorb carbon. In many areas even the carbon in the soil, accumulated over millions of years is being returned to the atmosphere.

Agriculture instead of absorbing carbon has become a major contributor, ranked by some as number three after power generation and transport.

Water the real baddie, not carbon.

By itself, a marginal increase in carbon dioxide would not necessarily be a big deal, the amount in the air is still minute and carbon dioxide is not even a particularly effective green house gas, so any resultant increase in temperature due to carbon dioxide by itself would hardly be newsworthy.

However a small carbon based increase in temperature leads to an increase in evaporation and water vapor in the atmosphere and everyone knows that a cloudy night is a lot warmer than a clear night. Water vapor and cloud cover are far more effective green house agents and are abundant in the atmosphere. Warming from a small kick off from carbon can be amplified by water vapor.

The global warming threat is upon us.

Looking at both sides of the equation

There is widespread agreement that the countries of the world should cooperate on a global basis to reduce direct emissions of carbon. Of course that is a '*good thing*'. The reality is that it is doubtful if cutting energy consumption by itself would ever bring the equation into balance.

Is that target achievable? It is a bit difficult to conceive the President of the US riding to the White House on a bicycle. With the ever present difficulties of international negotiation and the growth of China and India and no doubt the industrialization of many other countries you would have to have a pretty optimistic (or naïve) attitude to believe we can solve the carbon problem purely by reducing our consumption of fossil fuels e.g. from the demand side of the equation.

We need to look at the other or absorption side of the equation.

Reforestation

One popular alternative commonly promoted is simply planting more trees - but there is a snag. At first the forest will absorb carbon into the body of the trees themselves – so far so good. But there is a finite limit on how much carbon can be absorbed in the trees. At some point, the forest will mature and trees will die and much of the carbon will be returned to the atmosphere.

Reforestation should certainly be undertaken but we cannot continuously convert agricultural land to forest on an on going basis to achieve a long term balance of our energy consumption.

An essential ingredient of any viable long term sustainable solution is to change our agricultural systems to trap carbon in the soil.

This requires a major change in our agricultural system developing hybrid systems where our farmers are paid to capture carbon while growing our food. But we should not be limited to commercial farmers; wherever plants are grown we should be capturing carbon in the soil. This is already happening within environmentally sensitive groups.

We need the technology of capturing carbon to improve our soils instead of it being returned to the air.

This is the aim of the wicking worm bed.

What is a wicking worm bed?

The idea of the wicking worm bed came to me way back in the mid nineties while I was working with an NGO in Ethiopia looking for ways to provide sustenance food for peasant farmers in times of drought.

I was told the problem was lack of rain. I have since learned that when people blame lack of rain this is rarely true, it is more often the lack of the right sort of rain at the right time coupled with an inability to make use of the rain that does fall.

So it was in Ethiopia - where there is on average a reasonable but variable rainfall, it just needs a lack of rain, even for a couple of weeks when the seeds heads should normally be filling, to cause widespread famine.

These are the same problems as in Australia but without resources and technology to ameliorate the hardship.

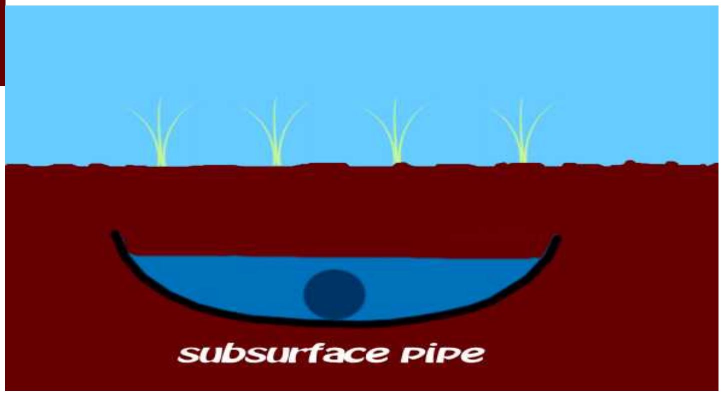
The first target was to store water, and the only practical way in those highly restrictive economic conditions was to store the water in the soil.

The second problem was that there was no really viable way of applying the limited external water (from springs) that was available. Furrow irrigation was the current method but the available flows were so limited that the water would simply soak into the ground before even reaching the end of the furrow – incredibly wasteful.

The wicking bed was the solution, simply dig a trench under the furrow, line with a plastics film and back fill. This formed an underground reservoir of water which increased storage in the soil many fold, gave good water distribution while preventing water leaking past the root zone.

This basic system was later improved by replacing the furrow with an underground pipe.

This virtually eliminated surface evaporation, and with no water lost by seepage all the water applied was used by the plants.



The third problem was the poor soil lacking in nutrients and structure.

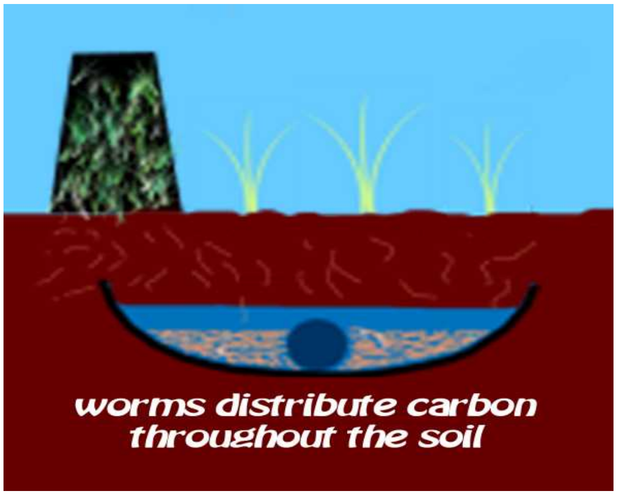
The overriding limitation was that the solution had to be really simple and cheap; farmers could simply not afford modern irrigation technology or fertilizers.

The major improvement was partially filling the trench with weeds which provided nutrients and further increased water holding capacity.

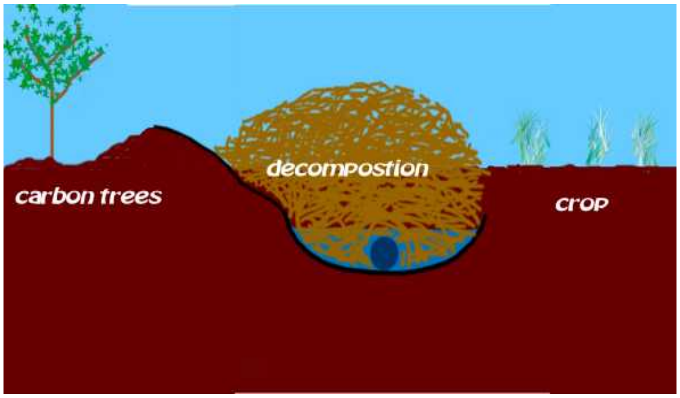
Worms were added to feed on the weeds as they decomposed to improve soil quality which led to a dramatic improvement in productivity.

Simple cheap and highly effective!

Since that time wicking beds have become popular in Australia particularly with the permaculture and alternative farming groups.



However the threat of global warming has thrown a totally new perspective on the invention of the wicking worm bed.



In the horizontal wicking bed used for carbon capture there are no plants growing above the wicking bed, this is used for decomposing organic matter. Plants grow along side the wicking bed fed by the water wicking up then sideways.

This carbon capture has implications way beyond the original objectives.

Wicking beds are essentially a micro eco system in which plants which are adapted to the local conditions are grown to provide the fuel, this is broken down to provide nutrients for crop plants which are typically much more demanding. The challenge is to create conditions in which the plants can break down to provide nutrients, while releasing the minimum amount of carbon dioxide.

The most effective way is to use observations of what happens in the natural world and use pragmatic experimentation coupled with incorporating knowledge of micro biology wherever possible.

In hot dry regions without water organic mater hardly decomposes at all but the destructive combination of oxygen and sunlight slowly oxidizes the carbon which is returned to the atmosphere.

At the other extreme lignin in the woody matter when immersed in water decomposes very slowly. Fred Pearce estimated up to 500 years 2.

Decomposition is best under moist conditions. It is fastest in the presence of nitrogen when the bacteria will dominate and significant heat may be generated, while lacking scientific confirmation these are thought to be the conditions which will give significant emission of carbon dioxide.

Lower nitrogen contents result in a largely fungal decomposition, much slower than bacterial, but with more (it is thought) of the organic material being retained.

We can see this in wet climates. Trees will decompose, largely by fungal attack, many nutrients released by the dead trees are taken up by new growth and are retained in the system but any that is not absorbed by new growth will be simply washed away by the high rainfall.

These are the conditions we are trying to create in the wicking bed but without the flushing action of excess water.

Water is required to achieve the right bacterial decomposition. The wicking beds may be more water efficient than conventional irrigation but they still need water. This need for water will be one of the major challenges for wide spread adoption, particularly in the marginal crop grazing lands where carbon capture could become a major alternative to cropping.

Where will the water come from?

The amount of water we catch in our dams is a minute proportion of the total rain that falls. We need to start tapping into the vast volume of rain that falls and is currently lost by evaporation.

Our rainfall is quite comparable with other continents the difference is our massive evaporation. The balance between evaporation and rainfall is more important than just rainfall.

The danger of relying on run off

It takes a certain amount of rain, (depending on the soil type and moisture level) to wet the soil before run off occurs. Typically this used to be of the order of 50 mm however with the increased evaporation which we can expect from future global warming (and have certainly experienced), this threshold value is significantly increased. For example following a long dry period a figure of 115 mm was needed before run off occurred.

In much of Australia evaporation is many times the total rainfall. Simply comparing total rainfall to evaporation is highly misleading, what is really important is the rainfall distribution. Small rainfalls of say up to 15 mm have little effect; the rain is simply absorbed by the dry soil and quickly evaporates providing virtually no benefit. Yet these small rainfalls make up some 40% of total rainfall.

Rainfall in the bracket of 15 to 50 mm bracket makes up 50% of the total rainfall and only 10% of rainfall is made up from rainfalls above 50 mm, the traditional level needed for run off (prior to global warming). As much of this rainfall is either in lowly populated Northern Tropics or South West Tasmania only some 5% of the total rainfall is available for capture and the limited number of good dam sites mean little of this rainfall is actually harvested.

Much of the rain, particularly the small rains, simply wets the surface of the soil and quickly evaporates. Some 60% of our rainfall is lost by evaporation without doing any useful work.

This forces us to look at different ways of satisfying our water needs.

So how can we make better use of the rain that is currently being lost by evaporation? We can answer this by looking at how desert plants survive.

In our deserts evaporation is many times rainfall, yet plants seem to survive quite happily. Many people attribute this to the remarkable adaptive nature of the plants, and there is some sense in this. Some areas, even the dry Simpson Desert have significant vegetation, even quite substantial trees, while other areas, such as Sturt's Stony desert are completely barren.

This shows the answer is not simply adaptation by the plants but lies in the fundamental physics of how water is captured and stored.

Desert regions are subject to periodic heavy rains which lead to rapid germination of the many seeds lying dormant in the ground. Most of these plants will die from lack of further rain, but they will have put down roots which will either rot or (more likely) be eaten out by termites. These ex roots form passages deep into the ground which will allow water to percolate into the ground.

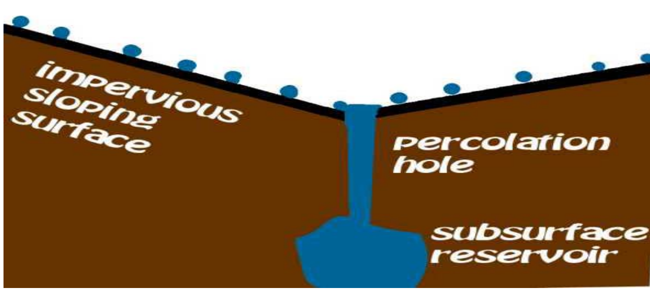
This is the first requirement – easy percolation into the ground.

While deserts may appear to be sand they are often layers of clay underneath the sand. The subsurface water will flow along these clay layers forming underground pools.

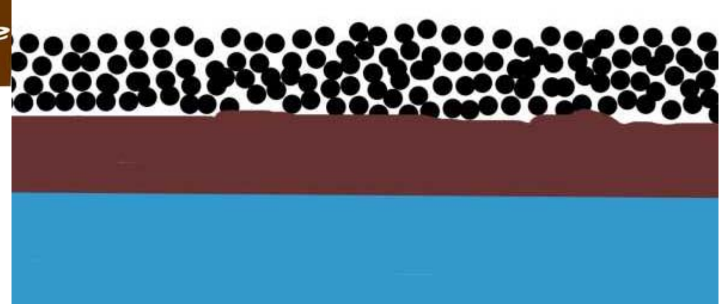
Any tree fortunate to be growing above these underground pools will survive. The others that die are sacrificial to support life for the survivors.

The three components are amplification - the capture of rain over a large area which is concentrated into a smaller area, transport - the water moving down through the soil and hence into underground pools and finally subsurface storage - with the water protected from further evaporation [3].

These three principles are the essential ingredients of the wicking bed for carbon harvesting.



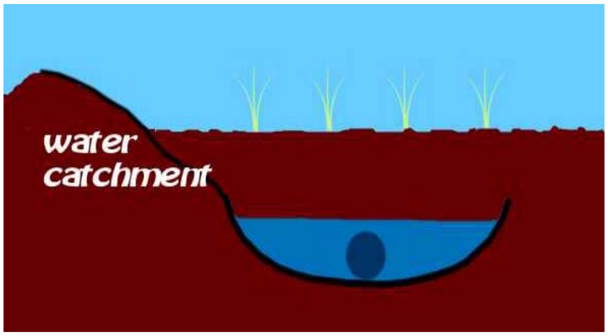
Rain, otherwise lost to evaporation can be captured using an impervious sloping surface directing water into a percolation hole for subsurface storage.



Small particles such as 5 mm pebbles allow liquid water to pass through unhindered but provide significant insulation to prevent subsurface water evaporating. Wood chips absorb little water and are also effective.

Both methods are used in the wicking worm bed.

There are many versions of the wicking bed. Horticulture plants, such as vegetables are grown immediately above the bed so their roots go straight down to the moist layer. This is fine where there is adequate supply of external water.



In other areas where external water is limited wicking beds use ‘wings’ or extensions to collect rain over a larger area. This is essentially using the principle of amplification used by the desert plants. A proportion of the land is used to catch water rather than grow crops.

The area that is needed is determined by the ratio of evaporation to rainfall. While land is wasted, in the sense that nothing is growing, it does enable plants with high water needs to be grown in the drier climates where they could not be grown without irrigation.

Catching smaller rains

Small rains falling on soil do little more than wet the surface which then will dry out without the water doing any useful work. To harvest smaller rains require a non absorbent surface which allows the water to drain deep into the soil and then restricts evaporation (like a bed of stones or wood chips).

In a small sideways wicking bed the reservoir could be covered by polythene sheet angled and perforated so the water drains down into the reservoir. This means the sheet has to be removed every time the bed is reloaded with fresh organic material. This is not very on a practical large scale.

A more viable approach is to grow a row of carbon capture trees (mallee, tipuana, casuarina etc). The polythene sheet used to form the reservoir can be used to insulate these plants from the reservoir by raising the edge of the bed above ground level.

These carbon capture plants are regularly trimmed so the cuttings fall on top of the wicking bed.

These trimmings allow water to readily percolate through to the lower layers and provide reasonable insulation from evaporation. The leafy matter soon degrades and falls into the lower layer so the top layer is woody and does not waste much water by wicking action.

A row crop is then grown on the other side of the bed. On this side, the side of the bed is below soil level so water can wick towards the crop.

Micro organisms (such as the bacteria and fungi used to decompose plant matter) and the worms (used to distribute the carbon) need the right moisture level to flourish.

The very top layer of the bed which will consist of freshly added waste will dry out and suffer some oxidation. Fortunately this is a slow process so the losses will be low.

The next layer comprising largely leafy matter will be decomposed by bacteria in the relatively oxygen- rich zone.

The lower layer comprising the woody material not decomposed by the bacteria will be digested by fungi which need to be protected from sunlight and require continuously moist conditions.

Worms will provide further decomposition in their guts and distribute the organic matter in the surrounding soil.

Worms are an important component of wicking bed technology. They are rather fussy eaters and will not excrete in their food supply if they can avoid doing so. Rather they will move away from their food supply, excrete and come back for more food. They may not wear napkins but they have surprisingly good table manners.

The great benefit of worms is that as they move through the soil they are distributing and trapping carbon in the soil benefiting both the atmosphere and the soil.

Amateur gardeners are leading the way with the wicking worm system, growing organic vegetables locally and reducing carbon loads.

Much of the experimental work has been done using boxes which enables better control of the environment and soil blends. The key is to build up a living ecosystem of micro-organisms and worms to improve the soil.

Standard wicking bed under construction. Vegetables are grown in the bed and watered from below. In the carbon capture beds the plants are grown along side the bed.

Carbon capture beds are asymmetric; here the left hand side is elevated to act as a water catchment while the side near the crops is below the surface to allow water to wick into the crops.

The beds are filled with waste material to provide nutrients, they will decompose and worms will carry the vermicast into the surrounding soil.

The asymmetric trench is dug with a small hill on one side to form the water catchment.

The trench can be filled with water to help adjust the level of the edge of the polythene so the water uniformly wicks into the plant bed.

How much carbon can be harvested?

A critical question is how much carbon can actually be harvested. At this stage with only a partial understanding of the percentages of carbon that can be converted only broad guestimates can be provided. There are really two scenarios.

We could use our better irrigated land where water for decomposition is available and the priority is still food production. Here catchments in the range of 20 to 100 million tones per annum look achievable.

There is an opportunity to exploit marginal land in our already dry regions relying largely on water harvesting. With the appropriate pricing for carbon capture much larger areas would be economically viable giving a potential of over a billion tonnes per annum. The actual amount would depend on the uptake by farmers which would be dominated by the economic returns from carbon capture, as yet unknown.

What can be said is that there is enough potential for serious carbon capture to move onto the next stage.

Action not procrastination

Wicking worm beds are an established and proven technology for growing crops with the minimum of water. There use is currently limited to small scale horticulture, but adoption is growing - limited by the resources available to devote to promotion.

Using waste organic material and worms to improve soil quality is a more recent development but certainly we have enough experience to know the system works. Like any emergent technology there is an urgent need for refinement and a scientific process for monitoring the carbon absorbed in the large scale applications needed for significant carbon capture.

To use wicking worm beds on a large scale to capture carbon is the next development which can only proceed as part of a National or International program of carbon capture. This means persuading those responsible for carbon capture to support the program.

The reality is that modifying our agriculture to be a major absorber of carbon looks the most viable approach to offsetting carbon accumulation.

Conclusion

Wicking beds combine a more efficient way of using water with the ability to absorb carbon into the soil. They are proven and are already being used in environmentally sensitive circles. However to have an impact on global warming they need to be adopted on a much larger scale trapping carbon in the soil.

1) Gabriel Walker- An Ocean of Air - Harcourt ISBN 978-0-15-101124-7

2) Fred Pearce - When the Rivers Run Dry - Beacon Press ISBN -13: 978-0-8070-8573-8

3) Peter Andrews - Back from the Brink - ABC Books ISB 13: 978 0 7333 1962 4

4) Karen Hussey and Stephen Dovers - Managing Water for Australia CSRIRO ISBN 9 78064309 3928

5) Robert Kandel - Water from Heaven - Columbia University Press ISBN 0 231 12244 6

6) John Pigram - Australian Water Resources
- CSIRO ISBN 978 0 6430393 379