The future of agriculture

Adapting to climate change and water shortages

(Talk prepared for China tour September 2009)

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Introduction

Thank you for inviting me to make this presentation at your well respected Institution.

Let me first make a few remarks about what I hope to achieve by this presentation. I believe we are all concerned about the future of food supply and the critical role that water plays in feeding the global population.

China and Australia have much in common; we both have large land masses with areas of low rainfall, high evaporation and are very dependant on river systems which start in mountainous regions and travel great distances overland to water our major food growing areas. In recent years we have both suffered drought which has reduced the available water and put great stress on our ability to produce food.

So I believe we face many problems in common.

Problems in common - Invitation for co-operation

In Australia we have been developing ways of managing shortages of water and in this talk I want to tell you about one particular technology, the wicking bed system, that we have been developing.

While China and Australia may have much in common there are still many differences. Our farming systems are different, our soils are different and our climates are different. However I feel, from what I do know about China, that what we have been doing in Australia is likely to be very helpful to China.

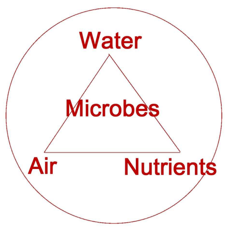
So I plan to tell you about our thinking and work and then you can consider if you feel that this may be helpful. If yes then we can talk about how we may be able to cooperate together, may be even setting up some trials in China.

So let me start by talking about some of the issues that are hot topics in Australia.

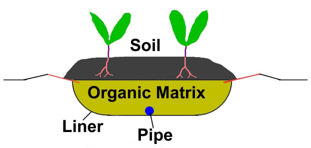
Part 1 Overview of Wicking beds

The real purpose of this talk is to introduce wicking worm beds, a growing system which gives exceptional growth rates and quality while requiring minimal water, nutrients and labour.

They are based on two basic technologies, micro hydrology and micro biology and later in the talk I will show how these technologies have been brought together.



Wicking beds are highly productive because they maintain the optimum balance of water, nutrients and air in the soil using a combination of microbiological action and water wicking up through the soil.



Wicking bed with water catchment wings

An underground reservoir or pool is filled with water, which then wicks up by capillary action to the roots above. It also acts as a decomposition zone to provide nutrients. The soil in the root zone above is maintained moist, without being saturated, by the wicking action, even though the reservoir itself is saturated with water.

Wicking beds can be very small and simple like this box with feeder pipe and drainage hole, or they can be on a much larger scale such as this semi raised bed.

There is no loss of water beyond the root zone and virtually no evaporation form the dry surface, so all the water supplied is used by the plant.

To get maximum growth from the wicking action the soil must be both full of nutrients and well structured. Special breeds of worms coupled with microbiological action in the bed will convert organic material into nutrients which are readily accessible to the plant. At the same time they work the soil giving a highly porous aggregated soil structure which aids the movement of both water and air.

A new horticultural system

In essence wicking beds are a new horticultural system. Some land is dedicated as the growing area using high productivity wicking beds. Other land areas, those with less value for agriculture - are used to harvest water and extract nutrients from the soil. Typically deep rooted plants which can extract nutrients from deep in the soil are used. These nutrients are incorporated into plant matter which is then decomposed to release nutrients in the base of the wicking bed.

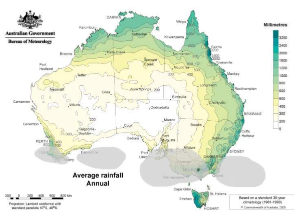
Some growers may resist the idea of giving up some land to harvest water and nutrients, but this may be the only way we can offset the effects of global warming.

Why do we need a new horticultural system, let us look at the problems of future food production.

Part 2 Fears about future Food Production

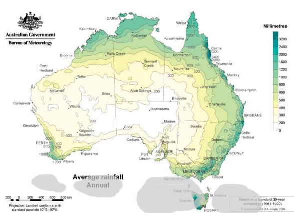
Science predicts that climate change will result in higher evaporation and lower and more erratic rainfall in many of our key food production areas. Of course higher evaporation must mean a net increase in rainfall but the rain may not be useful for food production.

Climate shift



The climate change can be more readily imagined as a shift in the traditional climate zones.

Traditionally Southern Australia, our major food production area, enjoyed reliable winter rain but over the last decade had suffered sever drought.



The climatic zones which used to provide reliable winter rains on the land has moved several hundred kilometers to the South and now drop their rain over the sea.

Key river systems in Australia are fed from melting snow on our mountains. This melting snow provides a natural and free water storage which is available in the spring providing water for irrigation. One of the threats from global warming is that this natural water storage will be lost to our farmers and put greater demand on our systems of dams to provide irrigation water.

It must be said that many of our important dams have been near empty for many years.

Although China's mountains are far larger and more magnificent than our rather poor mountains I understand that the situation in China is similar to Australia.

Competition for water

Even before the threat of global warming our water supplies were stressed from the increasing population, loss of land to urbanization and soil degradation. Again our cities are expanding with greater demand for high quality water and often this leads to a redirection of water, which would otherwise be available for irrigation, to be diverted towards the cities.

This conflict between the cities and agriculture is made worse by nutrient run off from agricultural chemicals. I believe both countries share this problem.

The higher temperatures and possible increased winds from global warming will increase evaporation which not only makes food production more difficult but also leaves soil more prone to erosion. Another problem I think both countries suffer from.

Do these threats mean that in the future the world will suffer from a shortage of food?

How real is the threat of food shortages?

Some people feel that any threat of food shortages if overplayed. They argue that food production has steadily increased with the improvement in farming techniques. In Australia this is very true with increases in production running between 2 and 3% p.a.

They also argue that plant genetics will develop new generation of crops which will be able to cope with less water and higher temperatures. And of course they are partially right. Agriculture has been continually refining genetics for over 5,000 years and the rate of development is faster now than ever.

There is no doubt that genetics will play and crucial role in safeguarding future food production. But will genetics resolve the threat?

Over recent years much of the world has enjoyed a food surplus, largely as a result of the so called green revolution based on improved plant genetics giving significant increases in productivity. However these improved breeds need higher inputs of both water and nutrients. The extra water has come from increased irrigation, from rivers, dams and aquifers, already subject to over exploitation.

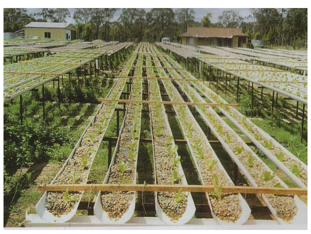
In many regions the limitation of water supply has meant that the benefits of improved genetics have not been able to be exploited.

Global warming will exacerbate this shortage of water with many rivers under threat from the reduction in snow fall, lower rainfall and higher evaporation. Solving this water crisis will be critical to resolving the future food supply.

Here I want to argue that while genetics will play an important part in offsetting global warming they will not be sufficient. Action is needs to harness the power of micro hydrology and micro biology.

The role of soil

Another potential threat to global food production is the role of soil. We are all too painfully aware of the problems of soil erosion by wind and rain. However this is more a symptom of the real problem.



Much modern agriculture is now more akin to hydroponics than traditional agriculture. The role of the soil is little more than to physically support the plant. Plant nutrients are provided by applied fertilizers. The innumerable pathogens and pest which attack plants are treated by an array of chemicals.

There is no doubt this is highly efficient for the short term production of food. The use of providing full nutrient balance to the root system by frequent short irrigations from sub surface pipes, as promoted by Claude Phenee shows how productive this approach is.

There are however two problems. First the inputs are externalized, the sustainability of supply is not assured long term and the costs, particularly to developing countries can be prohibitive.

The second problem is the control of pathogens and pests. Any one with experience of hydroponics is well aware that one of the major problems is controlling disease. This reason why is not instinctively obvious. Hydroponics systems are typically maintained scrupulously clean and there is no soil to harbor undesirable organisms.

Pathogens and disease

As modern farming practices have resulted in significant reduction in the health of the micro biological action of the soil, the incidence of plant pathogens has increased forcing farmers to rely even more on chemical methods of control.

Unfortunately micro organisms breed very rapidly and soon develop immunity to chemical control.

Pathogens and disease are a major threat to food production, ironically the farmers desire to have super clean environments leads to the explosion of harmful micro organisms.

This is now well recognized with insect control. Integrated pest management is now normal practice. However the same philosophy of control has yet to be widely applied to soils pathogens.

Any one reading a book on the various pathogens in the soil, from virus, nematodes to insects will wonder how it is possible to grow anything at all. While we have yet to fully understand the methods of controlling soil micro biology fortunately for us there is an innate tendency to move to some form of acceptable balance.

Pioneering species and competition

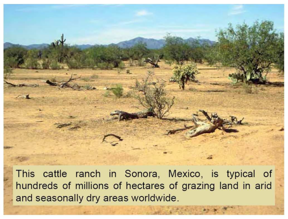
The reality is that micro organisms breed incredibly fast so a system may be sterilized perfectly but can be literally coated in micro organism within a matter of minutes.

It appears that micro organisms have a hierarchy like plants. In the plant kingdom we have pioneer species, commonly called weeds which grew and seed profusely so any bare ground is quickly covered with weeds. These will enrich the soil allowing slower growing plants to take over which will gradually out compete and replace these early pioneer species or weeds.

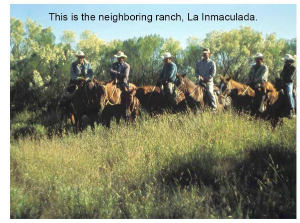
Similarly with micro organisms, we have pioneers species which will be the first to become established.

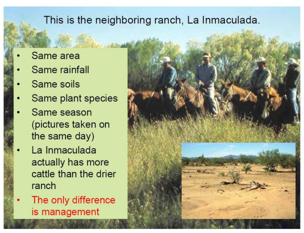
Unfortunately these pioneering are often the pathogens that do the damage. Later slower growing beneficial micro organisms will out compete and supplant these pioneering micro organisms so there is some balance and the pathogens, while still in the soil, are kept to an acceptable level.

Living soil



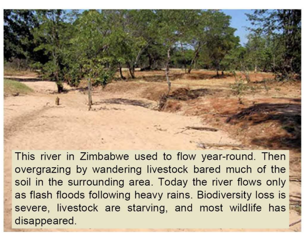
Managing the soil to increase carbon content and establish a healthy microbiology can have dramatic effects.

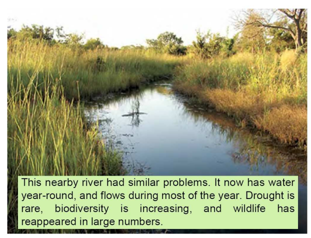


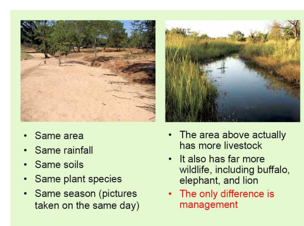


SOILS ARE THE ONLY SOLUTION THAT OFFERS SHORT TERM IMPACT ON GLOBAL WARMING

- The experts agree: only soils can sequester significant amounts of atmospheric Carbon in the next 30 years. Every other solution will take 30 years to start shifting meaningful volumes.







The reality of course in the short term is that it is more profitable for farmers to use high pressure chemically based growing techniques with the result that much of our soils are devoid of adequate micro organisms which in the longer term will lead to a reduction in food production.

Climate change in Australia

Climate change does not mean less rain, as some people suggest. Higher evaporation means that rainfall overall must increase however the shift in climatic zones will mean that rain may not fall over our traditional agricultural areas. This is particularly damaging in our southern agricultural belt which has traditional received a stable winter rainfall.

Much of this area has traditionally been irrigated from river systems which originate in the Mountains, but now rainfall and particularly snow fall has declined.

Yet tropical rainstorms, which are typically erratic, may be moving further south.

So it appears that we will have to rethink how we change how and where we farm.

Local water harvesting schemes

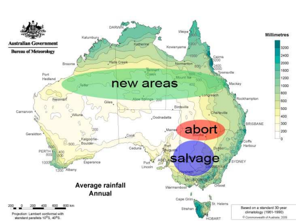
We can try and make our irrigation systems more efficient to help maintain agriculture in our traditional areas. As virtually all the river systems have been developed for irrigation we need to develop local water harvesting schemes so land away from the traditional irrigation areas can be developed.

But there is only so far we can go. It seems that some areas will have to be abandoned for agriculture. This seems almost inevitable in part of our Murray Darling Basin.

But we can also look at opening up new areas for agriculture.

Targets for Australia

We seem to be facing a major threat. So what do we do about it?



The key targets for Australia are to
1) Try and protect our Southern food production area from the increasing aridity.
2) Develop new agricultural land as the tropical summer rain belt moves further south.
3) Accept that some agricultural land has to be aborted.

Part 3 The importance of Micro biology

Land degradation

Let me talk about my personal experiences. Over thirty years ago in the early 1970's Australia suffered major dust storms with millions of tonnes of top soil lost. I was very concerned about this loss of top soil and decided to set up a series of experiments to find out how to regenerate top soil.

Fortunately now farmers have learned the value of top soil and changed there farming practices, for example using no till farming, but all those years ago I had no idea how dramatically farming practices would change to avoid soil erosion.

I just saw a potential calamity if the world lost too much of its top soil so my focus was on methods of soil regeneration.

When I read the literature on soil regeneration it seemed that it was inevitably a slow and tedious process with natural regeneration rates measured in mm per century. I wanted a system which could regenerate soil in a few years.

Soil regeneration

I looked around for anything that may regenerate soil. I bought up anything that looked as though it may help in soil regeneration, so called clay breakers in bottles, bags and by the trailer load, plus weird and wonderful plants which were supposed to be ploughed back into the soil to improve structure.

I then divided my block up into a series of little squares, in what I thought was a nice scientific approach, with control and duplicate squares and some with combinations of processes and we were off.

No single solution must use a combination of methods

Now it has to be said as a piece of scientific research this was a total failure. True some squares did show significant regeneration, but many did not. The single variable experiments seemed a total failure - there had to be a combination of processes, green manure and selected additives etc.

But it seemed impossible to see any order from the confusing results. I then stumbled across a mathematical technique called the Taguchi approach, widely used in Japanese industry to analyze multi variable problems. Even this failed to make any sense of the results.

The cruel reality was that I could have a certain set of variables which appeared to work really well on one bit of soil, and then if I tried to duplicate this success in another area it could just as easily fail.

It was clearly a waste of time trying to work out some magic formulae of so much of ingredients x, y and z combined with a combination of green manure crops.

I had to look beyond the results and find try and understand the mechanics of how the soil was being regenerated, e.g. look for some generic rule or law which can be reliably applied in most situations. I needed a common theme.

Water plays a crucial role

So I had to look again at my experiments to see if there was any common theme, outside the variables I was trying to control. It soon became clear that water was playing a crucial role. Now a paddock may look pretty uniform but this is rarely the case in nature. My paddock certainly did not even look uniform, for a start it was sloping down to a creek.

I used the creek to irrigate the paddock by using a small dam and pump. As I looked at my little squares and examined my soil samples it was pretty obvious that the water content varied significantly. As I looked around for the reason it became clear that the subsoil had fissures which led to the formation of underground flow paths. Not really creeks but enough to give a preferential pattern to the water flow paths.

This mean that some areas would become quite dry in the hotter months while others areas would be wet and almost boggy during the wetter months. The areas which were too wet or dried out in the heat showed little regeneration.

There only areas showing regenerations were those where the moisture level happened to be kept moderate and uniform throughout the year.

Micro biology regenerates soil

This was an important observation but it was not the real answer, water is inert and by itself will not regenerate soil. I concluded that the key was the micro-biological activity in the soil. This was confirmed by the number of worms in the soil. Worms cannot eat organic matter directly - it has to be processed by microbes first.

As I tried to understand microbiology I realized just how complex a subject it is with a totally bewildering number of species known. There is probably an even larger which have yet to be identified.

I did not need to have an in depth understanding of soil microbiology; all I needed was to understand the conditions which would lead to the proliferation of micro biological activity. Clearly microbes need food, which is readily supplied but equally they need the right moisture conditions.

This is not so easy in Australia where over the majority of the land mass evaporation is greater than (or even multiples) of rainfall

At first sight it looks impossible to maintain moisture levels under such dry conditions. However the top layer of the soil will soon dry out to form an insulting crust which prevents further evaporation so the sub soil can be maintained moist even though the top crust is dry.

To exploit this effect needs a rethink of how we manage our water.

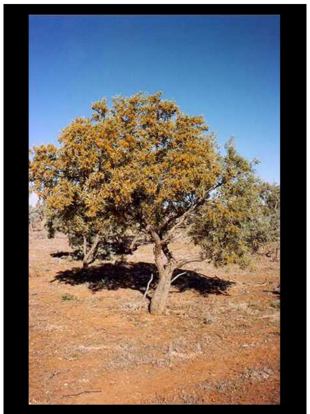
My task was therefore to find out how to manage soil moisture which lead me into the world of irrigation scheduling, subsurface irrigation, water harvesting and later the wicking worm bed which is undoubtedly the most successful method. These are described in the following chapters.

At that time, it is some thirty years since I conducted those experiments; I had no idea about global warming. With hindsight I now realize that these early experiments had major implication for capturing carbon in the soil.

Part 4 Micro Hydrology

I have already said that the climatic zones have been moving south. Perhaps we can gain a clear realization of how the climate will change over our major food producing area by experiencing the climate further to the North e.g. the dry inland.

The climate of central Australia has evaporation many times rainfall with erratic and dramatic rain storms which when they do occur can result in wide spread flooding.



Gidgee tree (*Acacia Georginae*) in the Simpson Desert, Queensland, Australia

We can learn a great deal about how to modify our agriculture by looking at the vegetation in this severe climate. Despite the ferocity of the climate there is extensive vegetation cover in many areas. At first sight this can be attributed to the extensive array of drought defying tools that the plants have evolved, and no doubt these are important but they are only part of the story.

Sturt and Simpson deserts

Sturt's desert is a barren plain with virtually no vegetation where despite the extraordinary genetic adaptation of these desert plants they are incapable of surviving.

The local micro hydrology plays a critical role in determining whether the desert plants or die.

The Sturt and Simpson deserts have fundamentally different hydrology's. The Sturt desert is a flat hard rocky plain, any rain that falls is absorbed by the top layer and quickly evaporates giving no chance for vegetation to grow.

In fact the Sturt Desert looks like many of our agricultural areas; huge flat paddocks with no trees, nor gullies to catch water. They could not have been designed better to minimize absorption of rain into the soil and maximize evaporation.

By contrast the Simpson Desert manages to support a relatively high level of vegetation with even some quite substantial trees, yet relatively close and in the same climatic conditions.

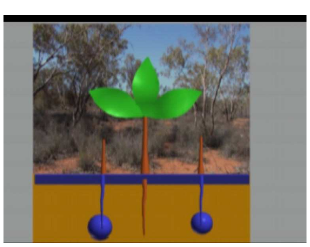
The Simpson has a much more complex structure with the classic sand dunes and clay pans typical of many deserts around the world.

The ground is full of seeds; these are well protected and will make no attempt to germinate until there is a major rainstorm. Within a few days of rain the entire area is a mass of green, the plants will flower and seed within few weeks and then under the fierce sun will die and the desert will revert back to its barren looking state.

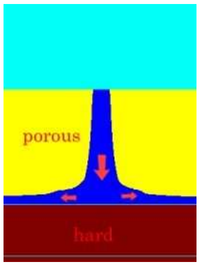
Importance of micro hydrology

Some small trees and shrubs may also germinate and grow for a period when they too will die. The desert is full of dead trees which never make it to full trees. They do however play an important role in desert ecology, their death is sacrificial and enables some trees to grow and survive for many years.

Percolation holes



These dead trees will have put down root system as deep as they can, but when the plant dies the roots die. These roots will either decompose or more likely be eaten out by ant or termites leaving what are in effect percolation holes in the ground. This allows some rain to penetrate deep into the ground where it is protected from evaporation.



In some areas of the desert there will be a layer of clay, possibly sloping, so when the water reaches this clay band it will run horizontally until it reaches an area where it will form an underground pond. Any trees above this pond will put down very deep roots; some acacias have roots hundreds of meters deep so they will grow and even prosper for many years until the next heavy rain.

There is obviously an important lesson here, and examining the causes shows that the plants and the local hydrology have combined together to create underground water sinks which enable the vegetation to survive under these adverse conditions.

The key features are
1) Amplify water into a concentrated area
2) Transport water underground
3) Store water underground to protect from evaporation

We can learn from this natural process which has been going on for millions of years to modify our agricultural practices.

Water amplification

Deserts sacrifice a significant amount of their area to act as collectors of water and nutrients. We can do the same, concentrating our resources into small areas of high productivity.

This conforms to general irrigation experience which shows that trying to poorly irrigate a large area from limited water is a waste of water. The plants may look green but there is no growth. It is far more effective to focus available water into smaller but highly productive areas.

Part 5 Sources of water

Our inland area has traditionally relied on our river system, which have now been fully exploited. But we can look at rain harvesting as an alternative source of water.

This is well illustrated in our eco village where I live. There are no permanent rivers, just ephemeral creeks which flow after heavy rains. There are some small hills but no mountains which would enable the construction of a large dam.

In our area evaporation far exceeds rainfall so a conventional dam would need to be very deep to be effective, say 6 meters deep. But unfortunately the hills and valleys are too small for such a big dam.

Instead we have made many small dams in the dry creek beds and one large dam at the lowest point in the creek. When it rains the water does not rush down the creek but fills up all these small dams. If the rain is big enough all the small dams will overflow and fill the lower dam. But the water in all the small dams soaks into the ground and fills the water table.

We do not even want these dams to be water proof, we want the water to percolate into the ground, using the same mechanism as desert plant survive, store the water in the ground where it is protected from evaporation.

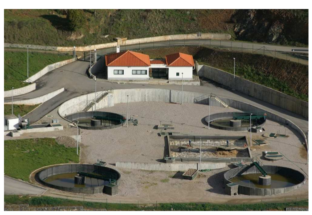
These small dams will soon dry up but there is a lot of water in the soil. When it is dry and we need water we pump from the lower dam and naturally the water levels drops. But as it drops water will soak in from the near by ground. We have pumped far more water than the nominal capacity of the dam.

With such a high evaporation and low rainfall we can only irrigate a small percentage of the total area, but we can use the non irrigated area to grow trees for nutrients to incorporate into the wicking beds.
Here we are growing a combination of Easter Casias, a nitrogen fixing acacia and Tipuana , a fast growing tree.

There is a big advantage in having some land set aside for tree production as it cools the area, increases the humidity and the prospects of rain. Away from the coast much of the rain that falls is from water that has evaporated locally. Clouds may be swept in from the sea but if the conditions are wrong it will not result in rainfall.

Clouds can be readily dispersed by radiation from dry earth. Reducing radiation and increasing humidity can trigger the rain to fall.

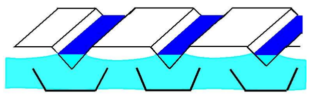
In the Amazon jungle some 70% of the rain that falls is just recycled water that evaporated locally. It is predicted that if the trees were cleared that even though clouds may be swept in from the sea they may not produce rain.



Sewage is a valuable natural resource however there is reluctance for wide scale adoption in agriculture due to health concerns. It is however ideally suited to supply water and nutrients to these ecological trees.

Part 6 The wicking bed technology

Background to the wicking bed system



I had been undertaking some experiments to improve flood irrigation by burying a sheet of plastic under the traditional furrows. This was to stop water soaking into the ground.

I was then asked to visit Ethiopia to see if I could come up with methods of providing sustenance food in drought times. I quickly realized that the problem was not so much a lack of rainfall but more the erratic nature of the rain so there was no water at the critical seed forming period.

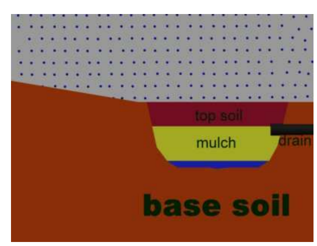
I needed a cheap and easy way of storing water and the concept of the wicking bed was born.

The underlying principle behind the wicking bed system is that subsurface reservoir of water provides nutrient rich water to the plant growing in the soil above. As the top layer of soil is dry there is virtually no evaporation and again water soaking beyond the root zone is avoided under normal conditions (although of course not all the water in a major storm can be harvested).

Just as water in deserts can be collected over a wide area and concentrated into a much smaller area, water can be collected over a large area and stored in the wicking bed.

But also waste organic material can be incorporated into the bed to provide nutrients generated as waste organic material decomposes under controlled conditions. With the correct management a healthy microbiology develops so pathogens are restrained.

Wicking beds can be supplied with water from normal irrigation sources or they can incorporate water harvesting systems.

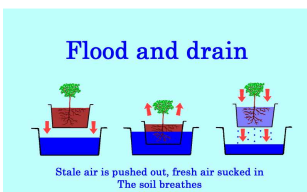


While wicking beds were initially developed as a way of managing an erratic rainfall, experience showed then to be a highly productive growing system.

Virtually all the water is used by the plant with no losses from evaporation from the surface and no loss of water past the root zone. The water concentration varies from totally saturated in the underground pond to totally dry at the surface. There is always a layer with just the right combination of water and air to give maximum growth

In conventional irrigation we water from the surface and have to wait for the water to soak into the ground, the water on the surface is lost by evaporation and if too much water is applied water and nutrients are lost to the soil below the root zone.

Water applied to the surface does not necessarily wet out the soil properly. If there is a fissure in the soil the water will pass right by without wetting the soil.



The wicking bed system is a bit like the old flood and drain system as water is forced into the pores of the soil or matrix ensuring that it is totally saturated. There is a natural cycles as the water is pumped in and used by the plants refreshing the soil air.

Applications

The basic principles are common to all wicking beds systems but there are many different methods of application.

The simplest wicking box may look very limited, it has however proved an invaluable tool for research to help understand how the wicking system actually works and has also been widely adopted by home gardeners with limited space. The box is half filled with organic waste then topped up with soil.

A pipe carries the water to the bottom of the box and drain holes ensure the soil layer does not flood. Food production from boxes is limited so in ground wicking beds were initially widely adopted.

However in our high summer rainfall areas with heavy clay soil there is a danger that the water cannot drain away fast enough. This has lead to the semi raised bed systems.

The top soil is skimmed off. This is very quick by setting the width of the bed to the size of the bucket in a small tractor.

The plastic sheet is laid in the bottom. The level may be checked by filling with water. The bed is then filled with organic waste and the top soil replaced above the normal ground level.

Many gardening groups do not have machinery for earth moving so they prefer above ground beds. Here a group of parents are helping install a wicking beds system at the local school.

Using an underground pond the soil is totally saturated (as opposed to being at field capacity). We used scrap organic matter, which is very coarse with a large void content so a large amount of water can be stored and yet be readily available to the plant.

Using coarse organic matter means that air, essential for good growth is available for the roots. It also helps fertilize the soil as it degrades and improves the quality and texture of the soil.

Many crops can be grown in the open in long rows; however Queensland is sub tropical with hot humid summers which creates ideal conditions for pest, pathogens and particularly insects.

Many growers prefer shade houses which cuts out directs sunlight and provides insect protection. The raised beds are less sensitive to soil pathogens.

There are many variations of the wicking bed. Here we are planting trees into heavy clay. We do not want the roots to be immersed in water during heavy rains so we use a raised bed. On first planting we make a water pond around the tree so we can water the tree while it gets established.

Under the tree we have a base of organic material which acts like a sponge to store water and is filled by a pipe. We do not use a plastic liner as the tree is deep rooted and will put down deep roots to use any water that soak into the ground below the underground pond. When the tree is established with deep roots we only water through the pipe.

Another method of watering trees is to use a water reservoir alongside the tree.

Narrow wicking beds can also be placed alongside a row of trees relying on the water to wick up and move side ways. Water storage is reduced but it makes a very practical irrigation system.

Part 7 Carbon capture

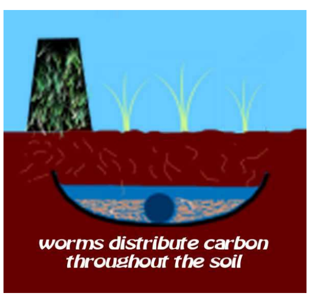
Plants absorb some thirty times all man made emissions. So why do we have a problem with rising carbon dioxide levels. The simple answer is that dead plant material are made from complex organic molecules which quickly break down either by UV degradation or by aerobic microbiological action which releases much of the carbon back to the atmosphere as carbon dioxide.

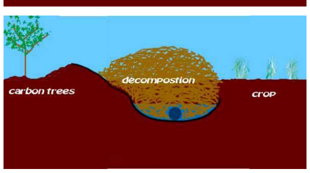
We have a dynamic state in which large amounts of carbon are extracted from the air and then rapidly returned. The net amount of carbon in the atmosphere is determined by the rate at which carbon is being absorbed and returned to the atmosphere.

With dynamic equilibrium we do not need to store the carbon permanently all we need to do is to slow the rate of carbon being returned to the atmosphere. The normal degradation processes of UV degradation of aerobic decomposition are fast so the carbon is only captured for may be just few weeks.

However if the organic material is decomposed away from sunlight in dark humid conditions decomposition will be fungicidal and the waste products further processed by worms which will lock the carbon into the soil for many years.

The wicking bed system has an advantage that we are just beginning to appreciate; - carbon can be captured in the soil. It is a sad reality that the easiest way of making quick money from agriculture is to use large quantities of artificial fertilizers. This however leads to soil degradation and eventually the soil will no longer be productive however much fertilizer is added.

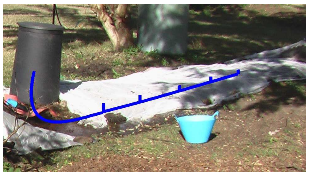




Sustainable agriculture is achieved by building up a well balanced soil structure with a high organic content. Economically, in the short term, this simply cannot compete with applying tonnes of fertilizers.

However farmers using such sustainable practices can absorb large amounts of carbon from the atmosphere. This provides one of the few genuine methods of resolving global warming. To have this recognized at the international level so farmers can get paid for removing carbon from the atmosphere would be a major achievement in the battle against global warming.

Biodegradable material can be added using a compost bin, in piles or in pipes covered by plastic sheet or soil.



Watering the biodegradable material pushes the decomposed material down into the water reservoir where it wicks up to provide nutrients to the plants. Worms will move along the reservoir distributing material and forming a porous matrix.

Paying farmers to absorb carbon ensures our future food supply and offsets our energy use.