Safeguarding future food supply

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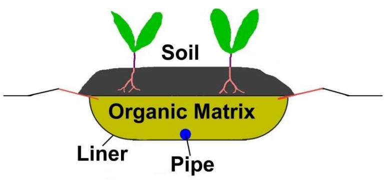
1.1 Summary

Wicking beds have many benefits, they are a successful way of growing crops with limited water, they improve soil quality and make better use of nutrients and have the potential to absorb large amount of atmospheric carbon.



Wicking bed with water catchment wings

They have significant potential in both reducing climate change and adapting to the anticipated flood and drought cycle.

The negative to date has been that they are labour intensive to construct which has limited their use to environmentally sensitive growers operating on a small scale.

The aim of this project was to develop a method of easily and cheaply installing wicking beds on a large scale.

An existing orchard was converted using multiple wicking beds linked together with overflow pipes down the slope. Pipes are the major cost of wicking beds so alternative cheaper methods of construction were trialed using wood chips, bamboo pipes, sticks covered with film and bubble wrap.

All system were effective if slow fill rates were used making final selection an issue of cost and availability of raw materials and ease of automation.

The improved water use efficiency of wicking beds has been well established but was not demonstrated in these test as yet as the long drought which has affected Australia for many years has broken with extensive flooding and consequent loss of crops.

An unexpected benefit was shown when the linked wicking beds provided an effective drainage system preventing the roots becoming water logged for extensive periods of time which would destroy the plants.

1.2 Background

The world's population continues to increase expecting to rise to 9 billion within the next 50 years placing greater pressure on our food production resources. On the other hand agriculture, particularly in the developed countries has steadily improved in efficiency at between 2% to 3% per year which in the past has more than compensate for the increased population.

Climate change, with the anticipated increased flood and drought cycle will require farmers to adapt to these changed weather conditions. Violent weather has catastrophic effects on food production, as demonstrated in Australia where years of drought led to reduced food production. The drought was broken by excellent rains which initially led to some of the best crops in years which were then largely destroyed by floods and heavy rains. This damaging effect of flooding appears to be equally devastating as drought.

Food production is and will be the critical issue with climate change. Wicking beds can both reduce atmospheric carbon levels and assist growers to maintain food production with the more violent flood and drought cycle. To be effective they need to be adopted on a large scale which requires developing the technology so it is both cheaper and easier to implement.

This is a provisional report of trials to expand the technology for low cost wide scale application.

1.3 Introduction – technology basics

The wicking bed technology was initially developed over ten years ago to solve the specific problem of lack of rain during the critical periods when seed heads fill out. An underground water reservoir, lined by a plastic sheet, fills with water which can wick up to the root zone above.

In the second generation the water reservoir was filled with waste organic material which would slowly decompose so the plants fed on a nutrient rich compost tea.

In the third generation inoculants of fungi and worms were coupled with the addition of nitrogen to control the decomposition process to improve soil quality and production even further.

It was then realized that this was a particularly effective way of embedding large amount of atmospheric carbon into the soil.

Plants are already absorbing some thirty times all man made admissions but unfortunately most of the carbon is rapidly returned to the atmosphere. The controlled decomposition in wicking beds embeds the carbon into the soil providing an effective way of reducing atmospheric carbon.

This technology is now widely adopted by many environmentally sensitive growers but on a small scale. Widespread adoption requires the solution of two key problems, first it must be developed for large area application at a low cost and secondly it must be accepted for carbon trading so the grower receives money for absorbing carbon.

This could then largely offset current man made emissions. For example China could offset its entire emissions if some 17 million hectares of land were converted, approximately one third of China's irrigated farmland. If other developing countries were to adopt this technology large quantities of carbon credits would be created which could be traded into emitter nations.

See www.waterright.com.au/resolving_climate_change.pdf

1.4 Aims of current research project

The aim of the current research project is to find a way of applying the wicking bed technology to large areas at an economic price and to establish a mechanism for carbon trading involving millions of small growers around the world.

The combination of low cost and revenue from carbon trading would make it economic for farmers currently using flood irrigation to upgrade to this simple but effective technology. Flood irrigation is the largest user and waster of water world wide.

1.5 Early conclusions

There are several options for large scale applications. Multiple beds can be linked together by a system of beds along the contour with interconnecting pipes down the slope.

Automation is needed to create the beds. The most promising at this moment appears to be a simple rotating wheel attached to the three point linkage on the back of a tractor (see schematic). This would dig the trench which would be lined with the plastic film, lengths of bored out bamboo or sticks placed in the channel, covered with a narrow film of plastics as a dirt shield, then the trench filled with organic waste and the trench graded level with a blade.

These trenches would be along the contour line, while a second set of trenches would be formed down the slope lined with pipe (either plastic of bamboo) with a small hump to divert the flow into the contour trenches.

A second possibility is to plough bubble wrap into the soil with a modified pipe layer.

A major advantage of this system is the drainage component in times of flooding.

2.0 Details of trials

Trials were carried out at Kookaburra Park Eco Village, near Gin Gin (near Bundaberg) in Queensland, nominally classified as the dry subtropics.

Many traditional wicking beds had been constructed previously and typically consisted of single beds which could be up to 20 meters long and 1.5 meters wide. This width is convenient for vegetables allowing easy access to plants.

Typically a 90 mm storm water pipe is used to distribute the water along the bed. Although highly effective there is significant cost (about $4 per meter) which would make this uneconomic for large scale application. Finding a low cost alternative for distributing the water is one of the objectives.

Alternative flow channels

Several alternatives to the pipes were tried. These included hollowed out bamboo covered with PE film.

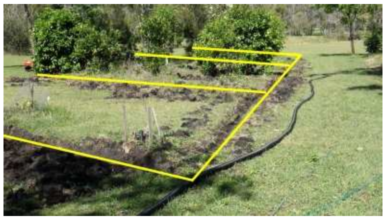
Random sticks essentially prunings about 0.5 meter long and covered with PE film gave an irregular but still very effective flow channel but were time consuming to collect, cut and lay.

Plastic bubble wrap (folded so allowing water to flow between the bubbles had lower flow rates but was better suited to automation

Sticks laid onto bubble wrap which was then folded over the sticks gave very efficient water transport and only needed a few sticks for efficient flow.

Open fillings such as wood chips were also tried in combination or by themselves.

Linking beds together



The second aim was to link many beds together so multiple beds can be irrigated simultaneously. It was felt that an area of about half a hectare for each system would be economic e.g. linked beds 50 meters wide and covering 100 meters long. An existing orchard was used for these trials.

The trees comprised mature citrus (grapefruit, orange and lemons), and younger mangoes, lychee and other subtropical fruits.

Wicking beds should ideally be located along a contour, the existing trees were generally but not totally located on a contour so there was some compromise. The beds were also not of uniform length. Again this was not ideal, but very much the sort of problem likely to occur in practice.

The first step was to dig channels very much like a traditional furrow irrigation system, except the furrows were along the contour e.g. had no significant slope. (Contour channels). These were connected by channels running down the slope. (Slope channels).

Naturally if water were applied to the slope channels it would simply run down that channel with nothing to direct the water into the contour channels.

A small plug of earth or hump was used to half block the slope channel just below each junction. Water would then run down the slope channel, hit the earth plug, fill the contour channel which would fill and then overflow the plug so water would flow down the slope to the next contour channel

Now if I can break with scientific tradition and use the first person I did this work myself and had to go into hospital for an operation on my right arm which meant the experiments were on hold for some months. During this period the system was operated as a contour furrow system where it performed very well. However this was largely due to the heavy black clay which is very impermeable. With a more porous soil there would have been a major loss of water by infiltration into the ground.

A flow rate of 20 liters per minute was used to fill the channels, this was adequate to irrigate with the heavy clay soil without excessive loss. A more porous soil would have required a much higher flow rate.

On my recovery the channels were converted to wicking beds by lining with plastics film. From a strict scientific experimental view all the contour channels should have been identical however for practical reasons channels with the various types of water transport were trialed in one system.

It also has to be admitted that I had to finalize the channels while my right arm was recovering from the operation so they were far from the perfect shape and precise measurement. The initial attempt was to cut the PE film to the required width so it could be laid directly into the channel. The theory was to lay the plastics into the channel then fill with water and ensure the plastic was uniformly some 10 mm above the water level. As the channels were far from accurate this meant significant fiddling, increasing or decreasing the width of the channel until the plastics was at the required level; - clearly impractical on a large scale.

Had the channels been machine dug and the plastics laid automatically the results may have been successful.

However (working under the constraints of my arm) an alternative approach was adopted by cutting the plastics wider than needed. The water flow systems (sticks, bubble wrap, wood chips etc) were then laid into the channel which was then partially filled with organic material then filled with water. The excess plastic was then simply crunched down to the required level by foot.

This sounds and is crude but it worked in the circumstances.

The slope channels were converted to pipes, using 50mm corrugated pipe, with the inlet pipe entering at the upper side, essentially at the level of the top of the wicking bed plastic and the outlet pipe resting on the earth plug sealing against the plastic film.

2.1 Findings

The initial plan was to test out the hydraulics first then operate the system to monitor plant growth and productivity, the ultimate test.

The tests were started in our normal dry season but we experienced heavy rains (frequent storms of over 200 mm in one day) and realized that the system also provided an excellent drainage system in post flood conditions.

Rainfalls of 200 mm a day create sheet flooding which no drainage system can cope with however plant roots will happily tolerate a short emersion as long as the water can be drained away quickly after the flood. Long immersion will kill most plants.

The high flow system using sticks could transport water at a far higher rate than the 20 liters per minute which was initially applied. This meant that the contour channel would completely fill then the full flow would be diverted to the overflow slope pipe.

Bamboo was even more effective but is not readily available in Australia.

The channels with bubble wrap and wood chips had much more resistance to flow and could not handle the initial 20 liters per minute flow rate so water would over flow into the slope pipe very quickly before the contour channel was filled.

This only had a head of some 10 mm feeding the relatively small 50 mm pipe which was inadequate with that flow rate resulting in the channel overflowing.

The inlet flow was then dropped to 5 liters per minute which solved both the overflow and low flow rates along the bubble wrap and wood chip lined channels.

As an experiment one channel had simply been filled with wood chips without a PE liner. The basic principle of flood irrigation is to get the water on as fast as possible before it has a chance to soak deep into the ground. This unlined channel with the low flow rate failed as the leakage was too high with the low flow rate.

One channel had been simply filled with bubble wrap (folded to make a flow path) and back filled with the virgin soil. This was trialed because this system could be easily automated using a modified pipe layer. Again this worked very well showing that there was a way of laying large area of land quickly and cheaply. This does not take directly advantage of the organic material for improving soil structure and nutrient level or embedding carbon into the soil. There may however be other ways of applying the organic material.

Two channels had been left as traditional open furrows. These proved to be a major problem preventing machinery from cleaning up weeds so they were converted to wicking beds filled with organic material.

2.3 Open and closed beds

Wicking beds can be open or closed. In a closed wicking bed the plant are grown in the bed where they have easy access to the water; however they are limited to shallow rooted plants such as vegetables.

Open wicking beds are used to irrigate deeper rooted plants; the plants grow along side the wicking bed so the water has to wick upwards, then move sideways after which it can soak down to the root zone.

These trials mainly used the open wicking bed system. (see www.waterright.com.au/wicking_bed_technology).

One bed however was a combination system. The bed was wider, e.g. 1.5 meters growing vegetables but with fruit trees growing just outside the bed. This combination system allows better use of land and proved successful.

All the other beds were much narrower, about 0.5 meters and purely used for irrigating the trees.

However it was decided to grow a cover crop in and around the bed. The real reason is weed control. These trials were conducted in the dry subtropics (25 degrees); the hot dry climate with periodic heavy rains encourages both weeds and insects which are a major problem for growers. The best way of controlling the weeds is to grow a cover crop such as a creeping grass like kikuyu or a legume and mow. An aggressive cover crop will out compete the weeds and improve soil quality. There is however a further advantage.

Wicking beds rely on surface tension to transport the water. Surface tension forces are relatively weak depending on the pore size and surface chemistry (hydrophobic or hydrophilic soils). While plants also use capillary action the combination of evaporation from the leaves and intermolecular forces generate much higher forces. Individual water molecules have a great attraction for each other (as seen in water droplets) so in a narrow channel they essentially act like a chain with a high tensile strength.

As the water evaporates from the leaves it literally pulls the water upwards. These are very strong forces enabling plants to grow many meters tall. During the day the sunlight provides the energy to lift the water from the soil or wicking bed but at night there is no driving energy so the water will flow back down into the soil. It does not necessarily go back down the same route but will follow the easiest path. This day and night or diurnal cycle has the effect of moving significant quantities of water both over distance and between plants.

2.4 Which is the best system

The simplest system is to simply fill a lined channel with waste organic material. This does have reduced flow so the length of the bed it limited and more slope lines would be required.

The most cost effective system, if adequate supplies of cheap labour and quantities of pruning or bamboo are available, is to use a simple liner with bamboo or sticks covered with film. This has excellent flow characteristics.

Systems using bubble wrap are the easiest to automate for large areas.

3.0 Adapting to climate change

In an ideal world carbon emission could be absorbed by using wicking beds. However this would require international trading with developing countries absorbing large amounts of carbon with the offset being traded with the developed countries.

This is technically and socially very desirable, solving the emissions problem and achieving a better balance between rich and poor people.

However desirable this may be there is the question what happens if there is no such international agreement and we are forced to adapt to climate change, specifically the flood and drought cycle.

In the Gin Gin region this is nothing new. The natural climate is erratic with no reliable rainfall. It is common to go for six months without rain. More likely is the odd shower of 10 to 15mm. With an evaporation of eight to twelve millimeters per day these small showers have virtually no impact, never penetrating into the soil and evaporating in a day or so.

The rain we get is essentially freak rain, typically the tail end of a cyclone where we can get 200 mm in a day. These rain depressions usually last for about three days then the normal blue sky with high evaporation returns. In winter we may get a storm from the South which is less but still severe. Reliable regular rainfall as occurs further south is uncommon.

Nevertheless growers have learned to adapt. Swales running around the contour lines, to catch the rainfall, are common. They are formed by digging a ditch and piling the earth into a ridge. Often trees are planted on the ridge to avoid water logging.

In a heavy soil plant are easily killed by water logging if planted into flat ground. Planting onto a ridge keeps some of the roots dry so even though the deeper roots may be killed off the plant survives and soon re-grows the deep roots.

Farmers adopt an opportunistic approach, growing crops when conditions are good and leaving the land fallow in droughts.

In our eco village we have constructed dams to store water and use leaky dams and swales to slow the water and give it time to soak into the water table. We protect the ground from erosion by gentle spillways and using deep rooted grasses.

In general we have managed to adapt quite well to the normal flood and drought cycle.

3.1 An exceptional year

This year, when the trials were being conducted conditions were certainly very different to normal.

We had a long period of severe drought lasting some ten years; this is amongst the longest droughts on record. It is quite common to have several years of drought and our systems of dams cope quite well but were totally inadequate for a drought of this length.

Normally a drought breaks with a major storm often with widespread flooding. The floods can be damaging but do not last long and fill the dams.

The weather we have experienced is very different to this typical cycle.

If all the other freak conditions of flood and drought around the world are considered it seems probable that we are already experiences the effects of climate change and this long drought followed by a series of severe storms is an example of condition we have to learn to adapt to.

There is nothing much you can do to protect against a 200 mm per day storm. Some areas are just a sheet of water and no drainage system can cope with that volume of water.

While the drainage flow may be relatively small the water around the wicking beds had drained away in ten hours while the other areas remained flooded for days.

In a normal year the storms would only last for two or three days followed by a dry periods which are excellent conditions for agriculture.

This year we had a series of major storms, even when there was no storm there was still heavy rain. The net result is that the ground has been continuously saturated for long periods of time. Some plants, where the drainage was not good enough, have died from continuous immersion.

The long drought was particularly bad for farmers however the excessive rains was disastrous as some of the best crops for years were ruined yet they had borne the early cost of seed, fuel and fertilizer early in the year for nothing.

This has been ideal for weeds to grow and the ground has been so wet that it has been impossible to get any machinery out to control these weeds.

We have also had major problems with rusts, fungi and rots which have badly damaged some crops. The steady rains and high humidity has caused excessive growth, particularly vegetables which have simply bolted and gone to seed and are useless.

These are new problems we are likely to have to learn to cope with climate change.

The wicking bed system was originally developed as a way of growing crops with limited water. It now appears that the accidental discovery of the drainage capability may be of major importance in adapting to the flood and drought cycle we can expect with climate change.

Conclusions

Climate change, with the anticipated increased flood and drought cycles present a severe threat for the future. The wicking bed system has the potential to mitigate climate change by embedding large volume of carbon into the soil. This requires international agreement which will require submitting independent scientific evidence to the negotiators.

If, as is feared there is no international accord on reducing atmospheric carbon levels, we will have to learn to adapt to a more severe drought and flood cycle. Wicking beds which use less water and can store water at least for short periods now have the ability to provide drainage offer a way to adapt to these adverse agricultural conditions.

It would appear that the previous limitations of cost of installation on large scale projects can be overcome.

A twin research approach is required to provide scientific data on the amount of carbon absorbed and to refine the technology of large scale low cost application.

If these two objective can be met we may have the solution to what has been described as the greatest moral challenge of our age.