Conservation Agriculture - Mulching
Comparing the effectiveness of natural loose mulching materials and fibre based matting applied to untreated soil in preventing loss of soil moisture compared to traditional tilling of soil.
Abstract

In the developing world, and particularly more arid areas, where subsistence farming is the norm, farmers are locked in a cycle of poverty; farming land that is slowly being degraded and depleted. At the same time, population growth and climate change are creating increased pressures for farmers to find ways to make their land more productive. The practise of 'Conservation Agriculture', (CA), as defined by the FAO, (Food and Agriculture Organisation of the United Nations), (J.Kienzle 2015) seeks to promote sustainable and profitable agriculture by minimal soil disturbance, permanent soil cover and crop rotation. The focus of this Science Research Project was in the area of conservation of soil moisture. One of the main problems faced by farmers adopting 'CA' is to obtain sufficient suitable mulch material to maintain continuous soil cover to maintain soil moisture and minimise weed growth.

The aim, of the experiment was to compare the rate of soil moisture loss, from evaporation, for soil samples treated with corn husk mulch, as currently adopted by African CA farmers, (S.Bunning 2015) with alternate mulch materials, including hemp matting and coir, and also with traditional tilling, against untreated and untilled, ‘control’, soil samples. Alternate mulch materials were selected based on potential practicality and cost. The growth of weeds was also observed throughout the experiment.

Polystyrene boxes were lined with waterproof plastic sheet to prevent water draining from the samples. Soil, prepared as a single homogeneously mixed batch of potting mix and composted garden soil. Garden soil was incorporated into the mixture, to simulate farm soil, as there is a high probability of it containing a variety of seeds of weeds and other plants. The boxes were filled with the soil to the same level. The soil was then evenly compacted, to simulate settling that normally occurs over time, and left to further settle for 1 week prior to any soil treatment being applied. To minimise the chance of error, 3 sets of 5 boxes were prepared to allow 3 samples of each of the 5 different soil treatments to be tested. The soil treatments were applied as follows:

1. No tilling and no mulch (ie untreated control)
2. Standard tilling – soil turned and any initial weeds removed.
3. Corn husks applied as a bed approximately 2cm thick.
4. Coir mulch applied as a bed approximately 2cm thick.
5. Hemp based matting applied as a single woven sheet in the manufactured thickness (approx. 1cm).

The boxes were arranged in an array of 3 x 5 boxes. Each of the 3 samples of each type of soil treatment was placed in a different part of the array to ensure that variations in conditions across the array was negated as a possible factor that might affect results.

Application of moisture to the soil was managed by pouring exactly the same volume of water into each soil sample. If rain was imminent, a large, clear plastic sheet, was suspended over the boxes to shelter them. The weather during the period of the experiment was one of the driest periods on record and so rain events did not become a factor that affected results.

The experiment was conducted in Sydney, in February and March, in hot, dry weather with long periods of direct sunlight, little cloud and daytime temperatures above 30°C and 20°C at night.

Each sample was observed over a period of 12 days and the soil moisture measured daily with two different instruments. ICT Data logger and MP406 soil moisture sensor and Decagon 5TM soil moisture sensor and hand meter. The MP406 measures soil moisture as a percentage. Air is 0% and pure water is 100%. The 5TM measures volumetric water content in m³/m³ of water to solids and air. It was found that the 5TM measures 0m³/m³ in air and 0.5m³/m³ in pure water.

The graphed and tabulated results confirmed the hypothesis that mulching the soil is more effective in retaining soil moisture compared to either tilling the soil or leaving the soil untilled. Coir was found to be the most effective in retaining soil moisture. Results also showed that, if no mulch is applied, tilling the soil resulted in better soil moisture retention than not tilling the soil. This could be because, in tilled soil, water can sink more deeply into the soil while the upper layer dries and has a lot of air pockets that may have an insulating effect. To prove this theory, further investigation is required. Weeds appeared first in the untilled soil samples. By the end of the experimental
period, Some weed growth was also apparent in the tilled samples as well as the sample treated with corn husk mulch. The samples treated with Coir or Hemp matting showed no signs of weed growth during the experiment.

**Introduction**

In agricultural crops all over the world tilling practices and techniques are utilised. However, who can determine what tilling method conserves the most moisture. Soil tillage refers to the method of soil preparation for seedbed preparation, sowing or transplanting, and for crops’ growth (Pan, 2015). Mulching of the soil refers to materials placed over the soil surface to maintain moisture and improve soil conditions (International Society of Arboriculture, 2011). My focus was the tilling method that is encompassed by farmers in Africa. They use a tilling method that requires the farmer to turn the soil with a shovel. This is supposed to remove the weeds and conserve some moisture. However, there has been a debate whether tilling the soil reduces the moisture because it would result in the soil become more looser and having a bigger surface area. I am determining how no tillage and tilling compares to mulching techniques such as corn husks, coir and hemp. No tillage and tilling (turning the soil) are common practices undertaken by farmers in developing countries. Corn husks, hemp and coir are trial mulch techniques to determine the effect they have on the moisture within the soil. These materials are all inexpensive and abundant in these areas. The questions under evaluation in my report are the difference between tilling and various types of mulching and does one significantly conserve more moisture than the other? Whilst conducting the experiment I will also observe how sunlight, weather, insects and weeds can impact and play a vital role on the moisture of the soil. These ideas are expected to be consolidated and possibly answered by the end of my experiment.

**Lack of Crops and Water**

The lack of crops and water in developing countries has had an immense impact on the sustainability of the country (Lean, Hinrichsen and Markham, 1990). The lack of crops makes it nearly impossible to produce food and has resulted in a number of famines. The absence of education on the structure of soil and lack economic resources like high quality seeds and fertilisers have worsened this case. Pests have destroyed over half of all world crop production. Water is vital to both plants and animals. Plants need water to transpire and to carry nutrients from the roots up through the stems to the leaves, flowers, fruits and seeds. It is also necessary for processes such as photosynthesis so that the plant has enough energy to grow stems, leaves and roots and produce fruit and seeds.

**Types of Tillage**

On-season and off-season tillage contain a variety of different techniques and are performed at two different times. On-season tillage operations are done for raising crops in the same season or at the onset of the crop season. It involves the deep opening and loosening of soil to uproot weeds and crop stubble when the soils are in a workable condition. It can also be carried out in the standing crop after the sowing or planting prior to the harvesting of crop plants including weeding, hieing, harrowing, earthing up and drilling. Off-season tillage operations are completed in order to condition the soil suitably for the coming main crop season. They are intended to serve specific purposes such as breaking the hard pan beneath the plough layer to reduce compaction, controlling weeds, supplying sufficient puddling water on dry land and dry land germination for plants that don't require sufficient moisture. Tillage reduces soil erosion by as much as 60% depending on the tillage method and amount of residue left to shield soil from rain and wind. It reduces soil compaction that can interfere with plant growth, reduces potential air pollution from dust and diesel emissions and decreases the farmers expenditures on fuel and planting because fewer tractor trips across the field are required.
Conservation Tillage

Conservation Agriculture, (CA) is an organisation that has minimised the use of resources to maintain and improve soil health. In developing countries such as Kenya and Tanzania, in Africa, where farming is still largely done by hand, with limited tools, without equipment such as tractors, without irrigation, reliable rainfall or other water sources, fertilisers, or expensive chemicals such as pesticides and herbicides. Farmers here also lack education.

One of the main techniques employed in conservation agriculture is to plant seed with minimal soil disturbance. Tilling breaks up the compacted surface soil and removes the plant stems and roots from the previous crop, to allow new seedlings to spread their roots more easily. It initially also removes competing plant species, (ie weeds), and allows air and water to penetrate further into the soil. Apart from being extremely labour intensive, vital top soil with nutrients can be more easily blown away in dry windy weather. Also, rain causes heavier compaction of tilled soil resulting in increased runoff and soil erosion. Research has shown that it is possible to plant and grow new crops with minimal soil disturbance (FAO, 2015). It has also been shown that soil moisture can be preserved and nutrient levels increased by application of a layer of mulch over the soil. AgriLife Extension 1915, based in Texas, America, state that:

“The earth’s crucial thin layer of soil must be protected, maintained, built and nourished. A mulch cover of various materials on soil enables, conserves and enhances the world’s delicate soil.”

In Africa, one of the most common crops is corn (Ortiz-Torres, 2006). The most readily available and lowest cost material for mulching the soil is the residue, (husks and stalks), from the previous corn crop. These husks can harbour pests and diseases that could infest the next corn crop to grow. As it is necessary for farmers to produce a crop from their land every year, it is not always possible to rotate crops to break pest and disease cycles. What are the alternatives?

The increased surface area of the crop would have made it easier for the moisture to escape from the soil. This affected the reliability because the measurements might have been based on the consistency of the soil rather than the actual moisture of it. This inconsistency in a crop would have resulted in the top soil being blown away. The mulch protects the top soil significantly compared to the non tilling and tilling methods.

Main Objectives of Tillage

To achieve this the soil is opened up and turned over.

• To prepare a good seed bed which helps the germination of seeds.
• To create conditions in the soil suited for better growth of crops.
• To control the weeds effectively.
• To make the soil capable for absorbing more rain water.
• To mix up the manure and fertilisers uniformly in the soil.
• To aerate the soil.
• To provide adequate seed-soil contact to permit water flow to seed and seedling roots.
• To remove the hard pan and to increase the soil depth.
The Importance of Conversation Agriculture in Africa

Fig 1: Erosion and loss of nutrient in semi-arid Africa.

Fig 2: Tilling the soil in Kenya

Fig 3: Conservation tillage aims to minimise disturbance of the soil when planting.
Fig 4: Educating the locals on the importance of Conservation Agriculture.

Fig 5: Need to get more farmers to understand the techniques and benefits of CA.
- “We need to capture more farmers because now some farmers are left unattended.”
- “You should believe that this is your office, with which you are able to sustain your family.”

Fig 6: Weed growth with Conservation Agriculture. The use of mulch would be beneficial.
Fig 7: Weeding is done manually if farmers cannot afford the chemicals. This is hard work.

Fig 8: Crop residue is used to mulch the soil.

Fig 9: Mulching improves soil moisture and fertility, leading to sustainably greater yields.
Fig 10: Erosion, continuous cropping and cattle feeding on residues reduces soil quality so...
- “That is why we should reflect on alternatives for soil fertility restoration...Conservation Agriculture is one possible alternative”

Fig 11: “With conservation agriculture I can now harvest two, three or four bags.”

Fig 12: With conservation agriculture a lot more produce is able to be collected.

Fig 13: Farmers struggle find material to maintain a permanent ground cover. Mulch is the biggest problem. People take crop residues.
- “People from here are not sensitised and will take the crop residues...Every harvest you have to leave the residues on the plot...The problem is that people do not know the value of the residues on the plot”
Fig 15: What is the impact of different amounts of mulch on the qualities of the field? “Can the qualities be maintained with smaller amounts of mulch?”

Fig 16: “So, we really have to intensify agriculture, because these systems are still mostly extensive”

Fig 17: CA supports sustainable intensification of agriculture vital to support the world’s growing population. The greatest benefit is soil health.

ACT brings together stakeholders dedicated to improving sustainable agricultural productivity.
Fig 18: The African Conservation Tillage Network (ACT) is a pan-African not-for-profit organisation.

Fig 19: ACT promotes and supports Conservation Agriculture adaptation and adoption, collecting and sharing scientific facts.

Fig 20: They support farmers and the creation of multi-stakeholder platforms to search for joint innovations.
Types of Mulching

A mulch is any material placed on the soil surface to conserve moisture, lower soil temperatures around plant roots, prevent erosion and reduce weed growth. Mulches can be derived from either organic or inorganic materials. The insulation and protection from mulch prevents evaporation of moisture and enables plants to grow more evenly. They break the force of rain and irrigation water counteracting erosion, soil compaction and crusting. It absorbs water faster, prevents splashing of mud, plant diseases. Some examples of mulch include: chipped branch wood, meadow/grass clippings

Nitrogen in the soil

“If [maize is] alternated with legumes, soil fertility is improved because legumes fix nitrogen in the soil…This calls for farmers to adopt conservation agriculture because, among others, it improves soil structure, water retention, organic matter content and fertility. All these lead to higher and more stable yields.” says Chilenga. (Msiska, 2016)

Aim

To compare the effect of traditional soil tillage to various types of mulching of the soil on water absorption and retention in the soil

Hypothesis

Mulching of the soil with coir will result in greater retained soil moisture compared with other methods of tilling and mulching the soil.

Risk Assessment

<table>
<thead>
<tr>
<th>Step 1: Identify the hazard</th>
<th>CSIS User code (for chemical s only)</th>
<th>Step 2: Strategies to minimise the hazard</th>
<th>Step 3: Assessment of risk (see table below)</th>
<th>Step 4: What if something goes wrong?</th>
<th>Step 5: Packing up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity Description: Testing different tillage techniques to determine their effect on soil</td>
<td></td>
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<tr>
<td>Water, plant matter and mud spillage causing falls and slips</td>
<td>na</td>
<td>Ensure that the experiment is conducted on non-slip surfaces where water and mud cannot pool. Ensure that the ground around the experiment is swept and kept free of dirt and plant debris</td>
<td>Consult a responsible guardian immediately. Wipe the spillage with paper towels immediately to ensure that no further accidents proceed.</td>
<td>Once equipment is clean, dry and packed away ensure the ground is completely dry</td>
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<td>Glassware can break and cause cuts</td>
<td>na</td>
<td><em>Place glassware away from edges of benches.</em> Do not leave on the ground where it may be accidentally trodden on. <em>Keep outer surfaces dry to minimise slipperiness.</em> <em>Place glasswear in a protective container after use to minimise the chance of accidental breakage.</em></td>
<td>In case of breakage consult teacher. Empty glassware, brush up and place in 'broken glass' bin. Wipe up any spills. If cuts occur, seek first aid.</td>
<td>Clean, dry and pack away carefully</td>
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<tr>
<td>Infection from soil and water borne bacteria and viruses.</td>
<td>Wear strong gardening gloves and closed shoes when working with soil. Thoroughly washing and drying hands after experimental work. Keep hands away from nose, eyes and mouth when working with soil. Observe health warnings on bagged compost/potting mix before use.</td>
<td>Flush dirt away from face and eyes with clean water. In case of any skin graze or cut clean immediately with antiseptic solution and apply a waterproof bandage or band-aid with antiseptic cream. Immediately report any signs of redness or soreness on or under the skin or around joints or glands.</td>
<td>Clean, dry and pack away carefully ensuring that there is no contact with infection.</td>
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<tr>
<td>Inhaling the soil and mulch</td>
<td>Observe health warnings on bagged compost/potting mix before use. Always wear gloves when handling soil, potting mix or compost. Keep hands away from nose, eyes and mouth when working with soil. Avoid inhaling the mix by wearing a facemask. Keep soil and potting mix moist to minimise the chance of causing airborne dust.</td>
<td>Flush dirt away from face and eyes with clean water. Immediately report any sign of ill health over the weeks following exposure and mention exposure to soil as a possible cause. Seek medical attention.</td>
<td>Wear a facemask to pack up and wash your hands thoroughly after contact.</td>
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<tr>
<td>Condition</td>
<td>Action</td>
<td>Risk Level</td>
<td>Notes</td>
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<tr>
<td>Allergic reaction to plant or</td>
<td>Make sure that you are aware of any allergies you may have</td>
<td>MODERATE RISK</td>
<td>Wear gloves and try and avoid contact with skin</td>
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<td>soil matter.</td>
<td>Wear gloves and try and avoid contact with skin</td>
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<td>Wash hands thoroughly after usage</td>
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<td>Immediately stop procedure and wash hands thoroughly</td>
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<td>Seek medical attention and treatment</td>
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<td>Wear gloves and a facemark to pack up.</td>
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<td>Ensure that no further plant or soil matter remains.</td>
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<tr>
<td>Sunburn</td>
<td>Wear a sunscreen with a sun protection factor (SPF) of 30 or higher</td>
<td>MODERATE RISK</td>
<td>Put a cold, damp towel on your skin.</td>
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<td>Wear clothing that covers the skin and hats with wide brims</td>
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<td>Consult a reliable guardian</td>
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<td>Seek medical attention</td>
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<td>Report any sign of ill health over the weeks following exposure and</td>
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<td>mention exposure to sun as a possible cause.</td>
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<td>Proceed with pack up after 4pm to ensure no extreme burn occurs.</td>
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<tr>
<td>Insect and spider stings/bites</td>
<td>Wear insect repellent when outside</td>
<td>MODERATE RISK</td>
<td>Wear thick gardening gloves</td>
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<td></td>
<td>Wear closed shoes</td>
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<td>Try and identify the insect and make observations</td>
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<td></td>
<td>Take care when picking items up and turning them over</td>
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<td>Consult a guardian</td>
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<td></td>
<td>Wear thick gardening gloves</td>
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<td>Seek first aid</td>
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<td>If serious, seek medical attention</td>
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<td>Pack away with care and aware of your surroundings</td>
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</table>

**Mandatory precautions:** Covered shoes, safety glasses, hair exceeding shoulder length tied back.

Date: ..................  Student Signature: .................................................................
Variables

Independent - The type of tillage / soil preparation
   - Traditional ploughing and turning of the soil compared with laying of a mulch bed (corn husk, coir, hemp) over the soil.

Dependent - The volume of water/moisture retained by the soil over a period of a week.

Controlled - Pot size, sunlight, amount of soil, consistency of soil, amount of water applied to each pot, rate of water applied to each pot, protection from rain.

Control - No tilling method

Equipment

15 x 43cm x 29.5cm x 12cm open polystyrene boxes
Plastic sheet and sticky tape to line polystyrene boxes – to make them watertight.
4 x 25L bags of potting mix
125L x ordinary garden soil
Clear plastic sheet for canopy to prevent rain entering containers.
Ropes and poles to support canopy.
1 x Shovel
1 x Wheelbarrow
1 x Watering can with sprinkler rose.
1 x Watch and calendar on mobile phone.
1 x 29cm and 42cm x 2cm sheet of plywood to tamp soil.
1 x Pair of thick gardening gloves
1 x Pair of goggles
1 x Black permanent marker
1 x Glass measuring cup
9 x 40cm x 47cm sheets of plastic
3 x 43cm x 30cm pieces of hemp / flax based worm matting
Corn Husks (3 x 2cm depth for 43cm x 29.5cm)
Coir mulch (3 x 2cm depth for 43cm x 29.5cm)
6 x Bricks
3 x Wooden Planks
1 x Decagon 5TM
1 x ProCheck Handheld Reader
1 x MP406 Moisture Sensor
1 x PC/Laptop
1 x ICT Combined Instrument Software (uploaded onto a PC)
1 x Voltage Sensor Logger
1 x Pair of scissors

Pictures of Equipment

Fig 21: 125L of Ordinary Gardening Soil

Fig 22: 4 x 25L Bags of Potting

Fig 23: Coir Mulch (3 x 2cm depth for 43cm x 29.5cm)

Fig 24: Corn Husks (3 x 2cm depth for 43cm x

Fig 25: 3 x 43cm x 30cm pieces of hemp/flax based worm matting

Fig 26: 15 x 43cm x 29.5cm x 12cm open polystyrene boxes
Method

1. Plastic sheet was cut, folded and taped to neatly line the 15 polystyrene boxes. (3 samples of each type of soil treatment).

2. 125L of ordinary gardening soil was loaded into a wheelbarrow.

3. 100L of potting mix and soil were thoroughly mixed together on a sheet of plastic.

4. The 15 boxes were filled to the brim with soil mixture using a shovel. (This was to ensure that water not absorbed by the soil could run over the side of the boxes without significant pooling).

5. The plywood sheet was placed on top of the soil.

6. The soil in each box was evenly compacted by placing a 40kg weight upon the plywood sheet.

7. The polystyrene boxes were labelled (no till, till, corn husk mulch, hemp matt, coir mulch). Each box was additionally labelled Test 1, 2 or 3 so that there were three samples of each soil treatment.

8. The compact coir mulch was broken up by adding water and shaving it with a shovel in a wheelbarrow (instructions on the packaging).

9. The coir was then placed on a plastic sheet and left in the sun to dry completely.

10. Mulch was applied to the boxes to match their labels. Where loose mulch material was added, an even 2cm deep bed was formed over the soil.

11. The 3 samples with the hemp matt were covered with a single 1cm thickness as the matt is a more dense material than other mulches.

12. The boxes were placed in a location outside where they were exposed to an equal amount of sunlight each day.

13. When predicted rain, the 3 wooden planks were spaced evenly along the boxes, one at either end and one in the middle. The plastic was suspended over the planks and the bricks were placed on top of the plastic (3 bricks at either end to ensure an equal amount of weight).

14. The initial soil moisture level of each box was measured using MP406 Moisture Sensor and the Decagon 5TM. Two measurements were made per box – one with each instrument in the middle of each half of each box.

15. Using the glass measuring cup 2000mL of water was measured, and applied to each box using the watering can to ensure an even distribution of water.

16. The soil moisture level was then measured each evening at 7pm using the MP406 Moisture Sensor and the Decagon 5TM. Two measurements were made per box – one with each instrument in the middle of each half of each box.

17. The results for 3 samples of each of 5 different soil treatments were recorded in a table.

18. The boxes were visually inspected each day to observe changes and to ensure that the soil treatments were in place.

19. Steps 12 to 13 were repeated each day for 12 days.
Preparing Boxes With Soil

Gardening soil and potting soil mixed together in an equal ratio.
Plastic Sheet with a brick to hold it down while soil is added.

Polystyrene Box (cool-lite box)

Fig 30

Fig 31

Mixed garden and potting soil
Fig 32

- Shovel
- Mixed garden and potting soil

Fig 33

- Polystyrene Boxes (cool-lite boxes) with plastic sheets in them and mixed soil
- Plywood board to compact the soil
- Person adding an equal 42kg weight to the board
Polystyrene Boxes (cool-lite boxes) with plastic sheets

Compact mixed soil

Polystyrene Boxes (cool-lite boxes) with plastic

Compact mixed soil
**Polystyrene Boxes (cool-lite boxes) with plastic sheets in them and mixed soil**

- **Fig 36**
  - Bricks - to hold down the plastic
  - Water pooling on the plastic
  - Plastic Sheet
  - Wooden Planks - to raise the plastic. This allows air flow (so no insulation happens) but not rain

**Fig 37**

- Polystyrene Boxes (cool-lite boxes) with plastic sheets in them and mixed soil
  - Wooden Plank - to hold down plastic, preventing it from covering the soil in the wind
  - Plastic Sheet
Moist coir (wet with water)

Wheelbarrow

Dry Coir

Shovel

Moist coir (wet with water)

Plastic Sheet

Coir being left to dry in the sun
Fig 40

Watering can to ensure equal rate and pressure of the water on the soil

Corn Husks

Hemp

Till

Coir

No till

Fig 41

Shovel lifting the soil for tilling technique

Hemp

Corn Husks

Till

Polystyrene Boxes (cool-lite boxes) with plastic sheets in them and mixed soil

Coir

No till
Soil MP406 with prongs in the bottom to penetrate the soil

Polystyrene Boxes (cool-lite boxes) with plastic sheets in them and mixed soil

Fig 42

Fig 43

Polystyrene Boxes (cool-lite boxes) with plastic sheets in them and mixed soil

5TM Moisture Metre

Soil
### Results

#### Fig 45

<table>
<thead>
<tr>
<th>3A - Corn Husk (M1)</th>
<th>4A - Hemp Mat 1 (M1)</th>
<th>4A - Hemp Mat 1 (M2)</th>
<th>5A - Till 1 (M1)</th>
<th>5A - Till 1 (M2)</th>
<th>1B - Coir 2 (M1)</th>
<th>1B - Coir 2 (M2)</th>
<th>2B - Hemp Mat 2 (M1)</th>
<th>2B - Hemp Mat 2 (M2)</th>
<th>3B - Coir 3 (M1)</th>
<th>3B - Coir 3 (M2)</th>
<th>4B - No Till 2 (M1)</th>
<th>4B - No Till 2 (M2)</th>
<th>5B - Hemp Mat 3 (M1)</th>
<th>5B - Hemp Mat 3 (M2)</th>
<th>1C - Till 2 (M1)</th>
<th>1C - Till 2 (M2)</th>
<th>2C - Corn Husk 2 (M1)</th>
<th>2C - Corn Husk 2 (M2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.283</td>
<td>0.315</td>
<td>0.243</td>
<td>0.238</td>
<td>0.263</td>
<td>0.273</td>
<td>0.243</td>
<td>0.303</td>
<td>0.29</td>
<td>0.282</td>
<td>0.28</td>
<td>0.213</td>
<td>0.211</td>
<td>0.302</td>
<td>0.212</td>
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<td>0.198</td>
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5TM Temperature Measurement (°C)
### MP406 Soil Moisture Measurement (%)

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*Note: The table continues with numerical data.*
**Key**

- Line containing average results
- Dotted line of best fit

**Average - Hemp Mat - MP406**

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**Average - Hemp Mat - 5TM**

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**Average - Tilled - MP406**

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**Average - Tilled - 5TM**

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**Fig 54**

**Fig 55**

**Fig 56**

**Fig 57**
### Fig 58

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<td>Coir</td>
<td>0.7627</td>
<td>0.0051</td>
<td>9.93</td>
<td>0.07</td>
</tr>
<tr>
<td>Corn Husk</td>
<td>1.2916</td>
<td>0.0068</td>
<td>15.99</td>
<td>0.09</td>
</tr>
<tr>
<td>Hemp</td>
<td>0.8771</td>
<td>0.0067</td>
<td>11.69</td>
<td>0.08</td>
</tr>
<tr>
<td>No Till</td>
<td>1.7343</td>
<td>0.0092</td>
<td>22.03</td>
<td>0.10</td>
</tr>
<tr>
<td>Tilled</td>
<td>1.2696</td>
<td>0.0063</td>
<td>16.47</td>
<td>0.09</td>
</tr>
<tr>
<td>Average of all soil treatments</td>
<td>1.1871</td>
<td>0.00682</td>
<td>15.22</td>
<td>0.09</td>
</tr>
</tbody>
</table>
Discussion

Accuracy

The following steps were taken to ensure that accurate results were obtained:

- As the boxes were rectangular in shape, two measurements were taken, one in the middle of each half of the each box and averaged to account for any differences in soil moisture across each box.
- Measurements were taken from the exactly the same positions in each box.
- Measurements were taken at the same time each day after sunset.

Close contact of soil with the sensor probes is necessary to obtain accurate measurements. Slight loosening of the soil over the duration of the experiment, in the positions where measurements were taken, may have contributed to inaccuracies in some measurements.

Instrument Precision and Accuracy

The MP406 measures soil moisture as a percentage. The reading in air is 0%. The reading in pure water is 100%. The 5TM measures volumetric water content in $m^3/m^3$ of water to solids and air. It was found that is measures $0m^3/m^3$ in air and $0.5m^3/m^3$ in pure water. Measurements from one instrument can be compared to the other by using the scaling factor 0.5:100 representing the ratio of readings of the two instruments in pure water.

According to the 5TM Decagon Moisture meter manual the instrument measurement precision is $+/- 3\%$ for soil moisture and $+/-1\%$ for temperature. The MP406 measurement accuracy is $+/- 5\%$, for soil moisture generally, and $+/-1\%$ if it is calibrated for a particular soil type. This implies that precision of the sensor $+/-1\%$ but to achieve better than $+/-5\%$ accuracy it is necessary to know the exact soil type. Hence, relative measurements in would be accurate to $+/-1\%$ in a consistent soil type even though absolute measurements of soil moisture might only accurate to within $+/-5\%$.

As the rate of change of soil moisture, and so the relative soil moisture, in the experiment conducted was more important than the absolute soil moisture, sensor precision was more relevant than sensor accuracy and so the $+/-1\%$ value for the MP406 applied.

Averaging of Data

Lack of instrument precision and measurement errors, for example, caused by probes not making good contact with soil, tend to be random due to patterns in nature. The actual soil moisture being measured is not. Successive sampling tends to negate random data and reinforces consistent data. By averaging two measurements from each box and by testing 3 samples of each soil treatment, 6 measurements were taken each day for each type of soil treatment. Additionally, two different instruments were used to make the measurements and the results compared.

Validity

Expert knowledge was obtained in use of the instruments and in soil moisture experiments through a telephone conversation with soil agronomist, Dr Peter Cull, Managing Director of ICT International Pty. Ltd. He explained the usage of tillage methods in many different circumstances around the world and their purpose in different environments. This further increased the validity of the experiment because it allowed me to understand the structure of soil and the effects of the tilling methods. He also critiqued the method compared past results

Measurements were taken daily over a 12 day period. The results from the 3 samples of each soil treatment were averaged. Rather than using the absolute values of soil moisture readings, a line of best fit was applied to the average of 3 samples plotted over 12 days to obtain the average rate of soil moisture loss. In doing this, if one reading was erroneous it had limited effect on the overall results. Even though the soil samples were prepared in the same way, from the same batch of soil, using the rate of soil moisture loss rather than the absolute soil moisture also eliminated errors that may have occurred if initial soil moisture levels were different.

The soil mixture used for the experiment may not have been the same as the depleted soils found in semi-arid region of the world. Possibly one of the main differences would be that the level of organic matter in the soil would be lower in semi-arid regions.
The validity of this experiment was challenged by the consistency of sunshine.

- Pattern of shading was consistent
- Placing boxes where the same material in different zones to ensure each type of material was exposed to range

3 of each exposed the same treatment

During particular parts of the day the sun was prominent in some areas and not others as seen in figure 44. It was not possible to find an area to conduct the experiment that was far enough away from trees and buildings to fully eliminate shading the boxes. As the sun went down it moved further away from the boxes, exposing some to more sunshine than others. To compensate for this the samples were arranged so that the 3 samples of each type of soil treatment were located in different areas of the array.

Due to time constraints and the fact that the experiment needed to be conducted over a few weeks it was not possible to repeat the experiment. To overcome this 3 samples of each soil treatment were prepared and monitored during the experimental period. A clearer and more valid result could have been assessed if more weeks were provided to test.

There was some rain during the experimental period and so boxes were covered with a plastic sheet, preventing rain and allowing sun. Wooden planks were placed underneath to continue the air flow. The set up of the plastic, wood planks and bricks can be seen in figures 36 and 37.

**Reliability**

The prongs of the MP406 measure a larger and deeper volume of soil than the 5TM. The MP406 has 4 round 60mm long prongs with one in the centre and three around the outside. The 5TM has 3 flat prongs in a line that are 50mm long. It was also found that the MP406 prongs caused less soil disturbance when inserted. Soil disturbance caused by daily measurements loosens the soil and increases the possibility of the sensor probes not making close contact with the soil.

Large particles such as stones and wood fragments can also affect how well the moisture sensor probes contact the soil and so may cause measurement errors.

The use of thermally insulating and reflective white polystyrene boxes ensured that sunlight and atmospheric conditions only affected the top surface of the soil as they would if the soil was in the ground. Polystyrene is a durable, strong and flexible material with a low water absorbency.
Relationships/Trends/Observations

Comparison of the Rate of Loss of Soil Moisture for each Soil Treatment

The table in figure 58 shows the average rate of soil moisture loss recorded using the MP406 and 5TM soil moisture instruments.

As can be seen, the rate of soil moisture loss was clearly smallest for samples mulched with Coir. This was confirmed by both instruments and shown to be 46% less than the average, as measured using the MP406 and 35% less than the average, as measured using the 5TM.

The application of corn husks was shown to be significantly better than no soil treatment, ie No Till, but slightly worse than tilling in reducing soil moisture loss.

The average rate of soil moisture loss for Hemp Matting, measured with the MP406, was shown to be significantly less than tilling the soil. However, this result was not confirmed by the 5TM measurements. This difference may highlight the difference in the soil volumes measured by each sensor. As a result it is not possible to conclude whether Hemp Matting is more effective than tilling the soil in retaining soil moisture. However, Hemp Matting was measured, using the MP406, to be approximately twice as effective as not tilling in retaining soil moisture. The 5TM measurement indicated that it was approximately 1.4 times better at retaining soil moisture.

The hemp matting treatment was a trial to test whether textile waste products, that end up in landfill, could be used as mulch. Although hemp is very dense and takes a few minutes for water to infiltrate it, it seemed to conserve moisture significantly. Coir was a test to see if a common mulching material would prove better than the tilling methods.

Tilling the Soil compared to Not Tilling the Soil

It was interesting to discover that tilling the soil resulted in a slower rate of water loss than not tilling the soil. The average rate of water loss from the No Till samples was measured by the MP406 to be 1.73%/day. For the Tilled samples it was 1.27%/day. This was confirmed by the 5TM measurements of 0.0092 m³/m³/day for No Till compared to 0.0063 m³/m³/day for Tilled samples. It was expected that the tilling the soil would create more surface area and therefore more moisture would be evaporated at a faster rate.

Moisture loss in the Tilled samples dropped and then recovered around days 5 and 6. As there was no rain during the experimental period, the cause of this was not identified.

Weed Growth

The absence of sunlight directly on the soil in the coir and hemp samples managed to completely suppress weed growth. Within one day of applying the mulch, existing weeds had died. Weeds grew most consistently in the No Till samples.

The sun infiltrated the gaps between the corn husks and eventually allowed some weeds to grow.

Tilling originally suppressed the weeds, however, over the duration of the experiment new weeds began to grow.
Insect Infestation

At night, a cricket was observed laying eggs in the coir. These insects feed on decomposing plant matter and do not decimate crops. Other similar insects such as locusts feed on new growth. In Africa, insects like locusts and crickets tend to lay eggs in the plant matter and soil causing crop disruption. A crop deterring these pests would have to be planted. This is an example of how a dissimilar cover crop that does breaks the insect life cycle could be useful.

A white fungus appeared under the hemp mat. As the soil dried the fungus disappeared. The fungus may have been caused by excessive moisture being trapped by the hemp matting on the surface of the soil. As soon as it was a warm temperature and the box was being exposed by the sun, the fungus died.

Areas for Improvement – further investigation

The differences in the rate of soil moisture loss measured by the two different instruments need to be investigated to determine why they occurred. Another measurement technique, such as accurately weighing the samples, could be introduced as it would indicate changes in soil moisture without requiring a probe to make good contact with the soil or being dependent on knowing the type of soil being tested. This would help to verify the accuracy of the MP406 and 5TM Soil Moisture instruments.

A longer period to conduct the experiment would result in more valid, reliable and accurate results.

Other potential mulch materials should be investigated. Although coir proved to be the best performing mulching material, what needs to be taken into consideration is the price of this material. The Food and Agriculture Organisation of the United Nations states that the cost of coir sourced from India is approximately AUD300/Tonne. It is estimated that a minimum of 2 Tonnes per acre would be required. Typical farm plots in Africa are about 1 to 2 acres. This is an expensive commodity for farmers in developing countries.

The effect soil treatments on water run-off was not investigated. To fully analyse the performance of various soil treatments, behaviour during rain events needs to be measured. In the boxes the water was contained and applied at a rate allowed all water to be absorbed. However, in a crop the rate at which infiltration occurred and the chance of runoff should be determined. This may have altered the result of the experiment because materials such as hemp are very dense and the water pooled for a few minutes before it was able to penetrate through the material. The more compact soil also pooled water and in a real situation in a crop, the water would have been able to run off easily.

Conclusion

Mulching the soil proved to conserve moisture significantly better than tilling the soil or leaving the soil untreated.

Self Evaluation

Overall the experiment was a success. The time allocated to conduct the experiment was planned and finished according to schedule.

Overall the project and experiment were successful. They have made me realise the importance of agriculture to human survival. The project has allowed me to become much more aware of world problems and the need to find solutions to them. The importance of conservation of land and water resources, the effects of overpopulation and climate change have also become much more apparent.
Acknowledgements
I would like to acknowledge Mr R. Otton, Mrs L. Eades and Ms V. Cull for their guidance and advice during the setting up and overall process of my experiment. I would also like to acknowledge Dr Peter Cull for his expertise and advice on soil moisture measurements.

Bibliography


