Establishment of an intensive market garden site

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Demonstrating Sustainable Farm Practices

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Introduction

The aim of this three-year sustainable agriculture project was to develop an intensive market garden utilising recycled water on land owned by Western Port Water and leased by the community group, Phillip Island Community Orchard Inc. (PICO). The demonstration ran from December 2014 to December 2017.

The site is managed under the auspices of the Phillip Island Community Orchard and Westernport Water, with involvement from community groups and interested individuals who are keen to learn more about growing vegetables successfully. Community groups include Phillip Island Community and Learning Centre Community Garden, Scope Disability, School groups, Sureways Employment Services and Community Corrections Victoria.

Figure 1 Schoolchildren planting seedlings

The objective of the project was to demonstrate the establishment of a sustainable horticulture garden on a difficult site using recycled water, while also illustrating how such an activity could embrace community groups and expose them to both the educational initiatives of production horticulture, and the value of healthy locally grown food.

Produce grown in the garden was distributed throughout the local community via organic box schemes, emergency food providers and social enterprise schemes.
The garden was irrigated using Class A recycled water, which demonstrated the benefits and safe use of recycled water to the community. Recycled water that does not contain pollutants or excessive nutrients can be used in organic agriculture/horticulture and is the principle strategy being used in this community garden.

Figure 2 Adrian James, Project Manager, at front of proposed garden area

The demonstration plot was north facing and exposed to sunshine all day. A native shelterbelt provides some protection from the predominant westerly weather patterns.

Demonstration site design and establishment

The total Phillip Island Community Orchard site is 1000m2 in size with a 600m2 (30m x 20m) area dedicated to the market garden demonstration site. As the site area is covered with compacted fill (comprised of various soil types and subsoil types) from the Western Port Water site, the garden design and management was based on a combination of sheet mulching with a no-dig garden methodology.

Figure 3 Solarisation of garden site

No-dig gardening, or 'minimal till' agriculture, has many benefits including improved soil structure, increased water retention and increased worm populations and soil biology (Intagliata, 2017, Oregon State University, 2013).

There were significant areas of kikuyu grass in the project area. As the garden is based on organic principles the intention was to use solarisation to suppress weed growth rather than using herbicides. This also provided the community with an opportunity to view an alternative method of weed control. Solarisation is a simple non-chemical technique that captures the radiant heat and energy from the sun and causes physical, chemical, and biological changes in the soil. These changes can control or suppress soil borne plant pathogens such as fungi, bacteria, nematodes, and pests along with weed seeds and seedlings. Solarisation consists of covering the soil with a plastic tarp for 4 to 6 weeks during a hot period of the year when the soil will receive maximum direct sunlight. When properly done, the top 6 inches (15 cm) soil can heat up to as high as 52°c. Over several weeks, that's hot enough to kill a wide range of soil inhabiting pests such as; wilt and root rot fungi, root knot nematodes and noxious weed seed (Elmore, Stapleton, Bell, Devay,, 1997.

The demonstration site was covered with 8 black plastic sheets with the edges dug in to seal it into place. The soil was covered for 6 weeks over summer. This killed off the majority of the kikuyu grass and weeds and allowed further bed preparation. Soil fertility was maintained through the use of composts, nutrient rich cover crops (green manures) and pelletised poultry manure. The fill material from this site consisted of broken fragments of sandstone and mudstone of Silurian age (400my) and formed a difficult substrate on which the market garden was to be established. There was minimal topsoil development across the site.

An initial investigation revealed the soil was compacted with minimal water infiltration and colonised by plant species (kikuyu and broad leaf weeds), which on this fill material provided poor root penetration. The site provided an excellent opportunity for the demonstration of no-dig gardening.

Figure 4 800mm cores from the garden site illustrating broken rock fragments from fill material

A soil assessment of the trial site indicated that the compacted fill material would be a major impediment to horticultural production. The two options to establish horticulture on this site were;

1. Import a higher quality soil with extensive and expensive cultivation and incorporation of organic material and mineral based fertilisers, or
2. Adopt a minimal cultivation strategy based on a well-documented no-dig gardening approach.

Option 2 was chosen for this demonstration site. No-dig gardening, as the name suggests, uses minimal cultivation strategies but still embraces organic soil management practices. These rely on the development of healthy fertile soils through the use of soil building crops of legumes, green manures, sound rotations and additions of compost and mineral fertilisers, where appropriate (Knight, 2008). The use of composted raised beds will lead to improved structure and allow crop roots to access increased moisture, oxygen and nutrients (Termorshuizen, A.J. et al, 2004).

Figure 5 Looking East down the garden rows

The site was initially fenced and solarisation was commenced to kill off the kikuyu grass and other unwanted weed species. Irrigation lines were put in place running from 4 water points, and compost windrows were established.

The 30m x 20m trial site involved 60 beds with a 2m wide central access pathway running the full length and width of the beds, managed with organic no-till methods. Local school students assisted in applying wood chip mulch between the beds, which proved to be an effective and long-lasting weed barrier. When the wood chip mulch had broken down it was applied to the beds to boost organic matter.

Figure 6 Comfrey used as an outside fence border

Comfrey was planted around the outside perimeter of the garden as a weed barrier. Its foliage is high in potassium and was added to the composting operation and used as mulch on the beds.

Vacant beds were planted with cover crops to be cultivated back into the beds increasing both organic matter and nutrient levels.

Compost was purchased and additional sourced ingredients were added to the compost, including horse manure, chicken litter, sawdust and spent potting mix. A surprising outcome from this project was the contribution of compost ingredients from many sectors of the community. In terms of adhering to sustainable principles of recycling this was very encouraging. The end product of compost was then used to establish the garden beds.

Pelletised poultry manure was applied pre-planting to boost nutrient levels. It had an analysis of N 3.5%, P 1.7%, K 1.6% and Ca 5.4%. It was applied at the rate of 2.5t/ha.

Figure 7 Bed forming with compost

Figure 8 Illustrating depth of garden windrow compost beds (>200mm)

Initial benchmarking included a visual soil assessment and a full soil analysis. Plant root development and earthworm numbers were used to demonstrate biological soil health. Observations of vegetable yield also provided valuable information to help determine the viability of the project.

Analysis of the compost and potting mix

Compost produced according to Australian standard AS 4454-2012 is approved by organic certification agencies and can be utilised in organic agriculture. The compost analysis from the initial delivery that were used to build the beds varied significantly from the PICO compost, which was made on site. The PICO compost consisted of purchased compost with spent potting mix, food and green waste added. The spent potting mix analysis was an interesting input in terms of additional nutrient elements such as the nitrogen, phosphorus and potassium that it added to the PICO compost. This compost was a crucial amendment in the restocking of nutrients to a deficient base soil profile.

An important indicator of the maturity of the compost is the carbon nitrogen (C:N) ratio, which in well-made compost should be less than 15:1. As the ratio becomes wider the availability of N reduces significantly. All composts used in this trial had ratios of less than 14/1 which enabled appropriate levels of N availability.

Analysis of key nutrients in the composts are tabulated below, and the variation between batches can be explained by the additional materials (potting mix, etc.), which have been added to the compost. The increase in magnesium (1.70% -> 6.80%) in the PICO compost is difficult to reconcile and does not appear to originate from known inputs.

Figure 10 Compost analysis

Nutrient	(Aussie Compost) 2015	Compost PICO 2016	Potting mix 2016
Nitrogen %	1.42	0.81	2.10
Phosphorus %	0.50	0.54	0.52
Potassium %	1.16	3.16	1.13
Sulphur %	0.14	0.12	0.27
Carbon %	18.40	7.90	27
Calcium %	2.05	1.75	2.34
Magnesium %	1.70	6.80	0.65
Sodium %	0.18	0.13	0.36
Conductivity dS/m	2.4	2.4	4.1
pH	7.3	7.3	6.9
Carbon:Nitrogen ratio (Desirable 14:1)	12.9	9.7	12.8

The potting mix that was a component of the PICO compost had a conductivity of 4.1. This is regarded as being potentially detrimental to plant growth (Ag Vic. AG0244, 1995). At this stage (January 2018) it does not appear to have affected the conductivity of the garden produced compost. It is possible that the increased organic matter inputs of the compost have provided a buffer to the additional sodium.

Figure 9 Field day participants

Water analysis (Class A Recycled Water - Westernport Water)

Class A recycled water was used as the primary irrigation source in the garden. The analysis of this is reported below. Plant growth of sensitive species and seedlings may be restricted at conductivity levels of 750-3000 µS/cm (Handreck, K. 2001). Crops such as onions, lettuce, beans, carrot and radish may have restricted growth at these sodium levels (DPI, NSW, 2016).

The recycled water supplied had a conductivity of 1259 µS/cm. The sodium absorption ratio of 5.8 suggests that the water is sodic and could increase the exchangeable sodium percentage (ESP) in the soil (DPI NSW). This is seen to be the case as the soil ESP increased markedly over the life of the project. It should be noted that the potting mix had a sodium level of 0.36%, which could also have contributed to increased sodium levels in the soil. Regular monitoring of soil nutrient levels is recommended to avoid a build-up of sodium levels.

Figure 11 Recycled water analysis from Western Port Water

July 2012 to March 2016	pH	Total dissolved solids mg/L	Electrical Conductivity µS/cm	Total Nitrogen (N) mg/L	Total Phosphorus (P) mg/L	Calcium (Ca) mg/L	Magnesium (Mg) mg/L	Potassium (K) mg/L	Sodium (Na) mg/L	Sodium Absorption Ratio (SAR)
Rolling average	7	740	1259	20	8.6	31	21	24	168	5.8
Rolling median	7.1	740	1300	18.5	9.3	30	21	26	170	5.8

Figure 12 Garden beds illustrating the irrigation set-up

Testing protocols

Benchmark testing and the monitoring criteria were based on an assessment of the soil's physical, biological and chemical characteristics. A full soil analysis was taken as the start of the trial as a benchmark. Annual soil tests were repeated at the end of each year.

Analysis of results

Physical observations

A benchmark soil assessment was carried out in December 2014. It indicated a shallow topsoil (80mm depth due to the site being filled) with poor soil physical characteristics. The most prominent soil constraints were identified as a lack of soil structure with poor water infiltration and minimal worm activity. Grass and weed root depth was limited and the reduced pore space indicated possible anaerobic conditions that were not conducive to microorganisms responsible for nutrient cycling (Pengthamkeerati et al, 2011).

Figure 13 Soil sod from uncultivated profile illustrating reduced soil structure at the commencement of the trial.

The soil that was sampled at the conclusion of the trial from under the garden beds showed improved soil structure, which was demonstrated by increased water infiltration and worm activity.

Solvita soil health tests

The Solvita soil test is a test that allows the soil CO2 respiration of microorganisms to be measured in the field. As biological activity increases and organic matter cycles, CO2 is released. The rate of release is regarded as an indicator of soil health. The indicator scale reads from 1-5 where 5 is the highest level of activity.

The control soil registered 3 (medium biological activity), while the base soil below the raised beds registered 4.5 (high biological activity). The wide range of soil amendments used to build the garden beds with high organic matter levels, and the subsequent leaching of nutrients from the compost, would have played a key role in stimulating biological activity in the base soil.

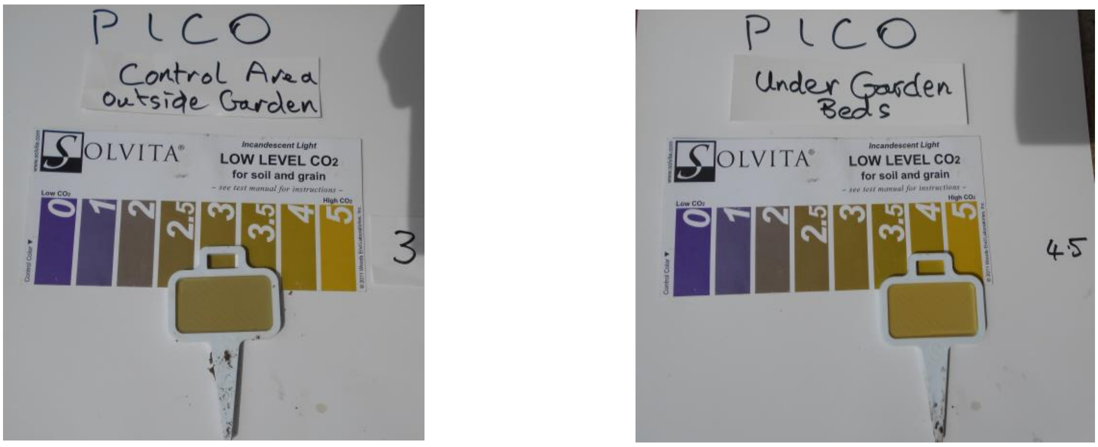

Figure 14   Solvita Soil Health Test – Control area registered 3, Soil under garden beds 4.5

Soil chemistry

Figure 15 Field pH test (~ 6) on soil core from proposed garden area

An initial soil analysis was taken from the proposed garden area, and subsequent soil analyses were taken from the base soil below the raised beds, to compare the soil chemistry.

The initial benchmark analysis indicated a moderately acid soil (5.48) rising to a favourable 6.47 at the conclusion of the trial.

Phosphorus Olsen P (as the most available P) level in the benchmark was 6mg/kg (desirable 20mg/kg) and Colwell P (which measures the potentially available phosphorus) was 29mg/kg (desirable 50mg/kg). At the conclusion of the trial Olsen P had risen to 25mg/kg and Colwell P to 94mg/kg (both substantial increases).

Available calcium initially registered at 238mg/kg (desirable 375mg/kg) and rose to 297mg/kg. Potassium (Morgan 1) initially registered 102mg/kg (desirable 60mg/kg) and rose to 188mg/kg. Sulphur initially registered 15.8mg/kg (desirable 8mg/kg) and declined to 14 mg/kg at the trial conclusion.

Organic matter initially registered 6.6% but decreased to 2.9% at the trial conclusion. This decline is reflected in the decrease in total nitrogen, which also fell from 0.25% to 0.15%.

Figure 16 Soil analysis

Nutrient	Benchmark 2015	Vegetable Bed Soil 2017
pH (1:5 water)	5.48	6.47
Available Calcium mg/kg	238	297
Available magnesium mg/kg	124	134
Available Potassium mg/kg	102	188
Olsen P mg/kg	6	25
Colwell P mg/kg	29	94
Nitrate Nitrogen mg/kg	4	9.6
Sulphur mg/kg	15.8	14
Total Nitrogen %	0.25%	0.15
Organic matter %	6.60%	2.9
Total Carbon %	3.76	1.65
Effective Cation Exchange Capacity cmol+/kg	5.84	5.66
Calcium/Magnesium ratio	1.5	1.9
Calcium CEC %	45	51.9
Magnesium CEC %	30.7	27.2
Potassium CEC %	7.5	11.6
Sodium – ESP %	5.4	7.6
Aluminium CEC %	7.6	0.2
Carbon/Nitrogen ratio	14.8	10.9
Solvita	3	4.5

Cation exchange did not change greatly over the trial period suggesting that the clay fraction of the soil is a major determinate in the CEC levels.

Exchangeable calcium initially registered 45% (desirable 69%), exchangeable magnesium 30.7% (desirable 16%), potassium 7.5% (desirable 5%), sodium 5.4% (desirable 3%) and aluminium 7.6%. At the conclusion of the trial calcium registered 51.9%, exchangeable magnesium 27.2% , potassium 11.6% ,sodium 7.6% and aluminium 0.2% .

These results demonstrate how the leaching of nutrients from the composted beds and the addition of pelletised poultry manure has increased the base soil nutrient levels. It is also evident that the recycled water with elevated sodium levels has increased the ESP sodium levels in the soil.

On a positive note the higher levels of calcium in the compost may have been responsible for decreasing the high levels of exchangeable aluminium seen in the control soil. High aluminium levels are seen as detrimental to a range of plant species (particularly legumes), stunting plant roots.

Vegetable yield and quality

All the crops grown on these mulched beds yielded well. It was the lack of ability to harvest the crops in a timely manner that impacted on total potential production.

The majority of the produce was good quality and positive comments were received concerning the flavour and sweetness of crops, such as tomatoes.

Figure 17 Tomatoes (above photograph) and beetroot (below) grown in the compost mulched beds

Costs and benefits

The project budget was $3,859.00 and additional contributions from Phillip Island Landcare Group and Western Port Water assisted in the set-up of infrastructure for the garden including earthworks, supply of commercial compost, fencing, black plastic, seeds and seedlings and irrigation. Once the beds were established and vegetables were planted, various community groups supplied the necessary labour sufficient for the on-going production and maintenance of the garden.

The sale of seasonal produce totalled over $3,000 and was sold to a range of enterprises including Food Fanatics, Freedom Organics, Udder and Hoe and Island Whole foods. All sales were invoiced, which meant an accurate production of supply and demand could be monitored.

At peak seasonal production times a shortage of labour for picking, packing and quality control sometimes meant that not all production could be marketed.

The no-dig gardening approach with the permanent beds illustrated that production into the future could easily be maintained with the use of composts and waste products with only minimal inputs of outside fertilisers.

Budget $3,859.00

Produce sold* > $3,000.00

* Limitations such as lack of harvest labour, variable and patchy local market, variable produce quality, managing climate extremes and difficult harvesting schedules impacted on the quantity of produce that was grown but not marketed.

Estimated on-going costs

It is estimated that on-going production and maintenance of the garden will incur annual costs as set out in figure 18.

Figure 18 Estimated annual ongoing costs

Seeds & seedlings	$500
Compost	$500
Chicken Litter	$600
Tools, material/equipment	$500
Labour Component (5hrs week @ $25)	$6500
TOTAL	**$8,600**

Summary

This project had three very successful outcomes.

1. **The use of a no-dig organic gardening approach on an impermeable and compacted site, and a demonstration of how the recycling and use of compost can be used to build a healthy fertile soil**.

   The benchmark soil assessment, including the physical, biological and chemical parameters indicated that the soil base had constraints that were reflected in the very compacted fill material with very little soil structure or biological activity. The chemistry also supported a depleted soil low in most major nutrients. This compacted fill material formed the basis of the demonstration of a no-dig gardening approach and is quite possibly the only way that the substrate would have supported vegetable production. The range of nutrients contained in the recycled wastes, including the supplied recycled water, provided important information about how various nutrient levels can be increased, and which nutrients to monitor in terms of plant sensitivity.

2. **The second major outcome was the involvement of wide sections of the community**

   The groups proved to be a valuable source of labour and inspiration in both the building phase of the garden, and the production and marketing. The attendance at workshops and field days (over 30 people attending) illustrated the learning and information transfer that took place and the high level of interest that this project generated. Community groups involved included;
   a. A highly successful Work for the Dole program. Participants took on a high degree of ownership over the project and were instrumental in providing the on-the-ground support needed to make the project a success
   b. The Phillip Island Harvest Enterprise followed the Work for the Dole project and was successful in selling thousands of dollars' worth of produce to local food outlets on Phillip Island
   c. Newhaven College Year 9's contributed to the project through regular participation and it is hoped that a partnership will develop into a more sustained and involved project, potentially with older students
   d. The venue was also utilised by a Certificate Horticulture Program and it is also hoped that the whole PICO site can be more fully integrated into the programs curriculum so that more extended and in depth programs can develop from this.

3. **The current on-going costs for the garden are greater than the profit levels of the garden.**

The garden manager believes that with increased attention to marketing, the income would better match expenditure. Un-costed benefits in terms of local food production, recycling strategies and community involvement however, demonstrate that this project was highly successful

Key learnings from demonstration

- No-dig gardening is a successful method of vegetable gardening on impermeable, compacted soil
- The use of compost with sourced additives can provide adequate nutrition for vegetable crops
- Considerable enrichment of the soil substrate occurred through the leaching of nutrients from the compost
- The use of recycled water may lead to elevated sodium soil levels but nitrate nitrogen levels can provide benefit
- Solarisation demonstrated that undesirable grass and weed species can be successfully removed without the use of herbicides
- The community involvement in both the production phase and the distribution of food was a very positive outcome
- Vegetable production demonstrated the effectiveness of the soil fertility management
- Workshops and field days were well attended and proved to be useful educational platforms for the local community
- The on-site production of compost from waste products demonstrated that recycling can return valuable nutrients to build a healthy soil
- The demonstration garden was used as an educational tool for a Horticultural program of a certificate level
- Over $3,000 worth of produce was marketed from the site over 3 years

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