SOIL3010

Suitability of sites within the Sydney College of the arts for use as community gardens

Sophie Gulliver
Adrian Carrillo Garcia
Joshua Godbee

Executive summary

The SOIL3010 unit from the University of Sydney undertook an investigation into the agronomic suitability of sites with the Sydney College of the Arts leasehold for the purpose of creating a community garden.

In order to establish the suitability of the soil for growing a range of plants as would be required in a community garden, physical soil samples were required. However, political and social pressures from the community meant that we were denied access to extract soil samples from any areas within Callan Park outside of the SCA lease. In light of this, three additional sites were included in the soil survey to gain a comprehensive understanding of the soil health status within the confines of the SCA grounds.

Of the six sites surveyed, site 1 was the only site deemed agronomically acceptable for the establishment of a community garden using the existing soil. The five other sites displayed varying soil depths, nutrient deficiencies and other physical attributes that are inhibitive to plant growth and development. Considering this, two recommendations have been proposed; the first involves a community garden at site 1 using the existing soil in conjunction with a soil remediation strategy to improve soil fertility and ensure plant productivity. The second recommendation involves the erection of raised garden beds at any of the sites which would negate the unsuitability of the existing soil. Raised garden beds would incur a greater cost of establishment however, it is a more culturally and socially sensitive alternative and would provide superior soil conditions for a sustainable and productive community garden.

Project outline

The University of Sydney's Sydney College of the Arts (SCA) have employed the students of the SOIL3010 unit to investigate the possibility of establishing a community garden within Callan Park, Rozelle. There are three main issues which must be overcome in order to facilitate a community garden project within Callan Park; these are:

1. Suitable sites for a community garden must be determined.
2. The agronomic potential of the soils at these sites must be examined.
3. The political and social stance of the local and broader community must be considered.

Introduction to the problem

Callan Park holds immense historical, architectural, cultural, and social significance for many members of the local and broader community as well as providing a unique open air space near the harbour that is relatively undisturbed and is available for the public to enjoy. However, much controversy surrounding the control and management of Callan Park has weakened the relationship between SCA and the community. In light of this, SCA has proposed the creation of community gardens within or proximal to the SCA campus areas with the aim of encouraging local community involvement by growing food, the creation of aesthetically appealing gardens, increasing the ecological literacy of local residents and widening the use of public open space. It is also hoped that it will strengthen the relationship and understanding between local residents and the university.

In order to meet the client objectives, we identified 5 areas within the SCA grounds and 3 proximal but external to SCA that could potentially be suitable for a community garden. These sites were chosen on the basis of community accessibility, ease of garden establishment and minimal disturbance to SCA students, existing standing structures and landscaped gardens. Upon site selection it was also ensured that the proposed sites would not jeopardise the historical and cultural significance of the precinct or upset community members who are opposed to dramatic changes to Callan Park due to their desire to preserve the legacy of the psychiatric hospital.

Preliminary research into the geology of Callan Park revealed that it is situated over sandy soils derived from Hawkesbury sandstone. These soils are generally shallow, acidic, highly permeable and low in fertility (Jensen 1998). No studies have been undertaken to determine the existing chemical and physical properties of the soils of Callan Park hence physical soil sampling was a necessary step towards determining the suitability of the soils for establishing a community garden. Physical soil samples were also required to assess the effect of any anthropogenic disturbances since European settlement in 1819. However, due to social and political opposition towards the development of Callan Park, permission was not gained from the Sydney Harbour Foreshore Authority (SHFA) to extract soil samples from the proposed sites outside of SCA. In light of this, our investigation into the agronomic potential of soils for the establishment of a community garden was limited to sites within the SCA grounds. Although this decision made by the SHFA reduced the number of potential sites for investigation it means that if a community garden is established, the SCA will be able to bypass the rigmarole associated with getting permission from the governing bodies to commence the project. Therefore, SCA will be able to establish a community garden within their grounds at their own discretion.

Field work and laboratory analysis

Field work

Of the 5 sites identified within the SCA grounds only sites 3-5 were accessible by vehicle (Fig.1). In August 2009, a total of 11 soil cores were extracted from sites 3-5 using a hydraulic corer attached to a university John Deere Gator.

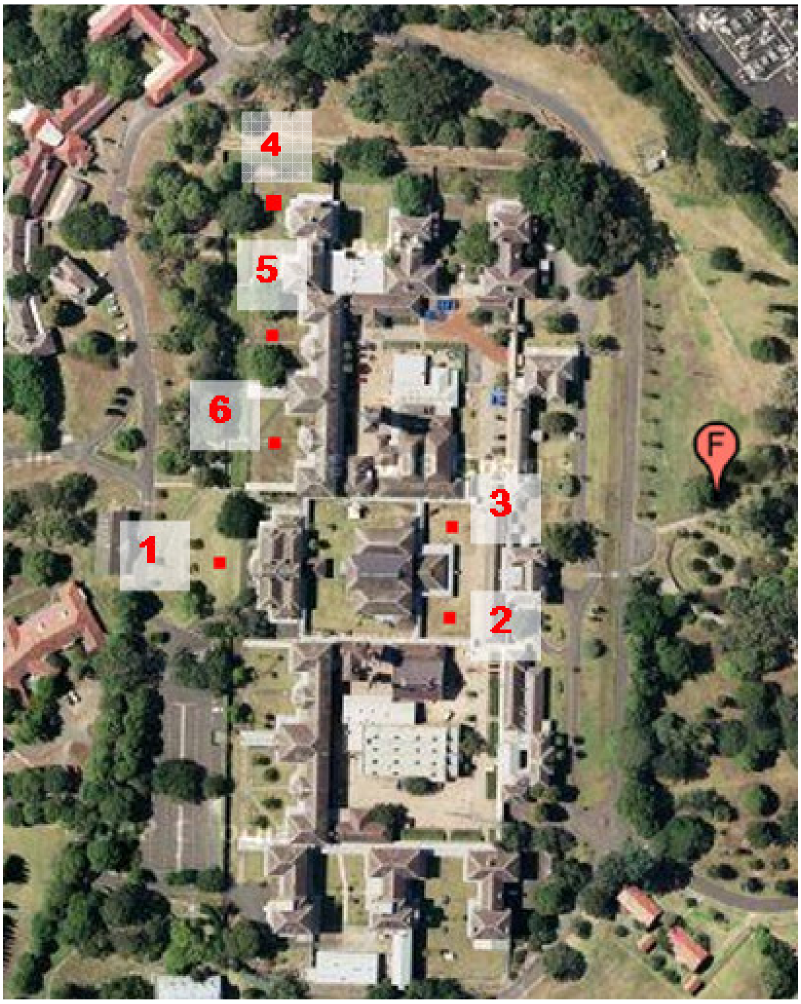

Fig.1 Aerial photo of SCA grounds within Callan Park; 5 potential sites for establishing a community garden (Google 2009).

At site 1, 6 soil cores were taken to a depth of 1m using a corer with a diameter of 44mm. The sample sites were allocated in a grid pattern of 2 x 3 (Fig.2). The actual location of each sample site was recorded using a Geographical Positioning System (GPS). Each individual soil core was placed in PVC half-pipe subsequent to extraction and ensheathed in a plastic sleeve for transport back to the university soil laboratory.

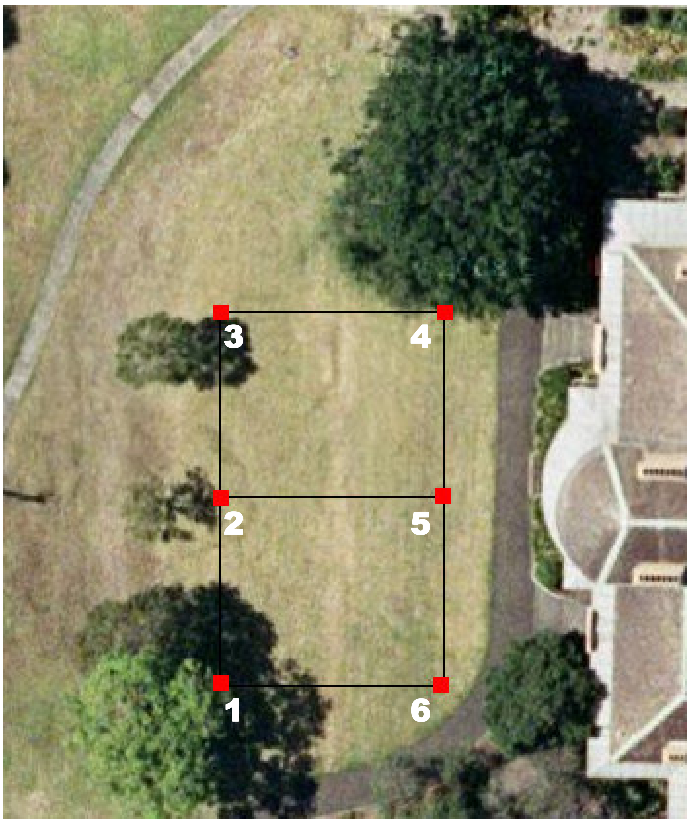

Fig.2 Aerial photo of site 1 with marked locations of extracted cores 1-6.

Two cores were extracted from site 2 (cores 7-8) using the same method as for site 1. Due to the first core (core 7) hitting rock at 30cm it was decided that a third core would be extracted (core 9) to determine whether it was an isolated case of shallow soil or if it was uniform across the site (Fig.3). Two cores were also extracted from site 3 in the same manner.

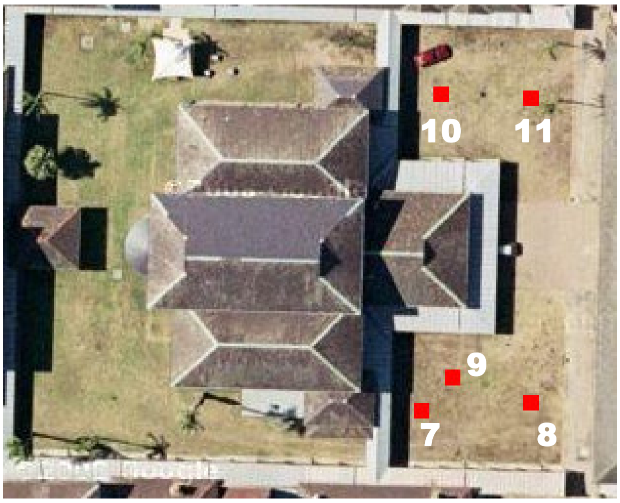

Fig.3 Aerial view of site 2 and 3 with extracted cores 7-11.

Due to limited vehicle access to sites 4 and 5 and 6 hand augured samples were extracted from each of these sites. At site 6 the hand auger hit rock at 30cm and so the full 1m soil sample could not be extracted. The samples were separated into 0-30cm and 30cm-1m where applicable and stored in a plastic soil bags for transportation to the university soil laboratory.

Fig.3 Aerial photo of hand augured sites 4, 5 and 6

Infiltration experiments were conducted at each of the sampled sites in close proximity to auger hole to reduce variation this infiltration data will be used to establish the hydraulic conductivity of the soil. The infiltration data was collected using the was done using the single-ring falling head permeameter method. This method determines the infiltration rate by recording the drop in the head of water within a ring of a know diameter at regular intervals until all water has infiltrated. From this data the cumulative infiltration rate can be determined and plotted which gives us the steady state infiltration rate. This steady state infiltration rate can then be used to determine the hydraulic conductivity

Sample preparation for laboratory analysis

The 11 soil cores were removed from their plastic sleeves and observed in the University of Sydney soil laboratory to enable a profile description of each core to be taken. The horizons within each soil profile were identified and the depth of each was recorded. The soil cores were then air-dried at 40C in the PVC half-pipe in a drying room for 10 days. The hand augered samples were simultaneously air-dried in open plastic bags.

Subsequent to air-drying, soil cores 1-6 were divided into topsoil (horizons A and B21), B horizons and B/C horizons. Each of these soil divisions in cores 1-6 were composited and ground to 2mm. The topsoil for cores 7-11 and the B and B/C horizons were composited for cores 8-11, however, the subsoil of core 7 was ground separately due to its shallow nature. Each of these samples were ground to 2mm.

The 0-30cm air-dried hand augered soil samples from site 4 were composited and ground to 2mm. Similarly, the 0-30cm and 30-1m soil from site 5 were ground separately to 2mm. The 30-1m soil from location 2 at site 1 was ground to 2mm.

In accordance with the sample preparation guidelines set out by CSBP Soil and Plant tissue Laboratory in Bibra Lake, WA, 500g of each ground sample was weighed and placed in labelled resealable plastic bags. Two duplicate samples were also prepared to ensure the reliability of the CSBP laboratory procedures. The soil samples were couriered to the CSBP laboratory to be tested for each of the attributes set out in Table x. These soil attributes were chosen based on their contribution to overall soil health and the role they play in hosting productive plants (Table 1). Guidelines set out in Hazelton and Murphy (2007) were used to assess the status of each of the attributes (low, medium, high).

Table 1. Soil attributes and their importance in plant productivity (Glendinning 2000)

Tested soil attribute	Importance in the soil-plant system
Texture	Indication of the soil particle size distribution which effects drainage, water retention, soil fertility.
Nitrogen (N)	Necessary for chlorophyll synthesis and photosynthesis which are vital for energy production and therefore plant growth. An essential component of amino acids which form plant proteins thus it is directly responsible for increasing protein content.
Phosphorous (P)	Essential for plant growth, no other nutrient can be substituted for it. Plays a role in photosynthesis, respiration, energy storage and transfer, cell division, cell enlargement. It is vital to seed formation and is involved in the transfer of hereditary traits from through generations.
Potassium (K)	Vital to photosynthesis and protein synthesis. It is important in the breakdown of carbohydrates and in fruit formation. It helps to control the ionic balance of plants and is involved in the activation of more than 60 enzyme systems which regulate the rates of major plant metabolic reactions.
Sulphur (S)	It is a constituent of plant enzymes and vitamins. It is essential for N fixation by legumes. Necessary for chlorophyll formation.
Exchangeable cations Ca, Mg, Na	Ca stimulates root and shoot development, increases the mechanical strength of plants, activates several plant enzyme systems and neutralises organic acids in the plant. Mg is strongly involved in photosynthesis as it is the central atom in the chlorophyll molecule. It also aids in phosphate metabolism, plant respiration, and protein synthesis. High levels of soil Na can result in sodic soils, leading to poor physical structure and limited movement of air and water.
Organic C	Gives an indication of the amount of OM in the soil which is a vital source of nutrients and trace elements that are essential for plant growth. Contributes to soil structure and water-holding capacity.
Electrical Conductivity (EC)	Indicates soluble salt concentration in the soil. This is important as many plants will not grow in saline soils.
pH (CaCl2 & H20)	Indicates the acidity/alkalinity of a soil. Most plants have an optimal pH range outside of which they will not grow successfully, if at all.
Micronutrients Cu, Fe, Mn, Zn, B	Cu is necessary for chlorophyll formation in plants. It increases cell wall strength therefore increases resistance to fungal attack. Fe is a catalyst in the formation of chlorophyll and acts as an oxygen carrier. Mn activates several important metabolic reactions and plays a direct role in photosynthesis by aiding chlorophyll synthesis. Mn promotes germination and accelerates the maturity of plants, while increasing the availability of Ca and P. Zn is necessary for the production of chlorophyll and carbohydrates. B is essential for the germination of pollen grains, growth of pollen tubes and seed and cell wall formation. It is also associated with sugar translocation and protein formation.

Laboratory results

Site 1

The cores extracted from site 1 were relatively uniform in horizonation (Appendix 1) and appeared to be similar in texture and colour (Fig. 4). The topsoil (A1, B21) at site 1 is a loamy sand with approximately 5% clay thus it is comprised predominantly of sand grains and is slightly coherent. The subsoil (B, B/C) is a loam which has approximately 20% clay, no obvious sandiness and is spongy and coherent. The A1 horizons appeared to have comparatively more organic matter compared to the rest of the profile and abruptly formed a B21 with lesser structural stability. The grey B22 horizons were similar across all profiles as were the B23 horizons which displayed a grey-yellow colour with scattered red patches. Towards 1m depth (B/C horizon) we hit white to yellow sandstone rock. The gravel content of the subsoils of site 1 ranged from 10-50%.

Fig.4. Site 1 air-dried cores 1-6 (from left to right).

The chemical analysis results for site 1 are summarised in Table 2.

Table 2. Chemical analysis results for cores 1-6 from site 1.

Soil property	Units	Site 1 (cores 1-6)		
		Topsoil	B horizons	B/C Horizon
Texture		1.5	2	2
pH (H20)	pH	7	6.8	6.8
Organic Carbon	%	1.3	2.07	1.88
Organic Matter	%	2.2	3.6	3.2
Electrical conductivity	dS/m	0.059	0.032	0.029
Exch. Calcium	mmol(+)/kg	34.3	65.3	64.1
Exch. Magnesium	mmol(+)/kg	7.9	6.6	6.5
Exch. Potassium	mmol(+)/kg	2.3	1.6	1.5
Exch. Sodium	mmol(+)/kg	0.6	0.9	0.7
CEC	mmol(+)/kg	45.1	74.4	72.8
Ammonium Nitrogen	mg/kg	3	1	1
Nitrate Nitrogen	mg/kg	2	2	2
Phosphorus Colwell	mg/kg	52	34	35
Potassium Colwell	mg/kg	149	126	117
Sulphur	mg/kg	3.31	4.33	3.73
DTPA Copper[1]	mg/kg	0.56	2.86	3.2
DTPA Iron	mg/kg	67.68	74.76	85.95
DTPA Manganese[2]	mg/kg	3.96	2.96	3
DTPA Zinc	mg/kg	4.33	6.44	6.63
Boron Hot CaCl2	mg/kg	0.4	0.5	0.5

Low
Moderate
High

[1] No Critical levels could be found
[2] Concentration data insufficient to predict deficiency or toxicity for plants

The pH of the soil at site 1 is 7.0 for the topsoil and 6.8 for the subsoil indicating that this soil has a neutral pH and is thus suitable for a wide range of plants.

Organic carbon (OC) levels in the topsoil of site 1 are considered moderate (1.3%), indicating average structural condition and stability and organic matter levels of 2.2%. Slightly higher OC levels were found in the B and B/C horizons at 2.07% and 1.88% respectively indicating good structural condition and stability. The OC percentages in the B and B/C horizons are equivalent to 3.6% and 3.24% organic matter respectively. These moderate to high levels of soil OC and OM confer an enhanced ability of the soil effectively function as a medium for plant growth, to regulate and partition water flow in the environment and to serve as an environmental buffer to potential harmful compounds present in the soil.

All horizons of the soils at site 1 display very low electrical conductivities (EC) (<0.07dS/m) signifying that salinity is not a problem in this soil. The soil has very low to moderate cation exchange capacity (CEC) throughout the entire soil profile with the lowest CEC in the topsoil (45mmol(+)/kg) signifying a high degree of infertility. This is confirmed by the low to very low levels of all the exchangeable cations to a depth of 1m with the exception of moderate levels of exchangeable Ca in the B and B/C horizons. The presence of high Ca levels could be attributed to historical liming when site 1 was constructed. Such low fertility in the soil suggests that a serious remediation strategy to boost nutrient availability in the soil would be necessary if a community garden was to establish successfully at this site. While Aluminium is present in low amounts in this soil it is not harmful as exchangeable Al only becomes significant at pH's less than 5.5 in water. The low levels of sodium are beneficial for this soil as it indicates that it is not sodic and therefore is not threatened by soil structure degradation via slaking and dispersion.

Nitrogen is essential for chlorophyll synthesis and thus requires N to produce energy for plant growth (Glendinning 2000). Ammonium and nitrate nitrogen are mineralised forms of nitrogen that are readily available to plants and thus have the greatest relevance in terms of assessing the agronomic potential of soils. Ammonium N and Nitrate N levels are very low (<3mg/kg) throughout the entire soil profile and considering the sandy nature of the soil it is likely that any soluble N would leach down the profile relatively quickly. However, such low levels also suggest that there is a high chance that this soil will respond well to N fertilisation.

For a sandy soil, the phosphorous status is considered very high if Colwell P values are >25mg/kg. Colwell P is an indication of the quantity of P readily available to plants. The Colwell P level in the topsoil of site 1 is 52mg/kg and ~35mg/kg in the subsoil revealing that this soil has very high P levels to a depth of 1m possibly as a result of the addition of fertilisers upon construction of the Kirkbride complex grounds. P fertilisers form complexes with Ca possibly explaining why Ca and P are in such high levels in this soil. Adequate P levels are beneficial for the establishment of healthy plants as it has an important role in photosynthesis and respiration, two biochemical reactions essential for maintaining a healthy plant-soil interface.

Critical values for available potassium (K) that begin to limit plant growth are around 80-200mg/kg. The K level in the soils of site 1 decrease with depth from 149mg/kg in the topsoil to 117kg/mg in the B/C horizon and are thus deficient throughout the entire profile. K fertilisation or increases in organic matter (OM) would be necessary to optimise plant growth in these soils, particularly if plants were to be grown for the purpose of harvesting food for consumption.

Sulphur is essential to the production of amino acids and therefore protein synthesis in plants. It stands to reason that deficient S levels, as found in the soils of site 1 to a 1m depth, can translate into reduced plant productivity and difficulty in plant establishment particularly with Brassica crops such as cabbage. Considering that OM is the primary source of S in soil, it would be of benefit to this site to increase the OM levels if a community garden with a wide range of plants is to establish itself successfully.

Several micronutrients were tested for in this soil, namely Copper (Cu), Iron (Fe), Manganese (Mn), Zinc (Zn) and Boron (B). While these micronutrients are not essential for plant growth they are essential for optimal plant growth. Their availability is largely affected by the pH of the soil. The optimal levels of each of these micronutrients in the soil differs for every plant. For example, Apple trees require 6-20mg/kg of Cu and 20-50mg/kg of Zn for optimal growth, citrus trees require 60-120mg/kg of Fe, and some Brassicas require 30-640mg/kg of Mn. While no formal assessment can be made as to whether the levels of these micro-nutrients are optimal in this soil, the laboratory results provided in Table x will provide a useful reference when deciding upon the types of plants and trees that would be most suitable in a community garden at this site.

Sites 2 and 3

Cores 8-11 from sites 2 and 3 revealed similar soils in terms of texture and colour (Appendix 1) however they differed in the depth of soil until sandstone rock predominated (Fig.5). The soil of core 7 was very shallow hitting white sandstone rock at 30cm and had a dark grey B21 horizon in comparison to the grey-white B21 and B22 horizons of cores 8-11 (Table 3). The topsoil and B/C horizons of all the cores are loamy sands with approximately 5% clay. Thus these horizons are very sandy and well-drained however this drainage could be restricted by the concrete structures surrounding the sites. The B horizons of cores 8-11 are considered loams thus have greater clay content (20%) conferring increased water retention compared to the loamy sands above and below.

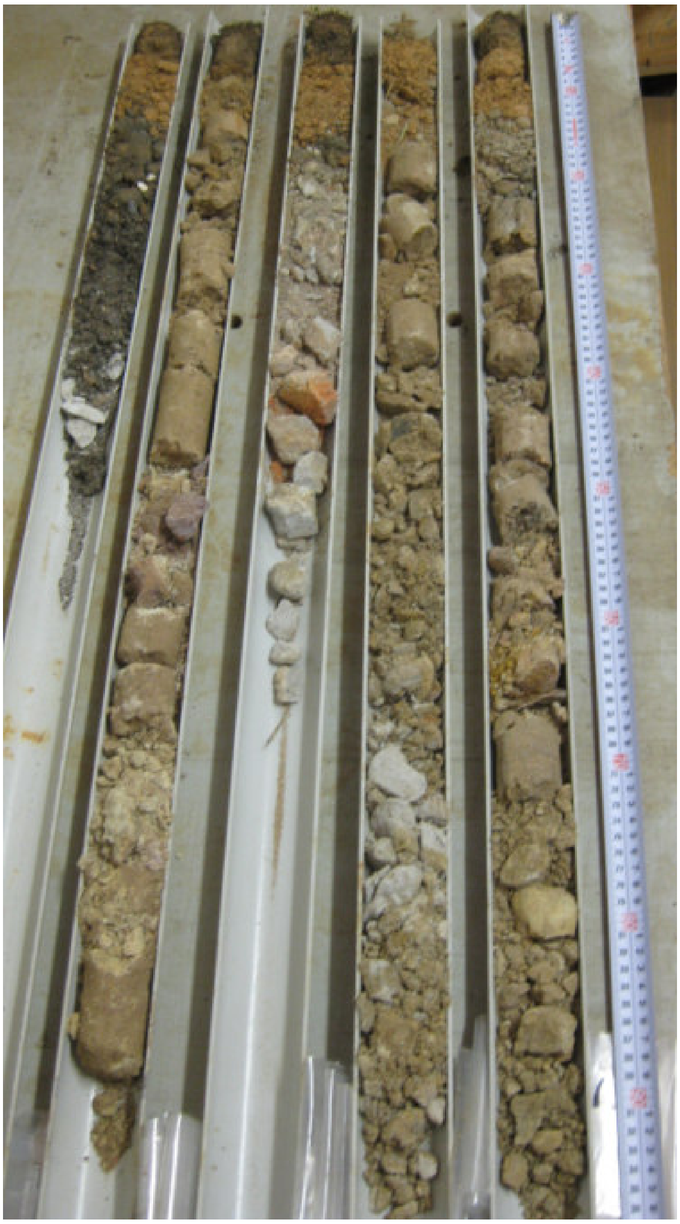

Fig.5 Air-dried cores 7-11(from left to right) from sites 2 and 3.

As can be seen in Fig.5, core 9 confirmed that the soil on the western side of site 2 is approximately 30cm deep underneath which sandstone rock occurs.

The chemical analysis results for cores 7-11 from sites 2 and 3 are summarised in Table 4.

Table 3. Chemical analysis results for cores 7-11 from sites 2 and 3.

Soil property	Units	Core7-11	Core 7	Core 8-11	
		Topsoil	B/C Horizon	B Horizon	B/C Horizon
Texture		1.5	1.5	2	1.5
pH (H20)	pH	7.4	8.9	8.4	9.3
Organic Carbon	%	0.8	2.67	<0.5	<0.5
Organic Matter	%	1.38	4.6	0.86	0.86
Electrical conductivity	dS/m	0.108	0.25	0.081	0.059
Exch. Calcium	mmol(+)/kg	103.8	275	77.9	99.6
Exch. Magnesium	mmol(+)/kg	10.9	4.7	7.7	6.5
Exch. Potassium	mmol(+)/kg	1.3	0.7	0.9	1.1
Exch. Sodium	mmol(+)/kg	1	0.7	1.1	1.2
CEC	mmol(+)/kg	117	281.1	87.6	108.4
Ammonium Nitrogen	mg/kg	2	2	<1	<1
Nitrate Nitrogen	mg/kg	1	3	1	2
Phosphorus Colwell	mg/kg	17	22	3	3
Potassium Colwell	mg/kg	116	71	79	99
Sulphur	mg/kg	10.9	126	7.48	59.8
DTPA Copper[1]	mg/kg	2.02	4.08	1.44	0.99
DTPA Iron	mg/kg	49.32	22.82	7.3	13.41
DTPA Manganese[2]	mg/kg	10.2	2.18	1.59	1.5
DTPA Zinc	mg/kg	4.29	21.14	10.67	3.57
Boron Hot CaCl2	mg/kg	0.2	0.4	0.3	0.3

Low
Moderate
High

[1] No Critical levels could be found
[2] Concentration data insufficient to predict deficiency or toxicity for plants

Examination of Table 3 reveals that the pH of the topsoil for all the cores is neutral while the B/C horizon of core 7 and the B horizon of cores 8-11 are moderately alkaline. The B/C horizon cores 8-11 have a pH that is strongly alkaline which could be caused by the presence of CaCO3 in the lower half of the profile. Due to all of the subsoil horizons being greater than pH 7.5, there are a number of plants that will not establish themselves successfully in such alkaline soils and considering the shallow nature of the topsoil (<15cm) it is likely that most plants would extend their roots into this alkaline subsoil.

The OC and OM levels in all horizons of cores 7-11 are low (<1.0%) with the exception of the B/C horizon in core 7 which has high OC and OM levels but despite the slightly improved levels of OC and OM in the subsoil of core 7, its shallow nature will be a physical impediment to the establishment of many plants. The EC levels are low for all soil samples from sites 2 and 3 except for the B/C horizon of core 7 which is moderate indicating that there is no salinity problem at these sites.

All exchangeable cations in the soils of sites 2 and 3 are considered very low to low except for calcium which is moderate in the subsoils of cores 8-11 and high in the topsoil of cores 7-11 and the B/C horizon of core 7. These high levels of exchangeable calcium in the soil are most likely due to the historical liming when the grounds were constructed or when the turf was layed. The high CEC of the core 7 subsoil could therefore be misleading as 97% of the CEC is due to exchangeable calcium, however the optimal proportion of Ca contribution to CEC is 65-80% for most plants. All other soil samples displayed low CECs indicating nutrient deficiencies in the soil.

The B/C horizon of cores 7-11 have a pH >8.3 indicating that the alkalinity is most likely due to the presence of Na. However, unexpectedly low levels of Na were found in these soils. It is also unusual to have high levels of Fe in alkaline soils as increasing pH's result in reduced availability of Fe and other micronutrients. This unexpected result may be due to prolonged weathering of sandstone or shale or may have formed from the oxidation of remnant building materials.

Plant available N and K levels in all cores from sites 2 and 3 are considered deficient and would therefore require amelioration strategies to improve the productivity of the soil for successful plant growth. P levels in the topsoil of cores 7-11 are moderate while levels in the subsoil of core 7 are more than adequate for most plants. However, P is a limiting factor to plant growth in the subsoil of cores 8-11 (3mg/kg).

Sulphur levels are high in the B/C horizons of cores 7-11 but are very low in the topsoil of cores 7-11 and the B horizon of cores 8-11. Improvements in organic matter would assist in lifting S levels in soils with inadequate S.

Sites 4 and 5

Profile descriptions were unable to be carried out on the soil samples taken from sites 4 and 5 due to the nature of the hand-auguring process. Therefore, we are particularly reliant on the chemical analysis from CSBP laboratory to provide us with in indication of the agronomic suitability of these sites for a community garden (Appendix 1). The results of the chemical analysis are summarised in Table 5.

Table 4. Chemical analysis results for hand-augered samples 1-3 from sites 4-6.

Soil property	Units	Site 4		Site 5	Site 6
		0-30cm	30-100cm	30-100cm	0-30cm
Texture		2.5	2	2	1.5
pH (CaCl2)	pH	5.1	5.4	5.4	5.1
pH (H20)	pH	6	6.5	6.5	6.1
Organic Carbon	%	2.5	0.89	1.13	2.22
Organic Matter	%	4.31	1.53	1.95	3.83
Electrical conductivity	dS/m	0.059	0.029	0.026	0.049
Exch. Calcium	mmol(+)/kg	70.3	47.7	38.9	48.8
Exch. Magnesium	mmol(+)/kg	12.5	5	6.1	11
Exch. Potassium	mmol(+)/kg	1	0.5	1.4	3.1
Exch. Sodium	mmol(+)/kg	1.1	0.8	0.6	0.9
CEC	mmol(+)/kg	85.6	55.1	47.7	64.5
Ammonium Nitrogen	mg/kg	2	2	1	7
Nitrate Nitrogen	mg/kg	10	1	1	7
Phosphorus Colwell	mg/kg	56	11	3	10
Potassium Colwell	mg/kg	96	68	129	212
Sulphur	mg/kg	3.85	2.64	2.37	4.91
DTPA Copper*	mg/kg	9.33	1.6	3.83	4.73
DTPA Iron	mg/kg	195.06	63.99	46.26	81.33
DTPA Manganese	mg/kg	2.48	0.71	0.9	2.69
DTPA Zinc	mg/kg	41.98	2.81	24.21	32.87
Boron Hot CaCl2	mg/kg	0.7	0.4	0.3	0.5

Low
Moderate
High

[1] No Critical levels could be found

[2] Concentration data insufficient to predict deficiency or toxicity for plants

The dark grey topsoil (0-30cm) at site 4 is classified as a clay loam with approximately 30% clay. It is smooth to manipulate but is compact and crumbly and forms a coherent plastic bolus. The dark grey subsoil (30-100cm) at sites 4 and 5 are loams with 20% clay while the topsoil of sites 5 and 6 are loamy sands with only 5% clay.

Examination of the results obtained for sites 4, 5 and 6 (Table 4.) shows a neutral pH through all samples which is conducive to growth for all plant species.

The OC and OM levels for the top 30cm for all cores are moderate to high suggesting the soils are adequate for plant growth. This result is tempered by the relative depth of the cores before they hit the parent material. Soils of only 30cm depth would be restrictive on the growth of many plant species. The EC is low for all sites indicating no problems with salinity at all sites.

All exchangeable cations for the three sites are considered low excepting exchangeable calcium and magnesium in the upper 30cm of site 4 and the exchangeable magnesium at site 6. The high calcium at site 4 may indicate the application of fertiliser in past years. The low CEC across all sites would be limiting to plant growth and is an indication of nutrient deficiency.

Soil N and K is considered low across all sites excepting potassium at site 6 and nitrogen in nitrate form in the topsoil of site 4. The large difference between soil K at site six and both sites 4 and 5 which are in close proximity suggest that this concentration is either an error in sample analysis or an isolated occurrence. Phosphorus levels are low and hence plant limiting in all samples again excepting the upper 30cm of site 4. The higher P levels in the top soil of site 4 can be linked with the higher Ca levels as the two are known to bind together.

Agronomic summary of the sites

None of the sites show overwhelming agronomic potential for the establishment of a community garden using the existing soil. All of the sampled sites are nutrient deficient with the exception of some profiles showing high levels of Ca due to the presence of $CaCO_3$. However, the soil cores that displayed high exchangeable calcium levels contribute >80% to the CEC which is not necessarily beneficial in terms of soil balance and therefore plant health.

Table 5. Infiltration measurements from sites 1, 4, 5 and 6

Site	Infiltration (mm/day)	Permeability Description
1	4819.94	High
4	30892.65	Extreme
5	8621.56	High
6	33929.73	Extreme

Infiltration experiments carried out at all sites showed that all but sites 2 and 3 had either high to extreme permeability (table 5.). This level of permeability is both good and bad as many plants like freely drained soil but this level of drainage may lead to rapid loss of water around plant root zones and hence water stress. Sites 2 and 3 were in a saturated state and infiltration measurements could not be completed.

Site 1 is the most appealing site within SCA for a community garden due to its size, community access, light availability, and its aspect to the water which is very aesthetically appealing. However, the chemical analysis of 6 soil cores from this area reveal that the soil at site 1 is deficient in many nutrients essential for plant growth such as N, K, S, Mg, Na. The soils here do possess adequate levels of OC and OM to a depth of 1m which may be a result of soil top dressing when this flat man-made area was created. The pH of the soils at site 1 is ideal for the growth and development of a range of plants.

The high pHs of the soil from sites 2 and 3 are potentially limiting to its potential for growing a range of plants as is often desired in a community garden. Most fruit trees and herbs will not establish in soils with high pHs and almost all vegetables will not grow in soils with a pH > 7.2. Improvements in OM could provide benefit to buffering the effects of high pHs as well as acting as a source of nutrients for the soil and plants. However, the shallow nature of the soil in some areas of site 2 and possibly site 3 may ultimately act as a physical barrier for successful plant establishment due to the inability of more deep-rooting plants to penetrate the soil to extract sufficient water and nutrients for optimal growth.

Sites 4, 5 and 6 are agronomically unsuitable for use in a community garden as they are now all sites are deficient in many if not all of the essential micro-nutrients which would limit plant growth. Reasonable levels of OM and OC are not limiting on plant growth and if the soil is improved through application of the needed nutrients through fertilisers the fertility of the soil would sustain plant growth. While the soils at all three sites could potentially be fertile enough to support plant growth the shallow nature of the profile would be limiting to the root zones of many plants.

In light of the aforementioned agronomic qualities of each of the sites, site 1 is the most agronomically suitable site for the establishment of a community garden however, if the community garden was to be dug into the existing soil, a fertilisation strategy would need to be employed if optimal growth of the garden plants is to be achieved. Alternatively, raised garden beds could be erected and a ‘no-dig’ policy adopted. Sites 2-6 are not agronomically suitable for the establishment of a community garden utilising the existing soil. Raised gardens beds would be the most suitable alternative if a community garden or small garden beds were to be established in these areas.

Recommendations

Chemical and physical analysis of the soils at sites 1-5 within SCA have revealed two possible alternatives for establishing a successful community garden. The first alternative is to use the existing soil at site 1 and implement a remediation strategy to improve the fertility of the soil. This alternative will require the soil to be dug up and may be limited in the range of plants suited to the soil conditions depending on the effectiveness of the remediation strategy. The second alternative is to erect raised garden beds at any of the sites and import soil that is suitable for hosting a wide range of plants.

Both scenarios require an organic approach based on the principles of permaculture. There are several reasons for this: it is a much more cost-effective and sustainable way of running a community garden, it provides natural sources of nutrients to the soil and plants and it eliminates the use of chemicals which could be potentially harmful to garden product consumers, by passers and SCA students and staff.

1. ***Community garden at site 1 using existing soil***

The creation of a community garden using the existing soil at site 1 will only be successful with the implementation of an effective soil fertility improvement program. While the soils of site 1 have adequate OM and OC they are deficient in the majority of essential nutrients for plant growth such as N, K, S and most micronutrients. This strategy would look similar to the scenario in Fig. 6.

Fig. 6. Example of herb and vegetable garden using existing soil.

1.1 Strategies to improve soil fertility

The first stage in this strategy would be to remove the turf in the areas designated for the garden beds keeping the pathways between the beds grassed and wide enough for safe passage of elderly people and wheelchair access. Due to a small layer of soil and OM being removed with the turf extraction, a new covering of organic soil and OM would be necessary. Australian Native Landscapes stocks ‘Vegetable and Seedling Mix’ which is a mixture of soil, sand, cow manure, composted sawdust and fertiliser and is an ideal top-dressing to apply to the soil prior to planting. A cheaper alternative is to use organic soil which can be turned into the soil before planting. Turning reduces soil compaction and increases aeration to give plants the best chance of survival. Mulch should also be added to help water retention and add nutrients to the soil as it breaks down.

An additional low-cost and very effective method to improve plant growth and development is through compost teas. We recommend setting aside a garden bed and planting stinging nettles a month prior to planting the rest of the plants in the community garden. Stinging nettles growing vigorously in a range of soils and are very high in N, K and many other micronutrients. Once they grow to a reasonable height they can be harvested and placed in a bucket of water for approximately 10 days. This creates a compost tea which can then be strained, diluted and poured across the garden providing water and essential nutrients for plant growth (Woodrow 1997). This foliar fertiliser strategy can be continuously applied throughout the year to the entire garden and can be done at no cost.

The nutrient status of the soil can also be cost-effectively maintained by having compost heaps within the garden. Community garden members can contribute food scraps to these compost heaps. The resultant broken down compost provides a sustainable and low-cost source of nutrients which can be scattered across the garden to improve fertility.

1.2 Suitable plants for site 1

The plants outlined in Table 6 have been recommended on the basis of their suitability to the soil at site 1 in terms of pH, soil texture, drainage of the soil, and available nutrients. They also suit the climatic conditions present at site 1 and the amount of available sunlight. The rows of the plants should run east to west with the taller plants sown on the southern end so they don’t shade the smaller plants.

Table 6. Recommended plants that are best suited to the soils of site 1.

PLANT	OPTIMAL CONDITIONS
Herbs (McLeod *et al.* 2006; Botanic Gardens Trust 2009)	
Garlic Chives Dill Basil Italian and Curly Parsley Thyme Rosemary Mint Oregano	• Herbs are tolerant of a wide range of growing conditions and they grow well with very little maintenance. • Prefer a light, well-drained, crumbly soil, but most will grow satisfactorily in fairly heavy soil provided there is good drainage. • Most prefer full sun but some can tolerate partial shade (eg. chives, parsley and mint). • Require plenty of organic matter. • Protection from wind is preferable. • Grow best in pH values of ~7. • Mint should be grown in confined conditions as it is very invasive.
Vegetables (Yates 1984; Salvestrin 1998)	
Beans Tomatoes Lettuce Carrots Cabbage Chillis Spring onions Pumpkins Potatoes	• Require full sunlight • Require a soil/potting mix with good structure and good drainage. • Grow best in soils with pH 6-7. • Will benefit greatly from mulching. • Need thorough water so the entire root system is moistened.
Fruit (Yates 1984; Glowinski 1997; Jackson & Looney 1999)	
Citrus fruit salad tree – can have a combination of two or more of lemons, limes, mandarins, oranges, tangelos. Strawberries Passionfruit	• Citrus do best in warm and mild climate zones. • Prefer lots of sunlight and water. • Protection from wind is preferable. • Free-draining soil. • Adequate mulch cover is necessary to prevent drying out as citrus tress have a shallow rooting system. • Need sufficient organic matter to bear good fruit. • Drip irrigation is a necessity for strawberries. • Passionfruits need something to climb over.
Ornamentals (Yates 1984; Rigby 2005; Australian National Botanic Gardens 2009)	
Lavender Bottlebrushes Grevilleas Red Salvia Agapanthas Magnolias Bay tree	• Lavender prefers well drained soil with lots of sun with a pH 6-8. Moisture required for seedlings but minimal for adult plants. • Bottlebrushes are very tolerant of dry and wet conditions and will grow in a wide variety of soils, except those which are alkaline. • Grevilleas are sensitive to poor drainage and salty conditions. • Red salvias prefer moist conditions and lots of sunlight. • Agapanthas must have a well-drained soil that is moderately fertile. They grow best in full sunlight. • Magnolias prefer lots of sunlight and protection from wind. • Bay trees prefer sheltered conditions and a west-facing aspect where it can get warm sunlight.

1.3 Irrigation

An irrigation strategy is recommended to ensure optimal plant health and growth. The most suitable method of irrigation would be to install a dripper system with timed watering to increase water use efficiency by watering after daylight hours and to ensure that the plants always receive adequate water.

1.4 Cost of strategy

The approximate cost of establishing a community garden using this strategy is outlined in Table 7. This cost analysis is based on a community garden with 8 garden beds 1 x 2.4m in area. However, this table does not include the costs of the plants or the cost of water for irrigation.

Table 7. The cost of the materials required for the establishment of a community garden using the existing soil.

Required materials	Cost per unit	Number of units	Total Cost
Turf cutter for extraction	Hire $120/half day	1	$120
Organic soil	$60/m3	2	$120
Hort bark mulch	$45/m3	2	$90
Fencing for stinging nettles	$7.50/post $4/m for chicken wire	4 posts 8m	$30 $32
Irrigation system	$2/m for dripper lines and fittings.	60m	$120
		TOTAL COST	**$512**

A cost comparison between various suppliers revealed that the cheapest suppliers for these materials are Kennards Hire for the turf cutter and Australian Native Landscapes for the remainder of the materials suggested in Table x.

1.5 Advantages/Disadvantages of strategy 1

- This strategy is a low-cost strategy but it may come at the cost of plant vigour if the soil improvement program is not successfully carried out.
- There is minimal labour and cost associated with its establishment.
- There could be difficulties for the elderly and wheelchair-bound to participate in the garden if it is at ground level. Working the garden at ground level could be painful for people in wheelchairs and the elderly due to the need to bend over for long periods of time or having to sit on the ground and get assistance to move to a different part of the garden. It could also be impossible altogether to reach the garden at ground level. This automatically excludes certain members of the community from participating.
- Another limitation is the stance of community members who disagree to any developments within Callan Park and who want to preserve the legacy of the psychiatric hospital. Such opponents, may reject proposals to dig up site 1 to

create a community garden. In this case, a 'no-dig' policy would be preferable and thus raised garden beds offer a more suitable alternative.

2. *Community garden at all sites using raised garden beds*

This strategy involving raised garden beds is more socially and culturally sensitive and it has the advantage of allowing a soil environment that is more easily manipulated to suit desired environment for the chosen plants.

2.1 Soil environment

The benefit of using raised garden beds is that the soil environment is more easily manipulated. Organic soil can be used to fill the garden beds and then covered in mulch creating a fertile and freely draining environment for the plants. In this way, it is not necessary to address any issues of soil fertility prior to the establishment of the garden, however the practices recommended in strategy 1 to improve and maintain soil fertility throughout the life of the garden would also be beneficial for this scenario.

In the case of sites 2-5 where shallow and alkaline soil can be found in certain areas, raised garden beds would increase the available depth for plant rooting and provide a less alkaline soil thereby allow a greater variety of plants to be grown. However, if sites 2-5 are not big enough for a community garden it could be scaled down to a vegetable and/or herb garden that the SCA students and staff could tend to.

From our investigation into the soils within SCA, we could infer that the soils outside of SCA but within Callan Park are also nutrient deficient but may vary in the depth of the soil. Therefore, if the opportunity arose in the future to develop a community garden outside of SCA, it could be of financial benefit to assume that the soils have a similar nutrient status and opt for raised garden beds instead of carrying out further chemical analysis on these soils.

2.2 Cultural and social issues

The erection of raised garden beds does not involve the destruction of any land on the site except for the turf extraction. Therefore, it is more sensitive towards the ideals of local community members whom do not want development projects or destruction of the landscape within Callan Park.

Raised garden beds at site 1 would be the most suitable for the elderly and people in wheelchairs as it has vehicle access via a concrete pathway all the way up to the side of the garden. The raised beds would also make it easier for the disadvantaged to reach the garden beds without having to bend over or sit down for long periods of time. People in wheelchairs can maintain the garden independently as they will be able to stay in their wheelchairs and would not require assistance to get out of their chairs (figure x). A strategy such as this would also be looked upon favourably by the community as it takes into consideration disadvantaged people in the local community.

2.3 Erecting the garden beds

It is recommended that second-hand hardwood timber railway sleepers be used to create the raised garden beds and held together using galvanised deck spikes. To cater for the elderly and wheelchair-bound garden beds of 4 timber sleepers high would be necessary and all other garden beds would be sufficient at 2 sleepers high (Fig. 7). Organic soil would be required to fill the raised garden beds and top-dressed with mulch to assist with water and nutrient retention. An irrigation system similar to that proposed in strategy 1 is recommended.

Fig. 7. Raised garden beds of different heights to suit all ages and abilities.

2.4 Suitable plants for use in a raised garden bed

All plants recommended in strategy 1 would be suitable for a raised garden bed situation. The improvement in the soil fertility using organic soil in the raised garden beds might also allow for the growth of Camellias, Azaleas, Viburnum and Roses which prefer more nutrient-rich soil that could not be provided by the existing soils of site 1 without a remediation strategy.

2.5 Cost of strategy

The approximate cost of establishing a community garden using strategy 2 is outlined in Table 8. This cost analysis is based on a community garden with 4 garden beds 1m wide x 2.4 long x 4 sleepers high and 4 garden beds 1m wide x 2.4 long x 2 sleepers high. This table does not include the costs of the plants or the cost of water for irrigation.

Table 8. The cost of the materials required for the establishment of a community garden using raised garden beds.

Required materials	Cost per unit	Number of units	Total Cost
Turf cutter for extraction	Hire $120/half day	1	$120
Timber sleepers	$12/sleeper	72	$864
Galvanised deck spikes	$150/60	60	$150
Organic soil	$60/m3	8	$480
Hort bark mulch	$45/m3	2	$90
Fencing for stinging nettles	$7.50/post $4/m for chicken wire	4 posts 8m	$30 $32
Irrigation system	$2/m for dripper lines and fittings.	60m	$120
		TOTAL COST	**$1886**

A cost comparison between various suppliers revealed that the cheapest suppliers for these materials are Kennards Hire for the turf cutter, timber sleepers from an independent source and Australian Native Landscapes for the remainder of the materials suggested in Table 8.

2.6 Advantages/Disadvantages of strategy 2

- Higher costs associated with erected the raised garden beds and more labour needed, however greater soil fertility may result in improved plant establishment,
- Better option for the elderly and disabled.
- Can easily be removed and returned to original state (minimal disturbance to landscape).
- More aesthetically appealing as it is neater and invasive plants can be more easily confined to designated areas.

Limitations to the study

- Restricted access to all possible sites within Callan Park meant we could not explore all possible options for the establishment of a community garden but instead had to extrapolate from the areas we were able to sample.
- Social and political issues had to be taken into account when considering all possible avenues of establishing a community garden.
- Budgetary constraints (Table 9) meant that we could not taken very dense soil samples and had to composite soil profiles according to horizons thereby losing information about the variability across a site in order to meet the budget.

Table 9. Actual expenditure for SCA community garden consultancy project.

Activity	Cost per unit	Number of units	Total Cost
Coring	$250/half day	1	$250
Sample preparation	$60/hr	10	$600
Courier	$60	1	$60
Lab analysis	$60	13	$780
Infiltration experiment	$60/hr	2	$120
Consultancy report	$60/hr	30	$1800
		TOTAL COST	**$3610**

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