

University of Wollongong - Research Online

Thesis Collection

Title: Limits to revegetation of clay capped landfill sites by Australian native plants

Author: Eleanor Jane Hannah

Year: 2006

Repository DOI:

Copyright Warning

You may print or download ONE copy of this document for the purpose of your own research or study. The University does not authorise you to copy, communicate or otherwise make available electronically to any other person any copyright material contained on this site.

You are reminded of the following: This work is copyright. Apart from any use permitted under the Copyright Act 1968, no part of this work may be reproduced by any process, nor may any other exclusive right be exercised, without the permission of the author. Copyright owners are entitled to take legal action against persons who infringe their copyright. A reproduction of material that is protected by copyright may be a copyright infringement. A court may impose penalties and award damages in relation to offences and infringements relating to copyright material.

Higher penalties may apply, and higher damages may be awarded, for offences and infringements involving the conversion of material into digital or electronic form.

Unless otherwise indicated, the views expressed in this thesis are those of the author and do not necessarily represent the views of the University of Wollongong.

Research Online is the open access repository for the University of Wollongong. For further information contact the UOW Library: research-pubs@uow.edu.au

2006

Limits to revegetation of clay capped landfill sites by Australian native plants

Eleanor Jane Hannah
University of Wollongong

Follow this and additional works at: <https://ro.uow.edu.au/theses>

University of Wollongong

Copyright Warning

You may print or download ONE copy of this document for the purpose of your own research or study. The University does not authorise you to copy, communicate or otherwise make available electronically to any other person any copyright material contained on this site.

You are reminded of the following: This work is copyright. Apart from any use permitted under the Copyright Act 1968, no part of this work may be reproduced by any process, nor may any other exclusive right be exercised, without the permission of the author. Copyright owners are entitled to take legal action against persons who infringe their copyright. A reproduction of material that is protected by copyright may be a copyright infringement. A court may impose penalties and award damages in relation to offences and infringements relating to copyright material.

Higher penalties may apply, and higher damages may be awarded, for offences and infringements involving the conversion of material into digital or electronic form.

Unless otherwise indicated, the views expressed in this thesis are those of the author and do not necessarily represent the views of the University of Wollongong.

Recommended Citation

Hannah, Eleanor Jane, Limits to revegetation of clay capped landfill sites by Australian native plants, M.Env.Sc. thesis, School of Earth and Environmental Sciences, University of Wollongong, 2006.
<http://ro.uow.edu.au/theses/631>

NOTE

This online version of the thesis may have different page formatting and pagination from the paper copy held in the University of Wollongong Library.

UNIVERSITY OF WOLLONGONG

COPYRIGHT WARNING

You may print or download ONE copy of this document for the purpose of your own research or study. The University does not authorise you to copy, communicate or otherwise make available electronically to any other person any copyright material contained on this site. You are reminded of the following:

Copyright owners are entitled to take legal action against persons who infringe their copyright. A reproduction of material that is protected by copyright may be a copyright infringement. A court may impose penalties and award damages in relation to offences and infringements relating to copyright material. Higher penalties may apply, and higher damages may be awarded, for offences and infringements involving the conversion of material into digital or electronic form.

**LIMITS TO REVEGETATION OF CLAY CAPPED LANDFILL SITES BY
AUSTRALIAN NATIVE PLANT SPECIES**

A thesis submitted in fulfilment of the requirements for the award of the degree

Master of Environmental Science (Research)

from

University of Wollongong

By

Eleanor Jane Hannah

B.Env.Sci (Hons) University of Wollongong

School of Earth and Environmental Sciences

2006

Thesis Certification

I, Eleanor J. Hannah, declare that this thesis submitted in fulfilment of the requirements for the award of Master of Environmental Science (Research), in the School of Earth and Environmental Sciences, University of Wollongong, is wholly my own work except where otherwise referenced or acknowledged. The document has not been submitted for qualifications at any other academic institution.

Eleanor J. Hannah

15 November 2005

Acknowledgments

This study was developed as an ARC-linkage project with Industry, with Camide Pty Ltd., as the industry partner. I thank them for their financial, practical and field support, especially from Miranda Kolega and the personnel at the field sites.

I have had a lot of assistance with the completion of this thesis, all of which is greatly appreciated. Firstly to my supervisors, Professors John Morrison and Rob Whelan, I could not have done better. To all those in the Environmental Science Unit, in Biological Sciences and in the rest of the School of Earth and Environmental Sciences, who have helped and encouraged me along the way, especially Sandra Quin, thankyou. A very big and special thankyou to those who assisted with my at times very difficult fieldwork, Melinda Leth, Justine Cox, Kirsten and Andy, Cathy and Michael, and Kate Austin. Rob's Ecology Group was a wonderful source of inspiration and support. Thankyou also to Professor Ted Bryant, who through his enthusiasm, helped to start me on my journey.

Meteorological data was kindly supplied by the Sydney office of the Bureau of Meteorology. Thankyou to Max from GHD, Mt Isa, for helping me with figures and diagrams. To all of my new friends in Mt Isa, and my old friends scattered to the four corners of the world, thankyou for being so supportive.

Finally to my family, Geoff who has helped and supported throughout, and my boys, Michael and Woden, who simply by being there, have given me a greater appreciation and understanding of my work. To my mum, dad, brother and sister, thankyou for your support, interest and encouragement. For all those who helped along the way and have not been otherwise mentioned here, thankyou.

Table of contents

Acknowledgments	iii
Table of contents	iv
List of figures	x
List of tables	xiii
Abstract	xiv
Chapter 1 Introduction	1
1.1 What are degraded sites?	2
1.2 Rehabilitation of degraded sites	2
1.3 Landfills as degraded sites	4
1.3.1 Landfill leachate	4
1.3.2 Capping	5
1.3.3 Landfill gas	5
1.3.4 Uneven settlement of waste	6
1.3.5 Limitations on future land use	6
1.4 Challenges to rehabilitation	7
1.4.1 General challenges to the rehabilitation of degraded sites	7
1.4.2 Challenges to rehabilitating landfill sites	8
1.4.2.1 Limitations to the revegetation of landfill sites	9
1.4.2.2 Plant excavation studies at landfill sites	10
1.4.2.3 Restrictions on the types of plants permitted on landfills	11
1.5 Individual factors affecting rehabilitation	13
1.5.1 Climate	13
1.5.2 Herbivores	14
1.5.3 Weeds	14

1.5.4	Species selection	14
1.5.5	The soil layer	15
1.5.5.1	Availability of topsoil	15
1.5.5.2	Soil compaction	16
1.5.5.3	Salinity	16
1.5.5.4	Soil pH	17
1.5.5.5	Soil nutrients	17
1.5.5.6	Soil moisture	17
1.5.5.7	Soil oxygen	18
1.5.5.8	Soil temperature	19
1.5.6	Landfill gas and its components	19
1.5.6.1	Methane (CH ₄)	20
1.5.6.2	Carbon dioxide (CO ₂)	20
1.6	Western Sydney as a suitable study location	20
1.7	Specific aims of this study	21
 Chapter 2 Characteristics of the study area, the experimental sites and species selection		 25
2.1	Environment of the Cumberland Plain	25
2.1.1	Climate	25
2.1.2	Topography and soils	27
2.1.3	General flora and fauna	28
2.2	Characteristics of the experimental sites	29
2.2.1	Site 1 – Horsley Park	30
2.2.2	Site 2 – Schofields	34
2.2.3	Site 3 – Londonderry	36
2.3	Species selection	39

2.3.1	Species selection criteria	40
2.3.2	Refining the species search	41
2.3.3	Seed treatment and germination	50
Chapter 3 Preliminary germination and growth studies		53
3.1	Introduction	53
3.2	Field germination Pilot study I: Site 1	53
3.2.1	Introduction	53
3.2.2	Materials and methods	54
3.2.3	Results	56
3.2.4	Discussion	57
3.3	Field germination Pilot study II: Site 2	59
3.3.1	Introduction	59
3.3.2	Materials and methods	59
3.3.3	Results	60
3.3.4	Discussion	61
3.4	Planting experiment: Sites 1 and 2	62
3.4.1	Introduction	62
3.4.2	Materials and methods	62
3.4.2.1	The plants	62
3.4.2.2	Measurement of plant growth and survival	63
3.4.2.3	Ground preparation	65
3.4.2.4	Planting	66
3.4.2.5	Tree guards	67
3.4.3	Results	67
3.4.4	Discussion	72

3.5	Implications of germination Pilot studies I and II and planting experiments: Sites 1 and 2	73
Chapter 4	Investigation of factors influencing germination and survival	75
4.1	Introduction	75
4.2	Influence of soil moisture on germination – Site 2	75
4.2.1	Introduction	75
4.2.2	Materials and methods	76
4.2.2.1	Germination in the field	76
4.2.2.2	Germination in the glasshouse	76
4.2.3	Results	78
4.2.4	Discussion	80
4.3	Soil moisture as a limiting factor for germination and seedling survival: Sites 2 and 3	81
4.3.1	Introduction	81
4.3.2	Materials and methods	82
4.3.3	Results	84
4.3.3.1	Species which failed to germinate	84
4.3.3.2	Germination and seedling survival for each treatment: Site 2	84
4.3.3.3	Germination and seedling survival for each treatment: Site 3	91
4.3.4	Discussion	97
4.4	Seed removal / loss: Sites 1, 2 and 3	98
4.4.1	Introduction	98
4.4.2	Materials and methods	99
4.4.2.1	Seed removal Time 1: Sites 1 and 2	100
4.4.2.2	Seed removal Time 2: Sites 2 and 3	100
4.4.3	Results	101

4.4.3.1	Seed removal per site and cache location after 1 week: Sites 1, 2 and 3	102
4.4.3.2	Seed removal after ~2 hours, 1 week and 40 days: Site 3	108
4.4.3.3	Seed movement, interference and damage: Sites 2 and Site 3	109
4.4.4	Discussion	112
4.5	Herbivory	114
4.6	Shape, size and general characteristics of the root systems	116
4.6.1	Introduction	116
4.6.2	Materials and methods	119
4.6.3	Results	120
4.6.4	Discussion	126
4.7	Factors limiting germination and plant survival	127
Chapter 5 Conclusions and recommendations		129
5.1	Summary of main findings in relation to project objectives	129
5.1.1	To provide an overview of research into the revegetation of landfill sites and limiting factors identified	129
5.1.2	To use the information found, plus local information, to identify potentially limiting factors to vegetation growth on clay capped landfills in Western Sydney	130
5.1.3	To develop a list of species that may be suitable for revegetating these landfill sites and to identify the limiting factors on the Western Sydney sites	130
5.1.4	To identify the most appropriate method of establishing native plants on these landfill sites	131
5.1.5	To determine the shape and extent of the root system and the degree to which roots penetrated the cap	132
5.1.6	To discuss the potential of these sites, and clay capped landfills in general, for establishment with native vegetation	132
5.2	Limitations and lessons	133

5.3	An adaptive management approach	135
5.4	Recommendations	137
5.4.1	Recommendations to landfill and degraded land researchers	137
5.4.2	Recommendations to the managers of landfill sites	138
5.4.3	Recommendations to the legislative requirements of landfills	139
5.4.4	Recommendations to the managers of land to be revegetated	140
	References	143
Appendix A	Soil results	155
Appendix B	Field recording sheets	157
B1:	Field recording sheet for 10 quadrat germination study at Site 2	158
B2:	Field recording sheet for planting experiment at Sites 1 and 2	159
B3:	Field recording sheet for mulching and watering experiment at Sites 2 and 3	160
B4:	Field recording sheet for plant removal experiment at Sites 1, 2 and 3	161

List of figures

Figure 1.1	Flow chart of thesis structure	23
Figure 2.1	Location map of the three study sites within the Sydney region	26
Figure 2.2	Site 1 – Horsley Park Map	31
Figure 2.3	Site 2 – Schofields Map	35
Figure 2.4	Site 3 – Londonderry Map	37
Figure 3.1	Field germination Pilot study I, plot set up	55
Figure 3.2	Plant survival at Sites 1 and 2 for each species after 6, 12 & 24 months	68
Figure 3.3	Plants alive and deaths attributed to herbivory at Sites 1 and 2 for each species after 6 months	70
Figure 3.4	Plants alive and deaths attributed to herbivory for each planting area and species at Sites 1 and 2 after 6 months	71
Figure 4.2.1	Overall percent germination by species, for the field, glasshouse and control	79
Figure 4.2.2	Overall percent germination in the field and glasshouse for each of the quadrats for the five species tested	79
Figure 4.3.1	Outline of mulching and watering experimental plots, example of Plot 1, Site 3	82
Figure 4.3.2	Site 2, cumulative numbers of seedlings appearing and numbers of these alive at 3, 6 and 12 months	85
Figure 4.3.3	Site 2, cumulative numbers of seedlings appearing and numbers of these alive after 12 months for each plot and treatment: a – no treatment; b – water; c – mulch; and d – water and mulch	86
Figure 4.3.4	Site 2, outline of Plot 10. Germination was highest in the left hand quadrat (as shown) and declined from left to right	89
Figure 4.3.5	Site 2, cumulative numbers of seedlings appearing and numbers of these alive after 3, 6 and 12 months for <i>Hardenbergia violacea</i> . Data are averaged across Plots 1-9	90

Figure 4.3.6	Site 3, cumulative numbers of seedlings appearing and numbers of these alive after 3, 6 and 12 months for all species. Data are averaged across 9 quadrats, with data for Plot 7 not included	91
Figure 4.3.7	Site 3, cumulative numbers of seedlings appearing and numbers of these alive after 12 months for each plot and treatment. Plot 7 values are for 8 months, before the plot was destroyed: a – no treatment; b – water; c – mulch; d – water and mulch	92
Figure 4.3.8	Site 3, cumulative numbers of seedlings appearing and numbers of these alive after 3, 6 and 12 months for each species. Data are averaged across 9 plots, data for Plot 7 not included: a – <i>Acacia linifolia</i> ; b – <i>Daviesia ulicifolia</i> ; c – <i>Hardenbergia violacea</i> ; d – <i>Kennedia rubicunda</i>	94
Figure 4.4.1	Overall seed remaining in caches and removed after 1 week for the Time 1 and 2 studies: a – Time 1 Site 1; b – Time 2 Site 2; c – Time 2 Site 2; d – Time 2 Site 3	103
Figure 4.4.2	Seed of <i>Acacia linifolia</i> remaining in caches and removed after 1 week for the Time 1 and 2 studies: a – Time 1 Site 1; b – Time 2 Site 2; c – Time 2 Site 2; d – Time 2 Site 3	104
Figure 4.4.3	Seed of <i>Atriplex semibaccata</i> remaining in caches and removed after 1 week for the Time 1 and 2 studies: a – Time 1 Site 1; b – Time 2 Site 2; c – Time 2 Site 2; d – Time 2 Site 3	104
Figure 4.4.4	Seed of <i>Bursaria spinosa</i> remaining in caches and removed after 1 week for the Time 1 and 2 studies: a – Time 1 Site 1; b – Time 2 Site 2; c – Time 2 Site 2; d – Time 2 Site 3	105
Figure 4.4.5	Seed of <i>Daviesia ulicifolia</i> remaining in caches and removed after 1 week for the Time 1 and 2 studies: a – Time 1 Site 1; b – Time 2 Site 2; c – Time 2 Site 2; d – Time 2 Site 3	105
Figure 4.4.6	Seed of <i>Hardenbergia violacea</i> remaining in caches and removed after 1 week for the Time 1 and 2 studies: a – Time 1 Site 1; b – Time 2 Site 2; c – Time 2 Site 2; d – Time 2 Site 3	106
Figure 4.4.7	Seed of <i>Indigofera australis</i> remaining in caches and removed after 1 week for the Time 1 and 2 studies: a – Time 1 Site 1; b – Time 2 Site 2; c – Time 2 Site 2; d – Time 2 Site 3	106

Figure 4.4.8	Seed of <i>Lomandra longifolia</i> remaining in caches and removed after 1 week for the Time 1 and 2 studies: a – Time 1 Site 1; b – Time 2 Site 2; c – Time 2 Site 2; d – Time 2 Site 3	107
Figure 4.4.9	Seed of <i>Calotis cuneifolia</i> remaining in caches and removed after 1 week in the Time 2 study at Sites 2 and 3: a – Site 2; b – Site 3	107
Figure 4.4.10	Site 3, early seed removal, percent seed remaining in each cache and the time recorded	108
Figure 4.4.11	Site 3, percent seed remaining by species after ~2 hours, 1 week and 40 days	109
Figure 4.4.12	Site 3: seed within the cache, within 200 mm of the cache and removed, for the Time 2 study at Sites 2 (after 1 week) and 3 (after 1 week, and 40 days)	111
Figure 4.5.1	Herbivory trial Site 2: percentage survival for each of species and treatment: marked; no treatment; tree guard	116

List of tables

Table 2.1	Summary of initial soil analyses for the three study sites	33
Table 2.2	Potential experimental species and their properties	42
Table 2.3	Base information about the target species	47
Table 2.4	Seed treatment and base germination for the target species	48
Table 3.1	Comparison of field germination Pilot studies I and II	59
Table 4.1	Species used in the glasshouse experiment, selection criteria and the number of seed used per punnet	77
Table 4.2	Site 2, the effect of Plot 10 on the overall results of seedling survival after 12 months, for each of the treatments	89
Table 4.3	Site 2, 12 month survival and total seedlings for each species and treatment, averaged over Plots 1-9	90
Table 4.4	Site 3, 12 month survival and total seedlings for each of the species which had some germination	96
Table 4.5	Site 3, results for 12 month survival and total germination for each species with 5 or more germinants in at least 1 treatment and over all species, using two-way ANOVAs (randomised block design)	97
Table 4.6	Site 3, damage to and movement of seed in the Time 2 seed removal study at Site 2 (1 week) and Site 3 (1 week and 40 days). Only those species with seed found within 200 mm of the cache, or had elaiosomes removed, are listed	113
Table 4.7	Plant removal summaries	122
Table A	Soil sample results for Sites 1, 2 and 3	156

Abstract

The revegetation of closed landfill sites is an important issue due to the large and increasing amount of land involved, and because the demand for that land, and its value, is constantly increasing. If successful revegetation is possible, then these degraded sites provide an excellent opportunity for the establishment of native plant communities in the middle of urban sprawl. Common problems identified with the revegetation of landfill sites have included the use of poor quality soils with low organic matter, low levels of available nutrients, the use of species not suited to the conditions, and landfill gas. The problems with the soils are compounded by compaction, resulting in low permeability and porosity, leading to very low available soil moisture. Little research, however, has been conducted on the revegetation of clay-capped landfill sites in Australia using Australian native plant species. The overall aim of the thesis was to test the survival and growth of indigenous plants at clay capped landfill sites.

I used three landfill sites in western Sydney as case studies. Species that may be suited to the early revegetation of these sites were identified and information available on plant growth of these indigenous was found to be limited. So I initially surveyed the germination potential of a range of the target indigenous species with two pilot studies, one at Site 1 the other at Site 2. At both sites, very low germination rates (0% in 4 species, highest 4.1%) were observed, with the possible contributing factors being low rainfall and subsequent low soil moisture levels and herbivory of seeds and plants.

In order to overcome the fragile germination and early seedling establishment phase, I conducted a planting trial at Sites 1 and 2 using *Acacia linifolia*, *A. ulicifolia*, *Indigofera australis*, *Kennedia rubicunda* and *Lomandra longifolia*. Survival rates from these experiments were also very low, with the main contributing factors inferred to be herbivory, and low soil moisture availability. Importantly, the most successful species in the planting trial was *Lomandra longifolia*, which had zero germination in the seeding trials.

The role of soil moisture in limiting germination or seedling and plant survival was tested in two experiments: a glasshouse germination study; and field study, in which mulching and watering were manipulated. Germination in the glasshouse with daily watering was 10 times higher than that in the field (one-way ANOVA, $F_{x,y} = 243$; P

<0.0001) illustrating that low available soil moisture is a limiting factor in the germination of the tested species. In the field experiment, the addition of the equivalent of 10 mm of rain once a week in the field did not significantly increase germination or seedling survival over 1 year for any of the species tested. A thin layer of straw mulch, however, did result in higher germination and 1 year seedling survival for several species at one of the sites (ANOVA *Hardenbergia violacea* $F_{x,y} = 3.64$; $P = 0.03$ and *Kennedia rubicunda* $F_{x,y} = 22.49$; $P < 0.0001$).

The role of herbivory and seed predation were tested in two other studies. Seed removal in May 1996 was not very high overall at either site, with just over 80% of seed remaining after 1 week. In February 1997, seed removal rates were higher with just 7.1% (Site 2) and 3.3% (Site 3) of seed remaining in the caches after 1 week. The higher seed removal in February was likely to be due to the time of year, with ants being more active in the warmer months. Several problems were encountered with the herbivory study: vandalism, the presence of domestic stock that was not anticipated; and a period of low rainfall. These three factors combined to result in very poor survival rates (11% after 4 months).

I concluded that no one strategy or range of species could be identified for successfully revegetating landfill sites in the short term. However, herbivory, low soil moisture, seed predation, vandalism and ongoing site works, could all limit success in particular circumstances. As a consequence, adaptive management approaches will be needed in developing solutions to particular sites and to ensure new information can be incorporated into ongoing management of a restoration program and the development of a better general understanding about limiting factors.