REVEGETATION OF RECENT SOIL SLIPS IN MANAWATU

A THESIS PRESENTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER IN APPLIED SCIENCE AT MASSEY UNIVERSITY

Kamal Kishor Prasad
2009
Abstract

*Trifolium repens, Lotus pedunculatus* and *Holcus lanatus* were oversown on two recent soil slip surfaces at AgResearch’s Ballantrae pastoral hill-country farm near Woodville. The two slip surfaces were located on (Manamahu steepland soil) sedimentary mudstone. One slip had a north aspect and the other had a south aspect. Both slips were located on a land class 6 with slope 28-33°.

The pasture species were oversown during early spring and the percentage seedling emergence and early establishment from viable seeds oversown was analysed at early spring (Day 15), late spring (Day 45), early summer (Day 90), and late summer (Day 120). The slip surfaces showed micro-climatic extremes in terms of both soil moisture and surface temperatures during the summer period. Significant differences (*P* < 0.05) were found in soil moisture between north and south facing slip surfaces. Higher soil moisture and lower soil mean temperature were recorded on the south aspect slip surface.

Significant differences (*P* < 0.05) were found between the three pasture species in terms of seedling emergence and early establishment. Significant differences (*P* < 0.05) were also found with aspect. The south aspect slip surface had a higher percentage of seedling emergence and earlier establishment for all the species. Interaction between species by aspect became significantly different (*P* < 0.05) at Day 90 and Day 120. The main effects of time and species were also significantly different (*P* < 0.05) illustrating seedling emergence and establishment as a race against time.

*Trifolium repens* was a more successful pasture specie, than *L. pedunculatus* and *H. lanatus* due to its higher consistency on both north and south slip surfaces. *Oversowing T. repens* during early spring is a viable option for rehabilitation of recent soil slips in Manawatu.
Acknowledgements

I would like to thank the thesis supervisors; Professor Peter Kemp (Head of Institute, Institute of Natural Resources (INR) and Dr James Millner, Programme Coordinator, BAgriscience, INR and Dr Alan Palmer of Soil and Earth Sciences, INR at Massey 2009. The objectives of this project wouldn’t have been realised without their continuous support and guidance.

Also thanking for the assistance provided by Mark Osborne, Ian Furket, Bob Toes, Anne West, Lance Currie, Mike Bretherton and LogaNathan of INR 09.

Sincere thanks goes to Professor Mike Hedley, Soil and Earth Sciences group, (INR, 09) for highlighting that renewing revegetation technology will lead to faster recovery of soil slips.

I would like to also thank Mr John Napier and Dr Coby Hoogendoorn, of Ballantrae AgResearch station farm near Woodville.

Also thanking Horizons Regional Council (Woodville/Palmerston North) and Landcare for all the assistance rendered.

I thank the sponsorship of this study, NZAID, together with international students support office team, Ms Syliva Hooker, Ms Sue Flyn and Ms Olive Primental.

Lastly, thanks to everybody especially my parents with all the family and friends.

Kamal Prasad

The green Earth is the meadow we graze in. the ground we are shaped from.

The daily bread, that keeps body and soul together.
# Table of Contents

Chapter 1  Introduction ........................................................................................................... 1  

Chapter 2  Literature Review .............................................................................................. 3  
2.0  History and importance of soil slip scar revegetation .............................................. 3  
2.1  Characteristics of soil slips ......................................................................................... 6  
2.2  Soil properties on soil slip surfaces .......................................................................... 9  
2.3  Previously tested pasture species to revegetate slips ............................................. 14  
2.4  The effects of soil temperature and moisture on seedling emergence .................... 17  
2.5  Effect of slope gradient and role of aspect ............................................................... 21  
2.6  Influence of defoliation and revegetation ............................................................... 23  
2.7  Seeds, oversowing and seedling emergence .............................................................. 24  
2.8  Pasture species selected for revegetation ................................................................ 25  
2.8.1  White clover ........................................................................................................ 26  
2.8.2  Morphological features ..................................................................................... 26  
2.8.3  Seasonal persistence ......................................................................................... 27  
2.8.4  Yorkshire fog ...................................................................................................... 29  
2.8.5  Morphological features ..................................................................................... 29  
2.8.6  Seasonal persistence ......................................................................................... 30  
2.8.7  Lotus pedunculatus ............................................................................................ 31  
2.8.8  Morphological features ..................................................................................... 31  
2.8.9  Seasonal persistence ......................................................................................... 32  

Chapter 3  Methodology ..................................................................................................... 35  
3.0  Introduction ................................................................................................................. 35  
3.1  Location of the Ballantrae Agresearch farm ............................................................... 35  
3.2  Description of study sites at Ballantrae ..................................................................... 35  
3.3  Experimental design ................................................................................................. 37  
3.4  Field materials for re-vegetation trial .................................................................... 37  
3.5  Soil moisture ............................................................................................................. 38  
3.6  Soil temperature ....................................................................................................... 39  
3.7  Germination test and oversowing .......................................................................... 39  
3.8  Visible seedling count .............................................................................................. 40  
3.9  Field materials for soil properties .......................................................................... 40  
3.10 Soil sampling and analysis ....................................................................................... 41  
3.11 Soil physical properties ............................................................................................ 41  
3.11.1 Bulk density ...................................................................................................... 41  
3.11.2 Soil porosity ...................................................................................................... 41  
3.11.3 Gravimetric water content ............................................................................... 41  
3.12 Soil chemical properties .......................................................................................... 42  
3.12.1 Soil pH ............................................................................................................. 42  
3.12.2 Olsen P .............................................................................................................. 42
3.12.3 Total Carbon and Nitrogen ............................................................... 43
3.12.4 Cations and Cation Exchange Capacity (CEC) ............................... 43
3.12.5 Extractable sulphate ......................................................................... 44
3.13 Total cover and herb cover ................................................................. 45
3.14 Statistical analysis - Repeated Measures (ANOVA) Design ............... 46

Chapter 4 Results ......................................................................................... 48
4.1 Soil fertility .............................................................................................. 48
4.2 Soil temperature ....................................................................................... 49
4.3 Soil moisture ............................................................................................ 52
  4.3.1 Ballantrae meteorological station ...................................................... 52
  4.3.2 Volumetric Water Content (W%) ...................................................... 53
4.4 Seed analytical report ............................................................................. 54
4.5 Seedling emergence and early establishment .......................................... 54
4.6 Effect of aspect on field seedling emergence and early establishment .... 56
4.7 Interaction between three pasture species with aspect ......................... 58
4.8 Main effects: Between and within subjects ............................................ 60
4.9 Correlation between species and weed cover after 120 days for establishment .................................................................................. 62

Chapter 5 Discussion ................................................................................... 65
5.1 Influence of soil fertility on seedling emergence and their early establishment .......................................................... 65
  5.1.1 Soil physical properties ................................................................. 65
  5.1.2 Soil chemical properties ............................................................... 66
5.2 Influence of soil temperature on seedling emergence ......................... 67
5.3 Influence of soil moisture on seedling emergence ............................... 68
5.4 Early-spring establishment of three pasture species on recent soil slips 69
5.5 Role of aspect on seedling emergence and early establishment .......... 71
5.6 Interaction between three pasture species by aspect ......................... 72
5.7 Seed quality .......................................................................................... 74
5.8 Essence of oversowing and effects of defoliation ................................. 75
5.9 Incidence of weeds and Herb cover ..................................................... 75

Chapter 6 Conclusion .................................................................................. 76

Limitations & Further research ..................................................................... 78

References ..................................................................................................... 79

Appendices ................................................................................................... 91
List of Tables

Table 2.1. Sediment budget of an erosion-inducing rainstorm (Cyclone Bola, 8th-11th of March, 1988) in Lake Tutira catchment, Hawke Bay (Glade, 2002). ........................................ 8

Table 2.2. Soil bulk density, particle density and porosity for different erosion classes, and deposition and wooded control sites (Ebeid, et al., 1995). (LSD - Least significant difference). ........................................................................................................ 9

Table 2.3. Mean soil fertility (1983-87), water contents (WC) and phosphate rock (PR%) for uneroded and eroded sites at different localities in New Zealand (DeRose, et al., 1995). ........................................................................................................ 11

Table 2.4 Target soil test ranges for near maximum production on recent Pallic and Brown soils (Source: Overseer Nutrient Budgets) (Hedley, 2005). ................................................. 13

Table 2.5. Slow and fast establishing seed mixtures were differentiated after seeding on a pastoral hill country farm the Wairarapa (Lambert, et al., 1993). .................... 15

Table 2.6. Water content as a volume fraction of the surface clay dominated soils at three soil water conditions. Adopted from (Marshall, et al., 1999, p. 11) ......................................................... 19

Table 2.7. Slope thresholds for rock types in the Manawatu- Wanganui region during extreme rainstorm if the vegetation cover is not woody (Dymond, et al., 2006). ................................................................................................. 22

Table 2.8. Effect of slope and aspect on T. repens flower head appearance per m² on rotationally grazed pasture at Ballantrae AgResearch farm. The main effect of aspect, and the slope aspect interaction, were significant at P < 0.001 (Chapman & Anderson, 1987), (Numbers represent flowerhead appearance per m⁻¹). ....................... 23

Table 2.9. The macronutrient composition (dry-matter %) of pasture and weed species from organic dairy pastures (Harrington, et al., 2006). ................................................................. 30

Table 3.1. Description of the respective treatments, seed rates, and plot rates........... 38

Table 4.1. Soil fertility on north and south aspect of the soil slip surfaces and the remnant adjacent pasture surfaces at Ballantrae AgResearch farm................................. 49

Table 4.2. Monthly rainfall data and 10-year rainfall mean from the meteorological station at Ballantrae AgResearch farm during the trial period in Woodville. ............... 52

Table 4.3. Water content recorded at Ballantrae AgResearch hill country farm on recent slip surfaces during the spring of 2008 and summer of 2009................................. 53

Table 4.4. Seed analytical report on the three species that were selected in this revegetation experiment (Seed Tech Services, Massey University)................................. 54
Table 4.5. LS mean (%) showing the main effect of seedling emergence and early establishment from viable seeds of three pasture species on recent soil slip surfaces, oversown early-spring at Ballantrae AgResearch farm in Woodville. (LS mean %- Least square mean %; Pr > l t l - Students t-test). .................................................................55

Table 4.6. Univariate analysis of variance showing the dates of analysis and their significance on seedling emergence and early establishment between three pasture species. (DF- Degrees of Freedom; Type III SS – Sum of squares; F value - Measurement of distance between individual distributions; Pr > F or alpha value set at 0.05). ..........................................................55

Table 4.7. LS mean (%) showing the main effect of north and south aspect on recent soil slip surfaces on three pasture species field emergence and early establishment from viable seeds, oversown early-spring at Ballantrae AgResearch hill country farm, Woodville. (LS mean %- Least square mean %; Pr > l t l - Students t-test). ......................57

Table 4.8. Univariate analysis of variance showing the dates of analysis on the role of north and south aspect recent slip surfaces on seedling emergence and early establishment. (DF- Degrees of Freedom; Type III SS – Sum of squares; F value - Measurement of distance between individual distributions; Pr > F or alpha value set at 0.05). ..........................................................57

Table 4.9. LS mean (%) showing interaction between three pasture species field emergence and early establishment from viable seeds on north and south aspect recent soil slip surfaces, oversown early-spring at Ballantrae AgResearch pastoral hill country farm in Woodville.(LS mean %- Least square mean %; Pr > l t l - Students t-test)..........................................................................................................................59

Table 4.10. Univariate analysis showing interaction between different pasture species and aspect on recent soil slip surfaces, oversown during early-spring at Ballantrae AgResearch pastoral hill country farm in Woodville. (DF- Degrees of Freedom; Type III SS – Sum of squares; F value - Measurement of distance between individual distributions; Pr > F or alpha value set at 0.05). .........................................................60

Table 4.11. Univariate analysis showing the effects of three pasture species on seedling emergence and early establishment from viable seeds on recent soil slip surfaces at Ballantrae AgResearch pastoral hill country farm, Woodville. (DF- Degrees of Freedom; Type III SS – Sum of squares; F value - Measurement of distance between individual distributions; Pr > F or alpha value set at 0.05).........................61

Table 4.12. The main effects over time on seedling emergence and early establishment on recent soil slip surfaces of three pasture species at Ballantrae AgResearch farm in Woodville. (DF- Degrees of Freedom; Type III SS – Sum of squares; F value - Measurement of distance between individual distributions; Pr > F or alpha value set at 0.05)..................................................................................61

Table 4.13. Coefficient correlation between weeds, herbage, total cover, weed cover herbage cover and establishment at 120 days.................................................63
List of Figures

Figure 2.1. Both shallow and deeper seated slipping in Mudstone (Mm) in Mangawhero hill country after 2004 storm event (Hancox & Wright, 2005)..........................3

Figure 2.2. Relationship of forest cover to recorded number of landslide-triggering rainstorm events between 1861 and 1981 in New Zealand (Glade, 1998).........................4

Figure 2.3. Bar plot of sediment delivered to stream resulting from a storm with 600 mm of rain, in each of the landslide prone systems, as a result of three different land cover scenarios: actual land cover (pasture), trees on steep slopes only (none in Wharekopae), trees everywhere (except Wharekopae) (Dymond, et al., 1999)..............5

Figure 2.4. Conceptual hydro-climatic landslide triggering model (Crozier, 1999)...........6

Figure 2.5. Histogram of normalised scar depths (Dymond, et al., 1999).............................7

Figure 2.6. Soil organic carbon in replicate soil cores taken to the bedrock interface in landslide scars and adjacent unslipped soil (Baisden, et al., 2002).................................10

Figure 2.7. Soil C in the upper 20 cm of the soil profile measured in landslide scars and in un-slipped areas. The solid line shows a simulation of recovery on a fresh scar using the CENTURY model (Baisden, et al., 2002). Sampling was conducted on adjacent aspects – North for sunny and south for shady. (Exact sampling dates were not mentioned)..................................................................................................................10

Figure 2.8. Availability of essential soil with differences to soil pH (McLaren & Cameron, 1996, p. 181). .................................................................................................................................12

Figure 2.9. Pori Station farm in Wairarapa. Note the vegetative succession of legumes grasses, ferns and weeds on old soil slip scars. .........................................................16

Figure 2.10. Relationships of soil texture to available water-holding capacity of soils. The differences between the water content at field capacity and the water content at permanent wilting point is the water available (Adopted from Foth, 1990)..............19

Figure 2.11. Landslide probability under non-woody vegetation versus slope angle for the four main rock types in Manawatu–Wanganui hill country. Landslide probability is calculated as the proportion of land in erosion scar (Dymond et al., 2006). ..........................................................................................................................21

Figure 2.12. Variability associated with differences in seed vigour that affects the germination processes of seeds (McWilliams, et al., 1970)......................................................24

Figure 2.13. Morphological features of white clover. Adopted from (Stewart & Charlton, 2006; Caddel, 2008).................................................................26
Figure 2.14. (A) Total leaf dry mass per pot; (B) Ratio of leaf dry mass; droughted: irrigated plants. Wi indicates when irrigated plants (controls) were watered. Wd indicates when droughted plants were watered. Bars represent 1 + S.E. Different bold letters (a, b, and c) indicate species means that were significantly different ($P < 0.05$) within each harvest date. Different italicized letters (a and b) indicate species means that were significantly different ($P < 0.1$) within each harvest date (Karsten & MacAdam, 2001). ................................................................. 28

Figure 2.15. Measured shoot and clean root nitrogen and estimated legume derived nitrogen in other fractions below ground (mg) for subterranean clover (McNeill, et al., 1997) ................................................................................................................ 29

Figure 2.16. Morphological features of $L$. pedunculatus. Adopted from (Stewart & Charlton, 2006). ........................................................................................................ 32

Figure 2.17. Percent germination over 20 days at $5^\circ$C of lotus species categorised by life cycle and seed size: (a) annual, small seeded; (b) annual large seeded; (c) perennial, small seeded; and (d) perennial large seeded (Kelman & Forrester, 1999).... 33

Figure 3.1. The two soil slips at the beginning of the revegetation trial. The left picture is the north facing slip face and the right picture is the south facing slip face.... 36

Figure 3.2. The two pictures showing recent hoof marks (A) on south facing slip and the effect of runoff on one of the north facing replicates. Some seeds may have washed away through these channels (B) but other survived. ................................. 36

Figure 3.3. Distribution of individual treatments (T) and replicates (R) under randomised block design at the two slips sites. ................................................................. 37

Figure 3.4. Location of the meteorological station at Ballantrae AgResearch farm at Woodville. ................................................................. 38

Figure 3.5. Placement of button temperature probes to record the soil surface temperature (a) and temperature at 5 cm depth (b) (covered after with soil) on both the soil slips surfaces................................................................. 39

Figure 3.6. 0.1 m$^2$ quadrants were placed and positions were marked within the all the individual plot area................................................................. 40

Figure 3.7. Soil sampling beside the soil slips ................................................................. 41

Figure 3.8. GBC atomic absorption analyser ................................................................. 42

Figure 3.9. LECO FP 2000 automated analyser ................................................................. 41

Figure 3.10. CEC Leaching Manifold................................................................. 44

Figure 3.11. Sulphate Auto analyser ................................................................. 44
Figure 3.12. An example of estimating vegetation and species cover using photoshop CS3 extended pixel count .................................................................45

Figure 3.13. Replicate that exceeded the estimated number of seedlings, resulting from the estimated number of oversown seeds .................................................................46

Figure 4.1. Mean bulk density on north and south aspect recent slip surfaces .................48

Figure 4.2. Weekly mean maximum and minimum surface temperatures on north and south facing slip surfaces at Ballantrae AgResearch hill country farm near Woodville .................................................................51

Figure 4.3. Field seedling emergence and early establishment from oversown viable seeds of three pasture species on recent slip surfaces at Ballantrae AgResearch hill country farm, Woodville ........................................................................................................56

Figure 4.4. Role of aspect on seedling emergence and early establishment of three pasture species on north and south facing aspect soil slip surfaces at Ballantrae AgResearch hill country farm in Woodville .................................................................58

Figure 4.5. LS mean (%) showing interaction between north (a) and south (b) facing aspect on seedling emergence/early establishment from viable seeds on recent slip surfaces at Ballantrae AgResearch hill country farm in Woodville .................................................................60

Figure 4.6. Comparison of individual pasture species and their interaction on seedling emergence and early establishment on north and south facing aspect slip surfaces at Ballantrae AgResearch farm in Woodville ........................................................................................................62
Appendices

Appendix 1. Mean bulk density from two recent soil slip surfaces at Ballanrae AgResearch pastoral hill country farm in Woodville. .................................................................89

Appendix 2. Soil fertility results of recent slip surfaces at Ballantrae AgResearch farm in Woodville .................................................................................................................90

Appendix 3. Weekly mean maximum and minimum surface temperatures on north and south facing slips during spring of 2008 to summer of 2009, at Ballantrae AgResearch pastoral hill country farm in Woodville. .............................................................................................................91

Appendix 4. The weekly mean climatic data recorded from metrological station at Ballantrae AgResearch farm at Woodville between 2008 spring and summer of 2009.................................................................................................................................92

Appendix 5. Weekly mean temperatures recorded on the slip surfaces and at the depth of 5 cm on north and south facing slips between 2008 spring and summer of 2009 at Ballantrae AgResearch farm. ..................................................................................................................93

Appendix 6. Rainfall data from the last 10 years at Ballantrae AgResearch farm at Woodville. The highlighted cells represent monthly rainfall accumulation during the revegetation trial period.(Shiferaw, et al., 1992) ................................................................................................................................................94

Appendix 7. Datasets for repeated measures of analysis........................................95

Appendix 8. SAS code for repeated measures of analysis.....................................96

Appendix 9. Graphs showing normalisation of the data using square root transformation at the 4 dates of analysis.................................................................97

Appendix 10. Aerial photo showing site locations and their accessibility via farm tracks at Ballantrae. ..................................................................................................................98

Appendix 11. Land Use Capability Map of Ballantrae AgResearch farm..............99