GEOG309: Research for Resilient Environments and Communities

Experimental tree planting at Lake Sarah Flats to benefit scientific research, community engagement and the environment.

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1 Executive Summary

- This research was conducted in fulfilment for GEOG309 at the University of Canterbury alongside our community partner, the Cass Research Advisory Board. Our GEOG309's goal was to provide suggestions around an experimental tree planting design for Lake Sarah Flats in the South Island, New Zealand.
- This proposed project will provide a valuable resource for science experimentation, as there are currently no large-scale, native tree planting experiments in New Zealand.
- The aim of this project is to benefit science, community engagement, and the environment.
- The research questions are:
  - What values does the Lake Sarah Flats site hold for different partners?
  - How can these values be optimised to provide sustained community engagement?
- The methods used for this research were an initial review of existing literature, a Maptionnaire survey of different parties about the values they held for the site, and a site visit to collect GIS data, which was processed to generate an orthomosaic image and a DEM.
- From the data we collected, we were able to use the DEM to suggest locations for the tree planting polygons. The results of the Maptionnaire survey indicated that the land is not currently in use, however it has the potential to be.
- Our research was limited by time constraints, COVID-19, and minimal GIS experience within the group.
- The future considerations section of this report offers suggestions for the development of this project. These are things for the Cass Research Advisory Board to consider before going ahead with the planting, and some potential GEOG309 projects for future years. These recommendations include considering soil type, pests, hazards, irrigation, public access, species selections and wind effects.

2 Introduction

Lake Sarah Flats is adjacent to the Cass Field Station, approximately a 1.5-hour drive from Christchurch City. This land has been vacant for some time and its potential has not been maximised by the University of Canterbury (UC). The Cass Research Advisory Board plans to use Lake Sarah Flats for experimental tree planting of New Zealand native species. Their aim is to plant the site with nine identical polygons (tree planting blocks) where each polygon contains 10 1 ha plots. One of the 10 plots will act as a control while the other nine plots each contain a monoculture planting of different native tree species, as seen in Figure 1.

Griselinia littorialis	*Kunzea ericoides*	*Cordyline australis*	*Sophora microphylla*	*Aristotelia serrata*
Control	*Carpodetus serratus*	*Fuscospora cliffortioides*	*Phyllocladus alpinus*	*Fuscospora fusca*

Figure 1. Example of potential arrangement of tree species for experimental plantings.

Throughout the project we had multiple assignments for GEOG309. The first three assignments required consideration of how to engage with mana whenua, a review of relevant literature, and a reflection on research methods and group work. The last two assignments involved a presentation of our findings and this report. The aim of this report is to outline the processes we used to answer our research questions, which were:

What values does the Lake Sarah Flats site hold for different partners?
How can these values be optimised to provide sustained community engagement?

Our work will provide a suggested arrangement for tree planting plots as well as creating a resource which the Cass Research Advisory Board will be able to use for future research.

Prior to this project, the values associated with the area were not clear to us. This led to the creation of a qualitative Maptionnaire survey which was sent to people and groups who are known to use Lake Sarah Flats.

To identify appropriate locations and arrangements of tree planting blocks a geographic information systems (GIS) survey of the landscape was conducted. This led to the development of a digital elevation model (DEM) and orthomosaic image. The DEM shows elevation changes across the site and the orthomosaic shows a geometrically corrected photographic representation of the area, which was used as a base map over which we drew planting suggestions.

The experimental tree planting project would provide opportunities to research the ways in which long-lived vegetation shapes ecosystems (I. Dickie, personal communication, July 26, 2021). This project would be the first of its kind in New Zealand. The use of trees instead of smaller plants in the study, as well as the climate at this site would make it internationally unique.

3 Literature Reviews

Literature was reviewed to determine the geological, historical, and ecological background/context of the Lake Sarah Flats site. Community benefits and geographic information systems were also researched to aid the progression and vision of the project.

3.1 Ecology of the site and tree planting design

Lake Sarah has a high biodiversity due to native plant species such as raupō (*Typha orientalis*), New Zealand flax (*Schoenus pauciflorus*), red tussock (*Chionochloa rubra*) (Cromarty et al., 1996). These species form a range of habitats such as swampland, shrubland and grassland. Lake Sarah is also a breeding site for great crested grebe (*Podiceps cristatus australis*), an endangered species. Vegetation has changed at Cass over the past century, illegal grazing occurred on the site and its effects on the ecosystem was not investigated. This shows the site and surrounding area have ecological values which may interest community partners such as researchers, Forest and Bird and tourists.

There were similar experiments in Cedar Creek, USA and Siemianice, Poland (Yang et al., 2019; Rożen et al., 2010). The researchers wanted to understand how ecosystems change under different climates and disturbances. Cass would be an ideal study site because of because it has high fire risk, storm disturbance, variable weather, and a high proportion of species endemic to New Zealand. Other experiments emphasised the importance of taking small scale spatial variation into account which means a site analysis of environmental gradients across the site is required before designing tree-planting blocks. Therefore, establishing tree-planting blocks in New Zealand can act as a parallel study to inform ecologists and researchers on how plants interact in different climates in a long-term scale.

3.2 Geology and Geomorphology

Geological history can inform the community partner on the physical processes that may occur in the future and impact the tree-planting blocks. The Cass area is mainly made up of marine limestone on top of the greywacke basement. On top of these layers are Quaternary deposits. During the glacial period, the site and surrounding areas were carved out by glaciers (Figure 2).

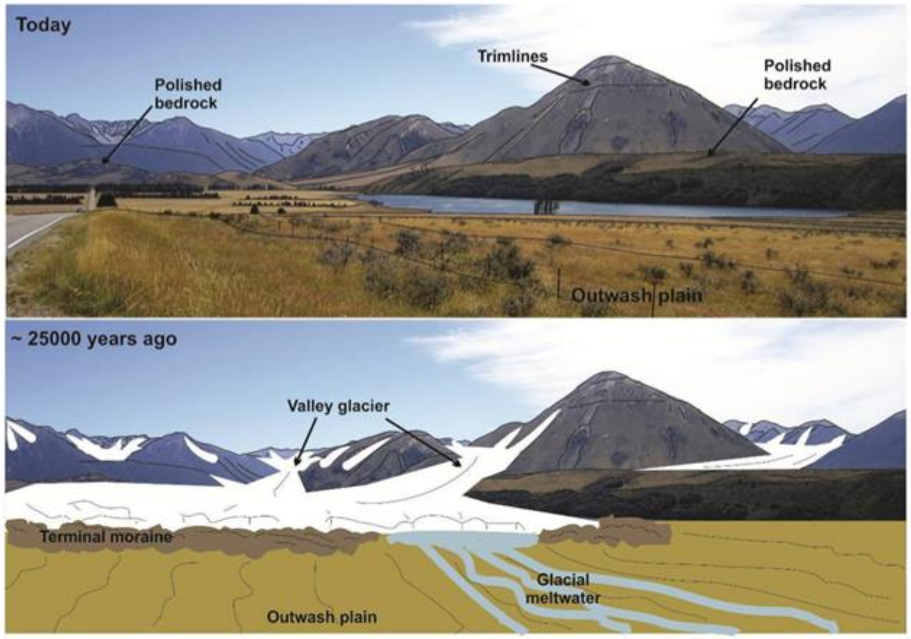

Figure 2. Top image shows Cass Valley with Sugarloaf Hill on the right, showing postglacial features as described on the image. Bottom image is a reconstructed model of the valley 25 thousand years ago with the last major glaciation in this valley.
Note. Figure 2 is from A Field Guide to the Geology of the Castle Hill Basin (p. 23), by N. Reznichenko, 2012, University of Canterbury. Copyright 2012 by University of Canterbury.

After investigating geological and geomorphological features, we can identify unique features. Features such as river terraces and alluvial fans are observed. River terraces reflect areas of old riverbed floodplains. Alluvial fans are depositional features found throughout the Cass Valley and surrounding area. These features and underlying geological processes may interest community partners such as geologists, glaciologists, and University clubs (Geology Society and Tramping Club). Therefore, the impact of the tree-planting experiment on unique geological features should be minimized or mitigated.

3.3 History

The amount of information about the history of the Cass area is limited, perhaps because Māori histories are traditionally oral. Currently, Ngāi Tahu is developing an online atlas called Ka Huru Manu which will make Māori history more accessible (Ngāi Tahu, 2021).

Māori used Lake Grasmere (Ōpōreaiti), which is adjacent to the Lake Sarah Flats site, as well as the Waimakariri River for mahinga kai. The Lake Sarah Flats site is near a route which Māori historically used to cross from the East Coast to the West Coast, as part of the pounamu trails (McLeod & Burrows, 1977).

The use of fire during Polynesian and Māori occupancy changed the ecosystems in the area as beech forest was replaced by low tussock grassland (Molloy, 1977). Since the Cass area has special cultural values to Māori, tree-planting experiments need to consider how the experiments will affect the land, water and mahinga kai in the area.

Since European arrival, farming activities started after indigenous vegetation removal in the Canterbury Plains (McLeod & Burrows, 1977). UC owns the lease of the Cass Mountain Research Area. They gave permission for cow grazing in the area. However, there were incidents of illegal ploughing which further changed the ecosystem and soil of the site (I. Dickie, personal communication, 26th July 2021).

3.4 Community Benefits

An initial idea for the Lake Sarah Flats design included a walking track. A walking track would help sustain community engagement by creating access for volunteers from tree planting days to return and observe the growth of the trees. Recreational activities such as walking, biking, and fishing could occur on the site.

Utilising walking tracks can provide benefits to mental, physical, and social wellbeing. They are proven to increase mood and self-esteem while decreasing stress and depression (Barton et al., 2009). Physical activity improves cardiovascular and pulmonary health, resulting in less risk of experiencing strokes or other related diseases. Furthermore, walking is a management strategy for joint pain, hypertension, cholesterol, and diabetes (Witten et al., 2008; Olafsdottir et al., 2020). Research shows incorporating different values into the site (e.g., aesthetic, cultural, spiritual, and social values) can help sustain community engagement (O'Brien et al., 2019). Some of the notable challenges of a walking track include the potential impacts on the controlled tree planting experiment, cost, the need for additional facilities, and public access to the site.

Sustained community engagement can be achieved from the community's involvement in tree planting and from collaboration with UC community. Tree planting provides community engagement for 6 to 9 years while tree planting is occurring (I. Dickie, personal communication, July 26, 2021). Sustained community engagement could be enhanced through community days where the public can learn about the experiment and observe its progress. Furthermore, UC students can be involved with the development of the project through a course such as GEOG309.

3.5 Geographic Information Systems

Literature on Geographic Information Systems (GIS) was explored to determine the most effective method for surveying the Lake Sarah Site. The methods explored include unmanned aerial vehicles used for structure from motion (UAV-SfM) and the use of a total station (TS).

UAV-SfM consists of an unmanned aerial vehicle flying over the desired site taking aerial photographs. The TS processes involve a person collecting data by walking around with a pole (Arango & Morales, 2015). Both types of technology are available at UC and were used in this research. The UAV-SfM is an accurate and time-efficient method for mapping the Lake Sarah Flats site, while the TSs provided information on the elevation of the site (Carrera-Hernández et al., 2020).

The GIS methods were used to construct an orthomosaic image and a DEM. These maps identify features in the area, inform where tree planting can occur, and areas for restoration and preservation. Overall indicating how and where the community can engage with the site and informing potential arrangements for the tree planting.

4 Methodology

The research questions for our topic were created during a weekend workshop to Living Springs with the GEOG309 cohort and staff.

After developing research focuses, we met up with our tutor Matiu Prebble and community partner Ian Dickie to fine tune the questions and come up with a draft plan on research methodology. The following methodology which will be expanded on in the following section:

1. Make a mana whenua engagement plan (Assignment 1).
2. Carry out initial research through individual literature reviews (Assignment 2).
3. Gather spatial data of the site using GIS methods to produce an elevation map and orthomosaic image.
4. Use the elevation map to plot suggested tree planting sites.
5. Make and send out a Maptionnaire survey to gauge others' opinions on the area.
6. Process and collate the survey results.
7. Reflect on scientific methods and group work (Assignment 3).
8. Present our findings to our course-mates, tutor, and community partner (Assignment 4).
9. Produce a formal report detailing our methodology and results (Assignment 5).

4.1 Initial Research

For our first assignment of this course, we were required to address why mana whenua would have an interest in the area and project proposal and how our community partner may communicate with mana whenua. Research into the cultural significance of the area led us to think about potential impacts of this project that may cause implications on the relationship between the Cass Research Advisory Board and mana whenua. From this research we concluded that consulting with mana whenua is a vital part of this project. The addition of native trees to vacant, previously ploughed agricultural land is not likely to harm to the land, water, or air, and would in fact likely have positive biodiversity impacts.

Initial research was carried out through literature reviews for our second assignment. This was to give a well-versed background into the area and add context to the project. Literature reviews investigated the geology and geomorphology, history, ecology, GIS methodology, and community benefits of walking tracks, these are summarized in Section 3 of the report.

4.2 GIS Methodology

A focus of our project became producing a detailed elevation map of the site, this was valuable for answering the research questions. Specifically, to aid the process of identifying locations suitable for experimental tree planting. The GIS methods for this project can be credited to Giles Ostermeijer. Field data was collected on the field trip on Saturday the 11th of September. Ruby Glasson, Jess Adamson, Matiu Prebble, Ian Dickie, and Giles Ostermeijer visited the site at Lake Sarah Flats.

Figure 3 & 4. Images of data collection at the site. Figure 3 shows the placement of a GCP and Figure 4 shows the GCPs' GPS coordinates being logged.

Giles used a total station (TS) to generate a DEM and used Structure from Motion with an Unmanned Aerial Vehicle (UAV-SfM) to generate an orthomosaic image. Both outputs are essential to understand which areas of the site are suitable for experimental tree planting. The DEM shows changes in elevation of the site, which helps identify locations with flat topography for tree planting plots. Bruelheide et al. (2014) mentions how flat land is generally more fertile than sloping land, which makes it more suitable for planting. The creation of an orthomosaic was valuable to define locations suitable for tree planting as it recreated the site from a bird's eye view. This meant we were able to locate areas suitable for planting blocks.

Firstly, the TS was set up in a location with a clear view of the site. The GPS coordinates of the TS were recorded, and we walked around the site and placed 10 Ground Control Points (GCPs) evenly around the boundary (Figure 3). GCPs were white or yellow 1 m squares. The locations of GCPs can be seen in Figure 5, which is also an output of the DEM of the site. GCPs are the blue flags with white squares/rectangles adjacent to them.

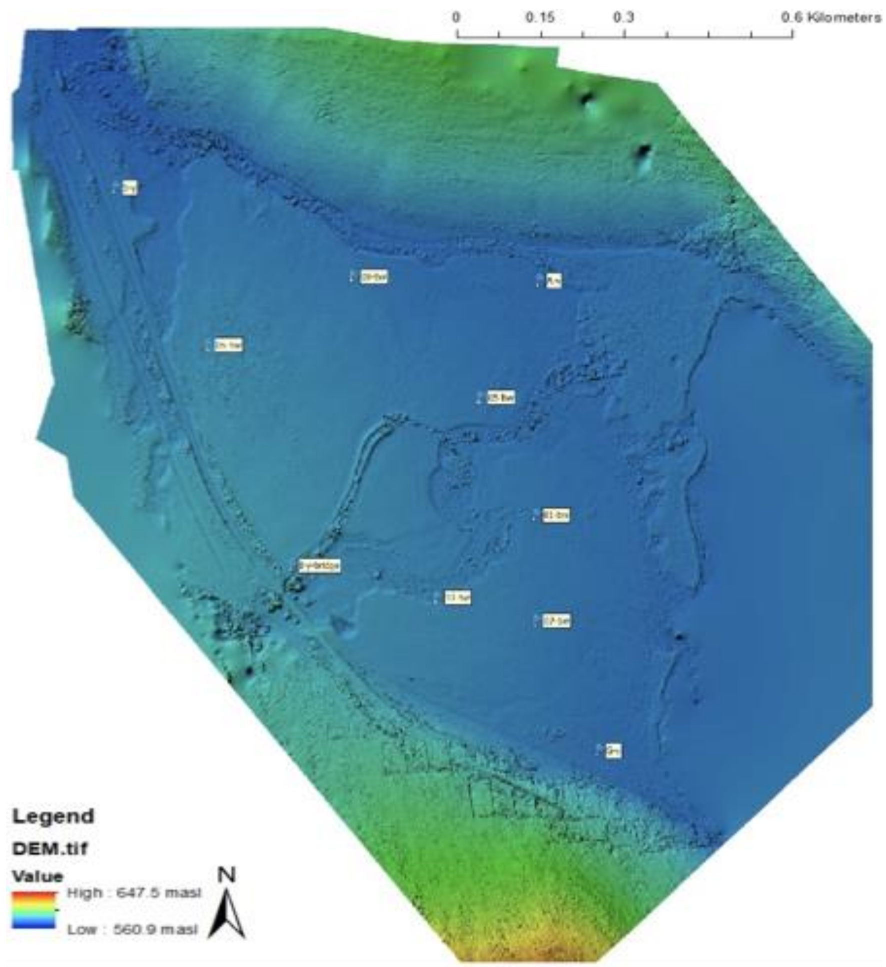

Figure 5. The locations of the GCPs placed around the Lake Sarah Flats site.

After thoughtful placement of GCPs around the perimeter of the site, Giles walked to their locations and collected their GPS location and elevation using a Trimble R8 GNSS Survey Grade Rover Receiver (Figure 4). This information was relayed back to the TS and was used in post processing to develop a DEM. Work by Kizil & Tisor (2011) outlines potential TS methodology for surveying land and assesses the accuracy of this technology, this is also a useful resource for further GIS understanding.

One of the limitations of the DEM is how it does not represent the actual terrain of the land and purely shows the elevation. To gain a more holistic understanding of what is present at the site an orthomosaic image is useful.

An orthomosaic image was created using the UAV-SfM processes. To begin, a flight path was digitally created which flew the drone to known coordinates of GCP locations. It is important the GCPs are evenly spatially distributed over the entire target area. This decreases any error which may be carried throughout the model as the GCP locations are used for georectification in post processing.

The drone then flew along the flight path and took hundreds of photographs of different angels and locations. These photographs are then used in post processing and are stitched together to recreate the scene of the Lake Sarah Flats site, producing an orthomosaic image. Aquera et al. (2017) discuss potential parameters which influence the creation of an orthomosaic and provide clear methodology which may prove useful for deeper understanding of GIS.

It is important to note GIS methods mentioned here purely reflect the processes which occurred in the field. For understanding of post processing contact Giles Ostermeijer, Drone Technician at UC.

4.3 Maptionnaire Methodology

In the final stages of data collection, qualitative data responses were gathered through a Maptionnaire survey. This survey tool is a map-based questionnaire, designed to gather data about community engagement within projects. We created a short survey on the Maptionnaire web page asking whether people currently use the land, are associated with any groups who use the surrounding area, and any ideas for community engagement. The survey was sent to staff within different departments at UC (mainly Science departments) as well as Forest and Bird, and owners of the Kiwi Rail bach near the site.

When sending the survey out we requested it be forwarded on to anyone else who may have an interest in the site through the UC's Field Services Manager. This meant we received responses from Lincoln University. The Maptionnaire formatting made it simple to process and analyse the responses, automatically creating bar graphs which answers were displayed on, as well as an excel spreadsheet which contained raw data.

5 Results and Discussion

5.1 Maptionnaire

We had nine respondents to our Maptionnaire survey which was sent to all potentially interested parties. The raw results will be sent to the Cass Research Advisory Board. The anonymous results of the Maptionnaire survey are outlined below:

Q1. Do you belong to a group who use the Lake Sarah Flats Site?

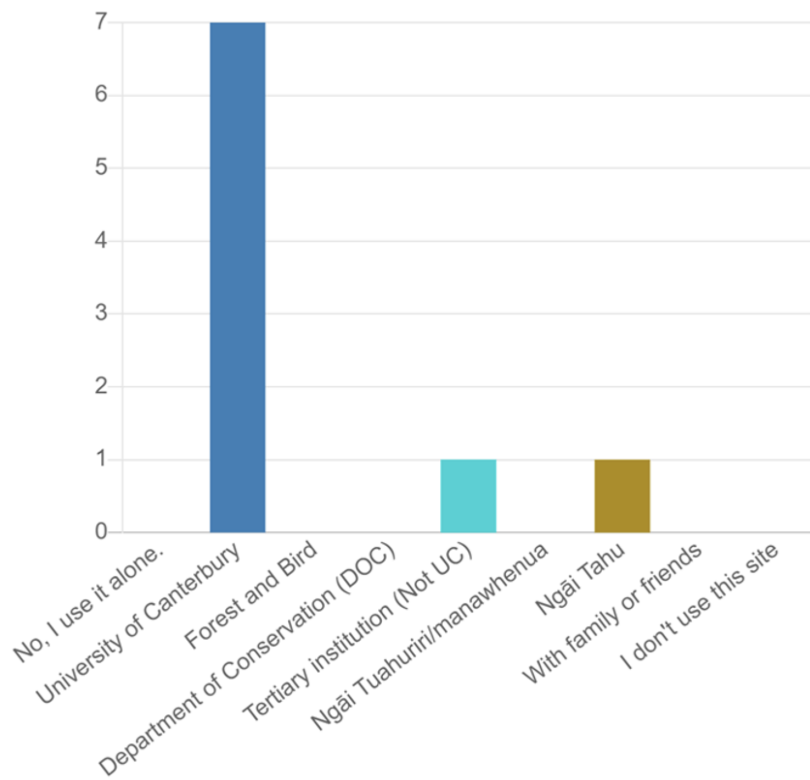

Figure 6. Showing which group/organisation survey respondents identify with.

From Figure 6 we see that the majority of the Maptionnaire respondents are from UC (seven responses), one from a different Tertiary Institution, and a response from Ngāi Tahu.

Q2. How do you use the Lake Sarah Flats site?

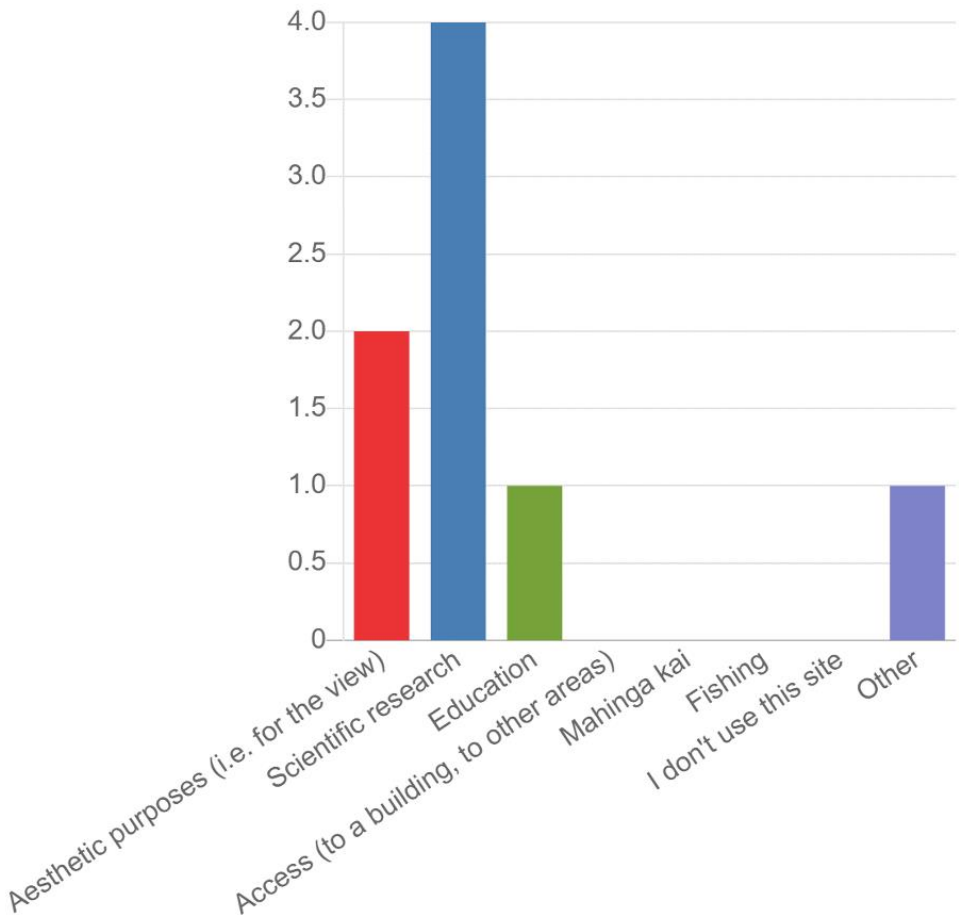

Figure 7. Shows how the survey respondents use Lake Sarah Flats site.

Figure 7 shows majority of the Maptionnaire respondents use the site for scientific research purposes (four responses), depending on the type of research this may link with the experimental tree planting project. Following this, two people/groups use it for aesthetic purposes, which shows the site offers community benefits as it is in a pristine mountain environment. Furthermore, one respondent utilises the land for education. Tree planting benefits can be incorporated to an educational trip to the Lake Sarah Flats site after planting.

Q3. What could the site be used for?

- Science research
- Education
- Ecological restoration
- Mahinga Kai
- Landscape Tourism

We posed the question "What can the site be used for?". The range of responses align with the values the experimental planting project may offer. Scientific research, ecological restoration, landscape tourism, and education will be potentially enhanced by the project, depending on how it is managed. Mahinga kai values could be impacted by the tree planting project, especially if chemicals are applied to aid the growth of trees and if water is extracted from the stream on the site or from Lake Sarah. Conversely, planting the site up with natives may restore the habitat and provide benefits to mahinga kai. There are native vegetation and wetland within the site. There should not be experiment blocks near or on this area. Management plan for mahinga kai living on this area may be required (Environment Canterbury, n.d.).

Q4. Do you have any engagement ideas?

- Research
- Educational loop walk
- School trips

The fourth question was "Do you have any engagement ideas?" Answers included research, an educational loop walk, and school trips. Research directly aligns with the proposed planting project, specifically biological and environmental research. Depending on how the site is managed, research from alternative academic disciplines may be limited if the entire site is used purely for planting.

Q5. How can your group potentially be engaged in this project?

For this question, there were three respondents.

A respondent said, "by providing better access to the site, an easy way to obtain permissions to visit the site, parking and toilet facilities, projects to contribute, setting up an online community of people interested in science, restoration and mahinga kai in the mountains".

A further respondent commented, "we would be happy to advise on what considerations are important for research projects and would certainly consider using the site in the future should an appropriate project arise".

The fourth respondent to this question said, "If a loop walk was developed there could be a glacial history interpretation point on the walk where people can stop and pause and learn about the landscape features they can see around them".

Q6. Additional ideas or information?

"We used the area for a common garden field study looking at how plants respond to high elevation, the site was perfect for our study, as access is controlled and the area is not currently used for grazing, etc."

A further valuable comment is how "Limited and controlled human access and disturbance are quite important for long-term research projects, which unfortunately can run counter to the desires of other users".

5.2 Maptionnaire Limitations

It is important to note the Maptionnaire results may not reflect the wide realm of Lake Sarah Flats users. This is because several respondents were predominantly from the UC Science departments. Therefore, may not represent the diverse range of perspectives over the site and surrounding area.

5.3 GIS Results

Before the drone survey, the best data available to us on the Lake Sarah Flats site was from Google Earth. The level of detail on Google Earth was insufficient for the purposes of this project. The data obtained from the GIS drone survey were generated into a DEM and an orthomosaic image. These were used to identify specific areas of flat land, and areas of lower elevation where the ground was noted to be boggy during the site visit. After the identification of these areas, the DEM and orthomosaic were used as backgrounds upon which to draw potential polygons for the experimental tree planting plots.

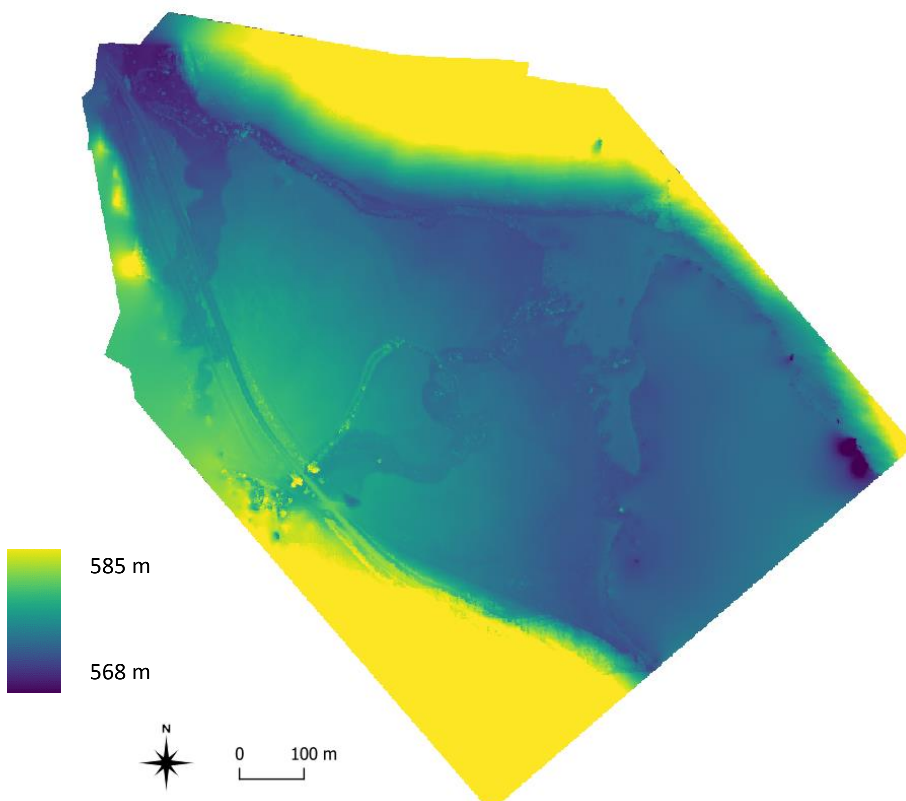

Figure 8 shows the changes in elevation of the land at Lake Sarah Flats.

Figure 8 shows the elevation is largely flat for the site. There is a dip in the top north west corner of the map which is shown by a darker blue and indicates a decrease in elevation. This area is not recommended to be included in the experimental tree planting plots. Furthermore, there is a lowering in elevation on the eastern side of the site which is due to a boggy area that was observed on the field trip to the site. We suggest this location is also not included in the planting design.

Figure 9. Orthomosaic image of the Lake Sarah Flats site (WGS1984).

The orthomosaic image (Figure 9) is useful to help provie tree planting suggestions and to identify existing features within the site. Figure 9 shows there are non-native grasses present, indicating the land has been stripped of its original vegetation. The stream running through the centre of the site can also be seen in the shape of the love heart extending towards Lake Sarah. This provides a valuable resource for the Cass Research Advisory Board because it documents the base line appearence of the site before the experiment starts

The map data we obtained will inform where to plant the experimental tree planting blocks, avoiding low elevation areas. With additional time and software expertise the data can be used to arrange the blocks within the areas of acceptable elevation, to make a design which best uses the space on the site. The data can also be used to calculate the slope of the ground at any point, and therefore the direction any runoff from rain or irrigation will flow.

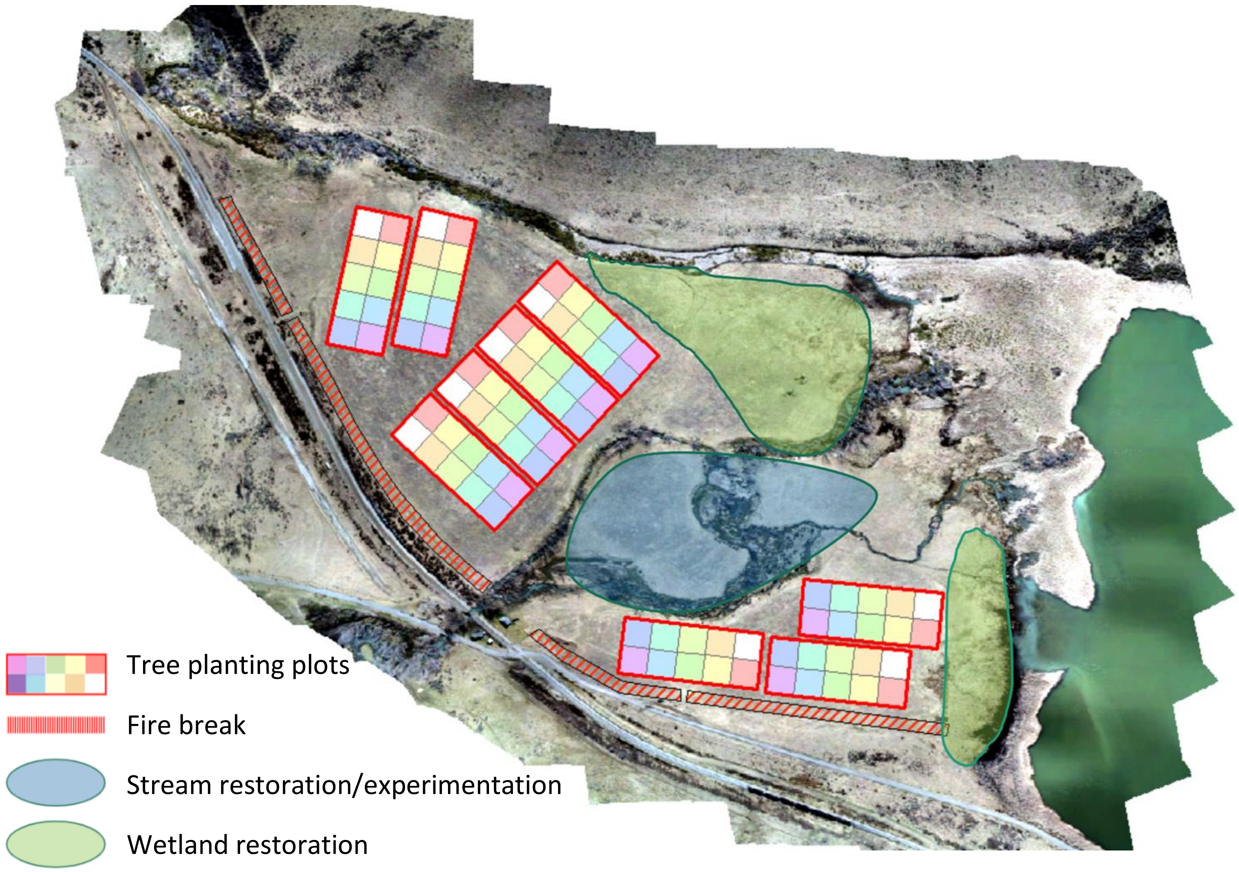

Figure 10. A suggestion for tree planting blocks at Lake Sarah Flats. The arrangement of the tree planting blocks was determined by the site's elevation, the position of waterways, and the distance from the fire break. Square plots were selected to minimise edge effects.

5.4 GIS Limitations

Initially the DEM and orthomosaic were displaying in the GIS software in the wrong projection by default. This problem caused shapes to be distorted (Figure 11) and made our initial designs for tree planting locations incorrect. Once the issue was identified and overcome by reprojecting the maps into NZGD2000 / UTM zone 59S, the next hurdle was identifying a way to draw accurately sized and shaped polygons onto the orthomosaic, while being able to rotate and reposition the plots.

One method involved drawing polygons manually, meticulously measuring the edge lengths. Using this method, the polygons were able to be repositioned.

Figure 11. Distortion caused by different projection systems. Note the roof of the buildings, the buildings in the left image (WGS 1984) are not at right angles (distorted) while the building in the right image (NZGD2000 / UTM zone 59S) are (normal).

A second method for drawing polygons was to use a grid layer on top of the map, which generated accurately sized polygons of ten plots (figure 10). However, this method was difficult because once each polygon was created, it was stuck in place and could not be relocated. This made arranging all nine polygons challenging. To a person experienced with GIS software, these issues would not present a significant challenge, and a layout for the polygons could be designed relatively quickly.

6 Conclusion

Our GEOG309 group has found this project highly engaging from start to finish. Our findings are the DEM and orthomosaic as well as the realm of perspectives and values gained from the Maptionnaire. The goal of the Maptionnaire survey was to identify site users' key values associated with the Lake Sarah Flats site.

Our GIS analysis led to the production of a DEM and an orthomosaic overlaid with suggestions for tree planting locations. Our limited experience with using GIS software restricted our ability to complete this analysis, and the results show potential locations and designs for potential experimental tree planting plots.

6.1 Future Considerations

In future, a consideration of potential risks should be thoroughly undertaken. Risks that we have identified through the course of our research include:

- Wild pigs are one of the major pests in the area. It will be important to consider how they may affect tree planting and human safety when planting trees.
- Fire risk caused by sparks from the railway. We researched fire breaks, yet this would need to be explored further.
- Variations in soil type or quality across the site.
- Potential requirements and methods for irrigation.
- Public trespassers, we got feedback from the bach owners when doing a site visit there are commonly people camping out on/near the site. This could also cause issues for the controlled experimental tree planting.
- Trees may be affected differently by the wind. At the north end of the site the wind would likely be greater than closer to the shore of the lake, as this would be sheltered by the other trees. This environmental parameter may affect the arrangement of trees within each polygon.
- The Cass Research Advisory Board could partner with UC's community to document and map the progress of the experiment. Tracking progress would be of value to the board as it is an experimental project, and the learning opportunities would be of value for UC students.

These risks have the potential to implicate the project and reduce the validity of results from experiments held in this site. Some of these risks could be worked on by future GEOG309 projects. However, while it is important not to rush into anything, another risk this project faces is time. It is easy to get caught up on finer details which would delay the planting. Doing so would mean the site is sitting there unused and the time frame for this long-term intergenerational project would further extend.

7 Acknowledgements

We thank our community partner Cass Research Advisory Board and main contact Ian Dickie for collaborating on this project. We thank our tutor Matiu Prebble for his time and assistance. We are grateful to the University of Canterbury for allowing access to the Lake Sarah Flat site to do a drone survey. We thank Giles Ostermeijer for the technical support, Jenny Ladley for logistical support, Abby Suszko for mana whenua engagement support. Guidance from GEOG309 staff and tutor team. We thank all the survey participants. Survey was conducted with ethical approval from the Human Research Ethics Committee in the University of Canterbury.

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