



Using Quality Spatial Data in Maximising Land Use Potential in the Southland Region: A Case Study

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Abstract



Maximising land use potential at the regional level requires quality resource information on critical factors for sustainable land use decisions. This paper describes a major community initiative underway in the Southland Region of New Zealand involving GIS mapping of 850,000 ha at a 1:50,000 scale. At a southerly latitude of 46 degrees the critical factors affecting plant growth are soil quality and air temperature. Air temperature is being measured with a network of 900 automated dataloggers positioned to represent key features of the landscape and recording hourly average air temperature. Data is differentially adjusted using the nearest long-term weather station to the site to generate a 30-year normal temperature record and consequent Growing-Degree-Day value for each site. Isocontour maps are then generated to identify local scale climates of interest within the regional landscape. Soils of the area are being mapped at the same time and to the same scale to allow integrated development of the critical information for sustainable land use decisions. Basic soil attributes will be interpreted to produce maps for crop suitability, vulnerability to structural degradation, and leaching risk. High class soils will also be identified. An Internet site and a bureau service will be established. This will provide technical support and interpretation of data for clients, to encourage wide use of information produced by the project. The project is being supported and funded by the local community in the belief that the provision of high quality resource information will lead to significant employment opportunities in the region.

Keywords and phrases: Topoclimate mapping, air temperature, soil vulnerability index, growing-degree days.

1 Introduction



Maximising land use potential at a regional level requires quality spatial information in order to provide the basis for better land use decisions for a more sustainable future. This need has been recognised by the Southland community, and in particular "Crops for Southland". Crops for Southland is a local focus group who have just commenced a major community initiative to upgrade the quality of the region's spatial resource information. This is part of a wider initiative to address a continuing population decline by stimulating rural enterprises. The Southland region already contributes some 18% of New Zealand's Gross Domestic Product, but is home to only 2.6% of the country's population. However, the region has a strong natural resource base, including large areas of high quality soils and micro-climates which are capable of growing a wide range of crops, pastures and trees. It is hoped that improved information will lead to better utilisation of this resource. The need for local scale topoclimate maps is increasing as the pace of land use change is quickening. Where pastoral agriculture is the dominant land use, topoclimates are possibly less important because mobile livestock integrate any differences in grass production by grazing over the variety of terrain on the farm. However, when cropping is being considered, the topoclimate becomes more critical and can give a large economic advantage to the grower.



The concept of “Topoclimate Mapping” has been developed to meet the needs of land users for integrated spatial information and also to take advantage of improvements in technology over the last two years including Geographic Information Systems (GIS), Geographic Positioning Systems (GPS), and the continuing development of automated temperature dataloggers. Land users have long recognised that the critical factors in determining land use potential in Southland are the quality of soils and the amount of accumulated heat available for plant growth and reproduction. The Topoclimate mapping process involves the integrated analysis and interpretation of soil and climate data at a scale appropriate for land users. The output information is expected to increase local understanding of the land resource, and assist landowners in lessening the risks associated with any changes to their farming systems.

The soils of a number of areas of Southland have been mapped previously, initially by the New Zealand Soil Bureau of the Department of Scientific and Industrial Research (DSIR), and latterly by the Landcare Research Institute (McIntosh 1989, 1992, 1992, 1993, McIntosh and Savage 1993). This work has been at a range of scales and did not always include sufficient chemical and physical information on different soil types in addition to spatial polygons defining their areal extent. The whole region had been mapped at a scale of 1 inch:4 miles in 1968 but this gave insufficient detail to allow for any individual property or district planning. The challenge for the Topoclimate Project then has been to fill in the gaps in the available soil data.

The identification of annual accumulated heat levels on a spatial basis follows work done by Turner and Fitzharris (1986), and Cossens and Johnstone (1987, 1988a, 1988b, 1989) in the Central Otago Region of New Zealand. These surveys were conducted at a local scale using manual methods, and had positive outcomes for the communities involved. New stone fruit growing areas were identified and a viable new wine producing area developed near Queenstown. The Topoclimate Project has extended the Central

Otago work by applying new technologies to make a regional scale survey possible.

This paper aims to:

- explain the circumstances that have led to this initiative,
- describe some of the innovative technologies being employed,
- outline the expected benefits of the information once it has been produced,

2 Topoclimate Mapping

Topoclimate Mapping has been defined by Hutchinson (1997) as “The combination of soil and climate mapping of a specific area done at the same time and at the same scale”. The integrated process involved in Topoclimate mapping gives greater benefits to the understanding of land processes than are obtainable by undertaking each part separately (either spatially or temporally).

3 Climate

Growing Degree Days (GDDs) are used as the measure of accumulated temperature or heat units above a reference temperature (Coulter 1974, Cossens and Johnstone 1987, 1988a, 1988b, 1989, Turner and Fitzharris 1986). Sturman and Tapper (1996) state that as long as light intensity, light duration, and water supply are adequate, crop growth is predominantly affected by temperature. GDDs are used as an index of the overall effect of temperature over time (Coulter 1974). This information becomes especially relevant as GDDs decline towards the minimum requirements for crops and grasses. The GDDs calculated for many of the weather stations in Southland are close to, or below, the minimum required for many crops and are only 25% of the accumulated heat units available in the Northland region of New Zealand (see figure 1). In this situation, the effect of topography in creating beneficial microclimates assumes much more importance. Soil temperatures are also considered important in crop growth (Barringer 1997), and are being measured to further enhance the usefulness of the final output information.

4 Sampling Techniques

There have been a number of innovations in technology since initial local-scale climate surveys were undertaken in the 1980's using maximum/minimum thermometers (Turner and Fitzharris 1986, Cossens and Johnstone 1987, 1988a, 1988b, 1989). Most important has been the development of electronic dataloggers with associated temperature sensors, which are now capable of recording and storing temperatures for extended periods of time. These dataloggers are small and portable, with a lithium battery power source. They are capable of operating for long periods without the need for downloading or servicing.

Although climate stations operated by the National Institute for Water and Atmospheric Research (NIWA) record information that is useful for broad regional selection of cropping sites, the network is too coarse to identify local scale climatic variations that are induced by topography. Most horticultural crops are established on areas of 10ha or less, often taking advantage of local climates in sheltered valleys or on slopes where the risk of frost is diminished. For this reason a network of 900 data loggers is being established at approximately 170ha intervals over the Southland landscape each year of the study. A total of 850 000ha will be mapped over a three year period. Temperature loggers are housed in specially designed PVC screens, and measure average hourly air temperatures. Landscape type is being considered in the siting of the temperature sensors, and spatial sampling techniques are being employed to accurately map the temperature over the topography. A 30 year normal temperature record is then constructed for each logger site by regressing the measured data against the long-term record of a nearby climate station. In this way a long temporal and fine spatial scale is achieved in the output.

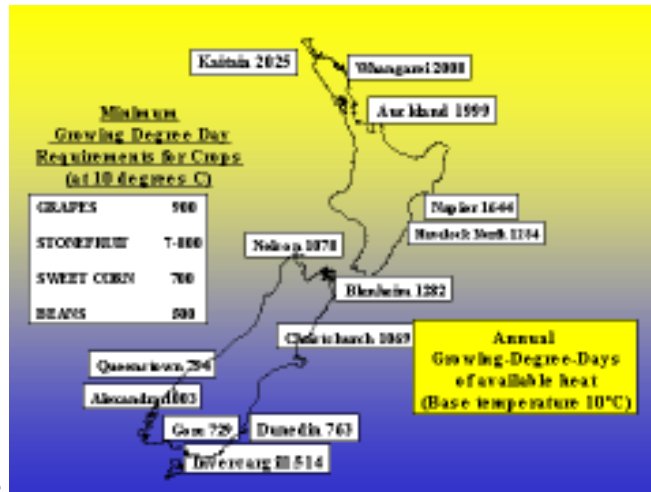


Figure 1: Average annual growing-degree-day measurements (above a 10 degrees C base temperature) for a range of long term weather stations in New Zealand (New Zealand Meteorological Service 1974)

5 Use of Geographic Positioning Systems and Geographic Information Systems

Field survey teams now have the capability to map directly onto laptop computers running the Project's own software. The systems also incorporate a MapInfo GIS package, providing background maps of the survey area, and Trimble Pathfinder GPS cards (incorporating Aspen software) for accurate positioning of each data point using satellite technology. This is a vast improvement in mapping techniques over manual processes formerly employed in terms of speed of both data gathering and collation processes. The project aim has been to create a virtually

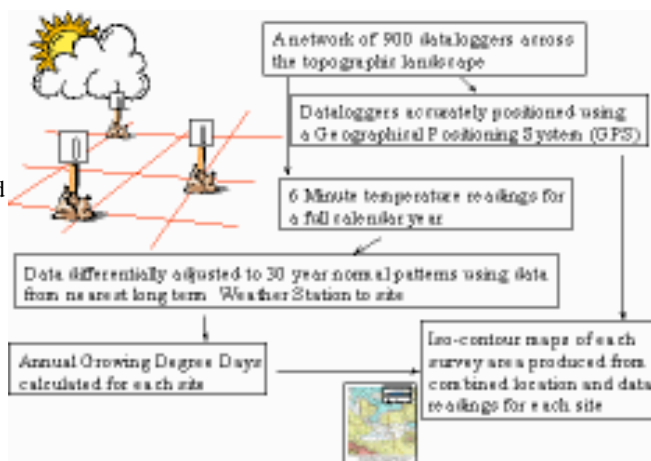


Figure 2: Topoclimate Mapping System for measuring Microclimates. (Hutchinson 1997)



Figure 3: Soil structure can be vulnerable to continuous cropping. This example of a silt loam in the Manawatu District demonstrates the impact of 11 years of continuous cropping for maize on both soil structure and soil organic matter.(Shepherd 1991)

paperless mapping environment for field staff. The system accelerates the pace of the mapping process whilst avoiding transcription errors. The general system employed by the Topoclimate South project is shown in figure 2.

6 Soil Mapping

Failure to recognise soil limitations for cropping can lead to severe degradation of the soil resource. Such degradation can take the form of deteriorating soil structure, increased bulk density, lower organic carbon levels, lower porosity, topsoil loss, root disease, and proliferation of pests such as nematodes. Soil degradation inevitably results in diminishing yields, increasing costs, and therefore lower profits (Shepherd 1991).

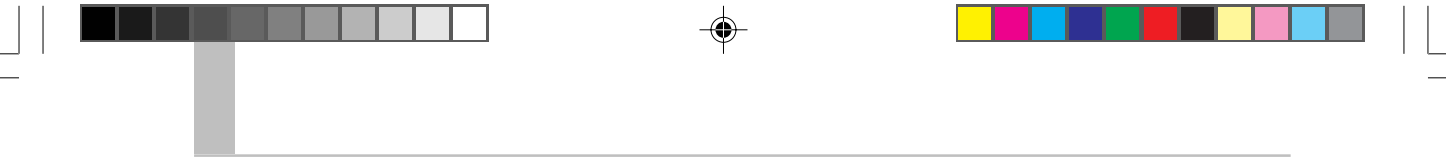
Soils differ markedly in their ability to withstand cropping impacts. For example, 11 years of maize cropping on silty soils of the Manawatu has had severe effects on crop yields and profitability of cropping as shown in figure 3 (Shepherd 1991) but the effects of 100 years of cropping on smectitic clay-rich soils of North Otago, although apparent, have been less severe. This difference in soil behaviour is attributed to the different mineralogy of the soils of

the Manawatu and North Otago (Otago Regional Council 1995).

A total of 850,000ha of land will be mapped by manual soil survey over the next three years, using auger holes, pits, and natural and road cuttings. Sites examined and boundaries located will be positioned accurately using Global Positioning Systems, and data stored and managed using Geographic Information Systems.

7 Soil Vulnerability Index

Differences between New Zealand soils were investigated by Hewitt and Shepherd (1997) who devised a "Structural Vulnerability Index", based on four easily-measured soil attributes (Phosphate retention, organic carbon, clay content and wetness). Making these measurements during a soil survey allows soils to be classified according to their resistance and resilience to intensive cropping. Such a classification is being made in this project. By matching crops to appropriate soils, the deleterious impact of intensive management will be minimised. This is the first time that sustainability questions have been taken into account when planning for new crops on a regional scale in New Zealand. This project will



classify soils for ground and stream-water contamination risk and leaching risk. In this way, best management practices for soils or groups of soils will be established. High-class soils (McIntosh 1993) will also be identified

While degradation of soils under pastoral use (Greenwood and McNamara 1992) and under cropping (Shepherd 1991) tend to be emphasised, there are also positive aspects of intensive land use to be considered, such as the amelioration of soil pH and an increase in fertility, in subsoils as well as topsoils (McIntosh and Hewitt, 1997). During topoclimate mapping baseline sites are also being established to measure such positive effects.

8 Transfer of Information to the Land User

Technology has become available in the past few years to distribute large amounts of information to a wide audience.

The Topoclimate South project aims to provide accurate and relevant information specifically designed for land users. To meet this commitment, a two-tier system for information delivery has been designed. Every farmer who agrees to access to their property will receive a soil and GDD map of their area at the conclusion of the survey work. As well, this information will be available through a free Internet web site. A Project Web site has already been established and may be viewed at www.topoclimate-south.co.nz.

In addition to these free services, which only relate to raw data, a Bureau Service is planned so that land users will be able to obtain inexpensive access to both raw data and technical advice for interpretation of the maps. This Bureau would also have access to a comprehensive crops, pastures and trees database which would outline the optimum growing conditions and ranges of most potentially economic species of plants.

Geographical Information Systems (GIS) and associated computer technology now allow for the processing of large amounts of data on a spatial basis. The economical combination of soils, topography and

climate information within GIS layers in an automated computerised process allows easy access for queries on specific areas of land.

By utilising the power of the GIS systems, the bureau will provide a very powerful analysis tool for land users to assist in a variety of risk management decisions. The information is also incremental in that because each data point is being accurately located using GPS, the information can be retrieved and used at a later date for more detailed surveys. This is a major advance on previous mapping processes, where data storage and later retrieval issues limited the onward usefulness of any mapping data gathered once scale was altered or temporal issues were considered.

9 Summary

Recent innovative technologies have enabled a large scale integrated resource mapping project to commence in Southland. Mapping of climate and soils at the local scale is underway and planned to continue for the next three years.

Global Positioning Systems and compact, affordable temperature loggers enable quick, accurate collection of data, while Geographic Information Systems are the key tools in the storage and retrieval of spatial information. This information, in an appropriate format, can then be accessed and used by land user groups and a wide range of interested parties through a comprehensive Internet web site and Bureau service. Information distribution tools such as the internet enable valuable data, once collected and managed, to reach a wide audience.

The technology to undertake such a large scale project, with the integration of climate and soil mapping and the manipulation of vast quantities of data, has not been possible until very recently.

The Topoclimate South Project hopes to provide increased information as a key tool for decisions relating to land use management in Southland. The identification of local scale climates and soil types and related information should allow the development of new or alternative crops. More sustainable land use will hopefully also result. The long-term benefits of this are expected to be increased employment in rural

areas leading to retention of rural services and a reversal of population decline.

10 Future Work

The Topoclimate South project in Southland is seen as a pilot programme to test the concept of integrated resource mapping and there is already demand from other regions of New Zealand and overseas for similar mapping systems to be implemented using this model.

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