The Topoclimate South Project to Map Long-term Mean Growing Degree-days in Southland, New Zealand

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ABSTRACT

This paper presents aspects of ongoing topoclimate and spatial mapping research to map growing degree-days in Southland, New Zealand. In cooler areas, temperature and patterns of accumulated heat are important limits to plant growth. Data on heat accumulation, commonly expressed as growing degree-days, is thus important for best management of both pasture and cropland, and also to guide crop diversification, productivity and environmental sustainability. As part of the Topoclimate South Survey project, 1-year temperature data at about 900 sites and long-term daily data from the national climate station network are being used to generate long-term mean daily temperature records and thereafter long-term, partially-synthetic records of growing degree-days for selected areas of Southland. Neither the 1-year records collected by Topoclimate South nor the long-term climate data from climate stations are complete. The latter especially are spatially sparse. Gap filling, extrapolation and interpolation strategies are therefore being employed to create complete daily records for all sites of interest and, thereafter, mean degree-day maps.

***Keywords and phrases*:** growing degree-day, temperature, topoclimate, mapping

1.0 INTRODUCTION

The Southland region of New Zealand includes substantial areas of high class soils and quality micro- to local-scale (0.1-50 km scale; Oke, 1987) climates. The region is capable of growing a wide range of crops, pastures and trees, and this capability is reflected in the region's contribution to New Zealand's Gross Domestic Product: 18%. This despite being home to only 2.6% of New Zealand's population (Hutchinson *et al*., 1999). The major socio-economic issue facing the region is population decline associated with declining profits from "traditional" farming systems, e.g. intensive sheep and beef farms. Over the last fifteen years the number of farm workers per farm has dropped from 3.5 to 1.2. Further, farmers and their partners are taking on paid work in urban centres, jobs traditionally given to school leavers. Consequently, the youth of Southland are leaving to seek work elsewhere (Hutchinson *et al*., 1999).

In general, pasture and crop growth is limited by solar radiation, stress on plants due to deficit or excess soil water content, nutrient availability and management practices such as grazing and harvesting. Although it is not always economic to do so, most water, nutrient and management related limitations can be ameliorated. For example, water can be added to soil (by irrigation) or removed (by drainage) so that optimal soil moisture levels are maintained. However, incoming solar radiation and outdoor temperature cannot be modified in this way—except by extraordinary engineering feats such as heaters. Thus, in cooler regions of New Zealand such as Southland, temperature and patterns of heat accumulation are important limits on pasture and crop growth, especially during the cooler spring and autumn months.

In areas of raised topography, greater solar radiation loading is received on slopes that are sun-facing, i.e. north-facing slopes in New Zealand. In contrast, aspect has little importance at night: cold air ponding and ventilation are then the critical processes that determine the “heat level” of a site. In depressions and at the valley floor, cold dense air tends to pond, whereas air tends to be warmer on surrounding slopes and at well-ventilated sites where ponding is inhibited (Sturman and Tapper, 1986; Oke, 1987). Taken together this means that, while one site in the landscape may be relatively warm by day and night, another site—maybe only 100 m away—can be cool, shady and frost prone. The spatial variation in climates related to topography is termed topoclimate. A site with a high quality topoclimate could potentially produce a high quality, specialist crop or high productivity for a traditional crop, and thus provide greater profits for the land user.

In Southland/South Otago, the farming community identified a crucial need for detailed data on soil and climate factors. Consequently, the Topoclimate Survey project was formulated. The project is currently mapping soil and climate characteristics over about 805 000 ha of Southland/South Otago using field surveys and a network of 900 automated data loggers. Temperature data for individual sites and from local stations in the national climate station network are being used to generate long-term mean daily temperature records and thereafter heat accumulation records. Maps of long-term mean growing degree-days for selected areas of Southland will then be created using a GIS. This approach builds on topoclimate research previously undertaken in New Zealand, e.g. by Turner and Fitzharris (1986) and Cossens and Johnstone (1988) in Otago.

This paper presents a brief overview, and some of the preliminary results of the project, which is still in the midst of gathering field data. Owing to the on-going nature and commercial sensitivity of the project, relatively few spatial data are available for publishing. However, permission has been obtained by the author to include some mapped data in this paper. It is expected that more images will be made available for the conference presentation itself.

2.0 OVERVIEW OF THE METHODOLOGY

Air temperature is being measured with a network of 900 automatic dataloggers positioned to represent key features of the landscape, e.g. valley floors, terraces and hillsides of varying aspect and slope. These loggers record air temperature electronically at 6-minute intervals for a full year. Daily extremes are then extracted and data are extrapolated using the nearest long-term climate station. A 30-year normal temperature record is thus generated for all 900 sites. Heat units are computed as growing degree-days (GDD in units °C). These are the sum of daily mean temperatures above a chosen base or threshold for a stated period, e.g. for 1 year:

$$\mathrm{GDD} = \sum_{Day\,1}^{Day\,365} \left(\text{Daily Mean Temperature} - \text{Threshold Temperature}\right) \qquad (1)$$

The daily threshold used varies depending on the plant cover or crop of interest, e.g. 10°C for cotton, grapes and sweet corn but only 3°C for peas. This defines the mean daily temperature below which the particular plant is inactive. These values are defined by plant physiologists, using laboratory and field testing of plants. Potentially suitable geographic ranges for crops are typically specified with reference to annual (or sometimes warm season) totals of growing degree-days, e.g. 2000 for cotton, 1100 for grapes and as low as 900 for peas, with the base temperatures as given above (Sturman and Tapper, 1996).

Initially, in this project, a 4°C threshold has been used because rural Southland is predominantly pastural, and this value represents the temperature below which temperate (i.e. not tropical) pasture grasses such as coxsfoot and ryegrass are inactive:

$$\mathrm{GDD}_4 = \frac{\mathrm{T}_{\mathrm{Max}} + \mathrm{T}_{\mathrm{Min}}}{2} - 4 \qquad (2)$$

The approach requires a daily and complete record of air temperature. Further, for the information to have general applicability, the daily data must be averaged. An ideal period of 30 years was chosen following World Meteorological Organisation protocols (in practice 30 years was seldom available). In theory this period averages out short-term climate fluctuations such as El Nino and La Nina, but is sufficiently short that it avoids long-term trends such as global warming. Neither the one-year site records collected by Topoclimate South nor the long-term climate data from climate stations are 100% complete. The latter especially are sparse spatially. Incomplete temporal records from climate stations meant that “gap filling” protocols had to be adopted to create complete daily records for these sites; in brief, these were based on averaging techniques. Temporal extrapolation was then required to create the desired partially-synthetic, 30-year data strings for each of the 900 logger sites. This required establishing predictive, mathematical relationships between appropriate data sets. Once long-term mean data was computed for each site, spatial interpolation strategies were then required to create heat pattern (degree-day) maps. Although ultimately the Project wants to automate these estimation procedures, to date the process involves considerable expert knowledge, and it is not a trivial task to duplicate electronically the wisdom involved in interpreting climate and landscapes and mapping topoclimates.

The maps being generated by the project are already helping to identify farm- and micro-scale (i.e. 1 km or less; Oke, 1987) climates of interest within the Southland landscape. Soils are being mapped at the same time to provide additional and critical information for land use decisions, e.g. for flower growing. Topoclimate Survey has provided here two images of maps for illustrative purposes. These are for the Heriot basin, in northern Southland. Figure 1 shows the long-term mean annual heat (growing degree-day) pattern summed for a “normal” year and a base temperature of 4°C. Figure 2 is the equivalent map for soil type. Such images are being produced at a scale of 1: 50 000, underlain by a topographic layer to indicate location and landscape form.

Several topoclimatic patterns, i.e. linking climate and topography, are evident in Figure 1. For example, landscape depressions are associated with low growing degree-day values (in blue), whereas north-facing slopes are associated with relatively high values (in red). In general, cooler minimum temperatures can be expected in the “frost hollows” due to ponding of cold, dense air at night. This means reduced daily mean temperatures at these sites and lower degree-day values. In contrast, sunny, north-facing slopes will be above the threshold often due to greater solar radiation loading by day, so will tend to accumulated greater degree-day values over the course of a year. Such patterns can be readily explained by climate theory. The patterns have also been corroborated by anecdotal evidence from local farmers, e.g. related to early and late harvest dates for “warm” and “cold” sites in the area.

3.0 CONCLUSION

There are numerous practical implications for the Southland community. For example, topoclimate and soil information can be used to inform choices of new crops, since specialist crops with potentially high financial returns tend to require special combinations of soil and heat, e.g. peonies require low degree-day values and stony soil to be a commercially viable crop (Topoclimate South, 2000). Integrated soil-climate data can be used to help plan fertiliser applications, e.g. to select sites worthy of extra fertiliser (i.e. sites with quality micro-climates and high class soils). Information from the Project can even aid real estate agents in the pricing of farms with quality topoclimates and, therefore, potential for increased profit if these are utilised.

The Topoclimate South Charitable Trust which runs the Topoclimate project is strongly committed to the effective communication of information to the local community and end users, be they farmers, scientists or teachers. To this end, the Trust have established a service to provide information and interpretation for the 4500 farmers in Southland and is issuing free soil and GDD maps to participating farmers in the survey area. Other productivity and diversification information is also being offered in conjunction with AgriQuality NZ Ltd as partners (Topoclimate South, 2000).

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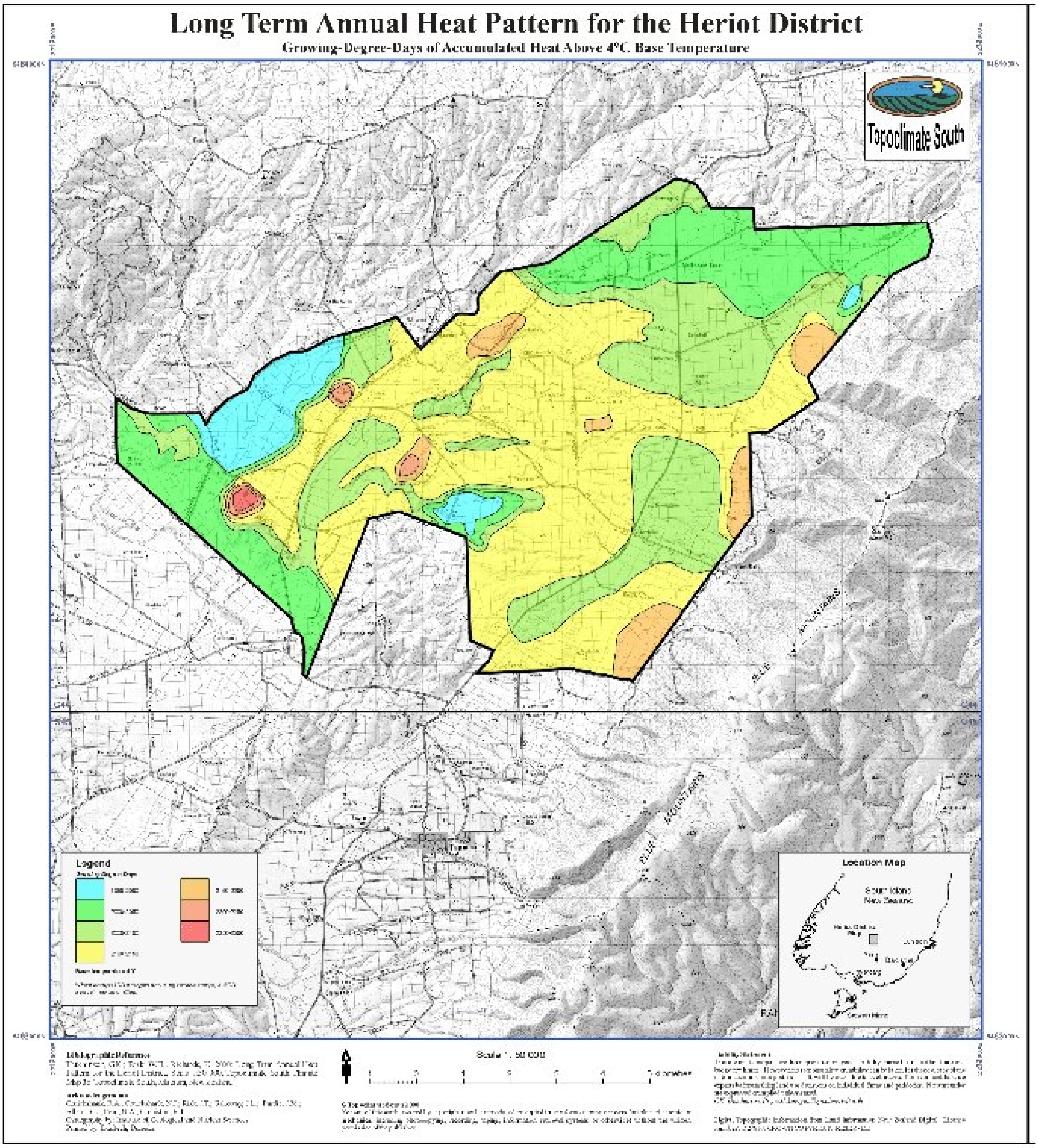

Figure 1: Illustrative image of a map produced by the Topoclimate South project: Long term annual heat (growing degree-day) pattern for the Heriot district above a 4°C base temperature. Values range from 2200°C (in blue) to 2600°C (in red). The mapped area is approximately 20 km in width and was produced at a scale of 1: 50 000 (© Topoclimate South; used with permission).

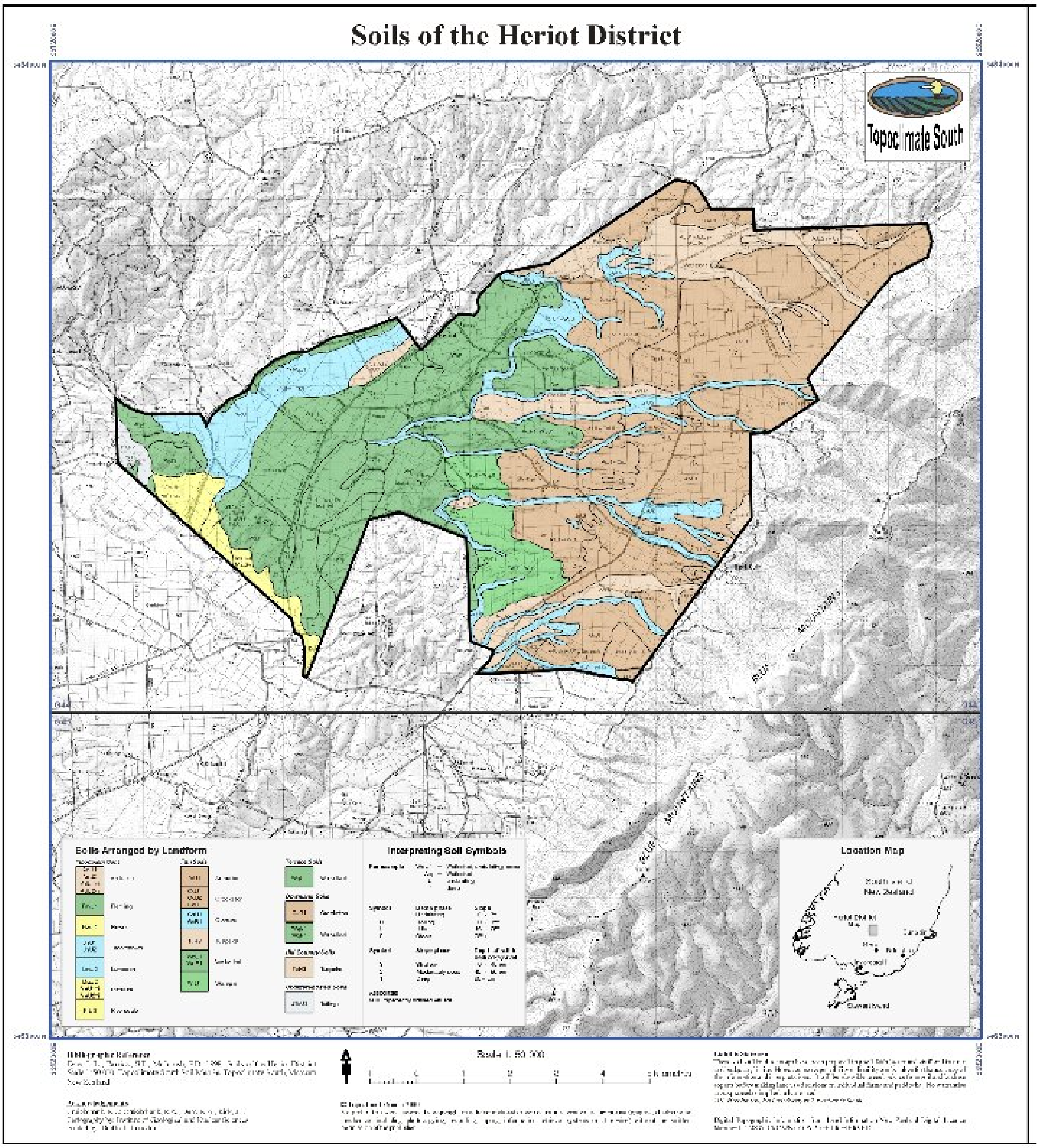

Figure 2: Illustrative image of a map produced by the Topoclimate South project: Soil distribution for the Heriot district, Southland. The mapped area is approximately 20 km in width and was produced at a scale of 1: 50 000 (© Topoclimate South; used with permission).

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