

Visualising Spatial Patterns in Fruit Quality and Productivity of Persimmon Orchards using Self Organising Maps

Alistair Mowat

Horticulture and Food Research Institute of New Zealand Ltd.
Ruakura Research Centre. Private Bag 3123, Hamilton, New Zealand
Phone: +64 7 858-4673 Fax: +64 7 858-4700
Email: amowat@hort.cri.nz

Presented at SIRC 2000 – The 12th Annual Colloquium of the Spatial Information Research Centre
University of Otago, Dunedin, New Zealand
December 10-13th 2000

ABSTRACT

Fruit quality and productivity datasets, obtained over two seasons from 24 New Zealand persimmon orchards, were associated with a self organising map trained on the spatial coordinates and geographic region of each orchard. Using this approach, a summary representation of the geographic distribution of the orchards was obtained from the projection plane of the self organising map. By overlaying fruit quality and tree productivity attributes as component planes, spatial patterns between orchards could be observed. In addition, climatic data from regional meteorological stations was associated with the map.

Keywords and phrases: visualisation, spatial data, self organising map, climate, persimmon, fruit quality.

1. INTRODUCTION

In New Zealand, about 100 persimmon orchards are geographically dispersed over six growing regions between 35°- 40° S. Within a geographic region, orchards are either distributed sparsely or in clumps, depending on topology and micro-climate. *Diospyros kaki* L. cv. Fuyu, the main cultivar grown for export in New Zealand, originated in the warm temperate region of Japan, where it is well adapted (Collins *et al.*, 1993). Over a nine month growing season, the mean monthly temperature in main Fuyu production areas of Japan is 18 °C, about 2.5 °C higher than the New Zealand persimmon growing regions (Mowat *et al.*, 1995). Quality and productivity characteristics of persimmon are affected by environment. For example, fruit quality, based on fruit weight, peel colour, soluble solids and soluble tannins, was highest when day/night temperature during growth stage II and stage III respectively was 25/25 and 25/20 °C, compared to higher (30/30 °C) and lower temperatures (15/15 °C) (Chujo, 1982). In addition, high rainfall in the latter part of fruit development can affect fruit quality (Mowat and George, 1994).

As persimmon in New Zealand is a new export industry, less than 20 years old, knowledge about the geographic sites most suited to commercial production is limited. Initially, the crop was planted in over a wide range of sites within Northland, Auckland, Waikato, Bay of Plenty, Gisborne and Hawkes Bay. Geographic influences on fruit quality and productivity were assessed once these orchards started producing commercial quantities of fruit (Mowat and Ah Chee, 1992, 1993). In these studies, geographic differences between fruit and tree growth characteristics were based on analysis of variance. More recently, for these persimmon orchards, self organising maps were used to assess tree characteristics and fruit development patterns (Mowat, 2000a; 200b). Here, a range of fruit and tree attributes were used as inputs into the self organising maps, whilst outputs consisted of clusters of orchards. For example, from self organising map analysis for the 1990-91 and 1991-92 growing seasons, the orchard samples were found to be grouped into three clusters based on productivity and maturity characteristics (Mowat, 2000a). In this work correspondence analysis (Greenacre, 1984) was used to relate the geographic regions of orchards to the clusters identified in the self organising map. Whilst correspondence analysis is suitable for studying relationships between categorical data, such as region and cluster membership,

many of the attributes of interest in this work were continuous variables such as fruit quality and tree productivity attributes. In the present study we investigate the use of self organising map algorithms to project the spatial coordinates and geographic region of persimmon orchards onto a two dimensional projection plane that can then be used to overlay quality, productivity and climatic data.

2. METHODS

The experiment, a 6x4x4x4 nested design, was performed in six climatic regions (Northland (~ 35°15'S 173°55'E), Auckland (~ 37°10'S 174°50'E, Waikato (~ 37°50'S 176°05'E), Bay of Plenty (~ 37°45'S 176°20'E), Gisborne (~ 38°35'S 177°55'E), Hawkes Bay (~ 39°30'S 176°45'E)) within New Zealand, on four commercial orchards per region. Four replicate groups of trees were selected in each of the orchards. A replicate consisted of a canopy bay of four adjacent trees. The replicate groups were located within the centre of an orchard block to avoid interference from perimeter windbreaks. Between orchards, the age of the trees ranged from 3–12 years. Trees were trained on a “Y-trellis” system, except for one orchard in Northland and three orchards in the Hawkes Bay. On these sites, the trees were trained on a palmette-espalier type system in rows orientated north/south.

The study was undertaken over two growing seasons, 1990-91 and 1991-92. At harvest (25 weeks from full-bloom), from each replicate, eight fruit from each replicate were selectively harvested at a minimum colour chart value of five. Fresh and dry weight, peel hue, soluble solids and soluble tannins were measured for each fruit using the methods previously described (Mowat and Ah Chee, 1992). In addition, for these fruit, a relative market quality score was calculated by taking the weighted sum of the normalised values of fruit weight, hue, soluble solids and soluble tannins, divided by the weighted sum of normalised values for a weight of 200 g, hue of 55°, soluble solids of 12.5% and soluble tannins of 0.06%, using the market weighting values described in Mowat and Collins (2000). After leaf fall, 32 fruiting units (two year old shoots carrying current season fruiting laterals) were randomly sampled from each replicate. From these fruiting units, fresh and dry lateral weight, and the number of laterals, buds (leaf scars), flowers (floral scars and fruit peduncles) and harvested fruit (freshly cut peduncles) were assessed. In addition, the trunk cross sectional area (measured 15cm above the graft union) and number of fruiting units for each tree was measured.

Viscovery SOMine (Eudaptics Software GmbH, Austria) was used to construct a 2000 node self organising map (Kohonen, 1997) from input features (latitude, longitude, and growing region) obtained from each orchard replicate. In the case of the growing region, a binary value was used to identify the orchard membership in each region. The self organising map algorithms projected the multivariate input data onto a two dimensional plane, preserving important topological features in the original dataset. Separate maps were constructed for each season. Fruit quality and tree productivity characteristics were then associated with each completed map. In addition, the mean monthly temperature and rainfall over a nine month growing season was calculated from regional meteorological sites and then associated with the self organising map.

3.0 RESULTS

In Figure 1, it can be seen that the projection plane of the self organising map was comprised of six clusters that correspond to the six persimmon growing regions. Moreover, the self organising map output retained the north to south axis, running from the top to the bottom of the map, and east to west axis, from the right to the left side of the map. The shape of each region within the self organising map is related in part to the geographic distribution of the orchards within each region. For example, in the original geographic coordinates, orchards within the Auckland, Gisborne and Hawkes Bay regions were geographically close to each other. In contrast, the orchards in Northland, Waikato and the Bay of Plenty were distributed across a wider geographic area. Here, the Northland the orchards were dispersed in an approximate northeast – southwest axis, an east – west axis in the Waikato region and a north – south axis in the Bay of Plenty.

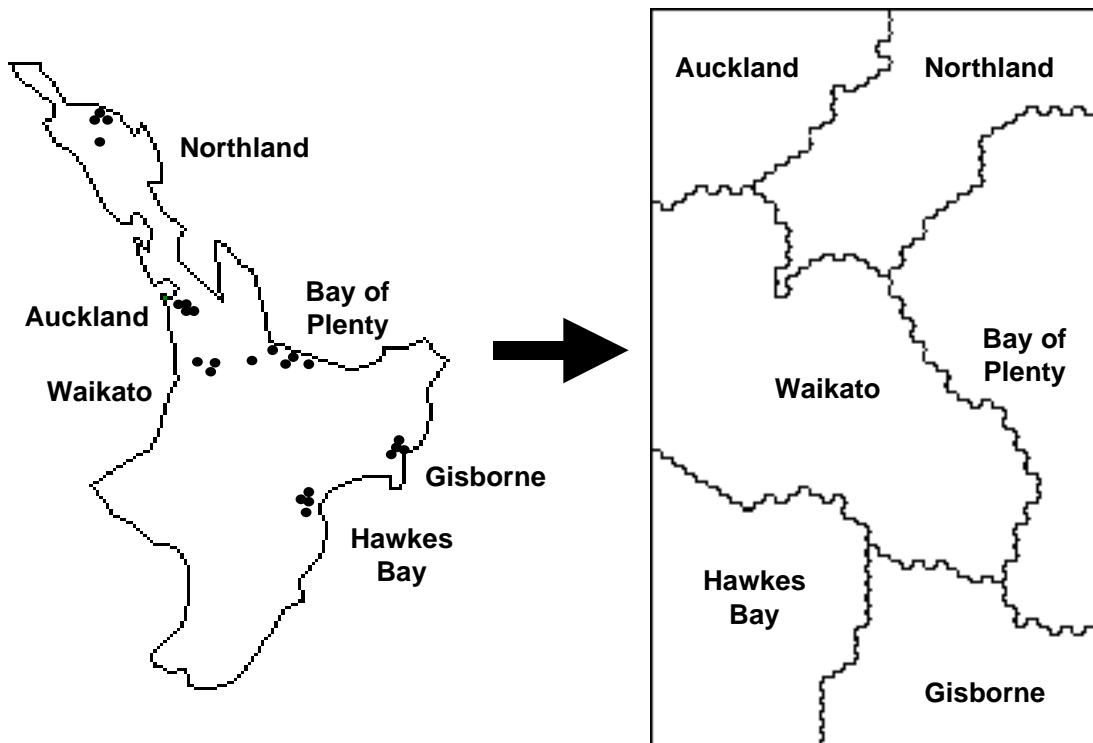


Figure 1: Transforming the geographic location and growing regions of twenty four New Zealand persimmon orchards (denoted as black dots) into the projection plane of a self organising map. Separators are used to define the perimeter of the growing region clusters within the projection plane of the self organising map.

Utilising the self organising map transformation of spatial data, patterns in fruit quality and tree productivity could be visualised. Furthermore, temporal changes in these attributes could be compared over the two growing seasons. For presentation purposes the original colour scales used in the output of the self organising map were converted to a grayscale. In Figures 2 and 3, the four orchards within each regional cluster could be readily distinguished, allowing patterns in orchard variability to be observed at the orchard, region or temporal scale. For example, in Figure 2a, fruit from the Northland, Auckland and Bay of Plenty orchards had a consistently lower market quality in comparison to the Waikato and Gisborne orchards. In general, market quality and productivity was highest in the 1990-91 season in comparison to the 1991-92 season (Figures 2, 3). In relation to within orchard variability, fruit quality and tree productivity was generally not distinguishable in the self organising map, although values for these attributes were based on the replicate groups of trees within each orchard.

Essentially the same process was applied to the regional meteorological data. For example, in Figure 4, the Waikato region was the coolest and Northland the warmest in both seasons. In addition, Hawkes Bay was warmer than Gisborne in the 1990-91 season and cooler than Gisborne in the 1991-92 season. Based on the visualisation of rainfall patterns in both seasons (Figure 5), the southern regions, Hawkes Bay and Gisborne, were drier in comparison to the central and northern growing regions.

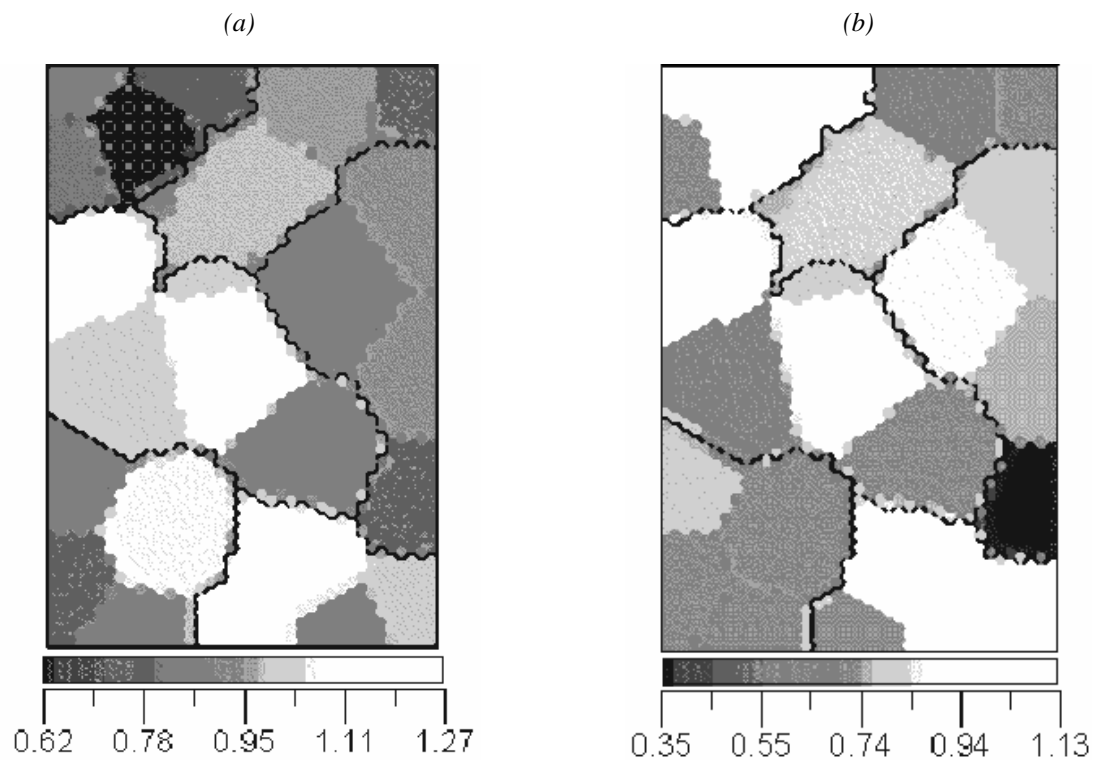


Figure 2: The distribution of the relative market quality score for the self organising map shown in Figure 1. (a) 1990-91 season; and (b) 1991-92 season.

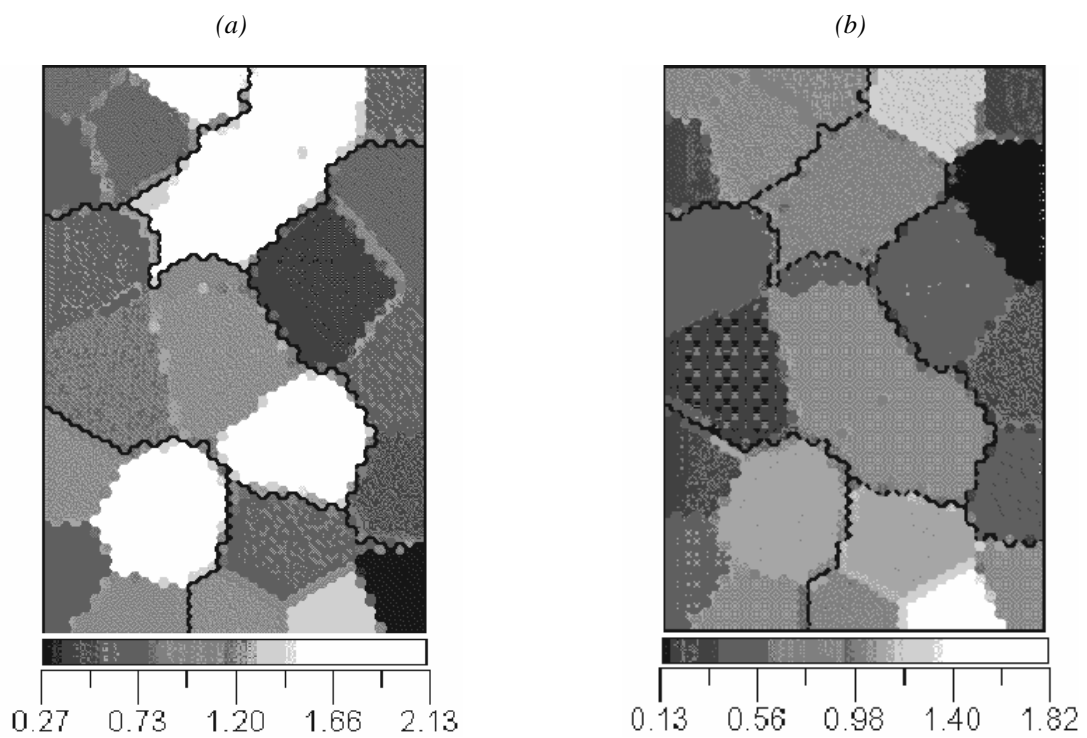


Figure 3: The distribution of the fruit yield per trunk-cross-sectional area (kg/cm^2) for the self organising map shown in Figure 1. (a) 1990-91 season; and (b) 1991-92 season

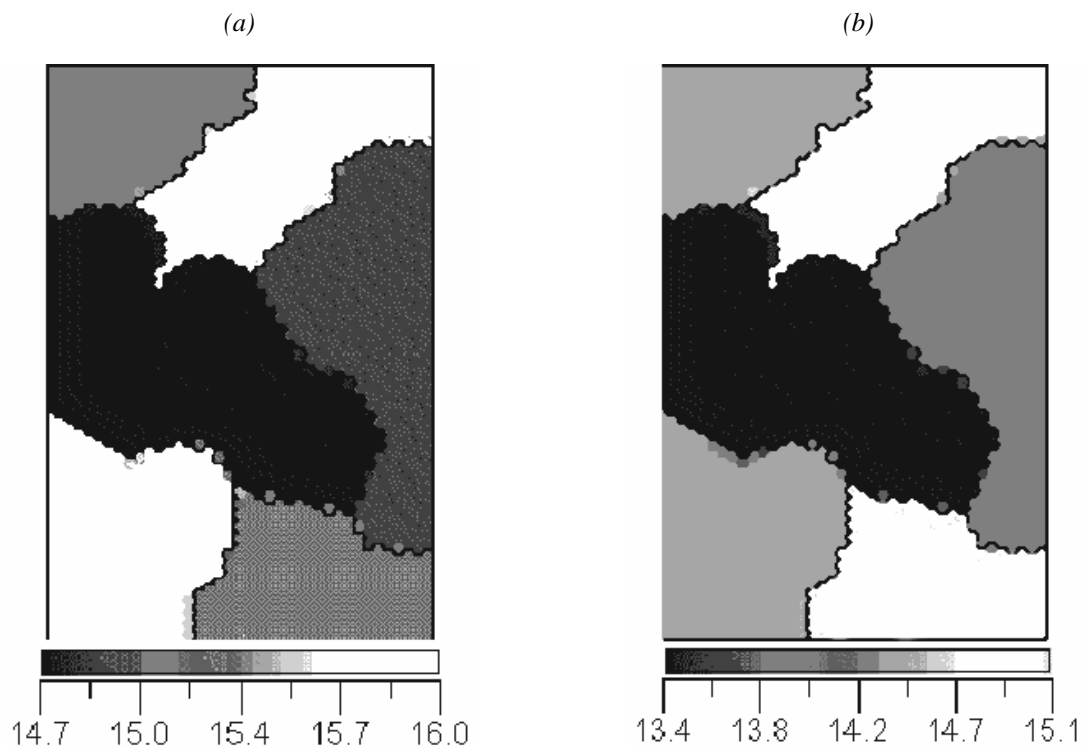


Figure 4: The distribution of the mean monthly temperature ($^{\circ}\text{C}$) over a nine month growing season for the self organising map shown in Figure 1. (a) 1990-91 season; and (b) 1991-92 season

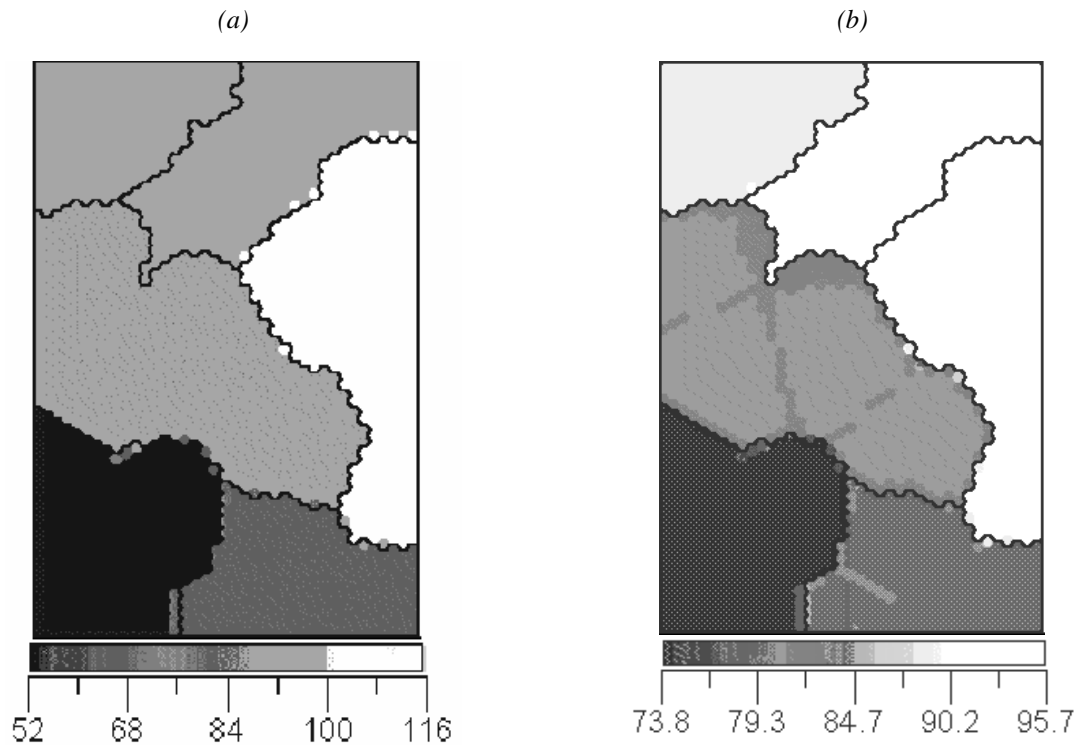


Figure 5: The distribution of the mean monthly rainfall (mm) over a nine month growing season for the self organising map shown in Figure 1. (a) 1990-91 season; and (b) 1991-92 season

4.0 DISCUSSION

Increasingly, geographic information systems (GIS) are being used in horticulture. For example, to identify suitable areas for the production of fruit crops (Rumayor-Rodriguez *et al.*, 1998; Bydekerke *et al.*, 1998), mapping yield distributions within an orchard (Whitney *et al.*, 1999), predicting wine quality from spectral images of vineyards (Johnson *et al.*, 1998), monitoring phylloxera infestation in vineyards (Johnson *et al.*, 1996) or visualising spatially distributed near infrared reflectance data collected from the sub-surface of fruit (Munro *et al.*, 1997). In these cases, GIS approaches covered a range of spatial scales, from the surface of an individual fruit to the climate and topology of a whole country.

Self organising maps have previously been applied to geographic datasets. For example to classify vegetation types (Gahegan, 1999) or residential areas (Openshaw, 1994). In these cases the self organising map algorithm was used to clustered samples, simplifying the multivariate complexity of the original dataset, in order to classify geographic regions, represented in conventional cartesian based geographic maps, by vegetative coverage or residential use. A similar approach was used by Mowat (2000a, 2000b) to classify groups of trees within New Zealand persimmon orchards on the basis of their vegetative and fruit growth and development characteristics. Alternatively, as shown in the present work, the self organising map could be used directly as a visualisation tool to display geographic information. Here, where geographic distances vary markedly between orchards, the general topology of the spatial location of orchards can be retained in the self organising map, whilst the detail of the geographic regions between these orchard locations is reduced. By using a regional identifier in conjunction with the spatial coordinates of each orchard, the self organising map can cluster the orchards on the basis of their regional membership. This step reduces the risk of orchards located on the edge of a growing region being incorporated into an adjacent cluster. For example, an orchard located near Waihou in the Waikato region and an orchard located north of Katikati in the Bay of Plenty have a close geographic proximity to each other but are separated by the Kaimai range. Once the self organising map has been trained on the spatial data then other data, such as fruit quality and tree productivity data, can be associated with the trained map and displayed.

In principal, a new orchard site with unknown fruit quality or tree productivity could be added to the trained self organising map, enabling prediction of these properties. For example, in the 1990-91 growing season, if a new Bay of Plenty orchard had been added to the map, the predicted quality and productivity values would be moderate to low, similar to the other orchards within this growing region. In contrast, the predicted quality and productivity values for a new orchard added to the Waikato region, where orchards show greater variation in these properties, could be calculated on the basis of the closest geographic orchard or the mean values for the Waikato cluster.

The patterns in fruit quality and productivity revealed by the spatially trained self-organising map suggest that climatic factors may have a dominant affect on these properties in regions such as the Bay of Plenty. Based on an understanding of the ecophysiology of persimmon (Mowat and George, 1994), and observations made on the growth characteristics of trees in these orchards (Mowat, 2000b), the cool-wet climate and fertile soils of this region may promote tree vigour at the expense of yield and quality. In other regions such as the Waikato, where variability in productivity and quality is high, localised micro-climates or crop management skills may ameliorate the influence of the regional climate.

5.0 CONCLUSIONS

A summary representation of the geographic distribution of persimmon orchards in New Zealand could be obtained from the projection plane of a self organising map that had been trained on the spatial coordinates and growing region identity for each orchard. Although the spatial map produced by this process is an abstraction of the original geographic distribution of the orchards, it preserves much of the original topology, whilst discarding unnecessary geographic detail. By overlaying fruit quality, tree productivity and regional meteorological data as component planes, spatial patterns between regions and orchards could be observed.

REFERENCES

- Bydekerke, L., E.-van Ranst, L. Vanmechelen and R. Groenemans, 1998. Land suitability assessment for cherimoya in southern Ecuador using expert knowledge and GIS. *Agriculture, Ecosystems and Environment*. 69: 2, pp89-98.
- Chujo, T., 1982. Studies on the effects of thermal conditions on the growth and quality of fruits of Fuyu *kaki*. *Memoirs of the Faculty of Agriculture Kagawa University*. 37: pp. 1-63.
- Collins, R.J., A.P. George and A.D. Mowat 1993. The world trade in persimmons. *Chronica Horticulturae* 33: 2, pp. 5-7.
- Gahegan, M. and M. Takatsuka, 1999. Dataspace as an organisational concept for the neural classification of geographic datasets. *Proceeding of the 4th GeoComputation '99*, Fredericksburg, Virginia USA. pp12. <<http://www.geovista.psu.edu/sites/geocomp99/abstracts.htm>>
- Greenacre, M.J., 1984. *Theory and Applications of Correspondence Analysis*, Academic Press, London.
- Johnson, L., B. Lobitz, R. Armstrong, R. Baldy, E. Weber, J. DeBenedictis, and D. Bosch. 1996. Airborne imaging for vineyard canopy evaluation. *California Agriculture*, Special Issue on Phylloxera 50: 5, pp. 14-18.
- Johnson, L., B. Lobitz, D. Bosch, S. Wiechers, D. Williams, and P. Skinner, 2000. Of pixels and palates: can geospatial technologies help produce a better wine? *Proceedings, 1st International Conference on Geospatial Information in Agriculture and Forestry*, Lake Buena Vista, Florida, 1998. <<http://geo.arc.nasa.gov/sge/crush/ERIM.html>>
- Kohonen, T., 1997. *Self Organising Maps*. 2nd edition, Springer Series in Information Science Volume 30. Springer, Hiedelberg.
- Mowat, A., A. Ah Chee, 1992. A study of the influences on Fuyu fruit quality and maturation in different growing districts of New Zealand. *HortResearch Client Report No. 92/125*.
- Mowat, A., A. Ah Chee, 1993. The influence of tree characteristics and management on Fuyu fruit quality and maturation in New Zealand. *HortResearch Client Report No. 93/248*.
- Mowat, A., A. George, 1993. 'Persimmon' in *The CRC Handbook on Environmental Physiology of Fruit Crops*, eds Schaffer B. and Anderson P., CRC Press, Florida, 1993, pp. 209-232.
- Mowat, A., R. Collins and A. George, 1995. Cultivation of persimmon (*Diospyros kaki* L.) under tropical conditions. *Acta Horticulturae*, 409: pp. 141-149.
- Mowat, A.D. and R.J. Collins, 2000. Modeling consumer buying behaviour to fruit quality. *Journal of Supply Chain Management* 54: 1, pp. 5-54.
- Mowat, A.D., 2000a. Fruit development patterns in persimmon (*Diospyros kaki* L. cv. Fuyu) grown under cool climate conditions. *Acta Horticulturae (in press)*.
- Mowat, A.D., 2000b. Characterisation of vegetative growth and productivity patterns between New Zealand persimmon orchards. *Acta Horticulturae (in press)*.
- Munro, H., K. Novins, G. Benwell and A. Mowat, 1997. Interactive exploration of spatially distributed near infrared reflectance data. *Proceedings of the 2nd GeoComputation '97 and SIRC '97*, Dunedin, New Zealand, 1997, pp. 19-24.
- Openshaw, S., M., 1994. 'Neuroclassification of spatial data', in *Neural Nets: Applications in Geography*, eds D.C. Hewitson and R.G Crane, Kluwer, Boston, pp53-70.
- Ruamayor-Rodriguez, A., J.A. Zegbe, G. Medina-Garcia and R. Monet, 1998. Use of geographical information systems (GIS) to describe suitable production areas for peach. *Acta Horticulturae*, 465: pp549-556.
- Whitney, J.D., W.N. Miller, T.A. Wheaton, M. Salyani and J.K. Schueller, 1999. Precision farming applications in Florida citrus. *Applied Engineering in Agriculture*, 15: 5, pp399-403.