A multivariate evaluation of sugarcane farm performance over time based on yield and commercial cane sugar

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Abstract

In both precision agriculture and broader catchment scale investigations, there is a need to understand and ultimately exploit the spatial variation of agricultural crops for an improved economic return. In many instances, this spatial variation is temporally unstable and may be different for various crop attributes and crop species. In the Australian sugar industry, the opportunity arose to evaluate the performance of 231 farms in the Tully Mill area in far north Queensland using production information on cane yield (t/ha) and CCS (a fresh weight measure of sucrose content in the cane) accumulated over a 12 year period. Such an arrangement of data can be expressed as a three-way array where a farm?attribute?year matrix can be evaluated and interactions considered. A multivariate technique, the three-way mixture method of clustering, was employed to identify meaningful relationships between farms that performed similarly for both cane yield and CCS. In this context, farm has a spatial component and the aim of this analysis was to determine if systematic patterns in farm performance expressed by cane yield and CCS persisted over time The analysis revealed that the relationship between farms was remarkably stable from one year to the next for both attributes and there was some spatial aggregation of farm performance in parts of the mill area. However there appeared to be no spatial relationship between the cane yield and CCS.

Keywords

Cluster analysis, mixture methods.

Introduction

In the Australian Sugar industry, large amounts of information are collected from farms on two important productivity attributes, cane yield (t/ha) and commercial cane sugar (CCS). This information is available at the block or paddock level and can be averaged to generate information on individual farm performance each year (1). In the Tully Mill area, situated in far north Queensland, annual productivity information on TCH and CCS was available for 231 farms for twelve years from 1988 to 1999.

In this instance, the variable ‘farm’ captures the combined influence of management and local variations in weather, as well as edaphic and biotic characteristics of the environment. Of these potential factors, one might reasonably expect some aggregation of climatic and edaphic characteristics based on the topography of the area, which could contribute to spatial patterns of variation of farm performance.

The variable ‘year’ captures all general temporal environmental effects (e.g. weather) that directly or indirectly influence TCH and CCS through other (e.g. biotic) factors. In this instance, we have utilised a three-way mixture method of clustering (2) that enables the three-way interaction between farm, year, and crop attributes to be explored. This allows the individual farms to be allocated into a discrete number of groups that perform similarly for the two attributes over time. The degree of spatial aggregation in farm group performance measures such as cane yield and CCS was therefore determined as was the temporal stability of these aggregations (i.e. the magnitude of the farm x year interaction for the crop attributes of cane yield and CCS).

Methods

The objective of the cluster analysis was to identify groups of farms that had similar response patterns for cane yield and CCS over the 12-year period of investigation. The three-way mixture method of clustering enabled all of the information (i.e. CCS and TCH) to be analysed simultaneously, avoiding the need to reconcile independent groupings of farms across years for both CCS and TCH or use an index like tonnes of sugar/ha (TSH) that amalgamated the information from the two attributes. Thus each group of farms has its own response pattern for CCS and TCH over years and the analysis captures any interaction between farm group and year for both attributes. In this instance, group-specific correlations were also obtained to evaluate the relationship between TCH and CCS for each group.

Results

The productivity information from the 231 farms was used to identify six groups of farms. Pronounced differences in TCH and CCS were detected among the six farm groupings (Table 1). However there was only a small farm ? year interaction in the group mean response for TCH (Figure 1a) where the response pattern across years was relatively consistent for all groups. The group means for TCH presented in Table 1 adequately described the 'among group' relationships in nearly all years. Group D consistently out-performed all other groups, while groups E and F were identical in almost every year. The difference in TCH between groups A and B appeared to fluctuate, ranging from 0.4 t/ha in 1997 to 12.5 t/ha in 1988. In recent years (1994 onwards), the difference between the two groups was small (Figure 1a). The difference in TCH between group A (lowest) and group D (highest) ranged from 36 t/ha in 1988 to 19 t/ha in 1999.

Year had a greater influence on group response to CCS, where there was negligible group variation in 1988 and again in 1990 (Figure 1b). In all other years, CCS was markedly higher in farm group F. Other group differences were small. For example, the mean CCS of groups A, B, C and D ranged only from 12.2 (B) to 12.6 (C) and it was difficult to draw any other strong conclusions from the analysis. However, the multi-attribute analysis did identify groups E and F, which respectively had the lowest and highest CCS of all groups, but almost identical yields. Again, with the exception of 1988 and 1990, the relationship between groups E and F for both attributes did not change from year to year. Conversely, the highest and lowest TCH was evident in groups D and A respectively, but no difference in CCS was evident between them. Overall, the response of all groups to year was remarkably uniform for both attributes. The correlations between TCH and CCS were low for all groups implying a poor relationship between the two attributes throughout the mill area.

Table 1. Mean response, correlation coefficients between the attributes TCH and CCS and the number of farms for each cluster group, in the analysis of farm ? year ? attribute responses in the Tully Mill area 1988-1999.

Group	TCH	s.e.*	CCS	s.e.*	Correlation (r)	Number
A	71.1	2.23	12.5	0.14	-0.01	31
B	75.7	1.29	12.2	0.07	-0.09	32
C	82.3	0.95	12.6	0.06	-0.20	67
D	98.2	1.31	12.4	0.07	-0.19	39

E	89.2	2.03	12.1	0.13	-0.05	33
F	90.6	1.60	13.1	0.10	-0.13	29

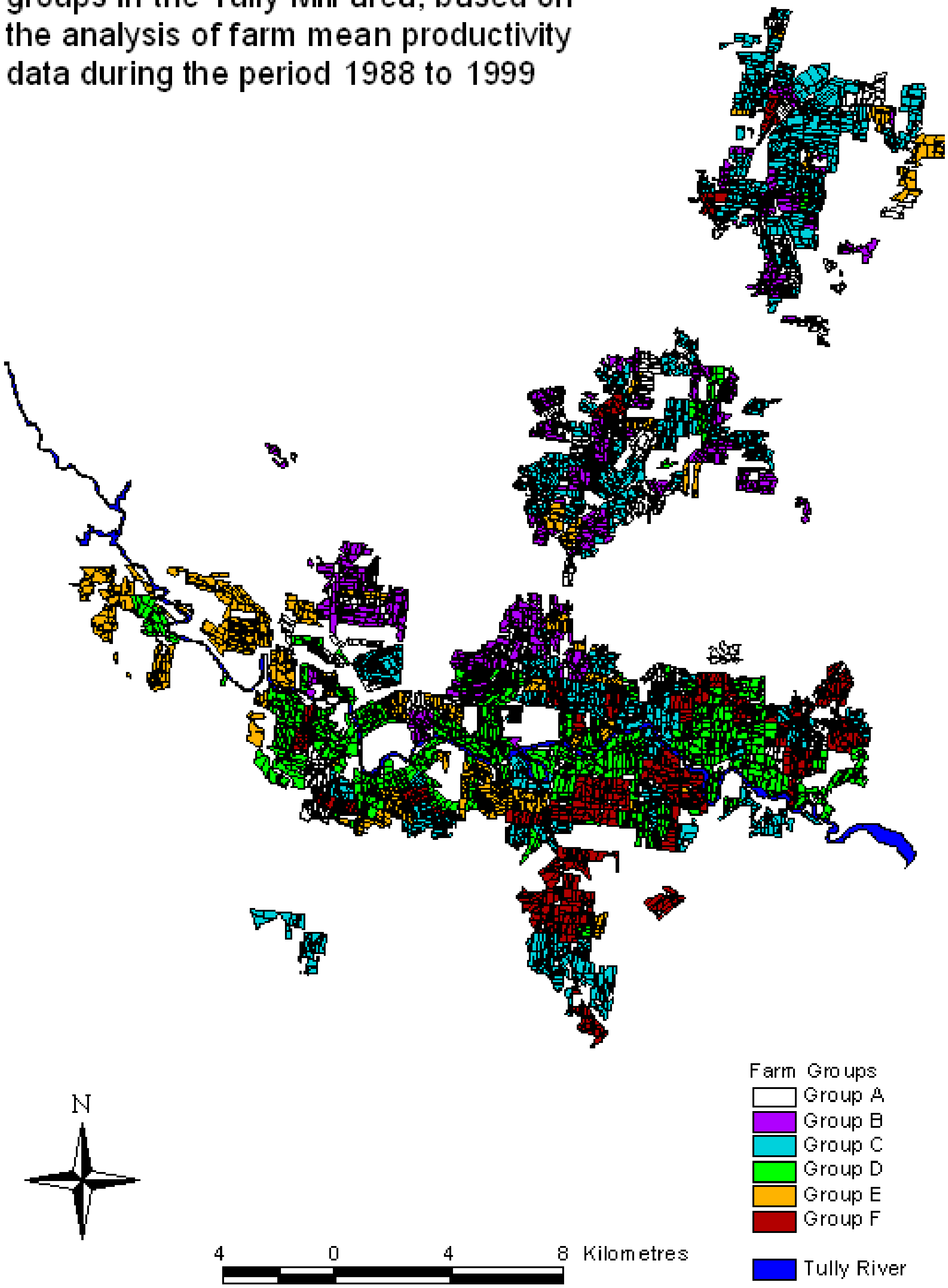
*s.e = standard error of the estimates

Spatial relationship of farm groups

There was some spatial aggregation of the farm groups (Figure 2). Farms in the highest yielding group, D, were predominantly located immediately on either side of the Tully River. Most farms in group E, also a high yielding group, but with lower CCS than group D, were located in the western part of the mill area, often beyond those group D farms along the river. The remaining group D farms were scattered throughout the mill area. Many farms in group F were situated beyond those group D farms along the river in the east-south-east part of the mill area. Farms in groups B, C and to a lesser extent A, the poorest yielding, were dominant in that part of the mill area located to the north of the Tully River. However, some farms from each group were located throughout the mill area, generally but not always in areas further from the river.

The moderate aggregation of farms, with the exception of group A and to a lesser extent group E, would suggest that there is some common underlying factor(s) influencing the TCH and CCS with many similarly grouped farms in close proximity to each other (Figure 2). Since the farm group by year interaction was relatively small for each crop attribute, we can conclude that the spatial variation of farm performance is relatively stable from one year to the next.

Figure 2. Geographic location of farm groups in the Tully Mill area, based on the analysis of farm mean productivity data during the period 1988 to 1999



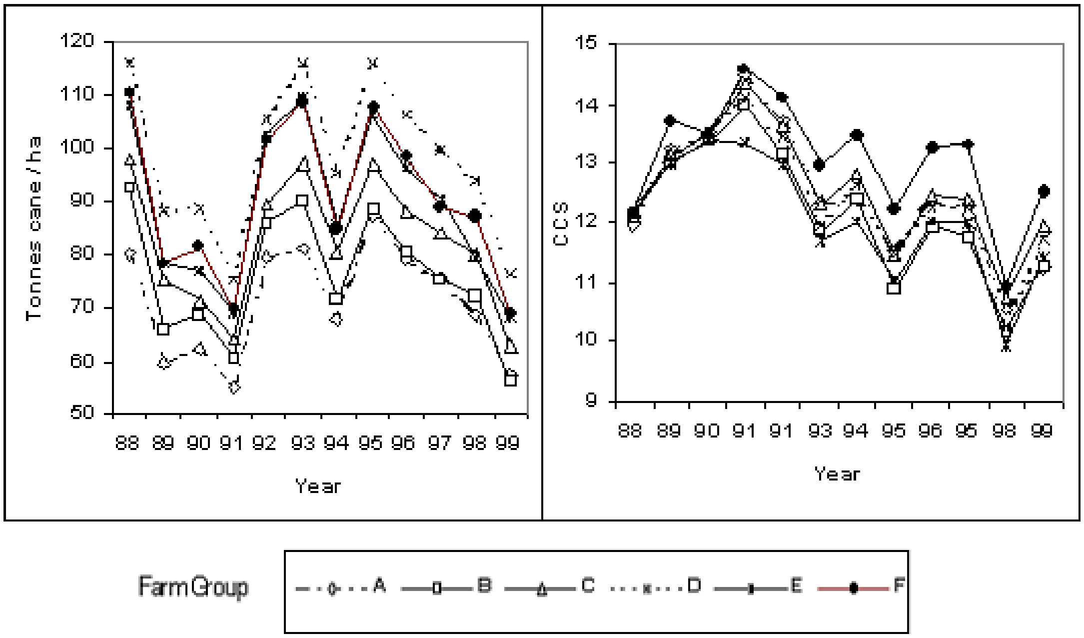


Figure 1. The response vectors for TCH (a) and CCS (b) for the six farm groups derived from the cluster analysis of the three-way array of 231 farms, 12 years and 2 attributes.

Conclusion

The three-way mixture method of clustering enabled information on two crop productivity attributes from 231 farms over 12 years to be classified into 6 farm groups. The relationship between these farm groups was relatively stable and there was some spatial aggregation of the farm groups. Therefore the spatial variation in both cane yield and CCS in the Tully Mill area was generally stable from one year to the next, although there appeared to be no relationship, spatial or otherwise, between these two crop attributes.

References

(1) Lawes, R.A., Wegener, M.K., Basford, K.E., McDonald, L.M. and Lawn, R.J. 2002. Aust. J. Exp. Agric., 42: 473-480.

(2) Basford, K.E. and McLachlan. G.J. 1985. J. of Classification., 2: 109-125.