CONCLUSIONS

The major conclusions of this study can be summarized as follows based on the results from the four objectives.

1. By examining the effects of spatial variation of certain soil properties on the winter yield of a lucerne stand, the following was concluded.

- The two identifiable soils on the study site, although similar in certain aspects, exhibited differences in $pH(H_2O)$, Ca, Mg and dominant clay minerals. These differences caused distinct bi-modal populations of data when subjected to statistical analysis.
- The majority of properties showed considerable variation and highly variable autocorrelation lengths.
- Simple linear regression analyses showed that the soil properties $pH(H_2O)$, organic C, exchangeable Ca and Mg contents are individually well correlated with green biomass lucerne yield.
- A prediction model for lucerne yield ($R^2 = 0.55$) was obtained from stepwise multiple regression analyses. The model had $pH(H_2O)$, organic C, exchangeable K and sand contents as variables. Although soil P status is a major nutrient element for lucerne growth, it did not feature in the prediction model.
- The geostatistical procedures allowed the construction of maps to demonstrate the spatial variability of soil properties and of lucerne yield. The fair resemblance between the measure and predicted yield maps supports the validity of the yield prediction model. The conclusion that the scale of variation of the yield can be related to that of soil properties is supported by this study. This can be useful in designing an appropriate sampling scheme for observing soil properties in future.

2. When the spatial relations between plant element uptake of a lucerne stand and soil properties were explored, the following conclusions could be made.

- Statistical analyses indicated that the two soil types affected soil and plant properties to different degrees. For some properties (*e.g.* pH, Mg content of the soil and electrical resistance) a distinct bi-modal population resulted, while there was hardly any effect on other properties (all plant element concentrations and organic C, P and K contents of the soil).
- A linear regression analysis, in general, showed poor correlations between the plant element uptake and soil properties, but with the use of a multiple regression analysis the major plant and soil properties that influenced the uptake of elements by plants were established.
- Geostatistical procedures allowed the estimation of elements to construct maps in order to demonstrate the spatial variability of plant and soil properties. The majority of variables showed considerable variation and highly variable autocorrelation lengths.
- This study has shown that there is little or no resemblance when comparing the spatial distribution of Ca, Mg, K and P contents of lucerne with those of the soil. However, making use of a multiple regression equation, good agreement was found between the spatial distribution of measured and predicted plant K. This emphasizes the fact that the uptake of elements by plants is not solely dependent on the concentrations thereof in the extracted soil solution, but on other factors as well.

3. During the investigation of the temporal and spatial relations of plant element uptake and yield of a lucerne stand it could be concluded that:

- Although the lucerne stand contains on average adequate concentrations of plant Ca, Mg, P and K, areas of K deficiency did occur in the field during both the winter and summer seasons.
- Lower plant P and K values during summer could be due to the "dilution effect" exerted by the larger summer biomass yields.
- Weak linear correlations existed between plant elements and yield. When ignoring spatial correlations, statistically significant differences were evident when comparing nutrient status and yield between winter and summer growing seasons.

- Similarities were discernable between winter and summer spatial variations of plant Ca, Mg, P and K, with summer values either higher (Ca, Mg) or lower (P, K) than winter values.
- Statistical relationships existed between soil Mg and K and plant uptake.
- In the case of Mg, clear spatial similarities were visible between the nutrient concentration in the soil and plant uptake.
- Temporal variations in lucerne yield were observed, with the lowest and highest yields in June and September, respectively. Although there were large differences in spatial variation of lucerne yields across the harvesting incidents, a similar trough of lower yields was evident towards one end (northwestern side) of the stand for each yield map.
- A clear resemblance between spatial plant K and yield existed, probably because the deficiency in plant K was a dominant factor in causing spatial variation in yield.
- Although this study revealed spatial and temporal patterns in plant element uptake and yield of a lucerne stand at a specific location, the results illustrate some useful practical aspects relevant to site-specific management of lucerne stands. They are: (1) the temporal effect on correlation range of lucerne yield should be taken into account when deciding on time frames for soil sampling, (2) temporal lucerne yield variability should be recognized, described and manipulated when decisions are made in terms of precision agriculture, and (3) the variation in correlation ranges of the various plant elements should be considered in plant sampling patterns.

4. When examining the spatial variation of soil and plant properties and its effects on the statistical design of a field experiment the following was concluded:

- Analysis of variance of a randomized complete block design that consisted of pseudo treatments with replications revealed statistically non-significant differences among treatments for various soil and plant properties, including yield. From this the conclusion could be made that the experimental field is homogeneous enough to lay out a standard block design experiment. A spatial map of soil pH(H_2O) showed a clear structure in spatial variability. The question was posed that if the latter spatial variation had been considered, would it have had any effect on the results of this field experiment, for example, in terms of yield?

- The consequent redesign of the experiment whereby all plots were randomly allocated to treatments and replicates, led to dramatically different results: significant differences were obtained for plant and soil properties as a function of the pseudo treatments.
- From this study it is clear that spatial variability of soil and plant properties can jeopardize the results of a standard block design field experiment. However, it was found that soil pH(H_2O) correlated very well with green biomass yield. It is, therefore, recommended that field experiments should be designed to the cognizance of the spatial variation of a soil property that correlates highly with a chosen response variate.
- From the results of this study a pre-trial sampling grid of 40 m with additional short distance sampling at a few randomly selected points is recommended to quantify the chosen response variate. Hence, in the final statistical analysis to test for treatment differences, the particular soil property must be treated as a covariate. Consequent experimental results can now be interpreted with much greater confidence.