Graphical Analysis of Spatio-Temporal Patterns in Forage Quality

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Introduction

Due to the highly structured topography in Switzerland, crop growth conditions vary within short distances. Differences in altitude are one of the major causes for climatic variation resulting in significant spatio-temporal effects on forage quality in terms of nutrient content and feeding value, particularly in grassland dominated regions. It is one of the goals of the Swiss feed database to support queries that visualize and quantify the temporal and spatial influence on feed quality.

Methods

Novel database designs using open source GIS techniques such as Google Maps API were implemented in the Swiss feed data base to provide an interactive web application with visual analysis tools for large, geo-referenced data sets. Over 600 feed types are defined including roughage and raw materials. The nutrient measurements are enriched with geographical, temporal, biological and technical information. For confidentiality reasons, sample origins are geo-referenced only by altitude and postal code. The visualization of the spatial sample density and nutrient density relies on the two-dimensional Kernel density estimation and weighted Kernel regression (Betschart 2012). The nutrient density at the location (x,y) is:

$$\hat{g}_h(x,y) = \frac{\sum_{i=1}^{n} K\left(\frac{x-X_i}{h}, \frac{y-Y_i}{h}\right) Q_i}{\sum_{i=1}^{n} K\left(\frac{x-X_i}{h}, \frac{y-Y_i}{h}\right)}$$

where X and Y are the coordinates from the sample origins and Q stands for nutrient content, K for Kernel function and h for bandwidth.

The bandwidth h controls the width of the base of the Kernel function and is therefore the degree of smoothing. The optimal bandwidth is computed from the variance and size of a given data set ($h_{opt} = \sigma * A(K) * n^{-1/5}$; Scott 1992). The next step needed to create an image involves the conversion of the nutrient density values into color values ranging from red to green to blue representing high to low density. The grid points with the highest and lowest density set the scale limits in a dynamic way. Finally, the colored image is placed on the map using OverlayView of the Google Maps API.

Results

Technical considerations

To improve runtime efficiency the Epanechnikov Kernal function was adopted rather than the Gaussian Kernel function. The accuracy of the interpretation of the color plots depends on the sample size and nutrient variability. In cases where there are only a few available samples, the Kernel regression causes large circles of the same color as the region of influence of a single data point becomes large. This clearly limits the interpretation. With more than 500 samples, images with smooth transitions are produced.

The hay survey as example

The yearly hay survey conducted by the extension service in collaboration with feed analysis laboratories contributes approx. 1500 geo-referenced samples a year (Boessinger and Python 2012). The hay data set gives evidence for spatial quality patterns. Particularly carbohydrate and mineral content of hay correlate with altitude, region and local animal density. As shown in Figure 1, hot spots in phosphorous content can be detected which coincide with regions of high animal density in central and eastern Switzerland. Green and blue colors prevail in the alpine regions indicating below average P content which reflects lower grassland use intensity. The web interface offers complementary information. In a second window section, the scatter chart displays the temporal variability of individual samples. In the case of phosphorous with an overall average of 3.4 g P/kg DM, the content in hay samples varies between 1.5 and 5.1 g/kg DM. Over the last seven years, there is no obvious trend in time.

Translated into practical feeding recommendations, it can be concluded that hay based rations for dairy cows are on average deficient in P if the hay is of alpine origin. In contrast to P, mountain hay is richer in Ca and Mg compared to lowland hay. With respect to cell wall constituents, again hay from mountain regions is characterized by high lignin contents. High sugar contents are limited to eastern Switzerland of low altitude, possibly due to higher proportion of ray grass, early first cut and favorable climatic conditions.

The queries can be refined by selecting defined time periods, provinces, and altitude classes or by a user defined radius search. The retrieved information is useful to fine-tuning animal feeding and resource use efficiency at the local level. This procedure is applicable to any nutrient in any feed type within the feed base.

Conclusion

The Kernel regression technique is suitable to graphically

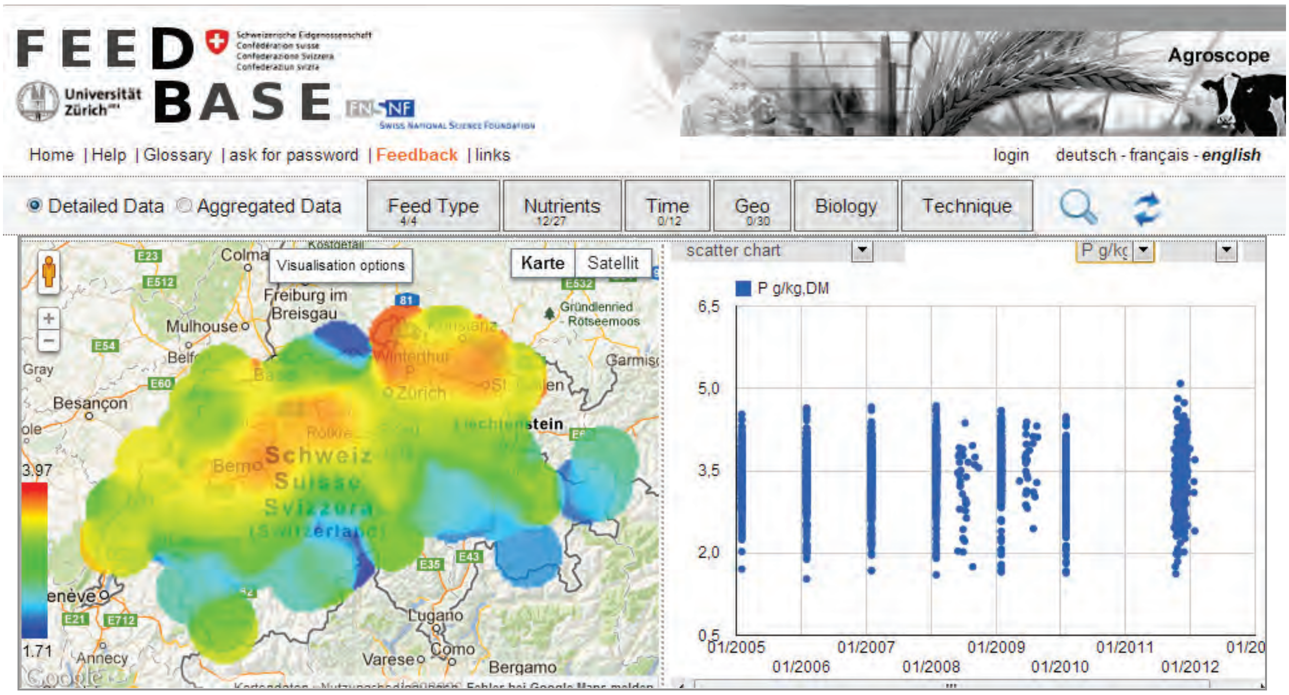

Figure 1. Screen shot of the web interface of the Swiss feed database displaying spatial patterns and scatter plot of phosphorous content in 1762 geo-referenced hay samples harvested between 2005 and 2012.

analyze patterns in forage quality provided that samples are geo-referenced and that the sample size is large enough and distributed over at least 3 locations.

When it comes to pattern interpretation some caution is required as an individual sample has more than a local influence on the map. The extent depends on the underlying bandwidth. Nevertheless, the interactive web application of the Swiss feed database allows dynamic queries and augments visual display of spatial and temporal information with statistics.

This data based monitoring of feed quality is beneficial for several user groups, farmers, researchers and government institutions.

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