Suitability of different methods to describe the botanical composition for predicting forage quality of permanent meadows at the first cut

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Abstract

The botanical composition is relevant to the forage quality of permanent meadows, as species differ from each other in their quality characteristics. A complete and detailed description of the botanical composition and the classification into a meadow type (MT) is time-consuming and requires advanced botanical skills. A quicker and easier method that is often used for the estimation of the forage quality is to assign the plant stand to one of the plant stand types (PT) 'rich in grasses', 'balanced', 'rich in forbs' or 'rich in legumes' based on the yield proportion of grasses, forbs and legumes. A large data set of about 6,000 forage samples obtained by sequential sampling at 202 environments in South Tyrol (Italy), describing the changes in forage quality along the phenological development starting from stem elongation, was used to investigate the effect of both MT and PT on 16 parameters of forage quality. Starting from a baseline model including design effects and growing degree days as a covariate, the improvement of the prediction accuracy of the model due to MT and PT was described by a five-fold cross-validation of stepwise forward-developed mixed models. PT contributed to improve the prediction accuracy of most of the investigated quality parameters and for 10 parameters was taken first into the model. MT was relevant as well for some of the parameters, but it played a less consistent role.

Keywords: forage quality, botanical composition, plant stand type, meadow type, permanent meadows

Introduction

It is well known that forage quality and its phenology-related changes over time are species-specific (Jeangros *et al.*, 2001; Bruinenberg *et al.*, 2002). For this reason, the botanical composition of multi-species plant stands is often taken into account for the prediction of the expected forage quality. Because of the effort needed to fully describe the botanical composition of the plant stand, a simplified system only considering the proportion of the species groups, such as grasses, legumes and forbs is used (Daccord *et al.*, 2007). The present paper addresses the question, whether a detailed description of the botanical composition, leading to the classification of the plant stand into a vegetation type, may improve the predictive accuracy of the parameters of forage quality.

Materials and methods

In order to answer the experimental question, a large data set was used, which describes the changes over time of the forage quality of permanent meadows between 666 and 1,593 m a.s.l. in South Tyrol (Italy) at the first cut. Forage samples were taken in fourfold replication per sampling event between 2003 and 2014 at 202 environments (site × year) by means of weekly sequential sampling for seven weeks starting at the stage of stem elongation (15 cm herbage growing height) and analysed for quality parameters (Peratoner *et al.*, 2016). Details about forage analyses are given in Romano *et al.* (2016). Growing degree-days (GDD) were computed for each sample according to Romano *et al.* (2014). For minerals and *in vitro* digestibility the four replications were pooled to one sample. Prior to harvest of each forage sample,

the yield proportion of grasses, legumes and forbs was visually estimated and each sample was assigned to a plant stand type (G = rich in grasses: more than 70% grasses; B = balanced: between 50% and 70% grasses; F = rich in forbs: more than 50% forbs, legumes less than 50%; L = rich in legumes: legumes more than 50%) according to Daccord *et al.* (2007). In contrast to the original method, no sub-classification of G and B based on the proportion of ryegrass-species and of F based on the proportion of forbs rich in stems was made. The plant stand type of mixed samples was determined according to Table 1.

Once per year, at the time of the third or fourth sampling event, the yield proportion of each occurring species was assessed at each environment. Each site was assigned to one of seven meadow types according to a cluster analysis of these data, which were averaged across the years and transformed according to Dietl (1995), using the squared Euclidean distance as dissimilarity measure and the Ward's method as a clustering algorithm. The statistical analysis was performed by means of mixed models (proc MIXED of SAS version 9.2), accounting for the design effects and for the effect of GDD, which was modelled by means of a polynomial regression (Romano *et al.*, 2014). The improvement of the prediction accuracy due to the inclusion of PT and MT into the model was investigated by means of a stepwise forward selection based on a five-fold cross-validation according to Hawkins *et al.* (2003). The predicted values of the fixed effects of the model were used. If necessary, data transformation was performed to achieve normality and homoscedasticity of residuals.

Table 1. Classification scheme of mixed samples obtained by pooling the four replications harvested at each sampling event.[1]

Plant stand type of the four replications	Classification of the mixed sample
At least 3 G	G
2 G and 2 B	G
At least 3 F	F
2 B, all other samples F or L	F
All other combinations	B

[1] G = rich in grasses; B = balanced; F = rich in forbs; L = rich in legumes.

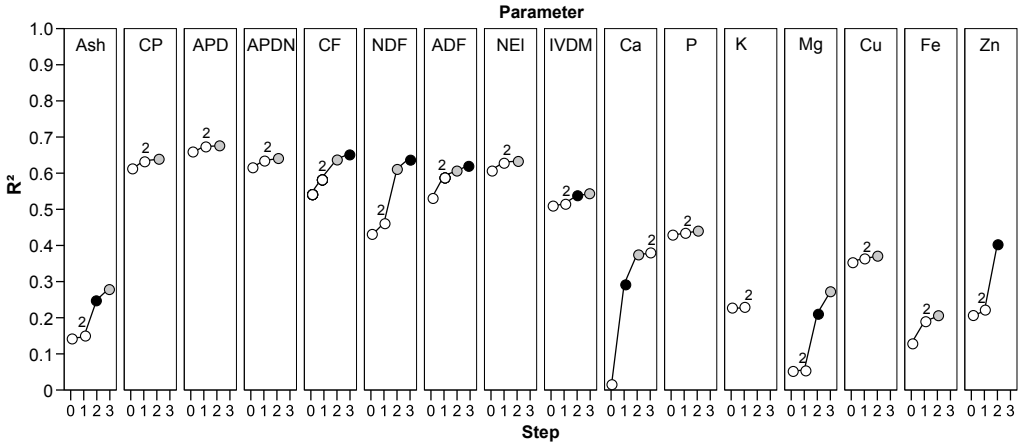

Figure 1. Changes of the prediction accuracy (squared correlation between predicted and observed value of the five-fold cross-validation) by stepwise forward model selection for 16 parameters of forage quality. White dots= GDD (2 indicates the quadratic term of the polynomial); grey dots = PT; black dots = MT.

Results and discussion

The prediction accuracy for ash and minerals was apparently lower than for all other parameters (Figure 1). The relationship between GDD and all quality parameters was best described through a quadratic polynomial. PT was added to the model in 14 of the 16 cases, with the exception of K and Zn, whilst MT contributed only for half of the quality parameters to improve the prediction accuracy. PT systematically exhibited higher relevance than MT for the prediction accuracy of crude protein (CP), absorbable intestinal protein (APD), absorbable intestinal protein based on the nitrogen available in the rumen (APDN), crude fiber (CF), neutral detergent fiber (NDF), acid detergent fiber (ADF) and net energy for lactation (NEl). For ash, *in vitro* digestibility (IVDM) and minerals PT exhibited a minor relevance. Only for four parameters (ash, Ca, Mg and Zn) the addition of MT to the model resulted in a notable improvement of the prediction accuracy.

Conclusions

A simple assessment of the proportion of grasses, forbs and legumes and the classification of the plant stand into a category, which represents a reasonable effort for practitioners, is a useful tool for improving the prediction of forage quality. More precise assessments of the botanical composition, resulting in the definition of a meadow type, improve the prediction accuracy of some parameters, but play a less consistent role.

Acknowledgements

We wish to thank the Regional Competitiveness and Occupation ERDF 2007-2013 for financing the project webGRAS and the Hydrographic Office of the Province Bolzano/Bozen for providing temperature data.

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