

# Alfalfa Yield and Quality Estimation with UAV Images and Machine Learning

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## Introduction

- Alfalfa, one of the most critical and stable legumes, is a valuable nutritious crop with a comparatively high yield, which is considered the fourth most valuable field crop in the United States.
- Traditional alfalfa production assessment methods are not only laborious and time-consuming but also do not provide the status of all crops at the same time.
- Image-based monitoring methods, especially UAVs, have a wide data coverage and offer flexibility in spatial, temporal, and spectral resolutions.
- This study was designed to (1) investigate the potential of using UAV multispectral for alfalfa yield and quality estimation, (2) Explore the impact of three types of features, vegetation index, statistic feature and environmental factor, on the assessment.

## Materials and Methods

### Data Acquisition

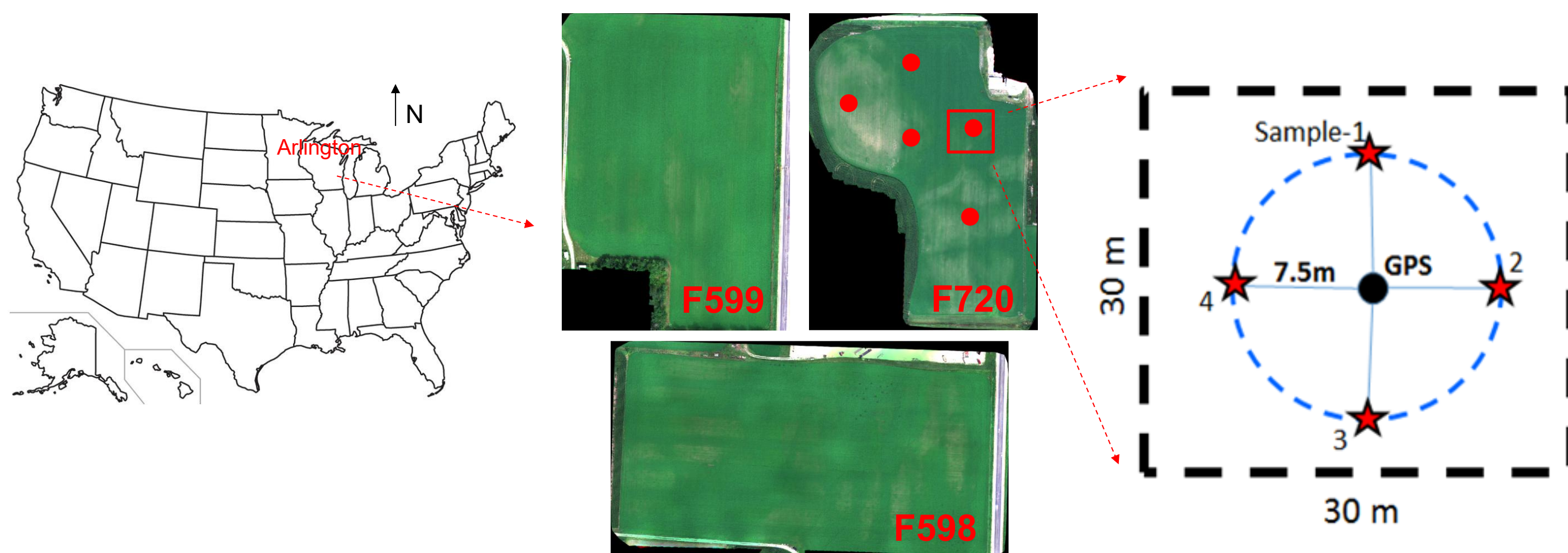


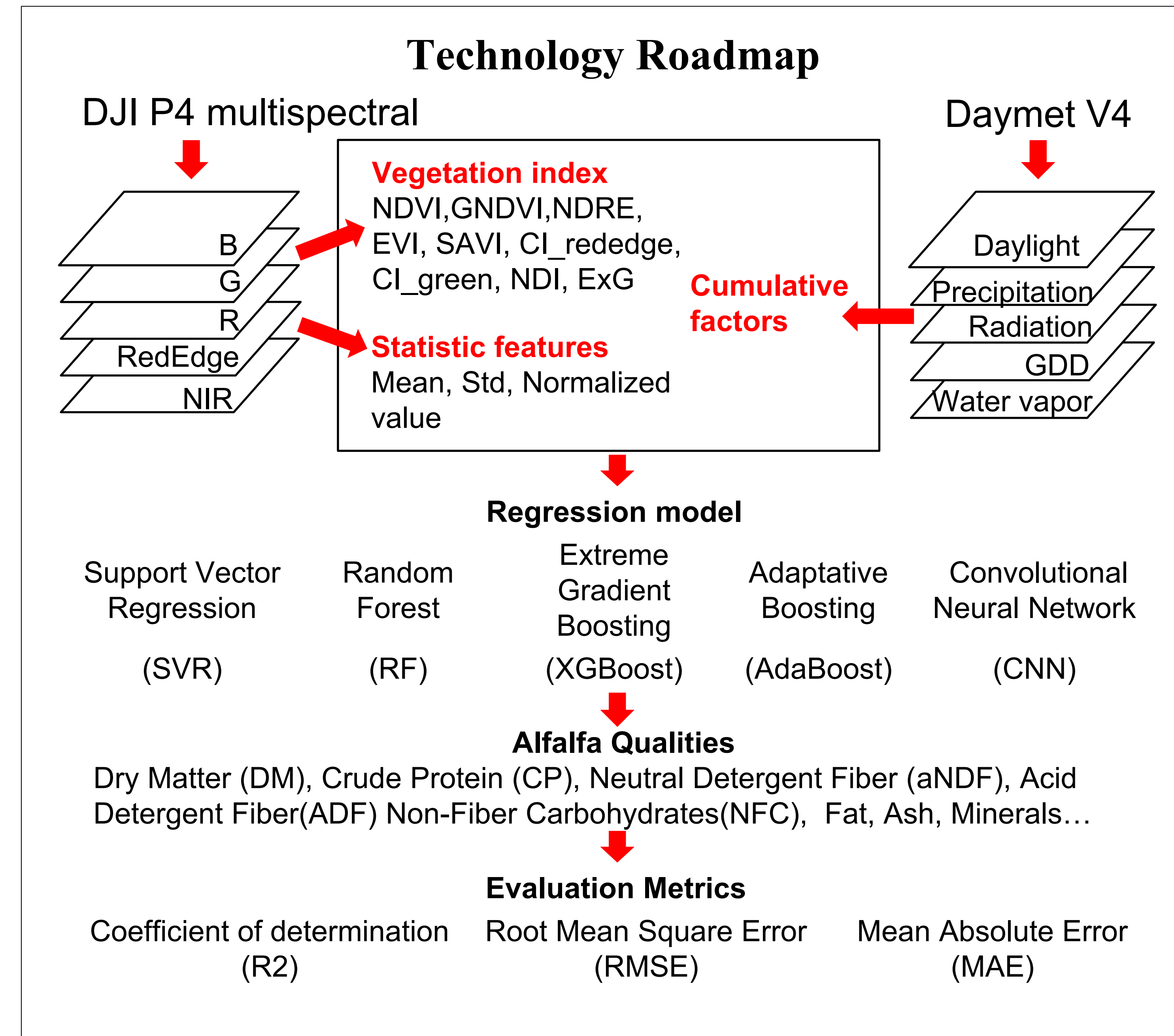
Figure 1. Experimental site in Arlington Agricultural Research Station and Sampling sites. F598, F599, F720 represent the name of three field.

- Field Data:** Alfalfa has **four** cuts from May to August at the end of each month in 2022. Between each cut, **three** or **four** times of sampling are considered for each field. There will be three days interval between two sampling. **Five** sites are selected for each time of sampling in a field.



Figure 2. UAV and calibration panels

- Multispectral images:** The multispectral data were acquired by a DJI phantom 4 multispectral that offers 5 spectral bands and then processed in Pix4D software.



## Results and Discussion

### Alfalfa Quality

- Before the first harvest, alfalfa has a long period to accumulate nutrients, and its plant height is also the highest, resulting in the highest dry matter content and relatively higher nutrient levels.
- After the first harvest, alfalfa re-enters the early growth stage of its growth cycle, so it may maintain relatively high nutrient levels, such as protein, but the DM content decreases significantly.
- Subsequent frequent harvests put physiological stress on the plant, leading to significant reductions.

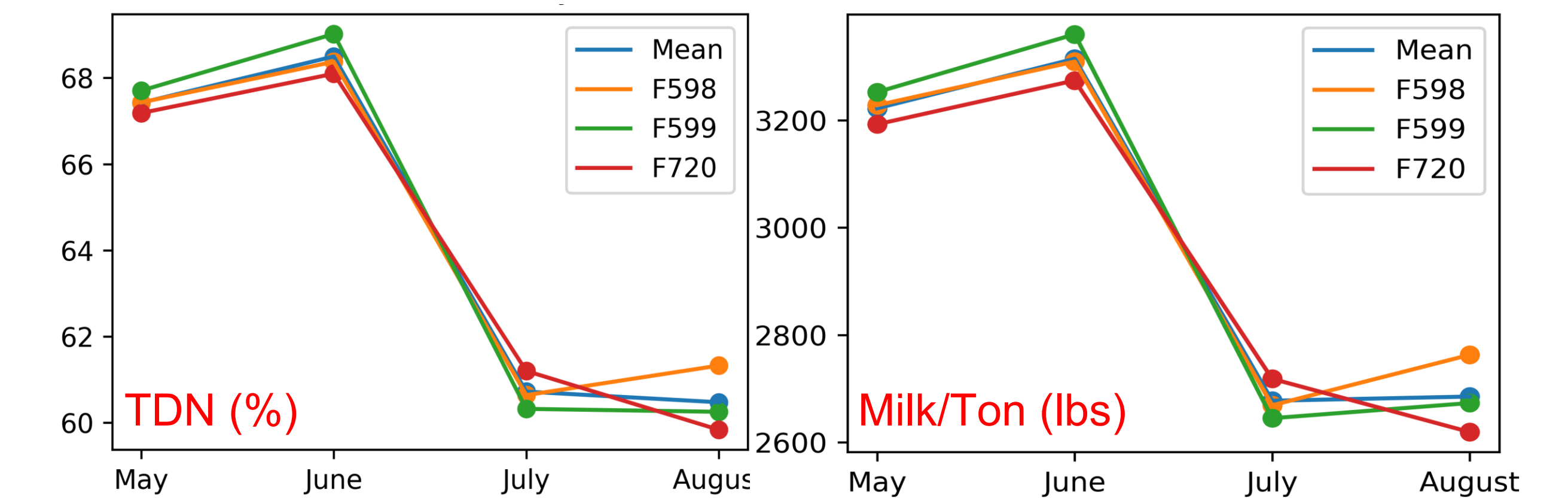
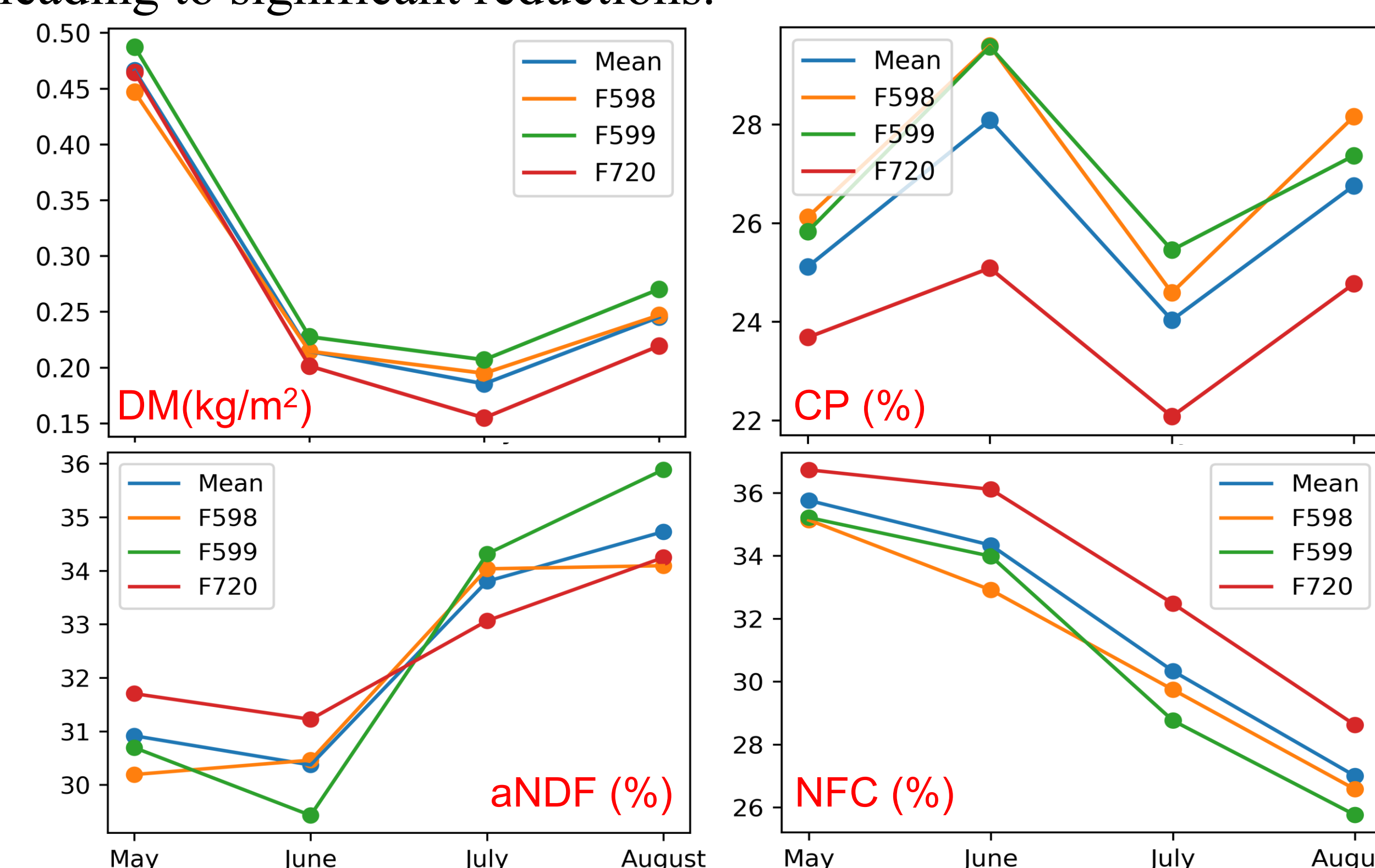


Figure 3. Trends in six alfalfa qualities.

### Estimation Results

- The quality with the highest estimated accuracy is DM, with an R<sup>2</sup> value reaching 0.935, while the lowest is Fat, with an R<sup>2</sup> value of 0.314.
- Compared to other methods, SVR is the least stable, showing two instances of very low results.
- When using only VI as the input feature, there is a notable variance in accuracy among different methods. However, when all three types of features are utilized, the accuracies of five models converge closely.

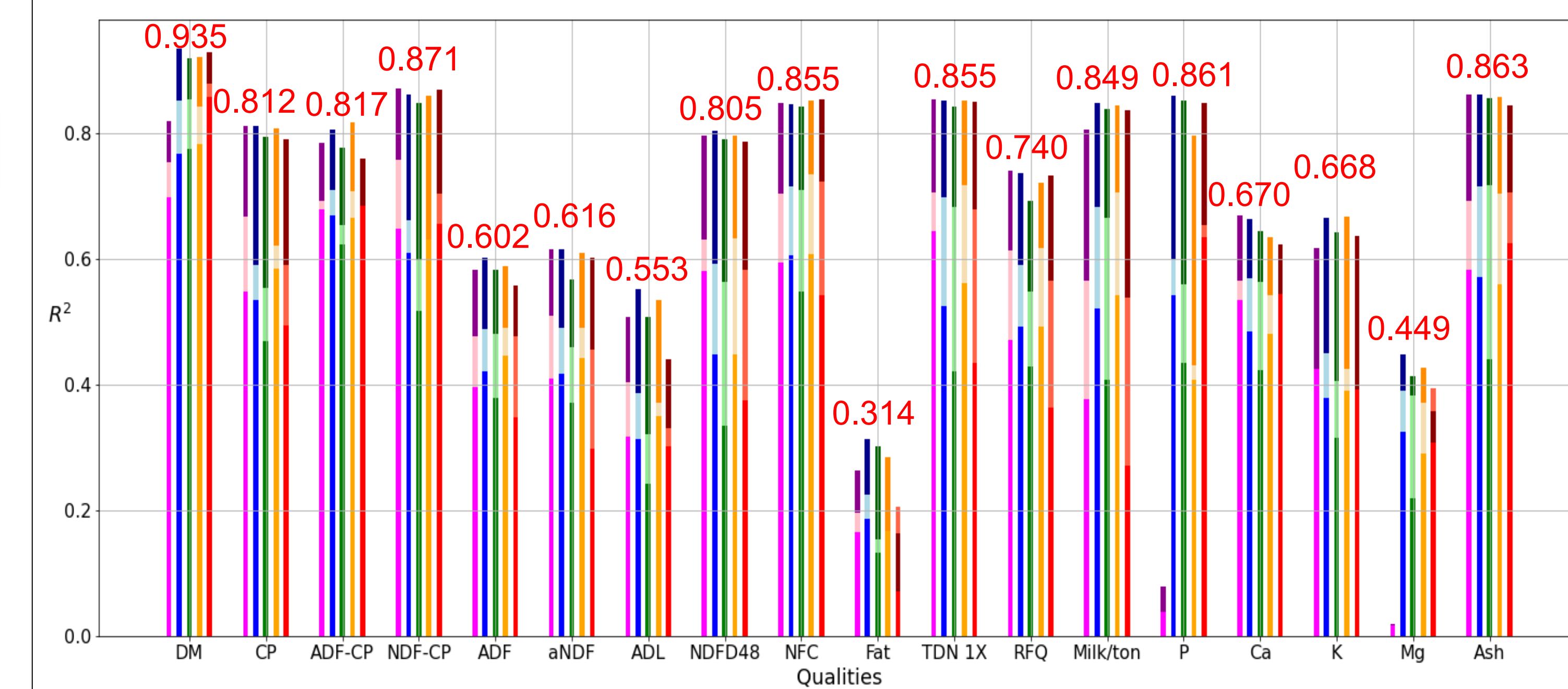


Figure 4. The accuracy of estimating various alfalfa qualities using five ML models. Normal color: VI, Light color: +statistical features, dark color: +environmental factors

## Conclusion and Future work

- The results of this study demonstrated the feasibility and potential of using UAV multispectral imagery and the machine learning technique for estimating alfalfa yield and qualities.
- Three types of features, vegetation index, statistic feature and environmental factor, have a positive impact on the estimation for the qualities. As the input features become more diverse, the differences between the models gradually diminish.
- To further improve the prediction performance, new research is underway to obtain spectral or other types of information directly or indirectly related to these qualities.