# Estimation of aboveground biomass in clover-grass mixtures using UAV-based vegetation indices and canopy height

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## Introduction

- **Clover-grass mixtures** are used as **forage crop** and **natural source of nitrogen** for subsequent crops [1]
- **Biomass** is an important parameter to quantify crop structure for developing appropriate **management recommendations**
- Currently, the determination of biomass in clover-grass fields is performed with laborious manual measurement methods [2]
- **UAV-based image data** can be used for **multi-temporal monitoring** of field structure development [3]
- **Goal:** estimation of aboveground biomass with multitemporal computed UAV-based vegetation indices and time corresponding canopy height

## Study site & database

- Study site is located near Osnabrück in the northwest of Germany (Fig. 1)

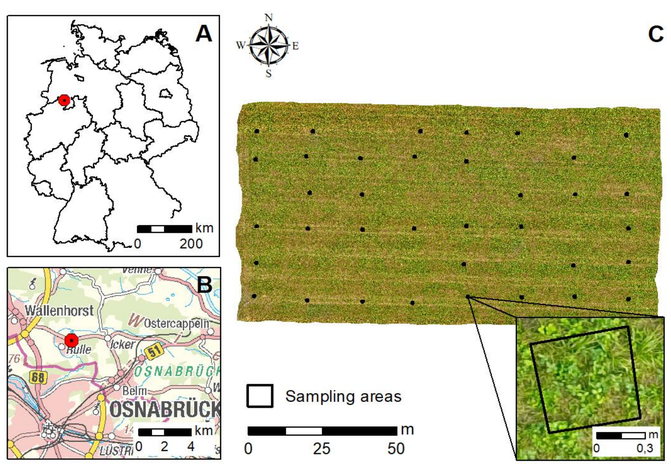


**Fig. 1:** Study site and distribution of sampling spots

**Tab. 1:** Flight dates

| Flight date | Date after mowing |
|---|---|
| 05.08.2021 | 16 days |
| 19.08.2021 | 30 days |
| 06.09.2021 | 48 days |

- **Multispectral images** were acquired during **3 flights** between 2nd and 3rd cut (Tab. 1)
- 36 sampling areas of size 0.25 m²
- **Destructive biomass measurements** were made from sampling areas at each timestamp

## Methodology

- Images were processed with Agisoft Metashape Version 1.7.2. (Fig. 2)
- **Multispectral indices** were calculated to model field measured biomass
- Canopy height was derived with **Structure-from-Motion (SfM)** technique
- **Multitemporal regression** approach was developed with IDE of R Studio
- All predictors were used singlewise and were compared to results of multiple regression approach with **Leave-on-out Cross Validation** (LOOVC)

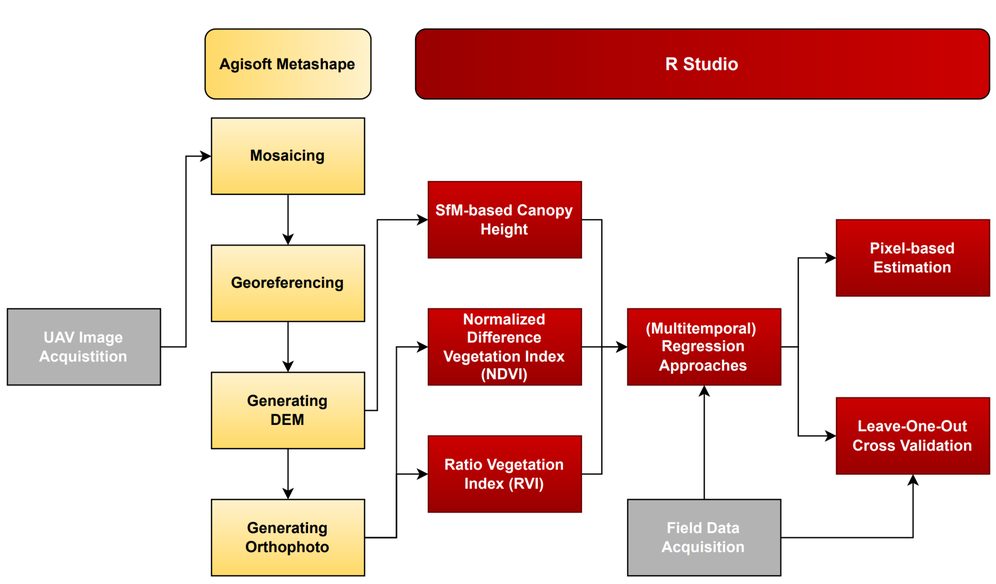


**Fig. 2:** Workflow

## Results

- Models with multispectral indices as **single predictors** for multitemporal estimation performed similar with **R² = 0.61 (NDVI)** and **R² = 0.64 (RVI)**
- Higher estimation quality was exhibited with **SfM-based approach (R² = 0.73)**
- Best results were achieved by **combing RVI, NDVI and SfM** with an **adj. R² = 0.75** (Fig. 3)
  - Due to merge of spectral information and estimated canopy height
  - Individual plant growth and reflectance behavior are taken into account in the evaluation of crop development
- Highly **emerging estimated biomass** observed **with densifying canopy** (Tab. 2)

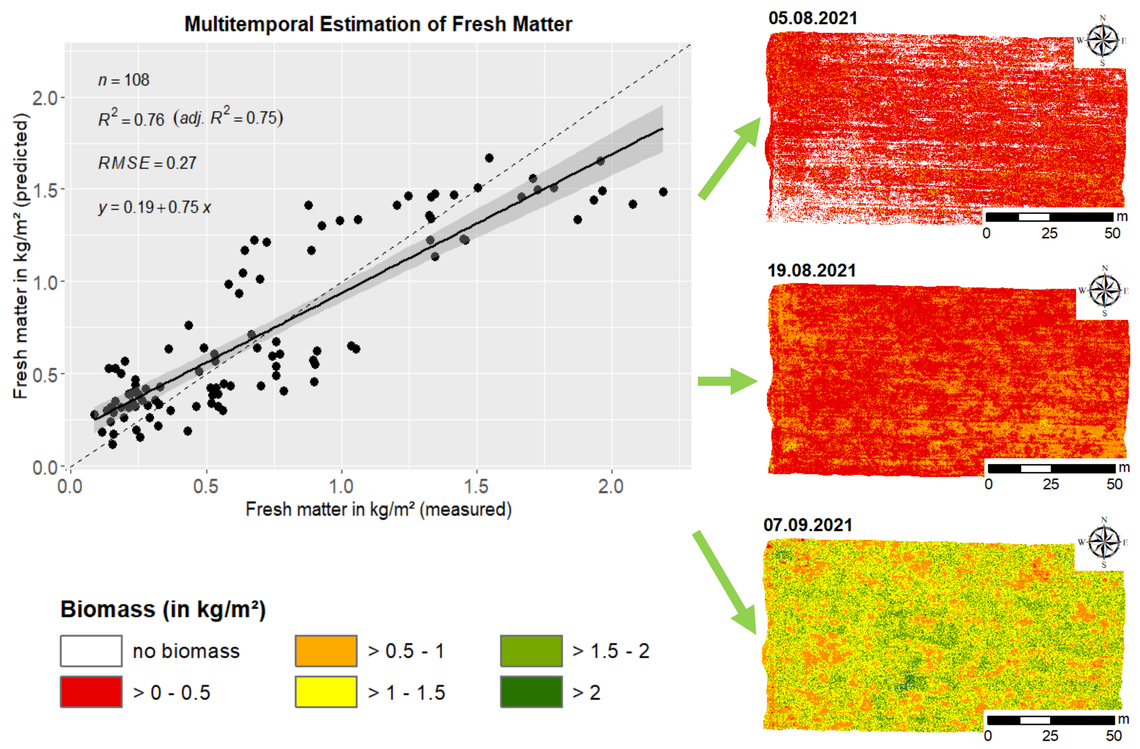


**Fig. 3:** Multitemporal regression model and image based biomass estimation

**Tab. 2:** Comparison of observations from field inspection and image based modeling

| Flight date | Field observation | Biomass estimation observations |
|---|---|---|
| 05.08.2021 | High spatial heterogeneity, soil segments | Sparse biomass, holes detected where soil is dominating |
| 19.08.2021 | Closed vegetation canopy | Compaction of clover-grass crop emerges biomass production |
| 06.09.2021 | Canopy continues to densify, faster growth of canopy height | SfM canopy height predictor makes it possible to map biomass growth |

## Discussion & Conclusion

- **Multispectral indices** as well as **SfM-based canopy height** are useful parameters for fresh matter estimation in clover-grass mixtures
- Multitemporal approaches increase the validity and applicability of the model **independent of the phenological point in time**
- Higher estimation quality is reached with **combination of all parameters**
- **Limitations** result from **saturation** phenomena in canopy height at higher phenological stages
- Increase of sampling rate for a single stage can improve estimation quality
- The experiment can be extended by examining other phenological cycles (e.g. before 1st mowing) in terms of biomass production
- Results can be used as basis for issuing a **site-specific management recommendation** for field management by transferring model predictions to UAV imagery data

## References

[1]: Stute, J.; Posner, J. [1993]: Legume cover crop options for grain rotations in Wisconsin, Agronomy Journal, 85(6), 1128–1132, 1993.
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[3]: Insua, J.; Utsumi, S.; Basso, B. [2019]: Estimation of spatial and temporal variability of pasture growth and digestibility in grazing rotations coupling unmanned aerial vehicle (UAV) with crop simulation models. PLoS ONE, 14(3), 1–21.

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