Forage quality predicted by hyperspectral reflection measurements across climate zones

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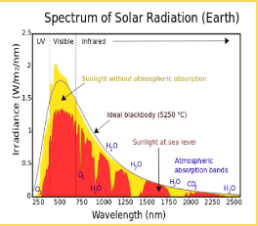
Grassland forage quality



Metabolizable Energy [MJ kg^{-1} DM^{-1}]
(dep. on protein, fiber, fat, ash, ... content)

Management

- Agriculture: milk and meat production
- AgroEcology: pasture carrying capacities

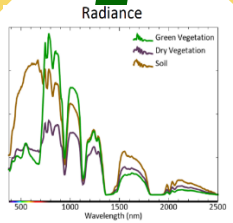
Challenges

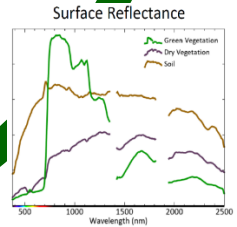
- Potential often unknown
- Expensive/labourous analysis

REMOTE SENSING OF FORAGE QUALITY

1. Hyperspectral prediction of forage quality
2. Upscaling from ground to field & landscape level

→ **Mapping of grasslands**





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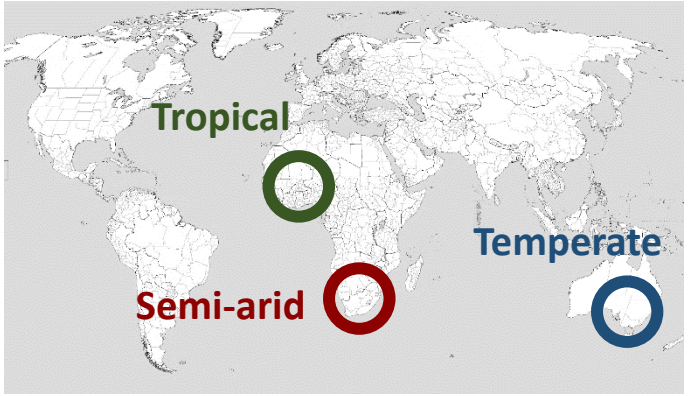
https://www.saiten.ch/alpfahrt-fuer-die-svp/

State of the art

- Ferner et al., 2015/2018:
  Metabolizable energy predictions in **tropical grasslands**
- Singh et al., 2017:
  Nutritive chemical prediction on **South-African savannahs**
- Smith et al., 2020:
  Nutritive value predictions on **temperate ryegrass** canopies



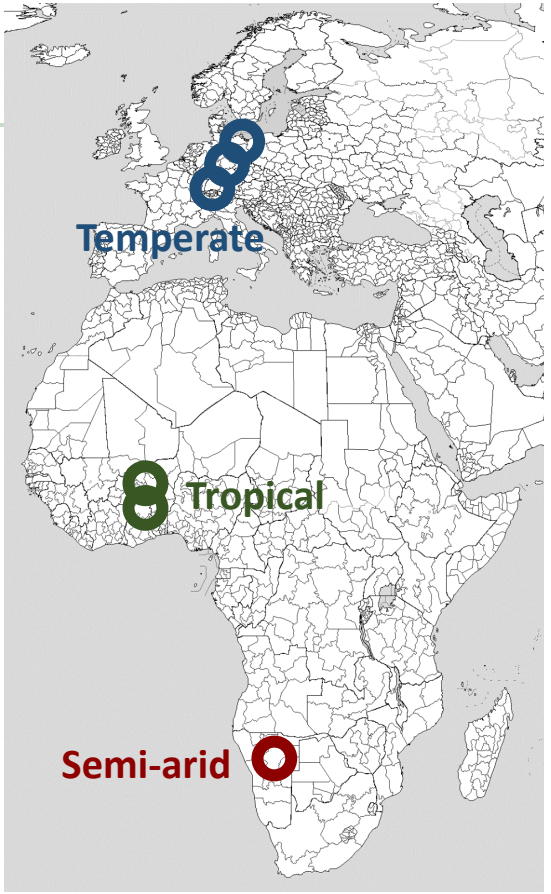
Research Gap
Forage quality prediction modelling limited to regional scales

Objectives
1. „Trans-climatic“ modelling of forage quality by hyperspectral measurements
2. Different predictor variables and model training/learning methods

Study sites

Grasslands (meadows & rangelands) under different climatic conditions

- **Temperate pastures (n = 110)**
  - Germany
- **Tropical grasslands (n = 101)**
  - Burkina-Faso *(Ferner et al. 2015)*
  - Ghana *(Ferner et al. 2015)*
- **Semi-arid savannah (n = 127)**
  - Namibia



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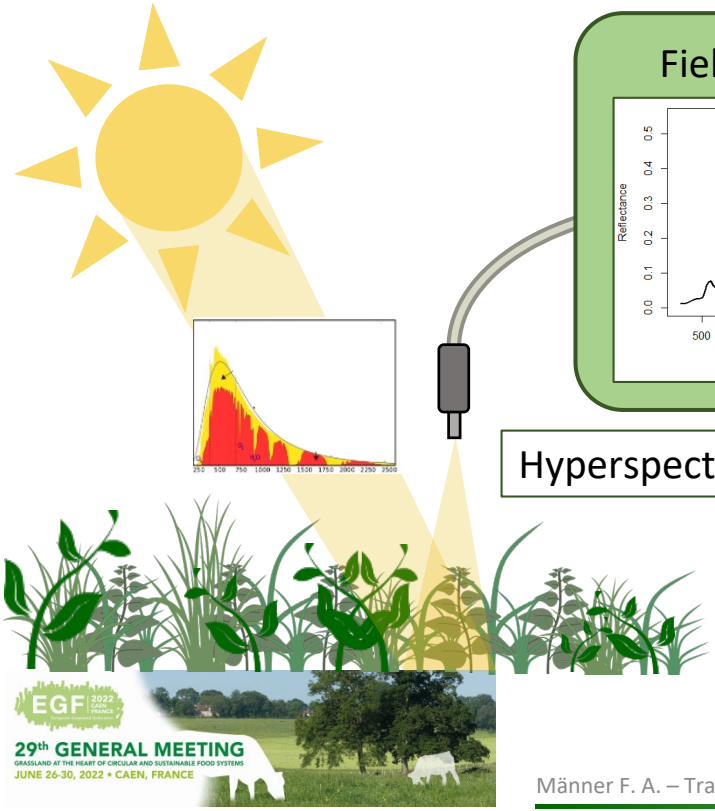
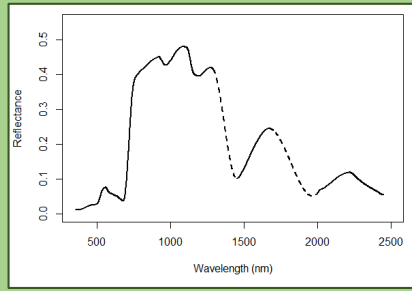
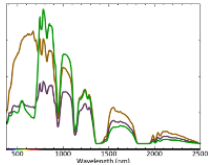
Hyperspectral measurements



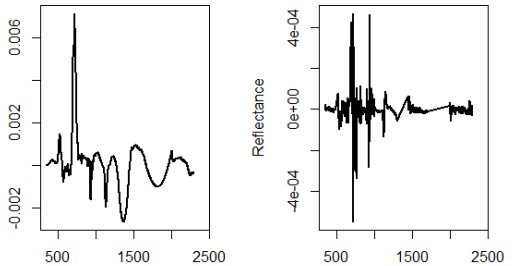
Field Spectrometer



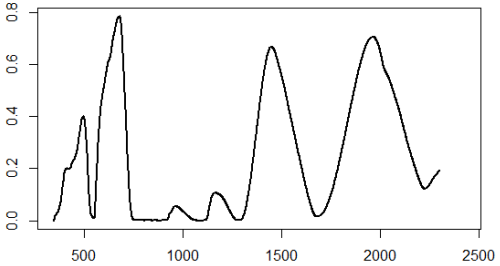
Hyperspectral canopy reflection



Derivations of spectra



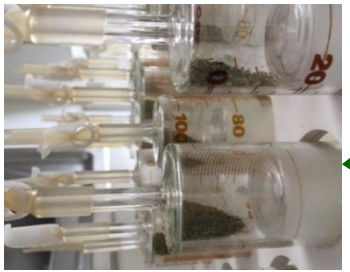
Features & indices



Forage quality measurements

1. Fermentation of biomass in rumen liquid *(Menke and Steingass, 1988)*
   → Measurement of **gas production** ($GP\ [\frac{ml}{200mg\ TM}]$)
2. Combustion of biomass in elementar analyzer
   → Measurement of **crude protein** content ($XP\ [\frac{g}{kg\ TM}]$)
3. Estimation of **metabolizable energy** ($ME\ [\frac{MJ}{kg\ TM}]$)

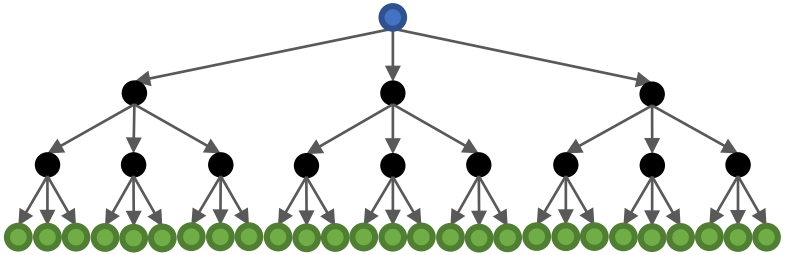
$$ME \approx 2.2 + 0.1357GP + 0.0057XP + 0.0002859XP^2$$



Prediction Models

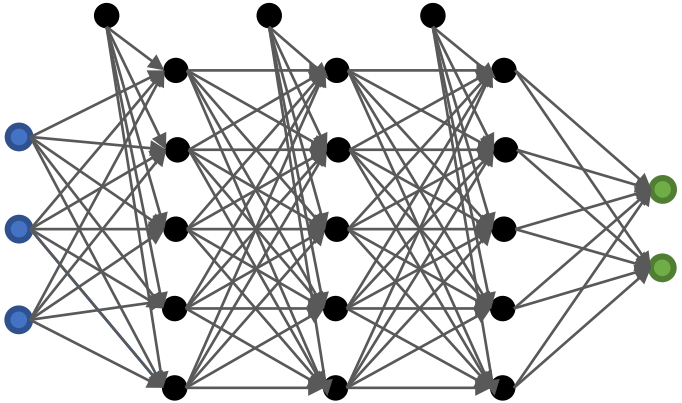
Supervised machine learning

- Partial least squares regression (PLS)
- Random forest regression (RF)

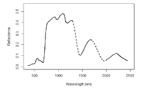
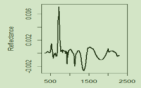
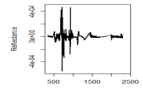
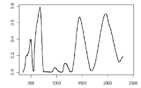


Deep learning

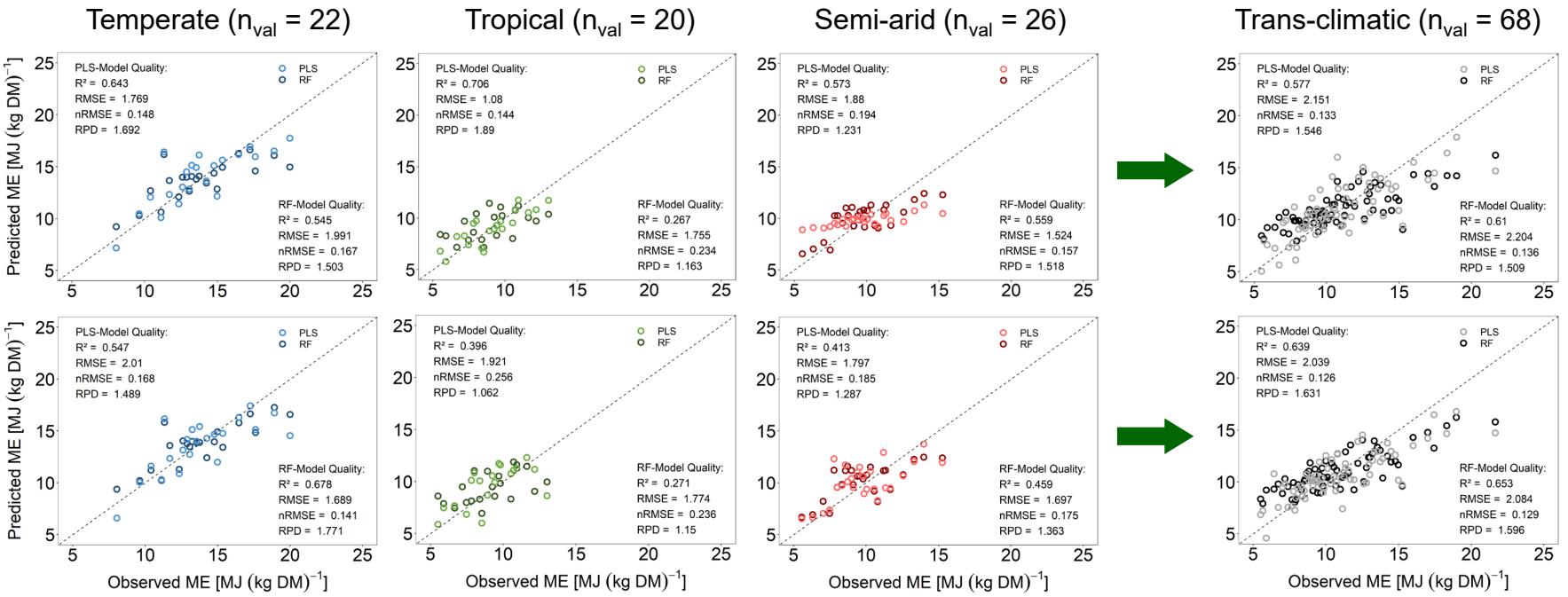
- *Deep neural networks (DNN – in dev.)*



Results & Discussion

			Random Forest Regression (RF)					Partial Least Squares Regression (PLS)				
			Temperate	Tropical	Semi-arid	Trans-Clim.		Temperate	Tropical	Semi-arid	Trans-Clim.	
	**Absolute spectra**	R2	0.310	0.290	0.275	0.438		0.712	0.500	0.430	0.700	
		RMSE [MJ (kg DM)$^{-1}$]	2.517	1.781	1.970	2.505		1.587	1.593	2.055	1.813	
		nRMSE	0.211	0.237	0.203	0.155		0.133	0.212	0.212	0.112	
		RPD	**1.189**	**1.146**	**1.174**	**1.327**	**1.209**	**1.886**	**1.281**	**1.126**	**1.834**	**1.532**
	**1st derivation**	R2	0.545	0.267	0.559	0.610		0.643	0.706	0.573	0.577	
		RMSE [MJ (kg DM)$^{-1}$]	1.991	1.755	1.524	2.204		1.769	1.080	1.880	2.151	
		nRMSE	0.167	0.234	0.157	0.136		0.148	0.144	0.194	0.133	
		RPD	**1.503**	**1.163**	**1.518**	**1.509**	**1.423**	**1.692**	**1.890**	**1.231**	**1.546**	**1.590**
	**2nd derivation**	R2	0.278	0.288	0.505	0.448		0.214	0.350	0.259	0.427	
		RMSE [MJ (kg DM)$^{-1}$]	2.502	1.711	1.701	2.488		2.760	1.756	2.044	2.510	
		nRMSE	0.209	0.228	0.175	0.154		0.231	0.234	0.211	0.155	
		RPD	**1.196**	**1.193**	**1.360**	**1.337**	**1.272**	**1.084**	**1.162**	**1.132**	**1.325**	**1.176**
	**Features/Indices**	R2	0.582	0.366	0.431	0.607		0.497	0.180	0.248	0.376	
		RMSE [MJ (kg DM)$^{-1}$]	1.903	1.586	1.744	2.105		2.091	5.799	2.083	2.726	
		nRMSE	0.159	0.211	0.180	0.130		0.175	0.772	0.215	0.169	
		RPD	**1.573**	**1.287**	**1.326**	**1.579**	**1.441**	**1.431**	**0.352**	**1.111**	**1.220**	**1.029**
	All predictors	R2	0.678	0.271	0.459	0.653		0.547	0.396	0.413	0.639	
		RMSE [MJ (kg DM)$^{-1}$]	1.689	1.774	1.697	2.084		2.010	1.921	1.797	2.039	
		nRMSE	0.141	0.236	0.175	0.129		0.168	0.256	0.185	0.126	
		RPD	**1.771**	**1.150**	**1.363**	**1.596**	**1.470**	**1.489**	**1.062**	**1.287**	**1.631**	**1.367**

Results & Discussion



Outlook

Current research

- Spatial/trans-climatic **cross validation**
- **Biomass prediction** with hyperspectral readings

- Upscaling to UAV/satellite imagery for **landscape forage mapping**

References

Ferner, J., Linstädter, A., Südekum, K.-H. & Schmidtlein, S. (2015) Spectral indicators of forage quality in West Africa's tropical savannas. *International Journal of Applied Earth Observation and Geoinformation*, 41(September), 99–106.

Ferner, J., Schmidtlein, S., Guuroh, R.T., Lopatin, J. & Linstädter, A. (2018) Disentangling effects of climate and land-use change on West African drylands' forage supply. *Global Environmental Change*, 53, 24–38.

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Thank you for your attention!

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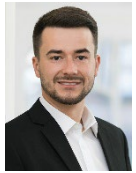

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