3D Data Acquisition to Monitor Cropping Systems: Sensors and Methods

Motivation - Methods - Results - “WYSIWYG“ - Zonal Statistics - Conclusions

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Motivation

- Precision Agriculture: need of spatial data for within-field variability
- Data demand: vitality, abiotic/biotic stress, biomass, nitrogen …
- Limitations of PreAg: rice, maize, grassland …
- Limitation of RS: clouds, repetition, resolution, costs …
- Opportunities: airborne, field border, super-high resolution …

Objectives

- 3D-Data: plant height, plant growth, emergence, biomass
- Hyperspectral: chlorophyll, nitrogen, stress, biomass
- 3D + Hyperspec.: vitality, abiotic stress, biotic stress, biomass, nitrogen

Nitrogen Nutrition Index - NNI

"… optimal nitrogen fertilizer application regimes in crop production have two requirements: (1) knowledge of the adequate N content for a given amount of biomass and (2) the development of fast, accurate methods to determine the actual N content and biomass (or N demand) of the crop plant … ."

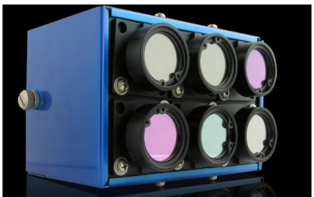
Bodo Mistele and Urs Schmidhalter (2008): Estimating the nitrogen nutrition index using spectral canopy reflectance measurements. Europ. J. Agronomy 29/4: 184-190. DOI: 10.1016/j.eja.2008.05.007

$NNI = N_{act} / N_c$

N_{act} = actual measured N content as a percent of the dry matter of the canopy biomass

N_c = the critical N content for the crops of each plot given their amount of dry weight

Sensors



www.tetracam.com

Multispectral

www.canon.com

RGB

www.oculii.com

Radar

www.rikola.fi

Hyperspec

www.agricon.de

Ultrasonic

www.pmdtec.de

TOF

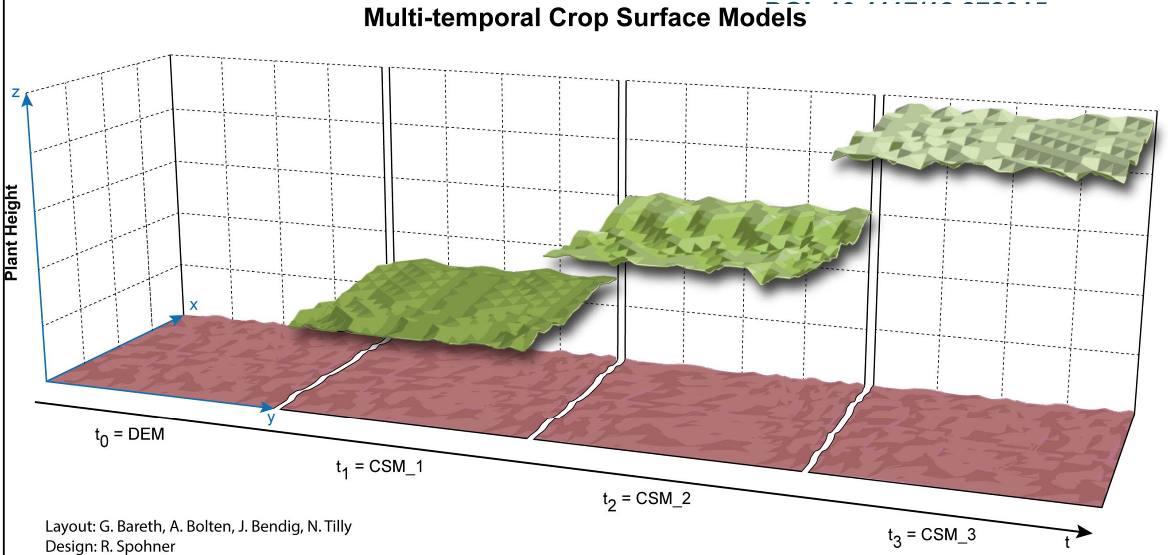
www.riegl.com

Laser scanner

www.agricon.de

Crop Surface Model (CSM)

HOFFMEISTER et al. (2010): High resolution CSM and CVM on field level by terrestrial lasers canning In: Proc SPIE, Vol. 7840, 78400E:



$\text{Plant Height}_{total} = t_3 - t_0$

$\text{Plant Height}_{in\text{-}season1} = t_1 - t_0$

$\text{Plant Height}_{in\text{-}season2} = t_2 - t_0$

$\text{Plant Growth}_{in\text{-}season3} = t_2 - t_1$

$\text{Plant Growth}_{in\text{-}season4} = t_3 - t_2$

$\text{Plant Growth}_{in\text{-}season5} = t_3 - t_1$

Terrestrial Laser Scanning (TLS)

Instrumental set-up:
(A) terrestrial laser scanner Riegl LMS-Z420i
(B) tractor with hydraulic platform
(C) ranging pole with reflective cylinder
(Tilly et al. 2015, in print)

Unmanned Aerial Vehicle (UAV)

Sony α5100

- RGB sensor
- CMOS sensor: 24,3 MP (APS-C; 23,5 x 15,6 mm)
- ISO 100-25600
- B x H x T: 109,6 x 62,8 x 35,7 mm
- weight: approx. 283 g
- format: jpeg / raw

- 20 mm / f 2,8; 69 g

Mikrokopter UAV-platform (< 5 kg):

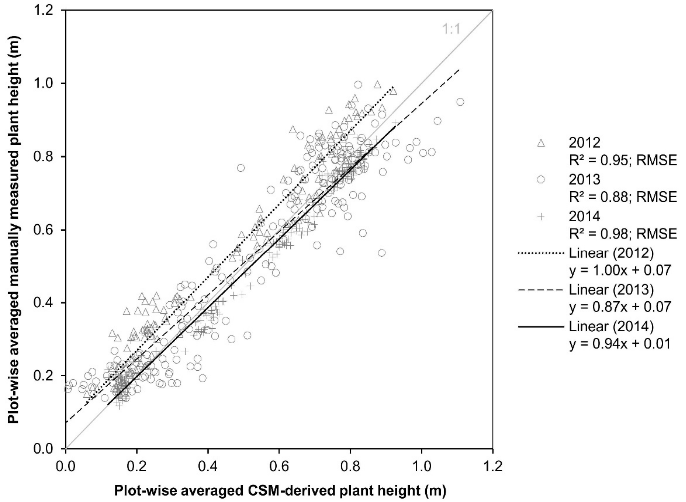
- rotors: 4 - 12
- payload: 250 g - 2500 g
- weight: 650 g - 1700 g
- flying time: 15 - 45 min
- distance: sight distance
- altitude: 350m
- sensors: gyroscope, acceleration, compass, GPS, barometric altitude

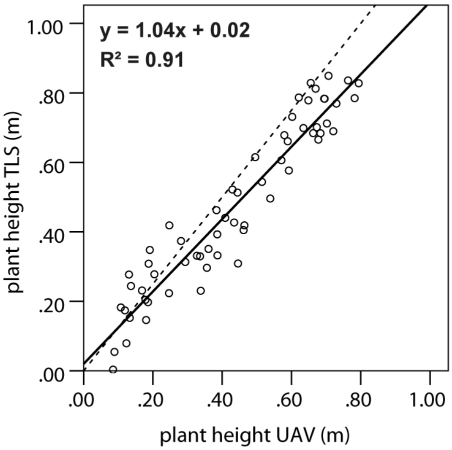
Low-cost UAV Approach

- UAV platform:
  - easy to use
  - lightweight
  - low-cost
  - uncalibrated digital camera

- DJI Phantom 2
- Canon Powershot 110
- Photo Scan
- ArcGIS
- GCP: RTK-referenced
- ASD FieldSpec3

CSM-derived Plant Height (TLS; UAV)



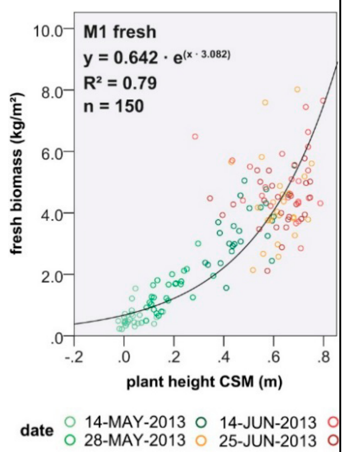


(Tilly et al. 2015, in print)

(Bareth et al. 2015, in prep.)

CSM-derived Biomass (UAV)

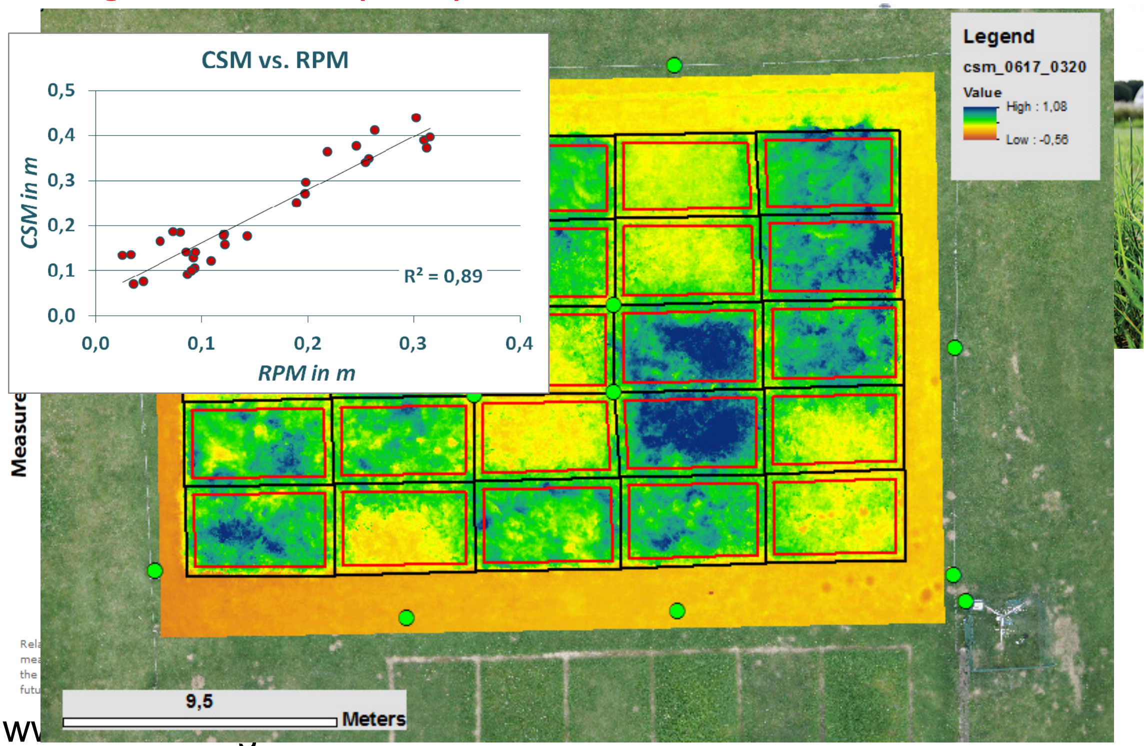
		Bivariate BRMs					Multivariate BRMs				
			Whole period		Pre-anthesis			Whole period		Pre-anthesis	
		Estimator	R^2	SE_E^a	R^2	SE_E	Estimator[b]	R^2	SE_E^a	R^2	SE_E^a
Dry biomass	Linear	*PH*	*0.65*	*10.03*	*0.76*	*5.73*					
		GnyLi	0.52	11.75	0.68	6.67	GnyLi	0.65	34.63	0.77	25.41
		NDVI	0.07	16.38	0.34	9.56	NDVI	0.69	21.49	0.76	20.73
		NRI	0.54	11.58	0.70	6.40	NRI	0.65	35.04	0.77	24.86
		RDVI	0.13	15.87	0.39	9.21	RDVI	0.69	19.18	0.76	21.40
		REIP	0.12	15.92	0.58	7.60	REIP	0.73	1933.86	0.76	258.29
		RGBVI	0.05	16.55	0.26	10.10	RGBVI	0.68	22.28	0.76	23.23
	Exponential	*PH*	*0.84*	*0.37*	*0.84*	*0.34*					
		GnyLi	0.80	0.42	0.85	0.32	GnyLi	0.86	2.43	0.88	2.14
		NDVI	0.30	0.77	0.61	0.53	NDVI	0.85	2.84	0.88	3.99
		NRI	0.81	0.40	0.87	0.30	NRI	0.87	2.29	0.89	1.96
		RDVI	0.41	0.71	0.68	0.48	RDVI	0.85	2.52	0.88	2.84
		REIP	0.37	0.73	0.77	0.40	REIP	0.84	30.37	0.86	48.49
		RGBVI	0.23	0.81	0.48	0.60	RGBVI	0.85	2.51	0.87	2.73



(UAV: Bendig et al. 2014)

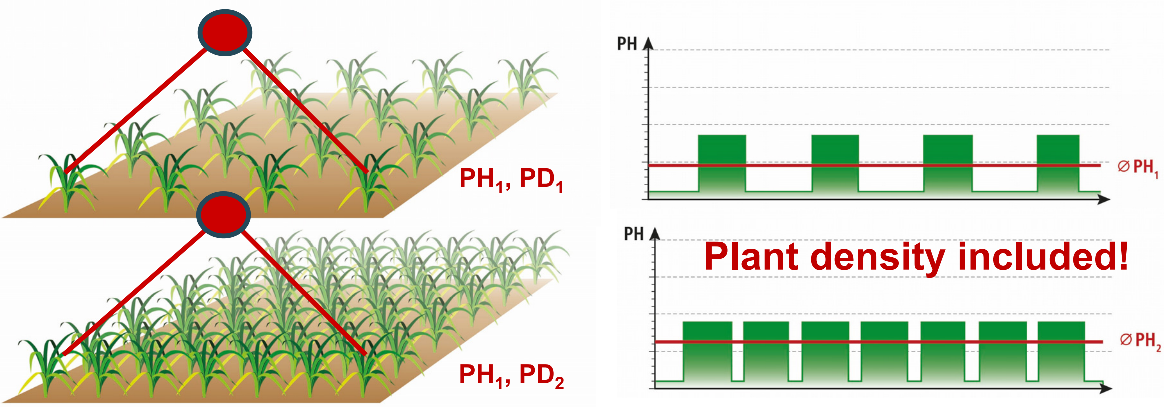
(TLS: Tilly et al. 2015, in print)

Rising Plate Meter (RPM) vs. UAV-CSM in Grassland

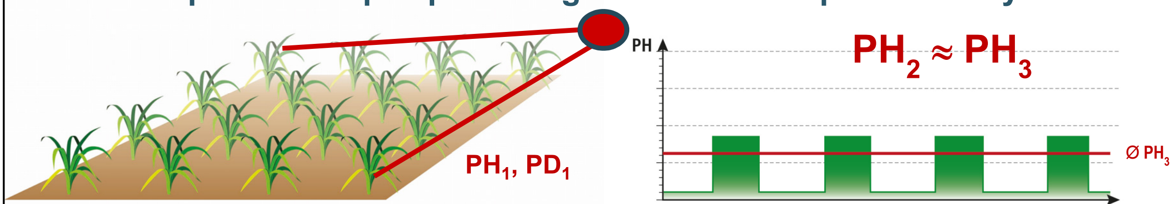


"What you see is what you get!" or "What do we see?"

- **Nadir view: equal plant height but different plant density.**

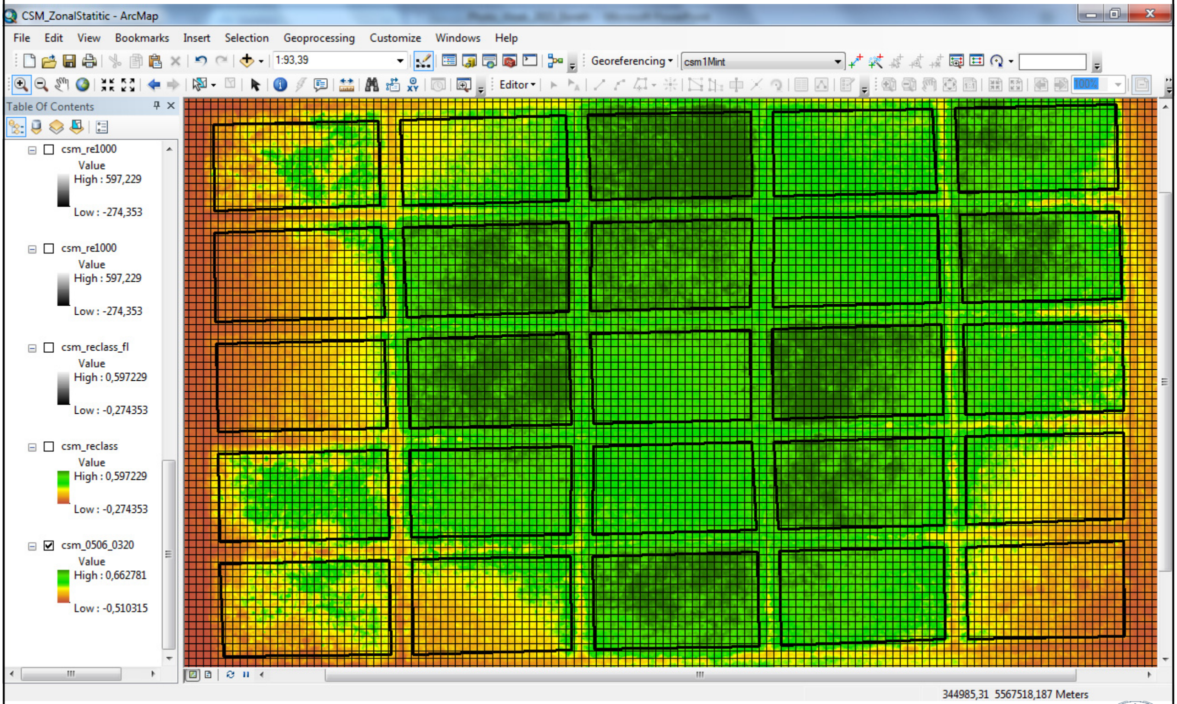


- **Oblique view: equal plant height but different plant density.**



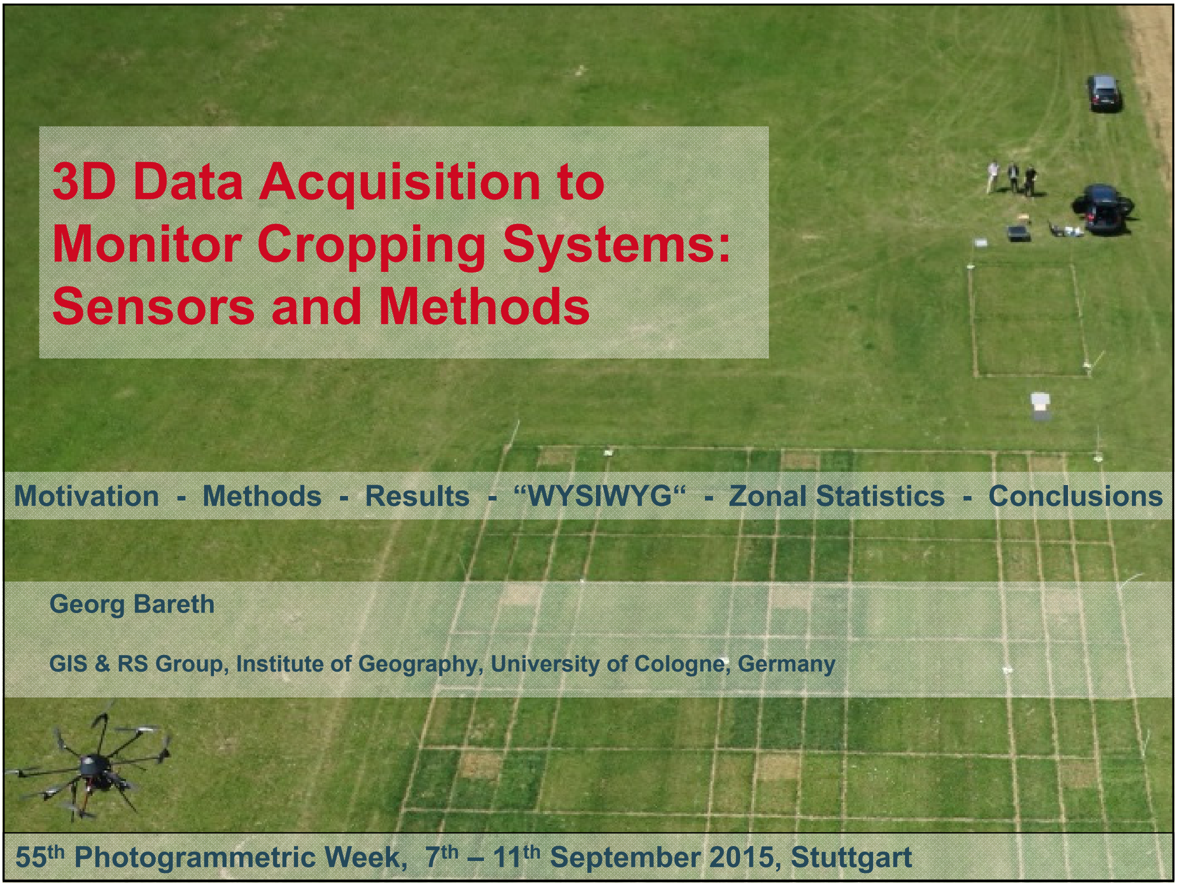
Polygon Grids - Zonal Statistics

- Zonal statistics is a standard GIS/RS software tool for descriptive statistics



Conclusion & Outlook

- plant height is a robust estimator for biomass
- TLS-/UAV-derived CSMs work well for biomass estimation
- low-cost UAV imaging system also works well
- polygon grids / zonal statistics preserve plant height variability and plant density
- UAV: precise direct georeferencing
- TLS -> MLS -> ALS
- approach works for hyperspectral frame cameras: 3D hyperspectral data (Aasen et al. 2015, in print)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