

Big Trials and Big Data: Taking pastures to a whole new level



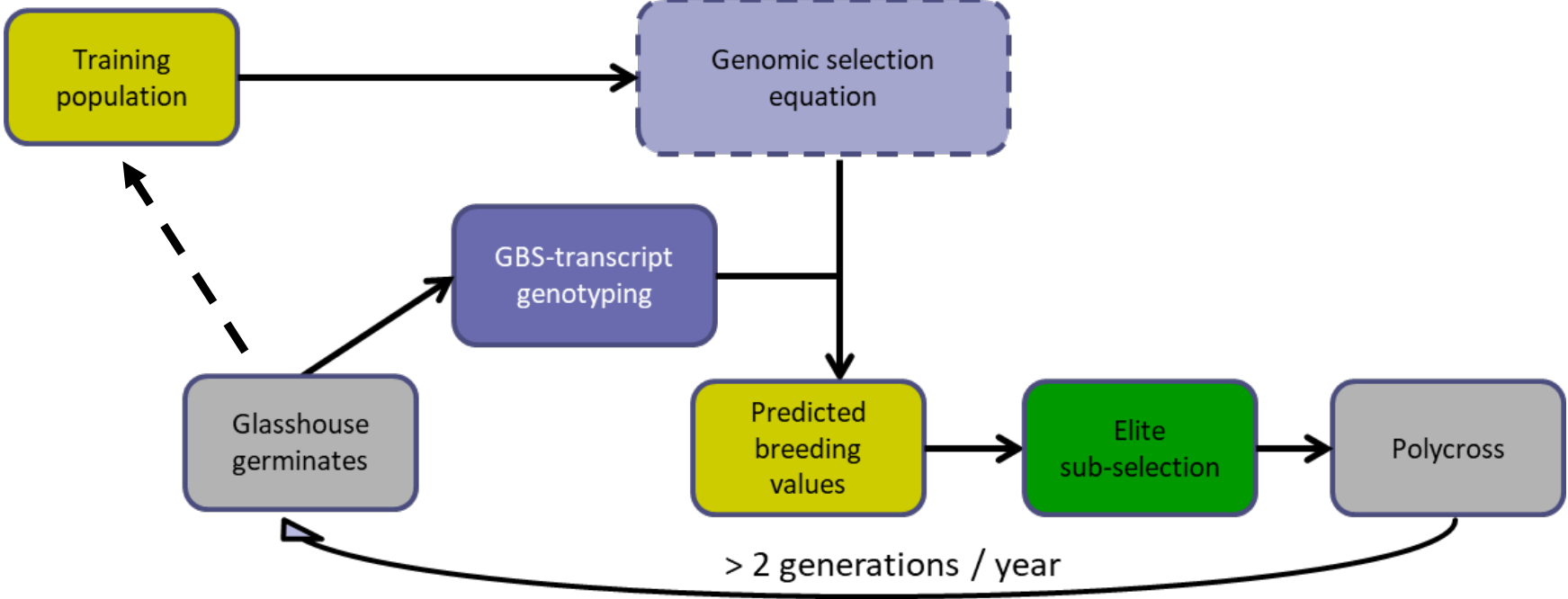
Pasture Breeding Traits



Pasture Breeding Traits



Genomic Assisted Breeding



Quantitative characteristics of smaller effects require large populations to link phenotype to genotype



Ryegrass Reference Population - DairyBio

- Global perennial ryegrass reference population
- Reference population consists of 270,000 plants representing 1,300 experimental varieties
- Weekly measurements on single plants



Traditional Measuring Methods to Measure Trial

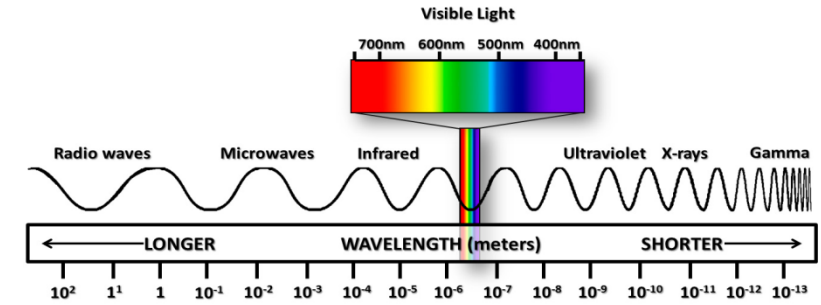
- Non-destructive biomass – visual score (1 – 5)
144 DAYS
- Destructive biomass – cut and dry method
3 YEARS
- Quality – processing of dried samples (lab), scanning on NIRS (lab)
44 YEARS
- Morphological traits – visual score, manual measurements



High-Throughput Field-Based Phenomics

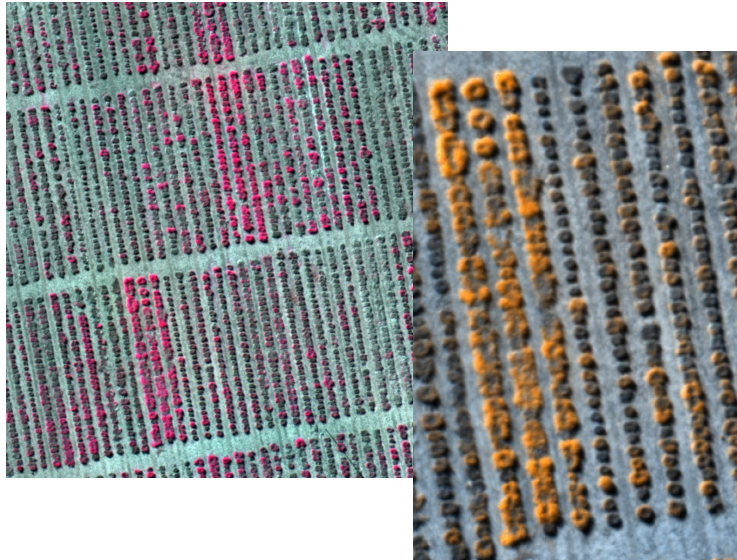
Non-destructive assessments of:

Establishment • Biomass yield • Growth rate • Heading date
Disease resistance • Herbage nutritive value • NUE & WUE



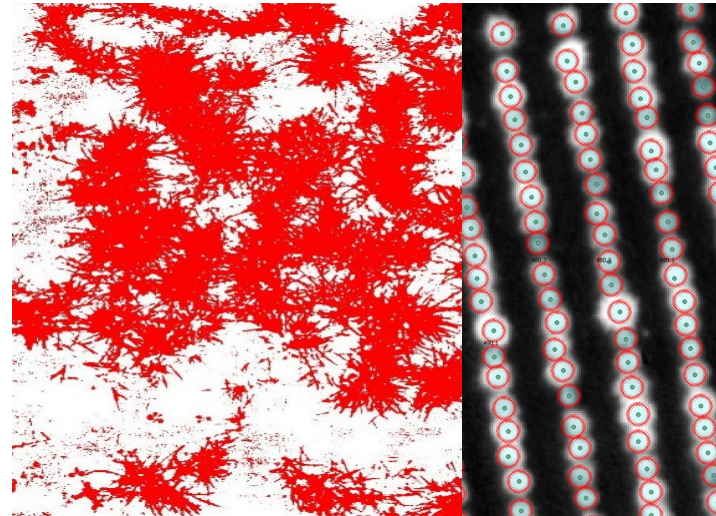
Spectral analysis

- Vegetation indices (e.g. NDVI)
- Temperature differences
- Quality trait calibration equations



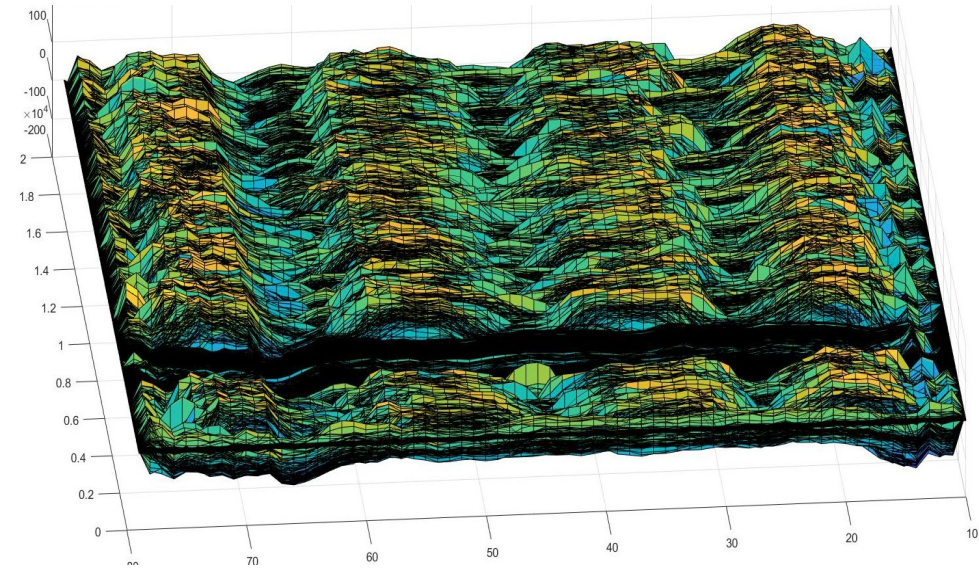
Object-based image analysis

- Plant density and area
- Plant count
- Disease presence
- Sward composition



Physical attributes

- Plant height
- Plant volume
- Plant structure
- Soil structure



High-Throughput Phenomics Ground-Based Platforms



High-Throughput Phenomics – PhenoRover



SICK LMS400
LiDAR



Baumer ultrasonic
sensor



Campbell Scientific
CR3000 datalogger



Navcom RTK GNSS receiver

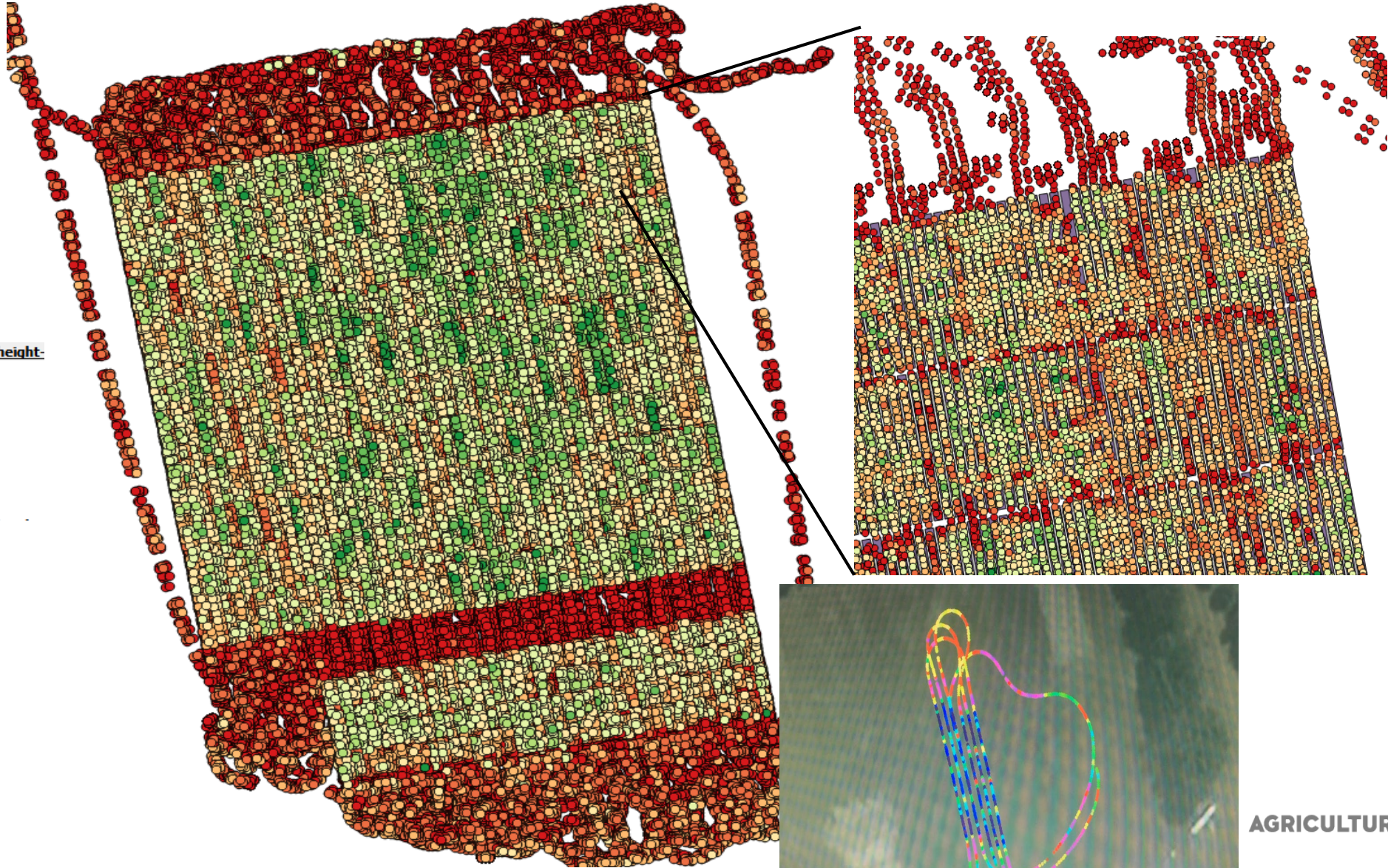


PhenoRover – Ultrasonic Sensor



20181023 pre harvest height:

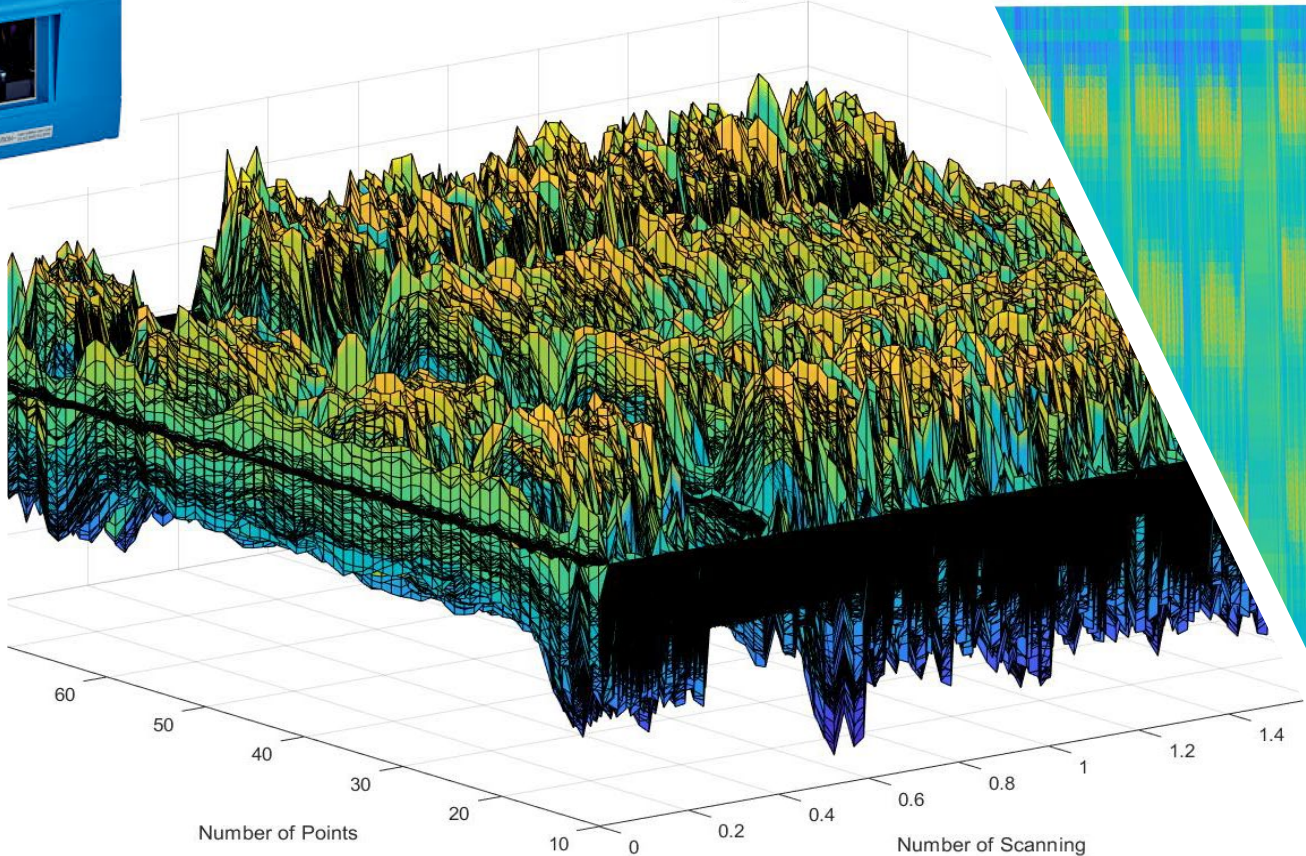
●	1.0 - 6.3
●	6.3 - 11.6
●	11.6 - 16.9
●	16.9 - 22.2
●	22.2 - 27.5
●	27.5 - 32.9
●	32.9 - 38.2
●	38.2 - 43.5



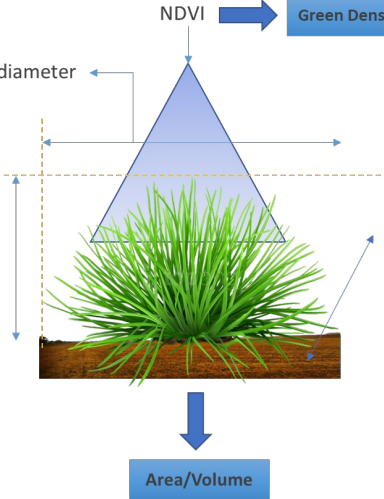
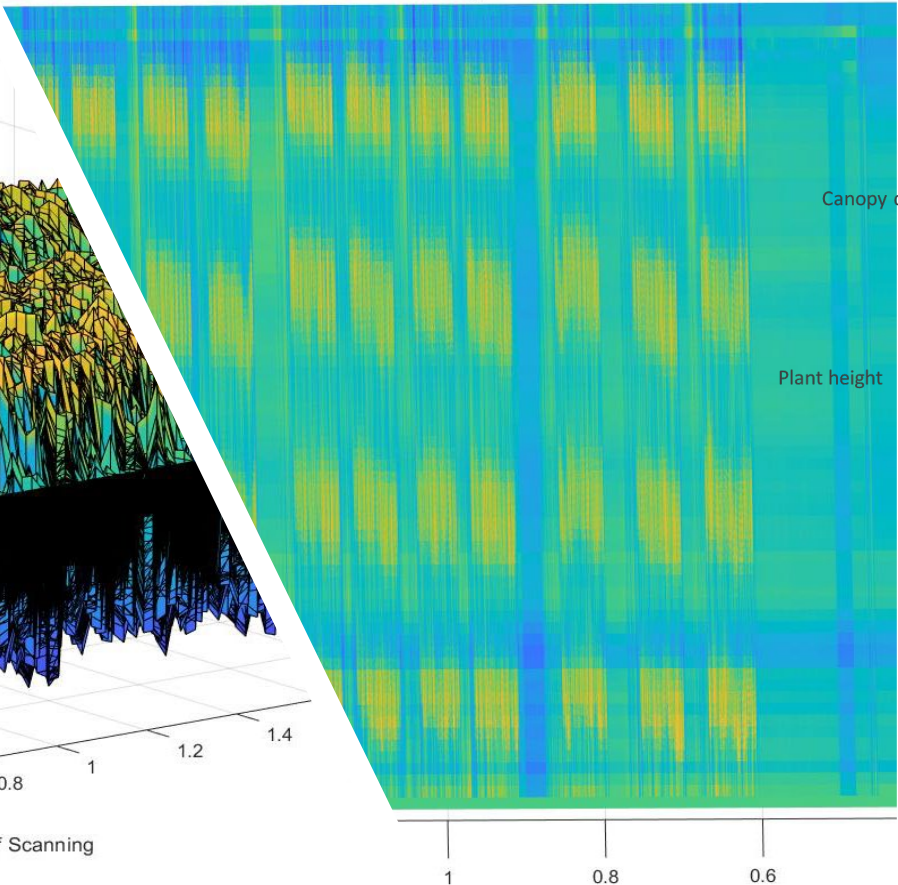
PhenoRover – LiDAR - Plant Volume



PhenoRover at 20001 scannings 2018-01-25 GSS lida



PhenoRover at 20001 scannings 2018-01-25 GSS lidar



Ground Vehicle Phenomics - Traits and Measurements



SICK LMS400 LiDAR



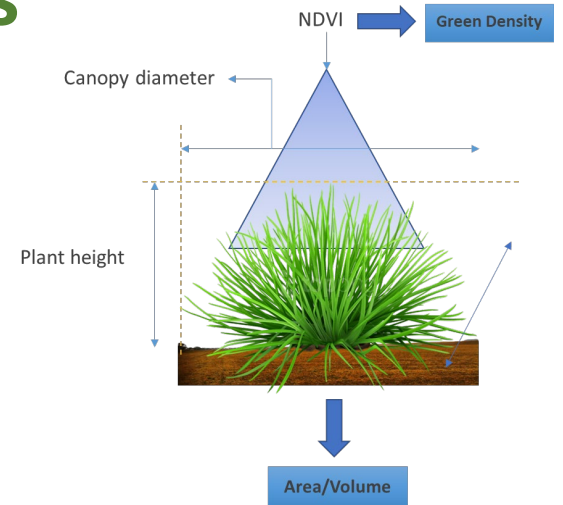
Baumer ultrasonic sensor



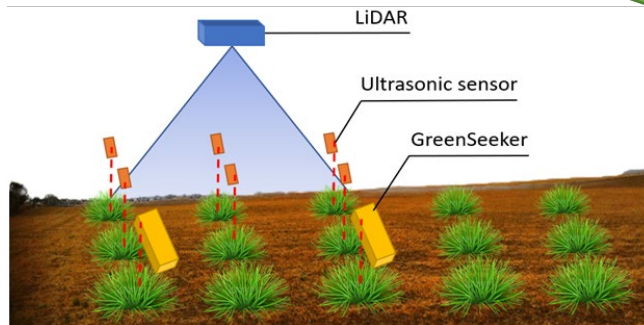
Campbell Scientific CR3000 datalogger



Navcom RTK GNSS receiver



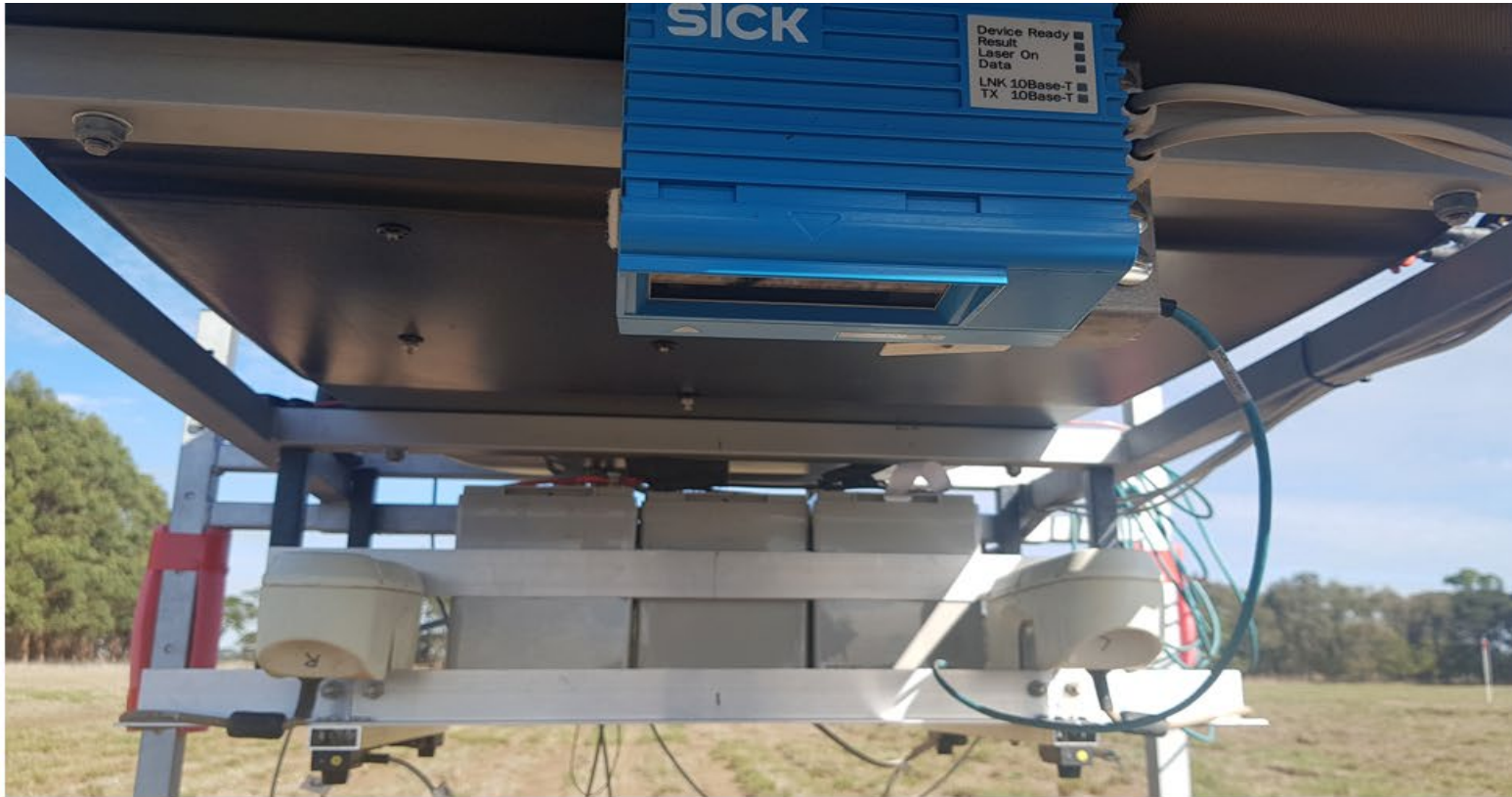
Measurement Method



Ryebot – Platform Development



RyeBot – Sensor Integration



Advanced Air-Based Phenomics Platform

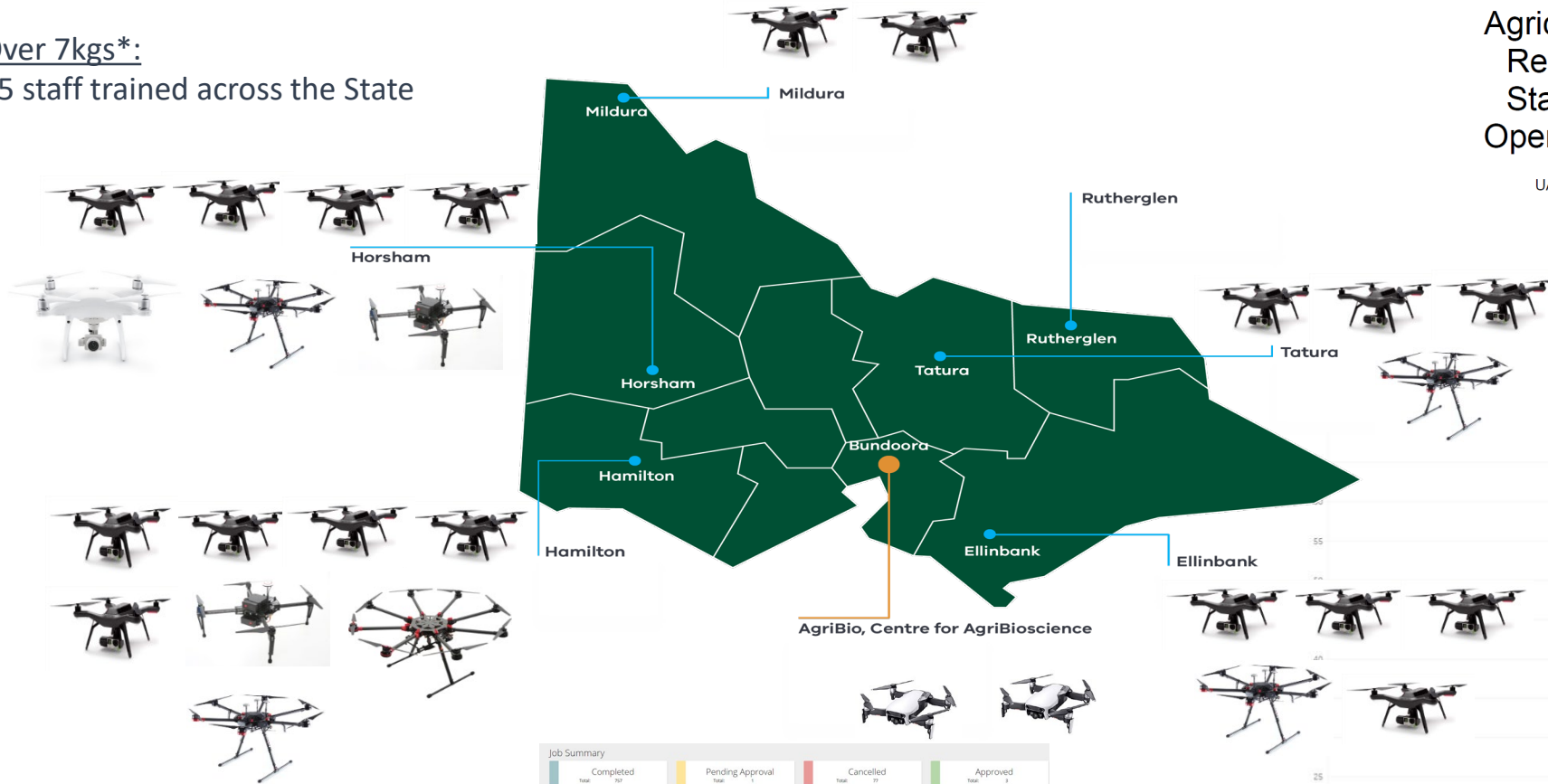


Agriculture Victoria Research RPA Capability



Under 7 kgs:
42 staff trained across the State

Over 7kgs*:
15 staff trained across the State



Agriculture Victoria Research of the State of Victoria Operations Manual

CASR Part 101
UAV Operators Certificate

Document Version 3.01
10/04/2017

RPA OPERATOR'S CERTIFICATE (ReOC)

Number CASA.ReOC/0785 Revision No: 2

This certificate is granted pursuant to regulation 101.335 of the Civil Aviation Safety Regulations 1988 (CASR) to:

AGRICULTURE VICTORIA RESEARCH OF THE STATE OF VICTORIA

ARNS: 1010052
Acting Through

DEPARTMENT OF ECONOMIC DEVELOPMENT, JOBS, TRANSPORT AND RESOURCES

The holder of this certificate is certified as a Remotely Piloted Aircraft (RPA) operator and is authorised to operate the RPA described in the attached schedules subject to any limitations and conditions in those schedules.

This certificate is effective from 24 October 2017 and will expire on 30 November 2020.

[Signature]

Dean Puric
Team Leader
Permissions Issue Team
Client Services Centre
Sustainability Group

Delegate of the Civil Aviation Safety Authority

24 October 2017

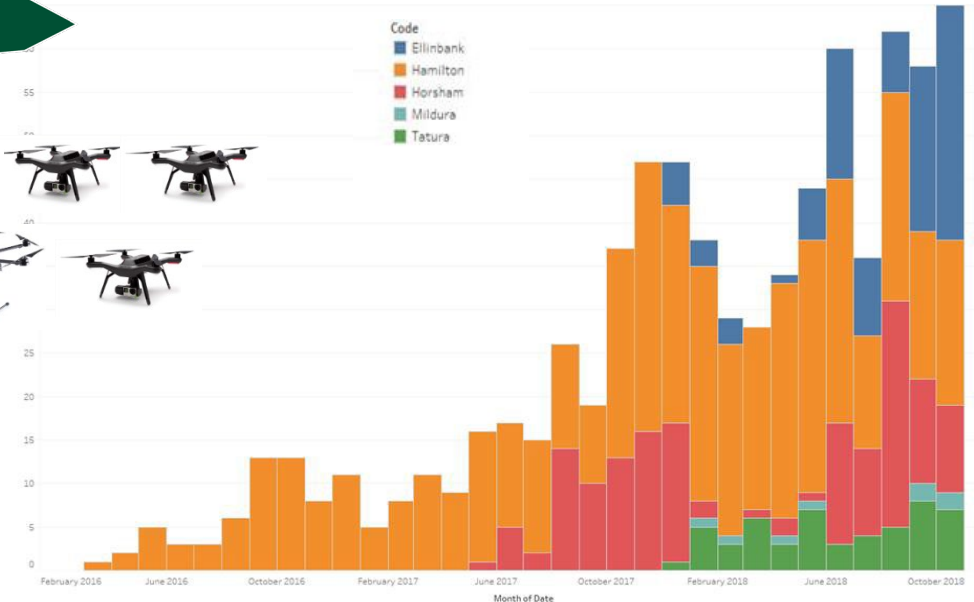


Job Summary

Completed: 707, Pending Approval: 1, Cancelled: 77, Approved: 3

JOB #	STATUS	JOB NAME	LOCATION	RPA MAKE/TYPE	PIC	JOB DATE	CLIENT	OPTIONS
000087	Completed	Standard - Multipass aerial imaging of research site in Central West of productivity project	Lindsay, Pimp	Yamaha R450g 4K	Damen Conner	08-04-2019 11:00	DS2/P, Victoria	Options
000088	Completed	Standard Flight over RPA Field 9	RPA Field 9 & Horsham	Horsham 4.0	Joshua Cox	08-08-2019 10:00	DS2/P, Horsham	Options
000089	Completed	Standard Flight over RPA Field 9	RPA Field 9 & Horsham	Horsham 4.0	Joshua Cox	18-08-2019 10:00	DS2/P, Horsham	Options
000090	Pending Approval	Standard Flight over Danby - RPA - DS2/P and T1	Paterson rd (NSP) DS2/P and T1	Horsham 4.0	Andrew Phelan	09-10-2019 14:30	Agriculture Victoria Research - USB Expansion	Options
000091	Completed	Standard - Farm 8 Flight Part 93	Ellinbank	DS2/P (Ellinbank, Jason C)	Ellinbank 2	08-04-2019 09:30	DS2/P, Ellinbank	Options
000092	Completed	Standard Flight - Pink Farm Lancaster trial one	134 Graham Road, Lancaster	Tatura 1	Grasma Pylaris	28-03-2019 11:00	DS2/P, Tatura	Options
000093	Completed	Standard Flight - Pink Farm Lancaster trial one	1322 Swaine Road, Lancaster	Tatura 1	Grasma Pylaris	28-03-2019 10:00	DS2/P, Tatura	Options
000094	Completed	Standard - Farm 8 Flight Part 93	Ellinbank	DS2/P (Ellinbank, Jason C)	Ellinbank 2	08-04-2019 10:00	DS2/P, Ellinbank	Options
000095	Completed	Standard - Farm 8 Flight Part 93	Ellinbank	DS2/P (Ellinbank, Jason C)	Ellinbank 2	08-04-2019 09:00	DS2/P, Ellinbank	Options

Code
■ Ellinbank
■ Hamilton
■ Horsham
■ Mildura
■ Tatura



The plot of sum of Code 1 for Date Month. Color shows details about Code.

Air-Based Phenomics Platform - Hamilton

3DR Solo



DJI M100



DJI M600



DJI S1000+



GoPro 5



Parrot Sequoia



Slanrange 3P



Phoenix LiDAR



Tetracam MCA



FLIR VUE-PRO



Micasense Red Edge-M



Micasense Red Edge-M



Specim FX17



Canon 5D

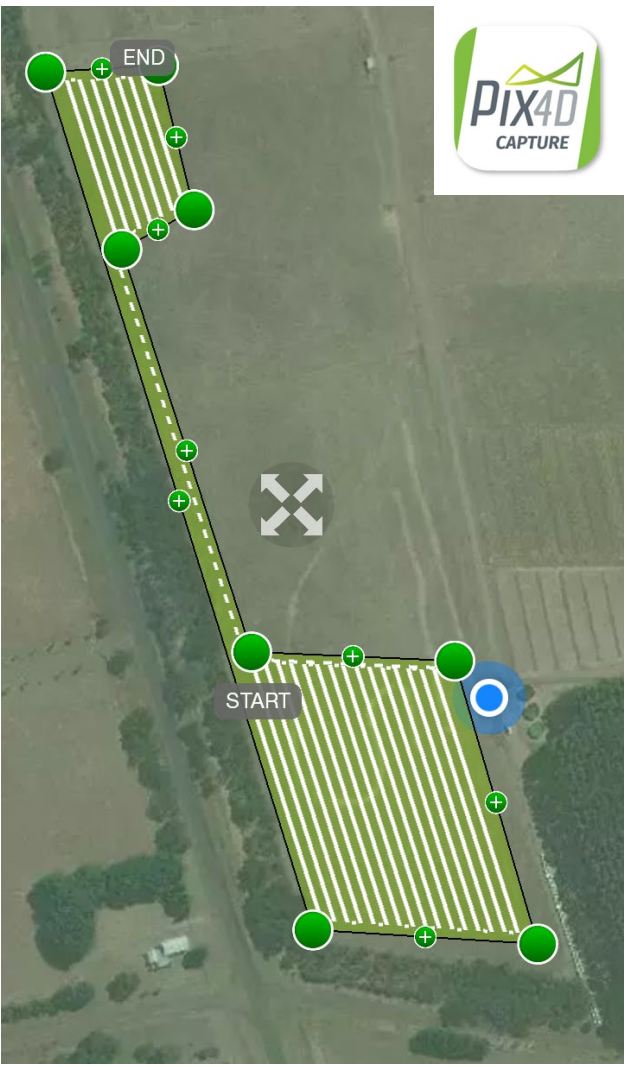
Air-Based Phenomics Platform – Weekly Flight Schedule

DJI M100 + RedEdge M

HSP Trial @ 40m; 16 min



GSS and F1 Hybrid @ 30m; 16 min

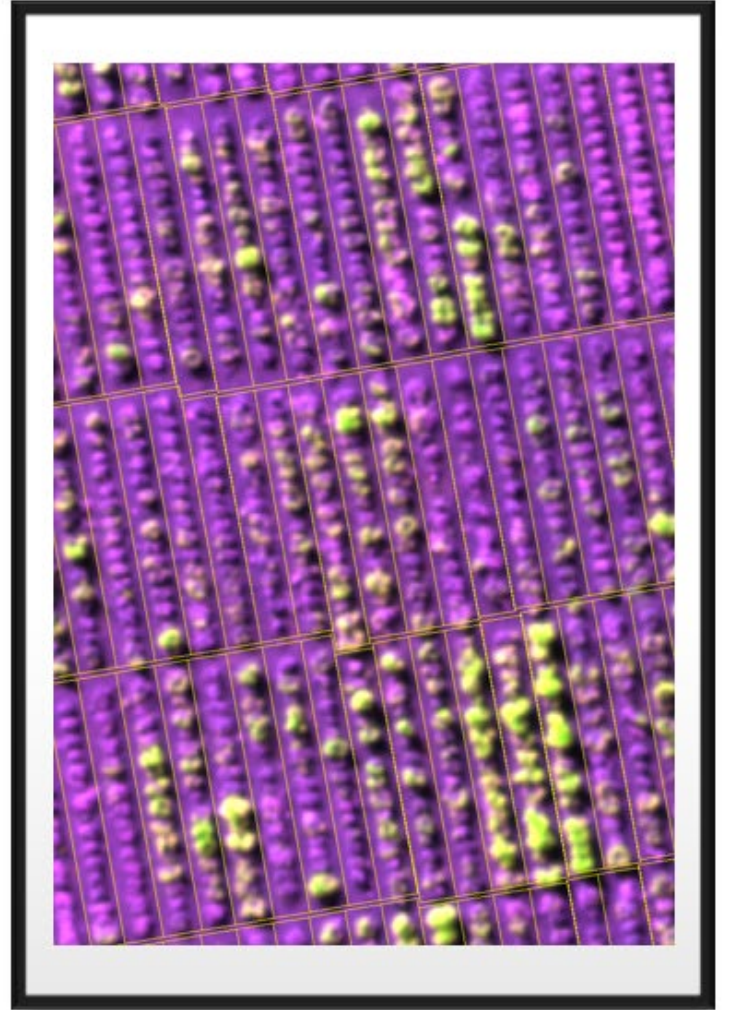
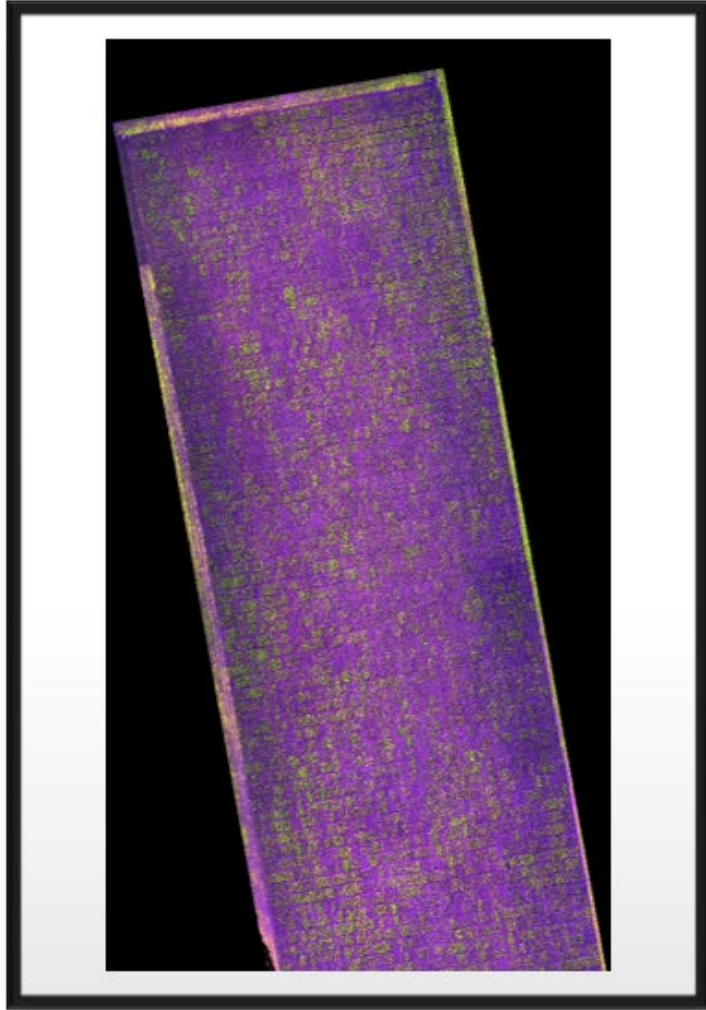


DJI M600 + LiDAR

GSS and F1 Hybrid @ 30m; 6 min

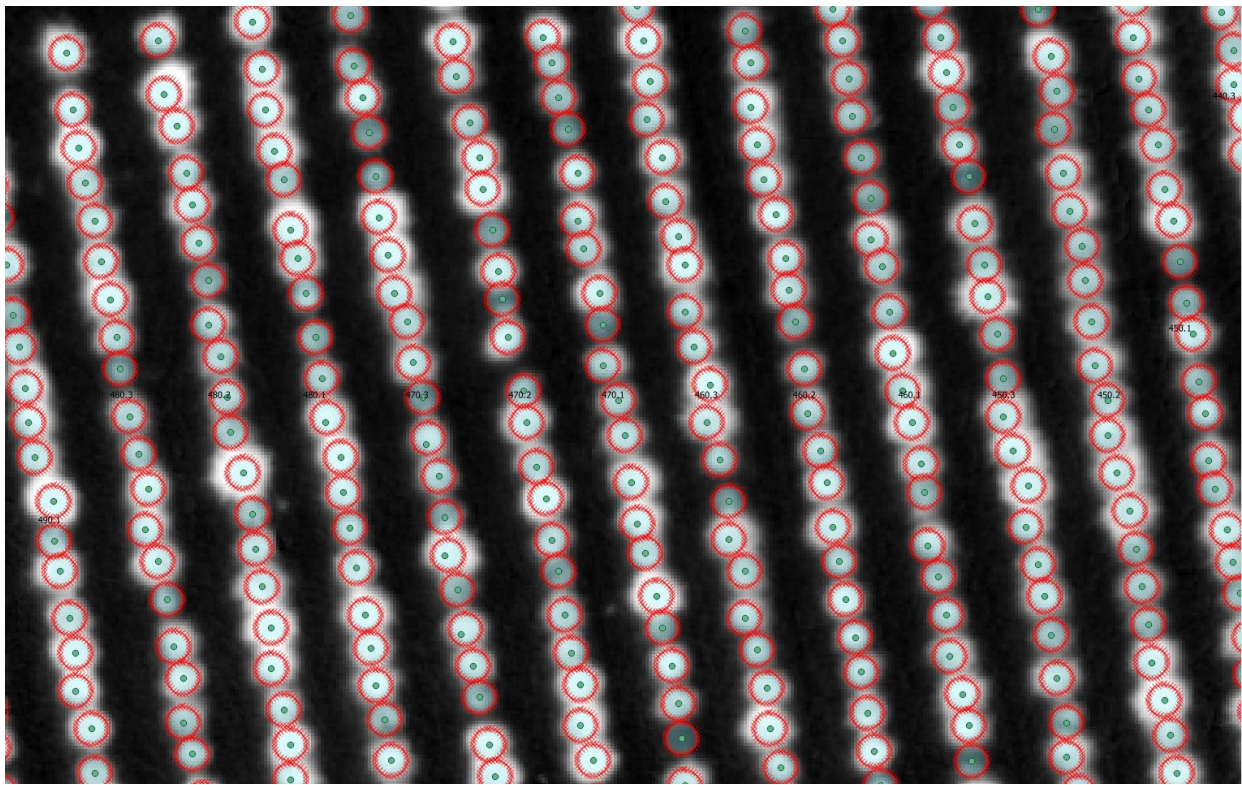


Large Data Sets – Manual Data Extraction?

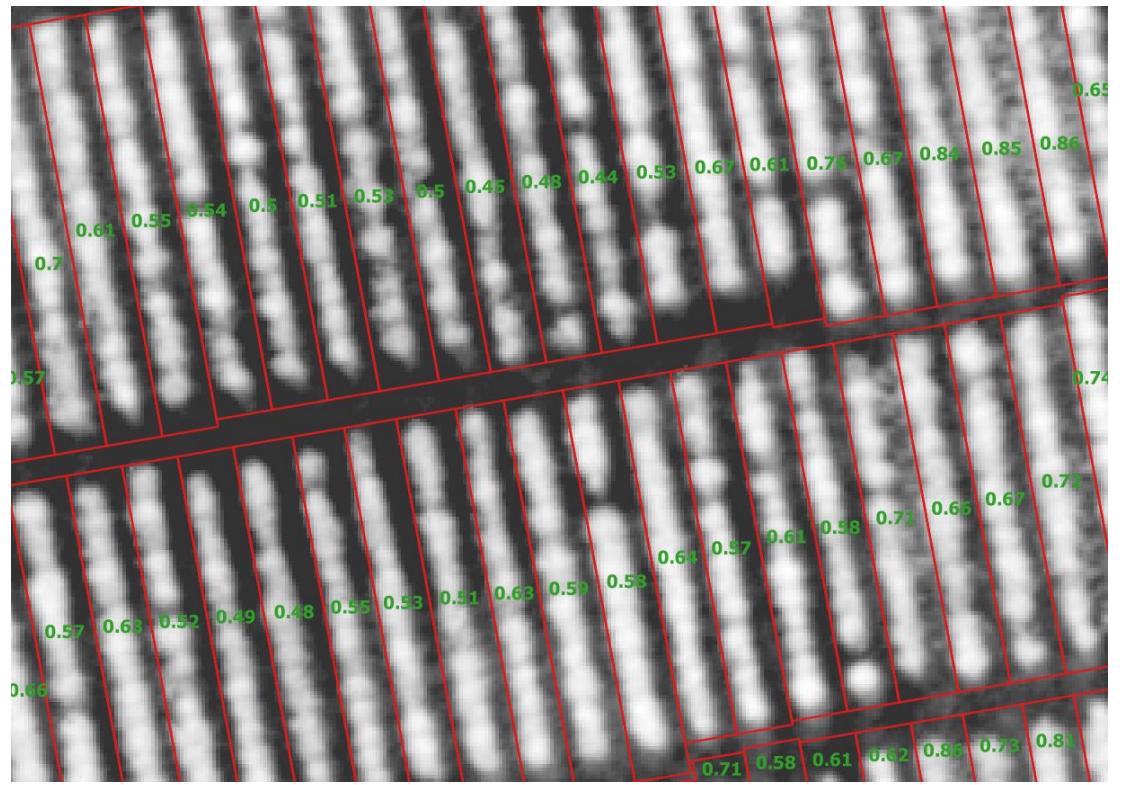


Phenomic Computational Pipeline

Identifying and defining geolocation on single plants



Identifying and defining geolocation on single rows



Phenomic Computational Pipeline

The screenshot displays the HSP Rows Developer software interface. The main workspace shows a map of agricultural plots with red and green overlays. The interface includes several panels:

- Process Tree:** A hierarchical view of the workflow, including steps like 'Segmentation', 'Class', 'Create Sub-row', and 'Classification of sub-rows'.
- Process Properties:** A panel for configuring the 'HSP Row' process, showing settings like 'Algorithm', 'Domain', 'Scope', and 'Condition'.
- Image Object Information:** A table showing features and their values, such as 'Layer values', 'Geometry', and 'Thematic object attribute'.
- Class Hierarchy:** A tree view showing the classification hierarchy, including 'HSP Row', 'Plants', and 'Soil'.
- Feature View:** A list of features and their associated metadata.

Plot	Subplot	Area_Pxl	MeanNDVI	AreaPlants_Pxl	AreaSoil_Pxl	AreaPlants_Rel	AreaSoil_Rel
1	1.1	1420	0.476981194	1318	102	0.928169014	0.071830986
1	1.2	1729	0.443177753	1389	340	0.80335454	0.19664546
1	1.3	1615	0.435756435	1176	439	0.728173375	0.271826625
2	2.1	1522	0.434615854	1104	418	0.725361367	0.274638633
2	2.2	1647	0.35033335	884	763	0.536733455	0.463266545
2	2.3	1628	0.362209837	917	711	0.563267813	0.436732187
3	3.1	1487	0.441651784	1062	425	0.714189644	0.285810356
3	3.2	1705	0.37083267	942	763	0.552492669	0.447507331
3	3.3	1725	0.427674902	1150	575	0.666666667	0.333333333
4	4.1	1470	0.45084289	1122	348	0.763265306	0.236734694
4	4.2	1664	0.416867864	1112	552	0.668269231	0.331730769
4	4.3	1645	0.439911454	1238	407	0.752583587	0.247416413
5	5.1	1486	0.438760594	1081	405	0.727456258	0.272543742
5	5.2	1703	0.358609885	948	755	0.556664709	0.443335291
5	5.3	1582	0.431775539	1154	428	0.729456384	0.270543616
6	6.1	1766	0.428117983	1181	585	0.668742922	0.331257078
6	6.2	1731	0.383226981	1032	699	0.596187175	0.403812825
6	6.3	1818	0.403855227	1130	688	0.621562156	0.378437844
7	7.1	1550	0.380115814	948	602	0.611612903	0.388387097
7	7.2	1707	0.353590451	877	830	0.513766842	0.486233158
7	7.3	1708	0.367701685	952	756	0.557377049	0.442622951
8	8.1	1614	0.382413121	964	650	0.597273854	0.402726146
8	8.2	1708	0.384955037	1025	683	0.600117096	0.399882904
8	8.3	1817	0.351413718	940	877	0.517336269	0.482663731
9	9.1	1474	0.382126729	900	574	0.610583446	0.389416554
9	9.2	1781	0.377163121	1005	776	0.564289725	0.435710275
9	9.3	1662	0.389887884	1044	618	0.628158845	0.371841155
10	10.1	1457	0.387009409	924	533	0.634179822	0.365820178
10	10.2	1804	0.36688589	969	835	0.53713969	0.46286031
10	10.3	1677	0.390985178	996	681	0.59391771	0.406808229
11	11.1	1487	0.398164949	1009	478	0.678547411	0.321452589
11	11.2	1705	0.350893686	859	846	0.503812317	0.496187683
11	11.3	1836	0.331894161	844	992	0.459694989	0.540305011
12	12.1	1538	0.399138694	975	563	0.633940182	0.366059818
12	12.2	1647	0.39483692	995	652	0.604128719	0.395871281
12	12.3	1793	0.363760188	976	817	0.544339096	0.455660904
13	13.1	1416	0.472069951	1128	288	0.796610169	0.203389831
13	13.2	1653	0.411735346	1047	606	0.633393829	0.366606171
13	13.3	1616	0.399292797	1002	614	0.620049505	0.379950495

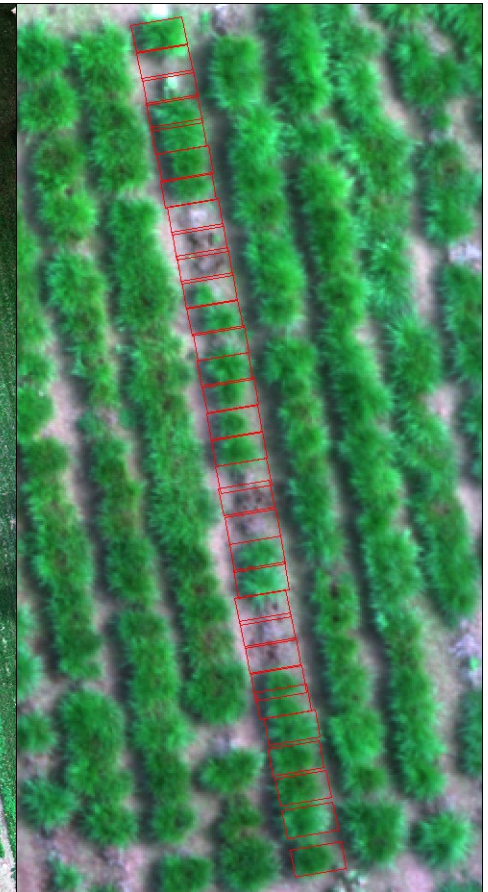
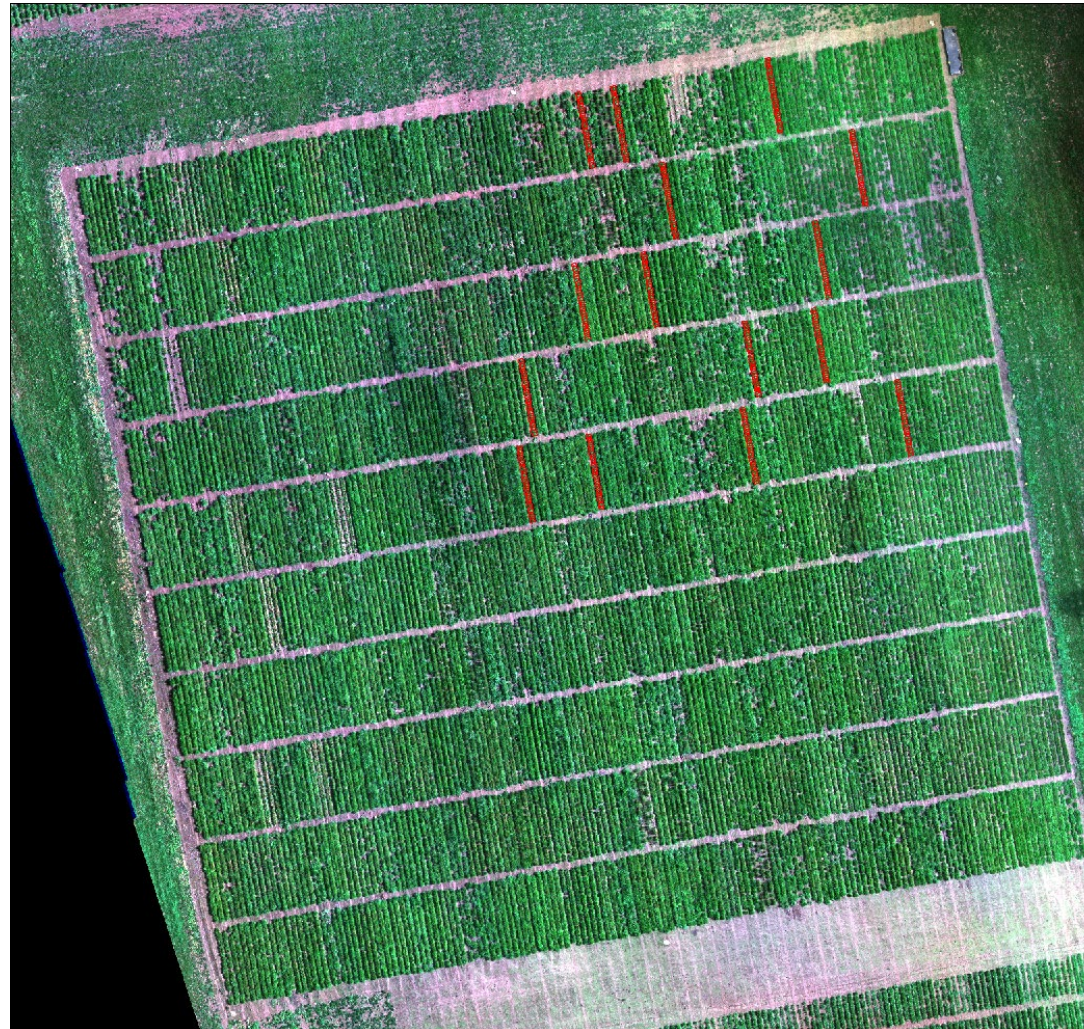


Non-Destructive Biomass Estimation

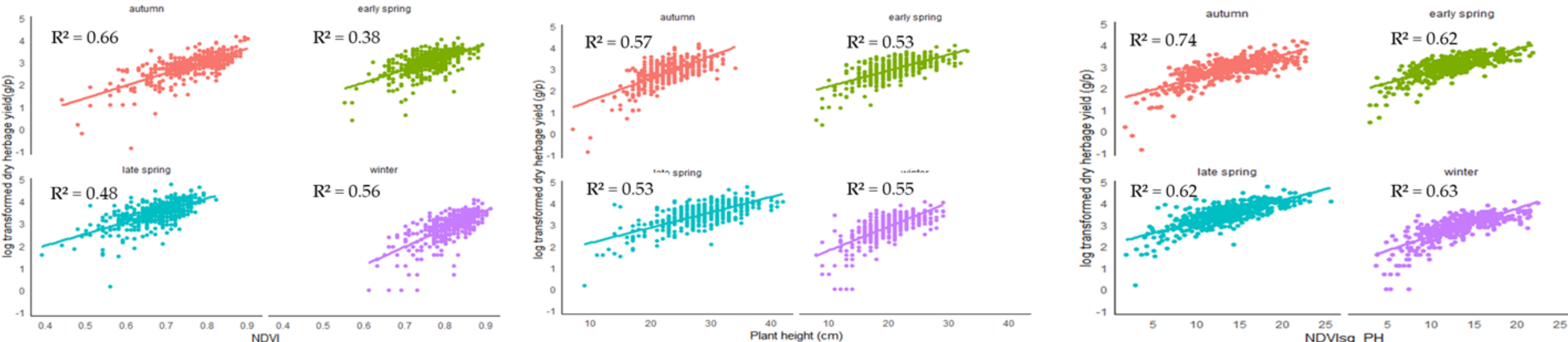


Non-Destructive Biomass Estimation Equation Development for GSS Single Plants

- Destructive sampling of 480 single plants
- Non-destructive measurement of height and NDVI prior to each harvest
- 8 harvests across all seasons in 2017 and 2018



Non-Destructive Biomass Estimation on GSS Single Plants



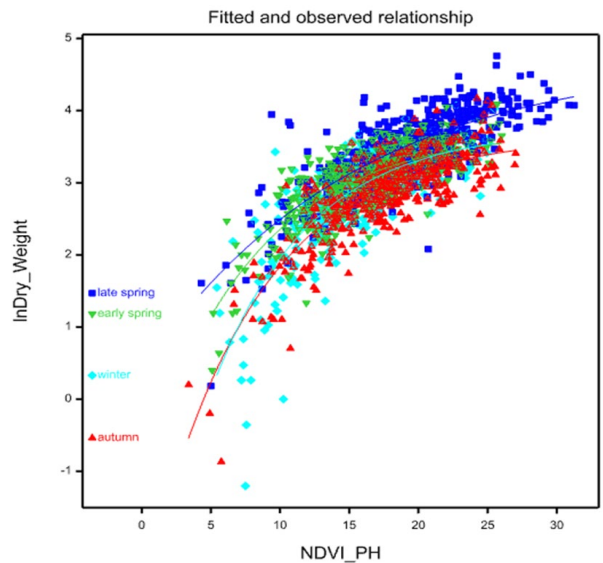
Nonlinear regression analysis

Response variate: InDry_Weight
 Explanatory: NDVI_PH
 Grouping factor: season, all parameters separate
 Fitted Curve: $A + B \cdot (R^{**X})$
 Constraints: $R < 1$

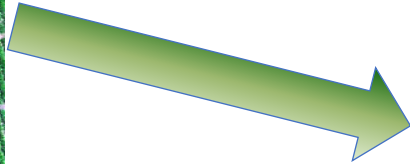
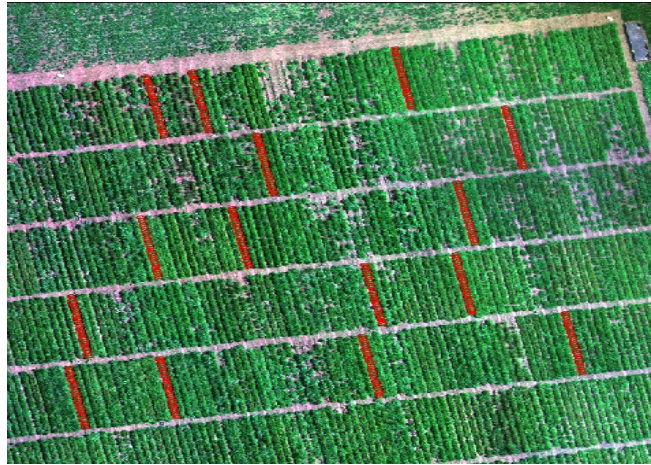
Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	11	483.4	43.9484	400.09	<.001
Residual	1888	207.4	0.1098		
Total	1899	690.8	0.3638		

Change	-3	-2.8	0.9231	8.40	<.001
Percentage variance accounted for	69.8				
Standard error of observations is estimated to be	0.331.				



Non-Destructive Biomass Estimation on 48 000 GSS Single Plants



Nonlinear regression analysis

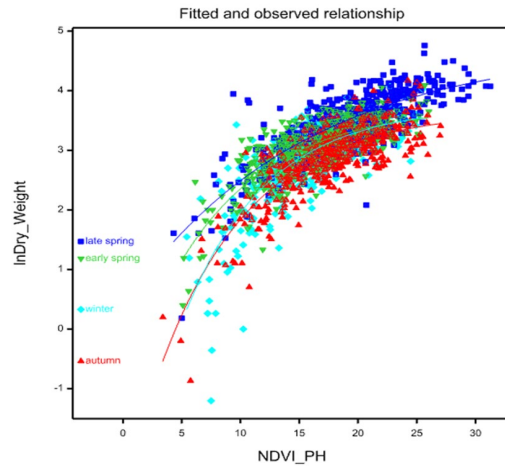
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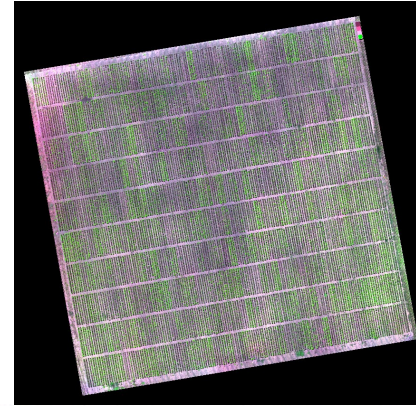
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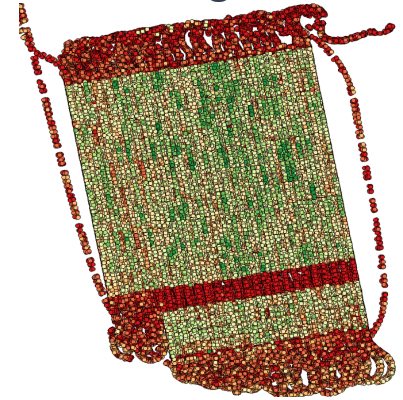


48000 plants in GSS field trial

NDVI



Height





AFIA - Laboratory Methods Manual

A reference manual of standard methods for the analysis of fodder



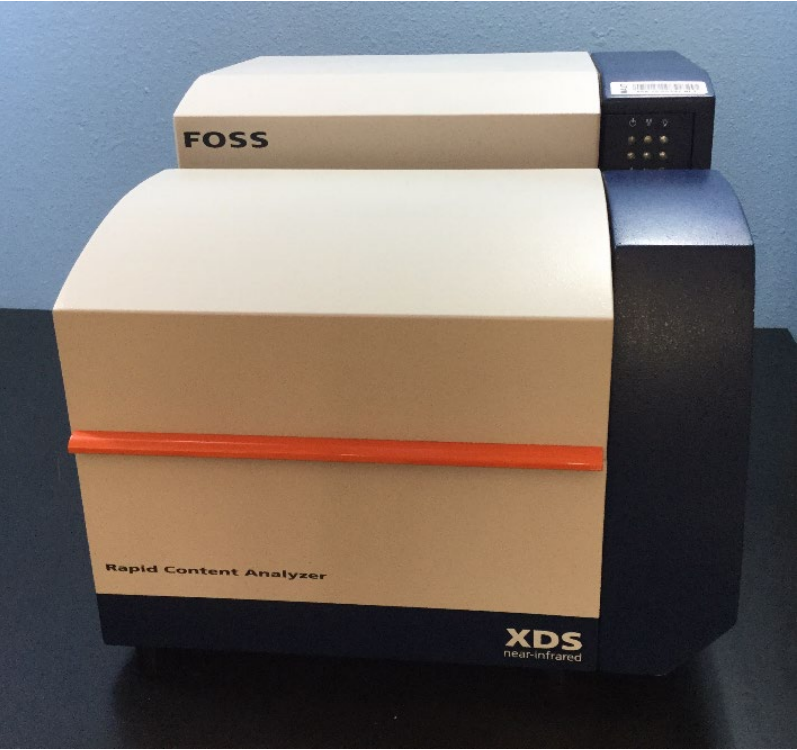
Version 7 - September 2011



Non-Destructive Nutritive Value Estimation

Non-Destructive Nutritive Value Estimation

Current Industry Standard



NIRS lab-based spectroscopy

AFIA - Laboratory Methods Manual

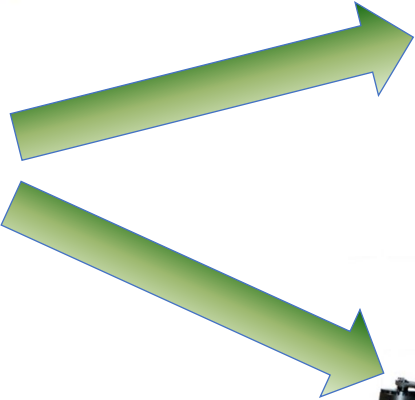
A reference manual of standard methods for the analysis of fodder



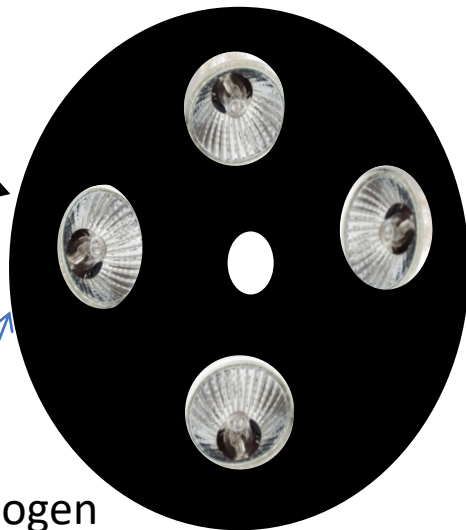
Version 7 - September 2011



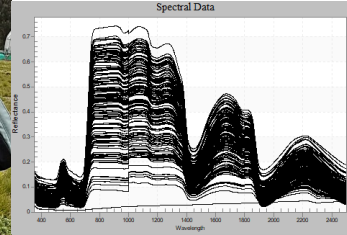
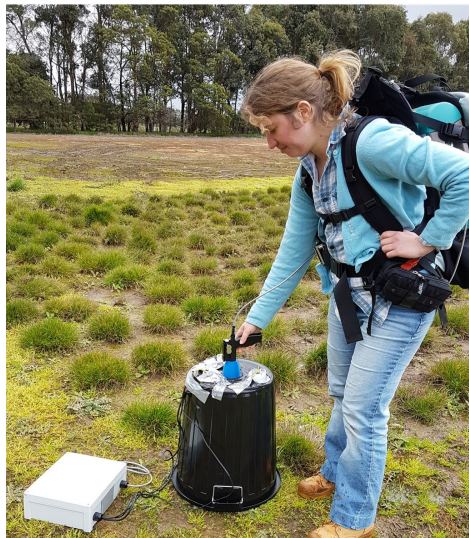
Subset validated with wet chemistry (AFIA)



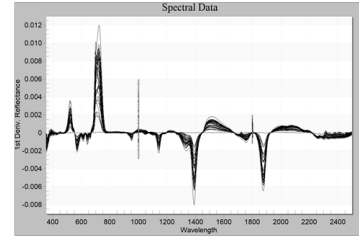
Providing a Stable Source of Irradiance (PhenoBucket)



Tungsten halogen lamp



processing



Laboratory Results

Principal Component Analysis (PCA)

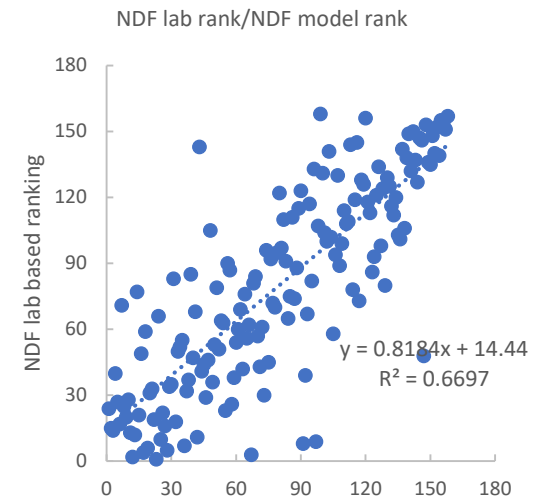
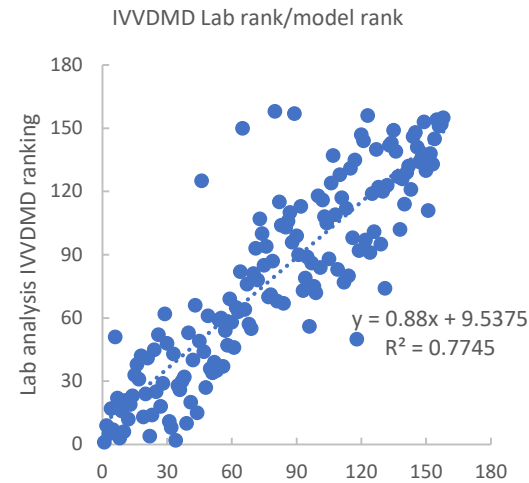
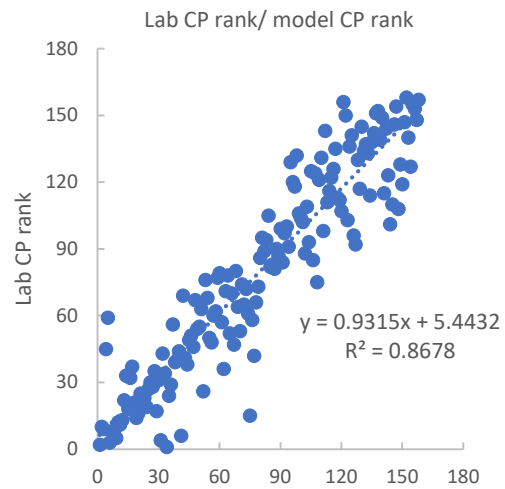
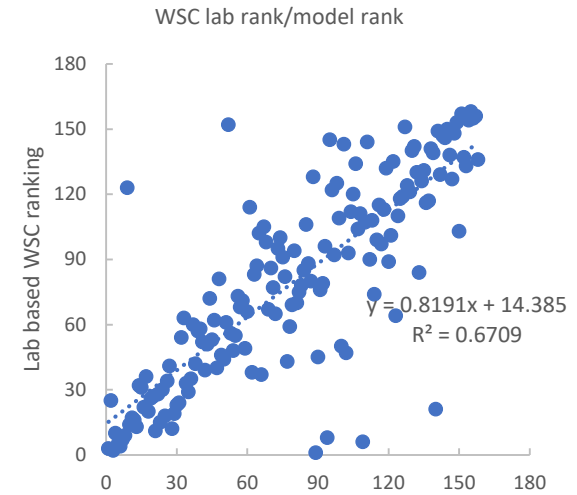
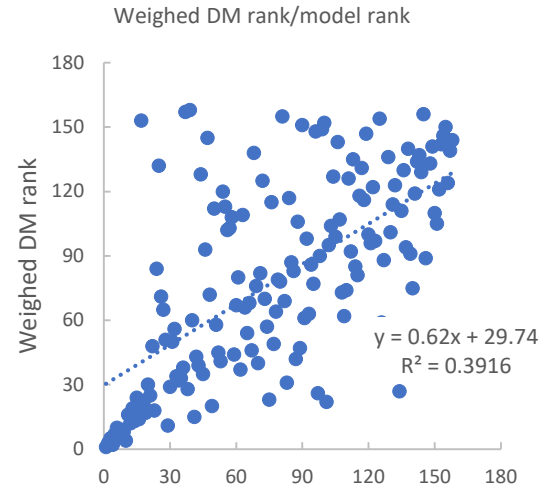
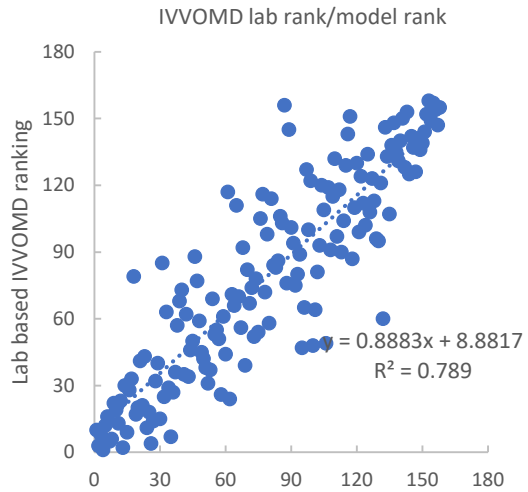


Predictive model for perennial ryegrass nutritive value

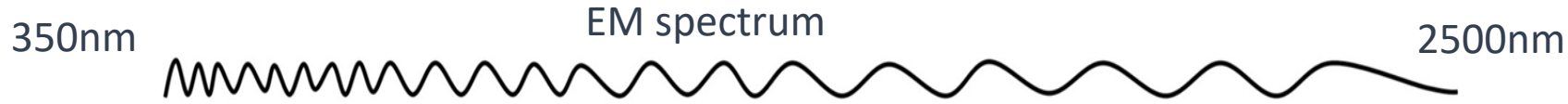
Model	DM		ADF		DMD		OMD		NDF		CP		WSC	
	RSQ	SECV	RSQ	SECV	RSQ	SECV	RSQ	SECV	RSQ	SECV	RSQ	SECV	RSQ	SECV
1	0.89	1.61	0.19	1.56	0.68	1.67	0.70	2.06	0.73	2.78	0.88	4.40	0.96	4.32
2	0.90	1.21	0.07	1.46	0.06	1.68	0.17	2.05	0.44	2.67	0.90	3.16	0.75	3.70
3	0.73	2.58	0.72	1.68	0.69	1.76	0.68	2.26	0.73	2.99	0.77	6.17	0.76	6.24
4	0.90	1.62	0.20	1.56	0.66	1.68	0.69	2.05	0.72	2.77	0.96	4.31	0.96	4.32
5	0.93	1.55	0.13	1.56	0.13	1.73	0.75	2.11	0.78	2.84	0.92	4.13	0.92	4.49
6	0.90	1.61	0.20	1.56	0.66	1.68	0.69	2.05	0.72	2.77	0.96	4.31	0.96	4.31
7	0.73	2.58	0.72	1.68	0.70	1.76	0.68	2.26	0.74	2.99	0.77	6.17	0.76	6.26
8	0.90	1.62	0.20	1.56	0.66	1.68	0.69	2.06	0.72	2.77	0.96	4.31	0.96	4.32
9	0.73	2.58	0.72	1.68	0.69	1.76	0.68	2.26	0.73	2.99	0.77	6.17	0.76	6.24
10	0.90	1.62	0.20	1.57	0.67	1.68	0.70	2.06	0.73	2.77	0.96	4.31	0.96	4.32
11	0.73	2.58	0.72	1.68	0.69	1.76	0.68	2.26	0.73	2.99	0.77	6.17	0.76	6.24
12	0.89	1.61	0.19	1.56	0.68	1.68	0.69	2.06	0.72	2.80	0.88	4.39	0.96	4.32
13	0.74	2.68	0.72	1.73	0.67	1.76	0.66	2.25	0.72	3.02	0.75	6.32	0.75	6.43
14	0.78	1.32	0.08	1.46	0.05	1.69	0.14	2.07	0.08	2.81	0.82	3.48	0.82	3.54
15	0.94	1.56	0.15	1.55	0.18	1.73	0.75	2.11	0.78	2.83	0.93	4.19	0.92	4.52



In-Field Prediction of Nutritive Value



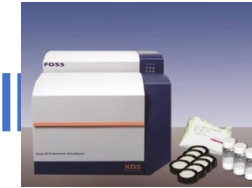
Spectral Resolution and Range – Ground-Based Sensors



Foss XDS



Resolution between 0.5-3nm



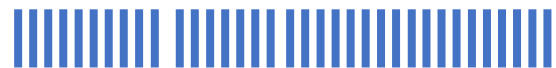
FieldSpec & AgriNIR



Resolution between 1-8nm



NIR quest



Resolution between 3-8nm



Scio micro



Resolution between 1-3nm



Spectral Resolution and Range – Aerial-Based Sensors

EM spectrum



Specim FX17



Captures images in many narrow bandwidths



Tetracam MCA12



Captures images in 12 bandwidths



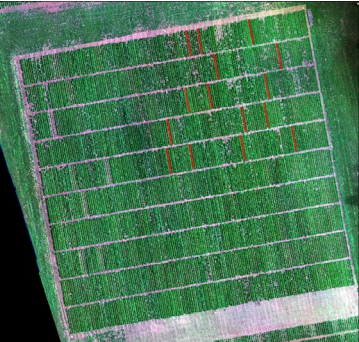
RedEdge M



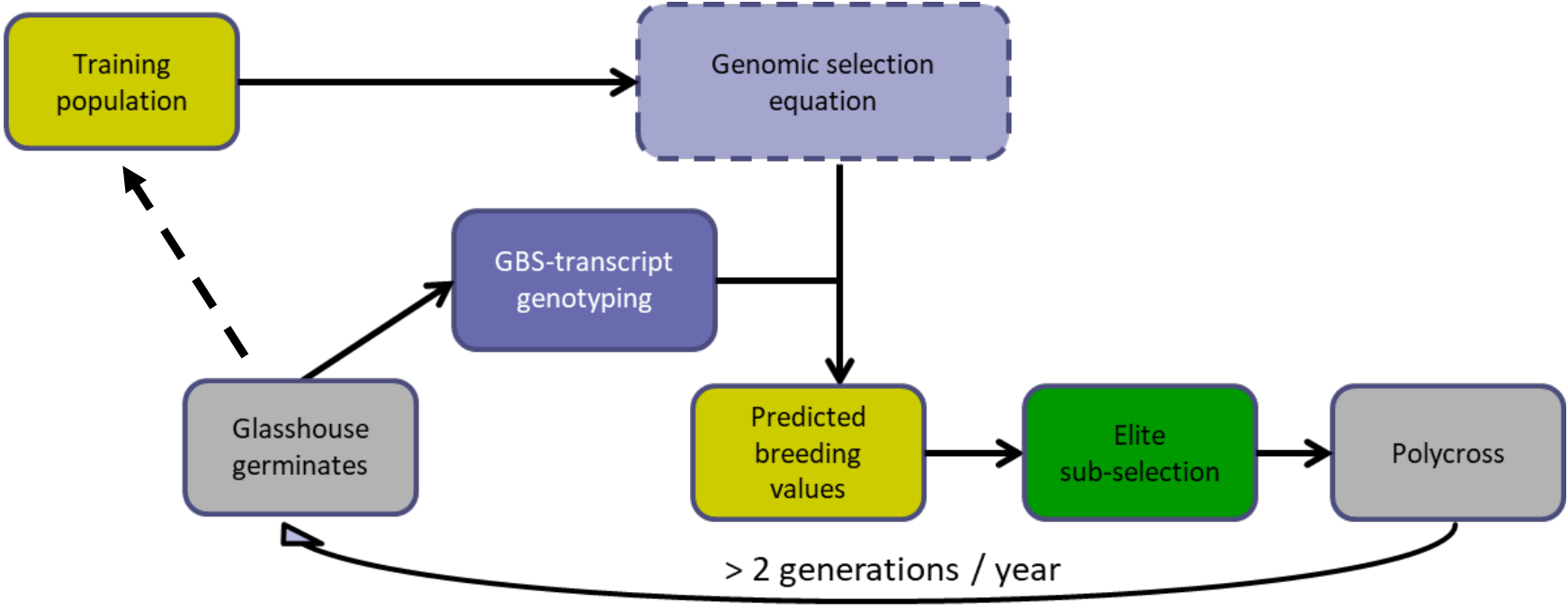
Captures images in 5 broad bandwidths



Genomic Assisted Breeding



Yield
Quality
Persistence



Quantitative characteristics of smaller effects require large populations to link phenotype to genotype



Questions?

