

# Methodology development to create methods for acquisition and integration of historical, UAV sensors and IoT data for agriculture

- Historical data – many decades of accumulated experience and data
- Variable data acquisition and storage methods
- The arrival of new technologies is getting faster and faster
- Huge competition, growing range of available solutions
- Lack of resources (intellectual, technical, material).
- The influence of weather conditions and other environmental factors

Basic problem: integration of data in a unified environment, analysis and final product for the user



## TED4LAT



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the European Union**

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TED4LAT, No. 101079206

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Mg.sc.ing. ViA SSII Research Assistant  
AREI Remote Sensing expert



## Vidzeme University of Applied Sciences cooperation with Institute of Agricultural Resources and Economics

Education institution and an important bioeconomy industry research and leading field plant breeding institute with more than 100 years of history cooperation with high school.

# History and operation

- More than 100 years of experience
- AREI scientists and specialists works:
  - In the bioeconomy sector
  - In the department of grain technology and agrochemistry
  - In field plant selection, agroecology and pre-election laboratory
- Priekuļi and Stende Research Centers, Technology Transfer Center and Agricultural Market Promotion Center
- AREI's activities are spread throughout Latvia, 4 main locations, as well as participation in international projects (experience in Lithuania, Estonia, Sweden, Norway)
- Much is being done in the field of knowledge transfer and learning new technologies, which is associated with various challenges
- Cooperation with Vidzeme University of Applied Sciences – what does it means: An experienced agricultural institute can pass on legacy knowledge, access new research, and develop future specialists, while gaining prestige, innovation, and practical experience. ***The long-term impact outweighs the short-term imbalance.***



**STENDES MIEŽU  
SELEKCIJONĀRE  
GENOVEFA  
TIMULE**

**Sadarbība  
ar AREI  
Stendes PC**

**Sadarbībā**  
**ar AREI**  
**Stendes PC**



23. Februari (adunsa)

x Bilas "Sauli" un etas istabas  
nomes loiy, an. WTO

2.9. Feb. afganšt' az talo istadi, kai tie  
oti neplyakst! 57  
2. marta (prieš tai n. vakarai) Nemėstė an 1850

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100. 7.00 bis 6.11 17 cm

Rod otoclojezi patoi.

-1-

1. Aprieti (Krimdžari) veļ saugs un nāvus šatņings paku  
nu zem pēds

Mitu  
Pavarsiti Krimdžari.

12. Aprieti (aridienā) pipovakar pastangasais

2. Storeji vai "METEC"  
storeja.  
(Cieņaņa cieņa)

15. Aprieti (Krimdžari)  
LATVIJAS mīcēnāsais  
Lecēja poi rīvada. patois  
(Mokotella alta)

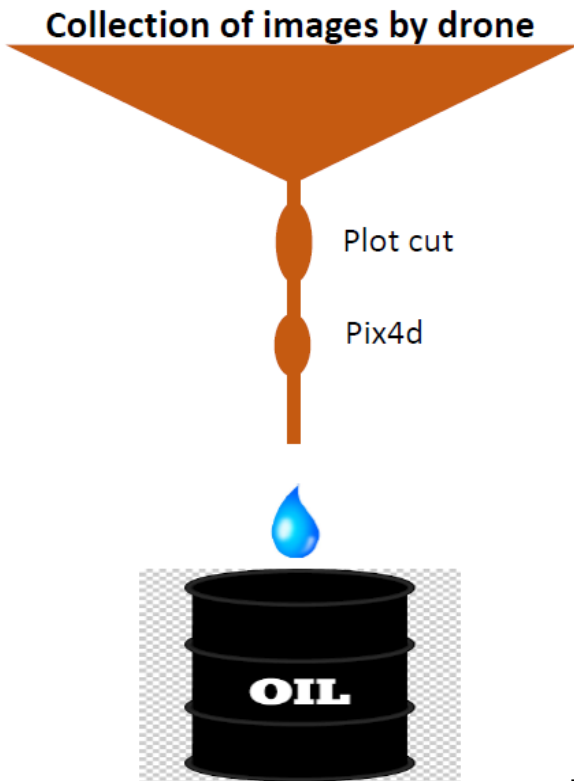
Storēdijs  
veit pois, pi  
Būtijs, Būtijs  
Jūs dūtēs

15. Matā (stundā) nogriez pēdējo  
"Sauls" kātu man pašai, un  
4. ziedlīm un 2 pumpurliem, smuki lili  
dīlo podu <sup>ziedi</sup> atgriež. no sākām, tur varēs kaut  
ko iestādīt vai iēsēt.

Šogad dāzā, saules "līgās"  
30. tu uz sēju pēlnu, un nezināto vēl  
devu var ne? Ang. loti smukas,  
1. Saule ar varākiem jūciem un  
pamphurim 5. jūlijā uz d. līgai Vīkstānei  
6. jūlijā milzīgs karstums un Saules"  
saka ziedēt daudzās  
7. jūlijā (sēti) ar karstums pēc tam  
milzīgs lietus. Tā plūdi, lēt  
no viām pilsētām

# Current experience

## Data pipeline from HTP with UAV



- Collection of «big data»
- Time consuming adjustments of images
- Large computer capacity needed
- Outcoming data difficult to integrate with other results

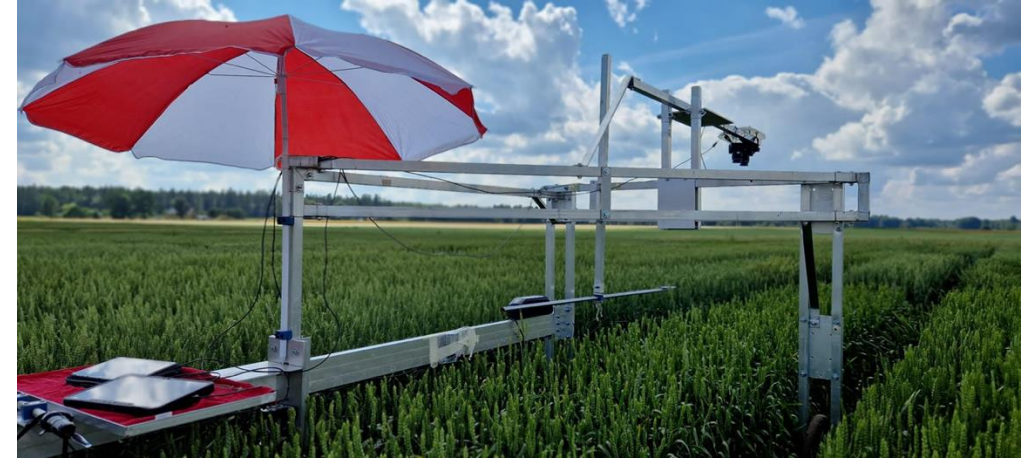
The view of Norwegian colleagues

 **Graminor**

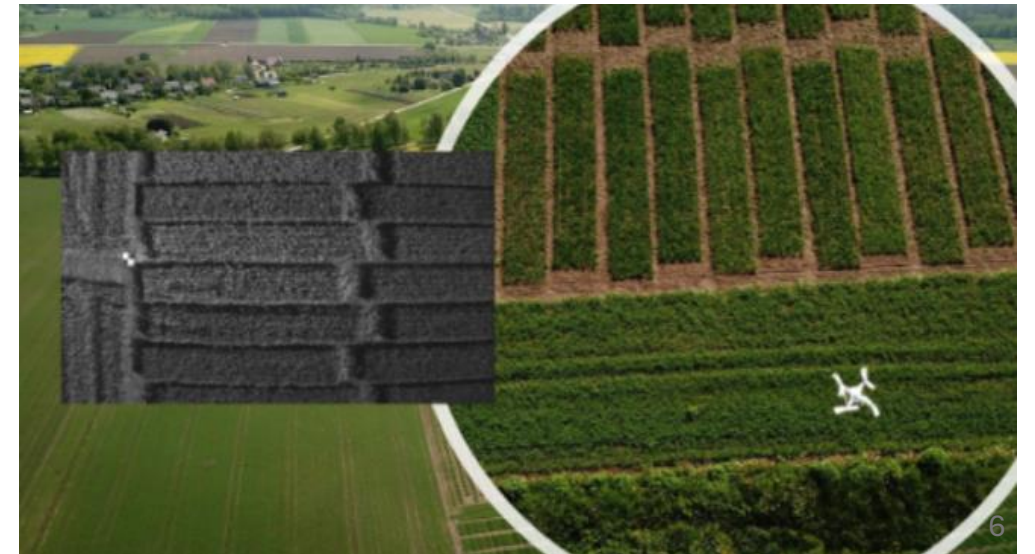


# International NOBAL Wheat Project

- A three-year project that gave us stability and confidence in what we do
  - Higher work efficiency
  - Improved competences
  - Better productivity
  - Innovative solutions
  - Cooperation experience
  - Market knowledge
  - Strategic thinking
  - New data collection methods
  - Improved data processing
- International cooperation
- Experienced consultants
- Networking opportunities



Phenomobile vs UAV





# Data series (3 years x 10 missions) using UAV





# Orthophoto map

- Gets data when and where it is needed, with the necessary accuracy and resolution
- Compatibility with other resources in the GIS environment
- Required GSD\* at least 1cm
- Shift of images between missions no more than 3cm

\***GSD (Ground Sampling Distance)** it is also known as "ground surface resolution". This term is used in photogrammetry and remote sensing technologies to describe the spatial resolution of an image on the earth's surface. Basically, it indicates the distance on the ground represented by each pixel in the image.

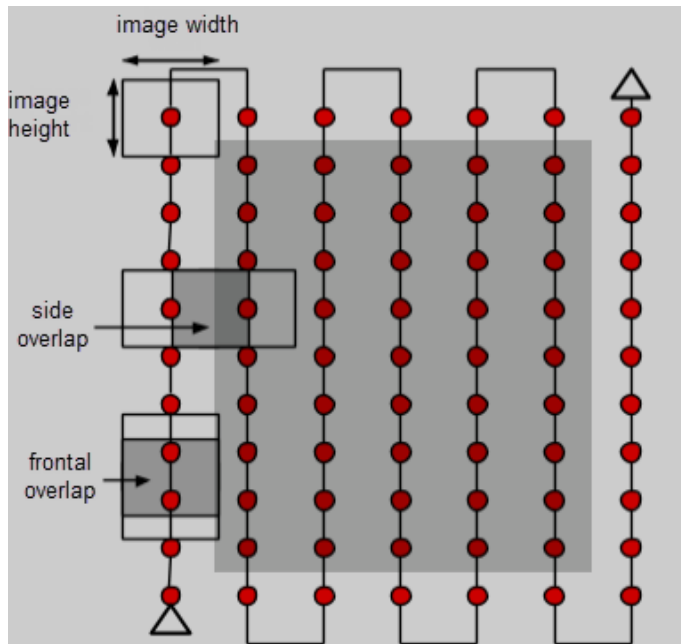




# RGB (color photo) and Multispectral camera

- RGB (Red, Green, Blue)
- RE, NIR (Red Limit, Near Infrared)
- Photos are taken while flying, in consecutive series

Correct protocols needed to collect data



The gray area is the research area.

Image coverage not less than 70% and not more than 85%.

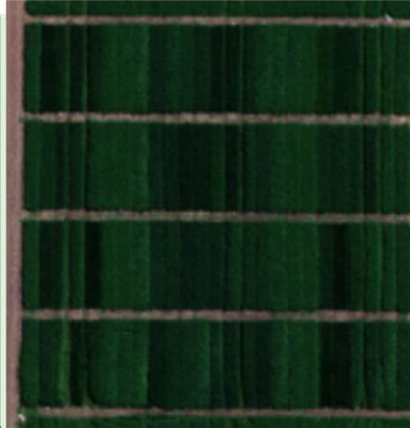
If you want to get a 2D orthophoto, then point the camera vertically down.

If a 3D object or surface model is required, the camera is turned at an angle of approximately 15 degrees from the vertical.

# Current field planning «Excel type GIS »

- NUE trial design for 16 genotypes at 2 N levels
- Split field design - the field is divided into four main blocks, and the application of both N fertilization levels is randomly distributed among these four blocks.
- Crop trial design, 300 spring wheat genotypes
- Design of random blocks

N75					N150					N150					N75						
Randomized					Randomized					Randomized					Randomized						
4	5	12	13	20	21	28	29	36	37	44	45	52	53	60	61	68	69	76	77	84	85
3	6	11	14	19	22	27	30	35	38	43	46	51	54	59	62	67	70	75	78	83	86
2	7	10	15	18	23	26	31	34	39	42	47	50	55	58	63	66	71	74	79	82	87
1	8	9	16	17	24	25	32	33	40	41	48	49	56	57	64	65	72	73	80	81	88



Replication 1; randomized																				Replication 2; randomized																			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
NW244	NW68	NW278	NW171	NW174	NW254	NW151	NW173	NW77	NW228	NW2	NW15	NW66	NW246	NW181	NW232	NW264	NW261	NW300	NW49	NW117	NW60	NW71	NW263	NW181	NW111	NW261	NW299	NW300	NW256	NW13	NW23	NW251	NW7	NW228	NW46	NW94	NW28	NW190	NW164
NW255	NW146	NW263	NW203	NW27	NW104	NW1	NW170	NW201	NW122	NW129	NW163	NW280	NW148	NW190	NW175	NW165	NW35	NW119	NW72	NW86	NW249	NW145	NW69	NW99	NW129	NW34	NW182	NW128	NW19	NW52	NW104	NW213	NW246	NW82	NW232	NW275	NW220	NW225	NW162
NW89	NW109	NW107	NW76	NW248	NW74	NW47	NW120	NW229	NW177	NW231	NW45	NW200	NW86	NW117	NW82	NW98	NW266	NW53	NW196	NW253	NW109	NW264	NW283	NW143	NW108	NW17	NW217	NW147	NW169	NW252	NW211	NW216	NW176	NW248	NW199	NW173	NW260	NW219	NW27
NW283	NW256	NW150	NW299	NW270	NW56	NW84	NW63	NW191	NW222	NW265	NW206	NW37	NW209	NW288	NW32	NW155	NW133	NW154	NW187	NW56	NW185	NW126	NW243	NW209	NW67	NW2	NW64	NW103	NW206	NW132	NW201	NW112	NW151	NW153	NW170	NW77	NW63	NW140	NW286
NW290	NW79	NW157	NW81	NW118	NW115	NW22	NW61	NW12	NW172	NW91	NW142	NW277	NW75	NW260	NW24	NW136	NW88	NW143	NW253	NW231	NW68	NW12	NW110	NW218	NW192	NW237	NW35	NW154	NW31	NW32	NW267	NW203	NW135	NW274	NW156	NW118	NW158	NW294	NW47
NW199	NW213	NW215	NW285	NW14	NW55	NW85	NW25	NW243	NW126	NW292	NW121	NW73	NW30	NW197	NW139	NW102	NW50	NW58	NW252	NW149	NW97	NW73	NW239	NW235	NW171	NW130	NW95	NW184	NW11	NW88	NW6	NW122	NW234	NW187	NW150	NW226	NW167	NW174	NW210
NW226	NW130	NW42	NW116	NW257	NW161	NW43	NW262	NW297	NW245	NW127	NW31	NW29	NW168	NW198	NW268	NW9	NW132	NW279	NW237	NW223	NW40	NW250	NW138	NW189	NW106	NW33	NW89	NW10	NW83	NW96	NW276	NW265	NW75	NW262	NW277	NW224	NW233	NW36	NW272
NW110	NW286	NW131	NW141	NW48	NW269	NW90	NW214	NW21	NW274	NW189	NW233	NW212	NW178	NW144	NW7	NW296	NW225	NW219	NW83	NW93	NW53	NW58	NW279	NW25	NW37	NW196	NW18	NW270	NW240	NW76	NW115	NW255	NW137	NW15	NW159	NW1	NW291	NW131	NW259
NW87	NW4	NW18	NW193	NW8	NW112	NW52	NW294	NW291	NW247	NW69	NW3	NW51	NW6	NW185	NW59	NW11	NW249	NW16	NW34	NW208	NW141	NW166	NW172	NW288	NW133	NW16	NW70	NW247	NW43	NW241	NW107	NW186	NW79	NW157	NW195	NW238	NW30	NW59	NW8
NW239	NW180	NW160	NW40	NW218	NW184	NW285	NW64	NW234	NW65	NW179	NW250	NW156	NW78	NW224	NW135	NW60	NW271	NW211	NW227	NW55	NW29	NW50	NW287	NW20	NW205	NW257	NW297	NW178	NW148	NW230	NW21	NW42	NW161	NW124	NW183	NW142	NW80	NW221	NW5
NW208	NW158	NW275	NW230	NW240	NW183	NW36	NW99	NW13	NW95	NW223	NW152	NW272	NW251	NW166	NW217	NW17	NW19	NW236	NW159	NW163	NW292	NW4	NW105	NW282	NW81	NW41	NW3	NW62	NW298	NW245	NW152	NW165	NW289	NW92	NW65	NW229	NW193	NW54	NW285
NW238	NW241	NW242	NW106	NW96	NW235	NW20	NW134	NW169	NW207	NW186	NW70	NW10	NW128	NW204	NW114	NW5	NW167	NW210	NW289	NW160	NW236	NW61	NW48	NW113	NW212	NW91	NW295	NW134	NW293	NW168	NW9	NW74	NW271	NW278	NW87	NW191	NW273	NW22	NW39
NW80	NW103	NW111	NW221	NW33	NW284	NW205	NW62	NW195	NW94	NW182	NW216	NW93	NW273	NW258	NW140	NW26	NW38	NW41	NW145	NW227	NW204	NW125	NW120	NW280	NW144	NW84	NW268	NW180	NW215	NW200	NW101	NW14	NW66	NW242	NW175	NW254	NW136	NW146	NW102
NW267	NW113	NW105	NW282	NW123	NW101	NW188	NW137	NW124	NW67	NW162	NW276	NW192	NW147	NW71	NW287	NW259	NW108	NW44	NW281	NW72	NW85	NW24	NW244	NW197	NW100	NW284	NW98	NW116	NW38	NW222	NW266	NW114	NW207	NW118	NW172	NW177	NW177	NW177	NW177
NW153	NW149	NW138	NW23	NW202	NW100	NW194	NW57	NW28	NW164	NW92	NW293	NW39	NW125	NW46	NW176	NW298	NW97	NW220	NW54	NW119	NW179	NW78	NW155	NW214	NW202	NW45	NW123	NW198	NW127	NW139	NW290	NW121	NW49	NW296	NW258	NW44	NW26	NW281	NW194



# Proximal phenotyping (growth stages)

- GS21 Beginning of jam formation:
  - Cereals begin to form side shoots, which will be an additional source of grain.
- GS65 Full flowering:
  - The plant is in full bloom and all the flowers have opened.
- GS73 Beginning of milk ripening:
  - The grains begin to fill with a milky liquid, but are not yet fully ripe.



A challenge for an IT specialist, specific knowledge in agriculture is required

# UAV missions

- 0-02-May
- 1-11-May
- 2-23-May
- 3-30-May
- 4-07-Jun
- 5-16-Jun
- 6-26-Jun
- 7-03-Jul
- 8-11-Jul
- 9-20-Jul
- 10-31-Jul





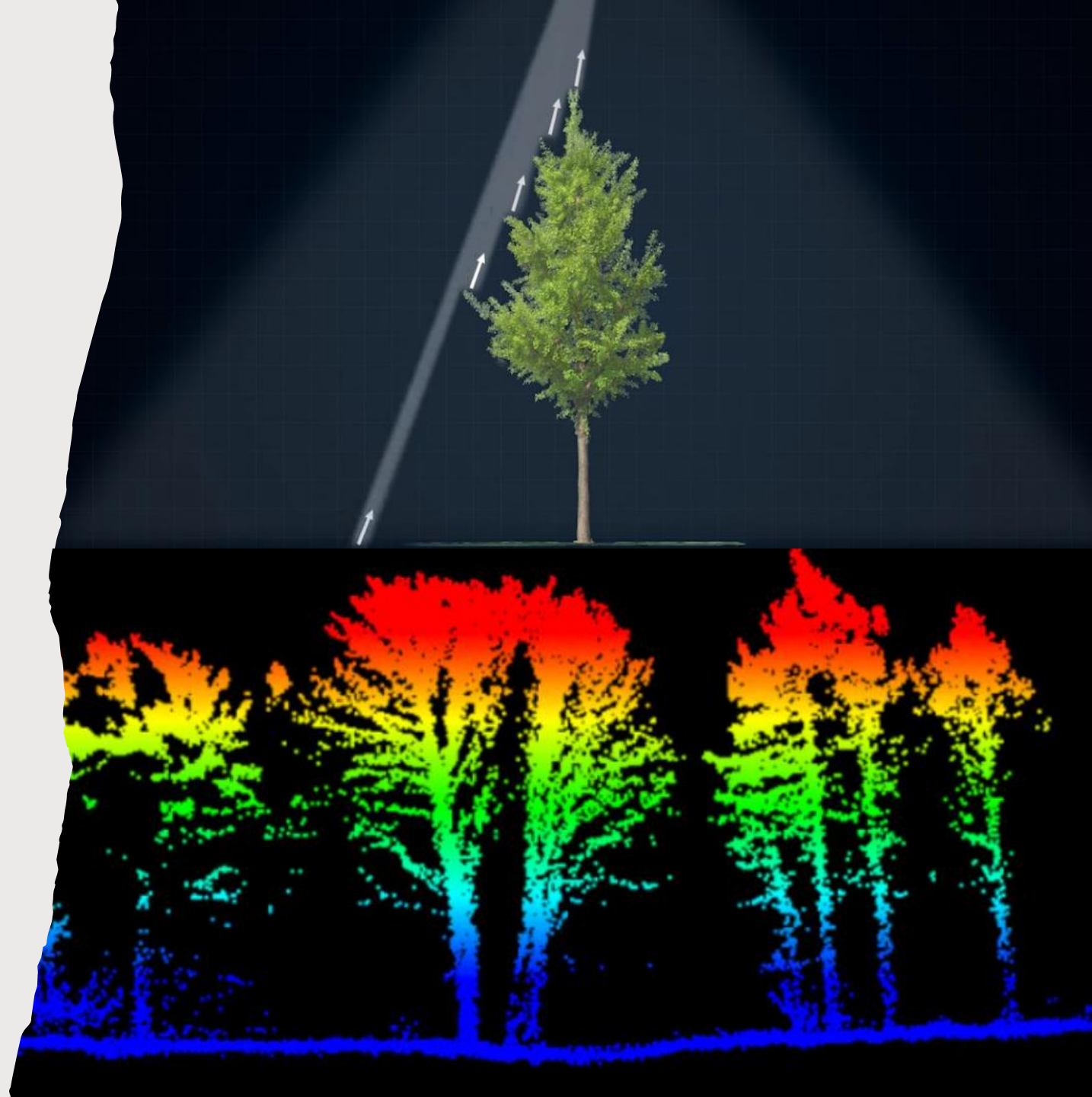
# The experiment (Stargate project)

## Another excel (the design)

Lauka, kas tiek ievesti		Mācību	
V01AD01	V01AD02	V01AD03	V01AD04
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151	157	163	169
175	181	187	193
200	206	212	218
224	230	236	242
248	254	260	266
292	298	304	310
316	322	328	334
340	346	352	358
372	378	384	390
396	402	408	414
420	426	432	438
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592	598	604	610
616	622	628	634
640	646	652	658
664	670	676	682
696	702	708	714
720	726	732	738
752	758	764	770
776	782	788	794
800	806	812	818
824	830	836	842
848	854	860	866
880	886	892	898
904	910	916	922
928	934	940	946
960	966	972	978
992	998	1004	1010
1016	1022	1028	1034
1040	1046	1052	1058
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1224	1230	1236	1242
1248	1254	1260	1266
1280	1286	1292	1298
1304	1310	1316	1322
1328	1334	1340	1346
1360	1366	1372	1378
1392	1398	1404	1410
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1560	1566	1572	1578
1592	1598	1604	1610
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1800	1806	1812	1818
1824	1830	1836	1842
1848	1854	1860	1866
1880	1886	1892	1898
1904	1910	1916	1922
1928	1934	1940	1946
1960	1966	1972	1978
1992	1998	2004	2010
2016	2022	2028	2034
2040	2046	2052	2058
2072	2078	2084	2090
2104	2110	2116	2122
2128	2134	2140	2146
2160	2166	2172	2178
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2224	2230	2236	2242
2248	2254	2260	2266
2280	2286	2292	2298
2304	2310	2316	2322
2328	2334	2340	2346
2360	2366	2372	2378
2392	2398	2404	2410
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2560	2566	2572	2578
2592	2598	2604	2610
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2792	2798	2804	2810
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2880	2886	2892	2898
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3048	3054	3060	3066
3080	3086	3092	3098
3104	3110	3116	3122
3128	3134	3140	3146
3160	3166	3172	3178
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3200	3206	3212	3218
3224	3230	3236	3242
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3560	3566	3572	3578
3592	3598	3604	3610
3600	3606	3612	3618
3624	3630	3636	3642
3648	3654	3660	3666
3680	3686	3692	3698
3704	3710	3716	3722
3728	3734	3740	3746
3760	3766	3772	3778
3792	3798	3804	3810
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3880	3886	3892	3898
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3992	3998	4004	4010
4000	4006	4012	4018
4024	4030	4036	4042
4048	4054	4060	4066
4080	4086	4092	4098
4104	4110	4116	4122
4128	4134	4140	4146
4160	4166	4172	4178
4192	4198	4204	4210
4200	4206	4212	4218
4224	4230	4236	4242
4248	4254	4260	4266
4280	4286	4292	4298
4304	4310	4316	4322
4328	4334	4340	4346
4360	4366	4372	4378
4392	4398	4404	4410
4400	4406	4412	4418
4424	4430	4436	4442
4448	4454	4460	4466
4480	4486	4492	4498
4504	4510	4516	4522
4528	4534	4540	4546
4560	4566	4572	4578
4592	4598	4604	4610
4600	4606	4612	4618
4624	4630	4636	4642
4648	4654	4660	4666
4680	4686	4692	4698
4704	4710	4716	4722
4728	4734	4740	4746
4760	4766	4772	4778
4792	4798	4804	4810
4800	4806	4812	4818
4824	4830	4836	4842
4848	4854	4860	4866
4880	4886	4892	4898
4904	4910	4916	4922
4928	4934	4940	4946
4960	4966	4972	4978
4992	4998	5004	5010
5000	5006	5012	5018
5024	5030	5036	5042
5048	5054	5060	5066
5080	5086	5092	5098
5104	5110	5116	5122
5128	5134	5140	5146
5160	5166	5172	5178
5192	5198	5204	5210
5200	5206	5212	5218
5224	5230	5236	5242
5248	5254	5260	5266
5280	5286	5292	5298
5304	5310	5316	5322
5328	5334	5340	5346
5360	5366	5372	5378
5392	5398	5404	5410
5400	5406	5412	5418
5424	5430	5436	5442
5448	5454	5460	5466
5480	5486	5492	5498
5504	5510	5516	5522
5528	5534	5540	5546
5560	5566	5572	5578
5592	5598	5604	5610
5600	5606	5612	5618
5624	5630	5636	5642
5648	5654	5660	5666
5680	5686	5692	5698
5704	5710	5716	5722
5728	5734	5740	5746
5760	5766	5772	5778
5792	5798	5804	5810
5800	5806	5812	5818
5824	5830	5836	5842
5848	5854	5860	5866
5880	5886	5892	5898
5904	5910	5916	5922
5928	5934	5940	5946
5960	5966	5972	5978
5992	5998	6004	6010
6000	6006	6012	6018
6024	6030	6036	6042
6048	6054	6060	6066
6080	6086	6092	6098
6104	6110	6116	6122
6128	6134	6140	6146
6160	6166	6172	6178
6192	6198	6204	6210
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6424	6430	6436	6442
6448	6454	6460	6466
6480	6486	6492	6498
6504	6510	6516	6522
6528	6534	6540	6546
6560	6566	6572	6578
6592	6598	6604	6610
6600	6606	6612	6618
6624	6630	6636	6642
6648	6654	6660	6666
6680	6686	6692	6698
6704	6710	6716	6722
6728	6734	6740	6746
6760	6766	6772	6778
6792	6798	6804	6810
6800	6806	6812	6818
6824	6830	6836	6842
6848	6854	6860	6866
6880	6886	6892	6898
6904	6910	6916	6922
6928	6934	6940	6946
6960	6966	6972	6978
6992	6998	7004	7010
7000	7006	7012	7018
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7080	7086	7092	7098
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7304	7310	7316	7322
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7400	7406	7412	7418
7424	7430	7436	7442
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7480	7486	7492	7498
7504	7510	7516	7522
7528	7534	7540	7546
7560	7566	7572	7578
7592	7598	7604	7610
7600	7606	7612	7618
7624	7630	7636	7642
7648	7654	7660	7666
7680	7686	7692	7698
7704	7710	7716	7722
7728	7734	7740	7746
7760	7766	7772	7778
7792	7798	7804	7810
7800	7806	7812	7818
7824	7830	7836	78

# LiDAR capabilities

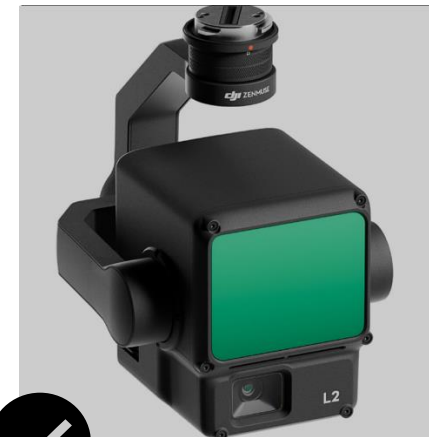
- Several levels of light beam reflection
- Classification
- Resources for research
  - <https://levelfivesupplies.com/100-real-world-applications-of-lidar-technology/>





# Technical resources

- We have
  - DJI Matrice 300
  - Sentera Multispectral
  - Pix4D Mapper
  - QGIS
- Purchased, but needs to be learned
  - DJI Zenmuse L2 LiDAR\*
- New learning challenges
  - AI (Artificial Intelligence)
  - GIS (Geographic Information Systems)



**LiDAR**(Light Detection and Ranging) is a technology that uses laser beams to measure distances and create three-dimensional (3D) images and models of the surrounding environment.

# Problem

- Economic productivity and competitiveness are essential for improving national well-being. The advantages are in high value-added sectors. **The untapped potential of technology is still an underutilized growth opportunity.**
- **We live in an era where technology and society are evolving faster than most companies can adapt.** Survival will not depend on strength or intelligence, but on the ability to adapt.
- **Technology is evolving exponentially, while society's ability to use it is lagging behind.** There is a growing digital divide between technological transformation and the ability of companies to apply it in production and management to drive efficiency and innovation.

• January 2019 DOI: [10.22364/pctni.06](https://doi.org/10.22364/pctni.06) In book: Produktivitātes celšana: tendences un nākotnes izaicinājumi = Raising Productivity: Trends and Future Challenges. Juris Binde



# Research question and focus

- How can a scalable and flexible system be designed to integrate diverse data sources (multispectral, LiDAR, IoT sensors) with actual manual field observations, meteorological information, harvest data and historical data for precision agriculture?
- Focus: System architecture and modularity.

## Problem statement:

Integrating multispectral, LiDAR, sensor, and historical data into a unified geospatial model for precision agriculture presents key challenges. The gap between technical experts and agricultural professionals highlights the need for a unified approach, shared understanding, and clear methodology for data acquisition and transformation in an ever-evolving technological landscape.

## Aim of this work:

- UAV mapping and optimization in precision agriculture;
- Development of comprehensive methodology for designing and rapidly adjusting data acquisition, processing, and maintenance systems for data science applications in precision agriculture.

# All stakeholders must come to a common understanding

- This is the first version – general understanding
- The goal must be formulated to the end, separate tasks must be allocated
- Tools and methods must be chosen
- The author's new contribution must be specified

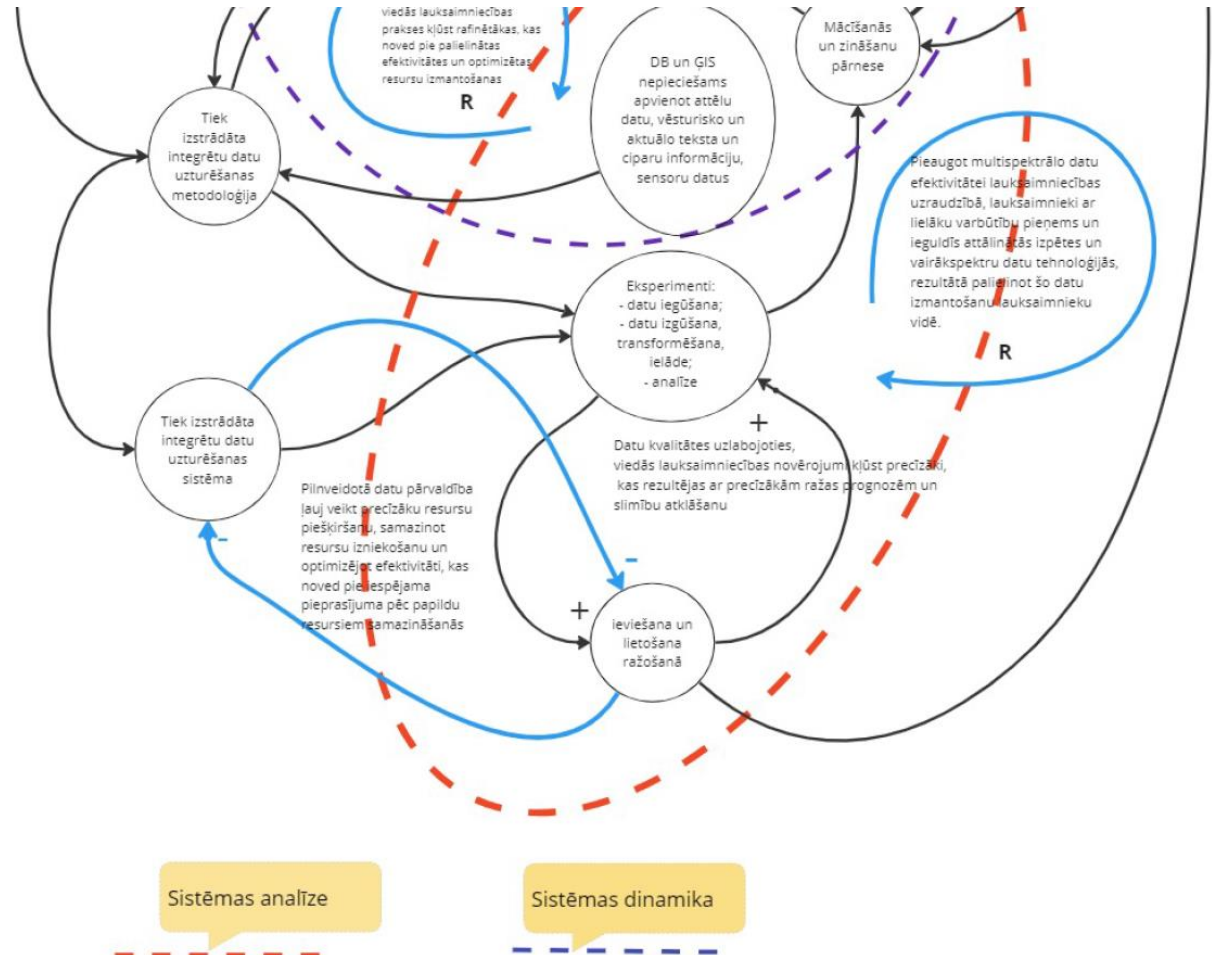


A transparent, universally understandable concept must be validated and verified

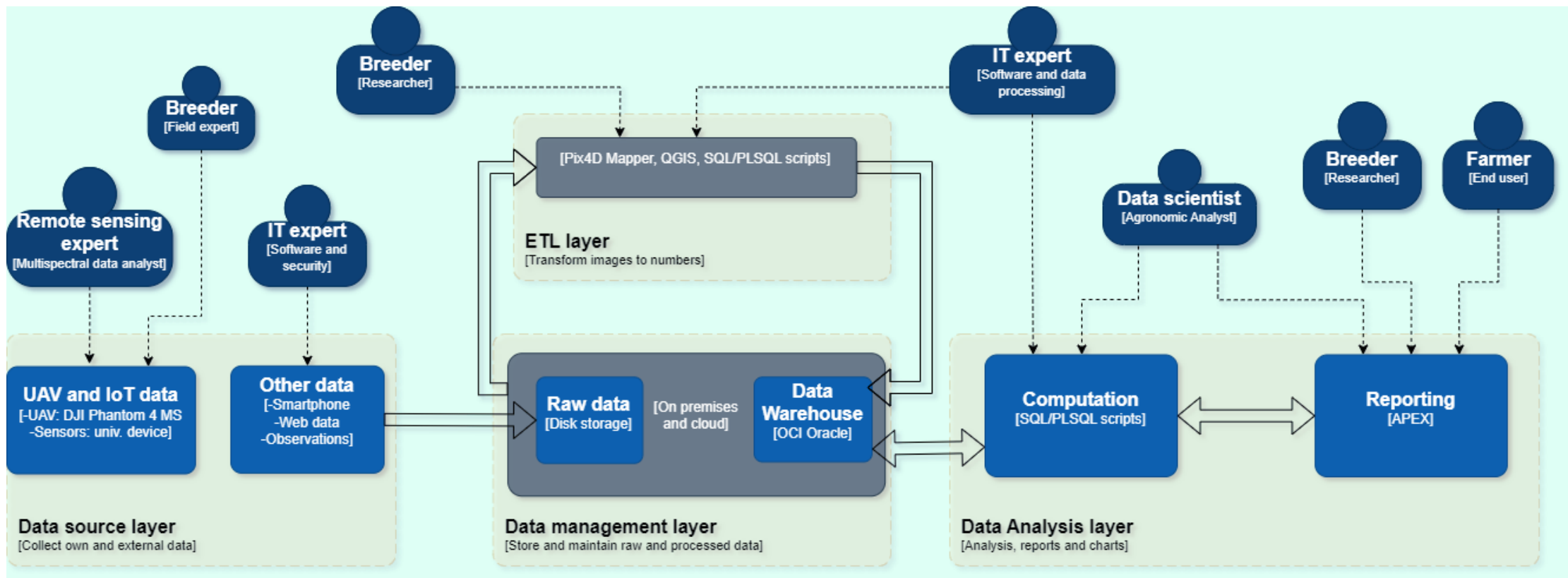


# How to perform these tasks?

- Requirements model, the creation of which has several (as many as necessary) iterations
- Financing and implementation

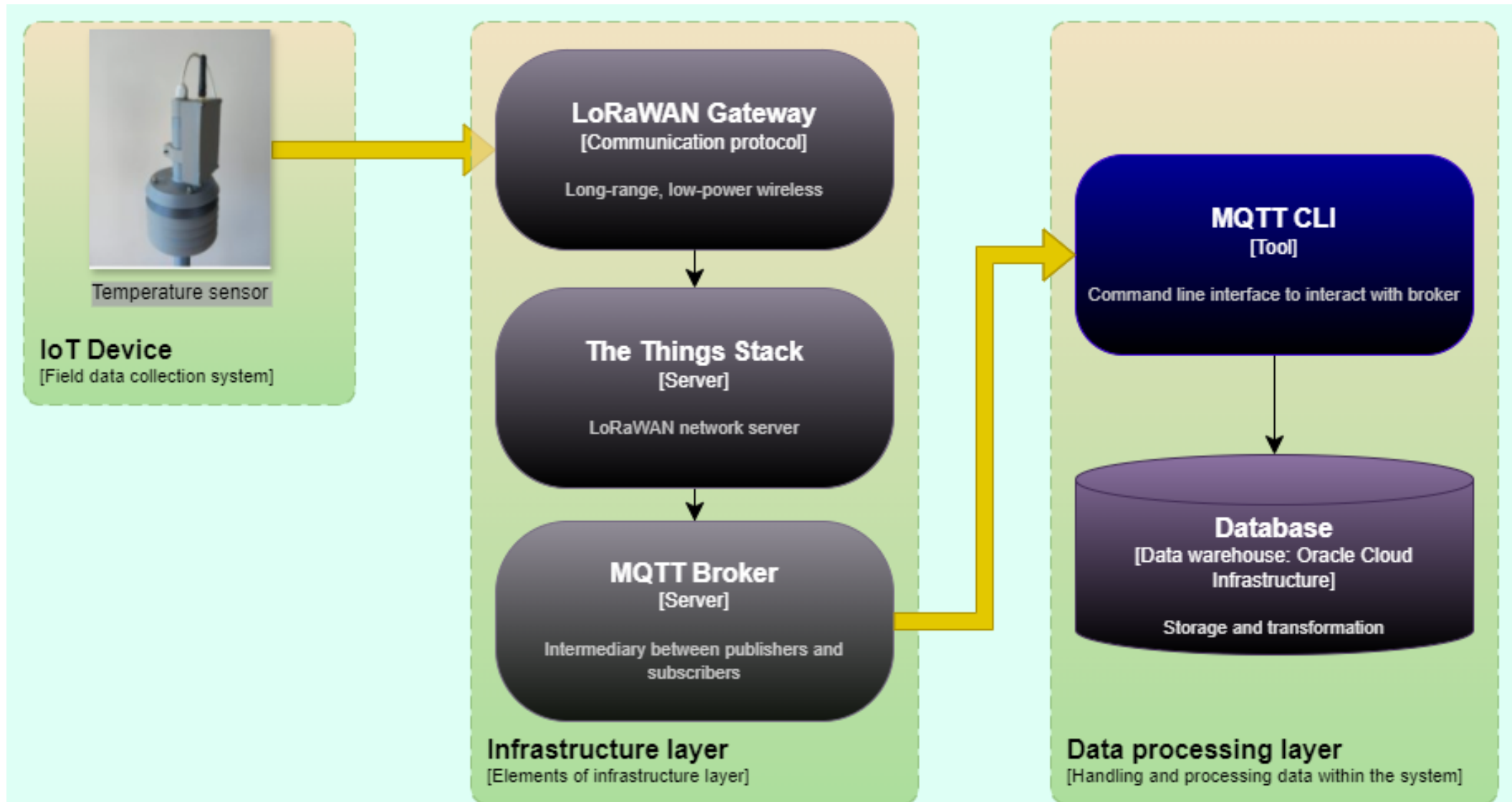


# Architecture for multispectral data acquisition, integration and analysis





# IoT data processing architecture



# Database: OCI as platform and flexible Data model

Generativity.

It is a technology's capability of producing new outputs without input from the originator.

Scalability.

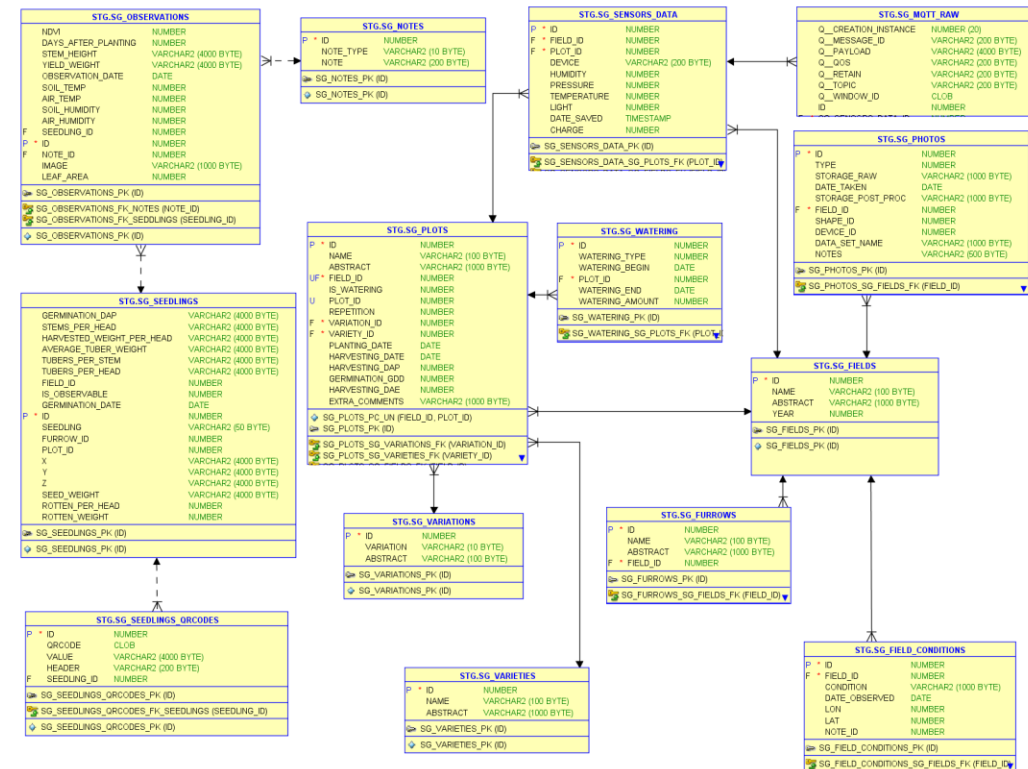
Ability to handle growing volumes of data and increasing complexity of processes as precision agriculture advances.

Accessability.

Easy access for different users, with varying levels of expertise.

Interoperability.

Compatible with various tools, databases, and platforms, allowing users to integrate other technologies or data sources easily.

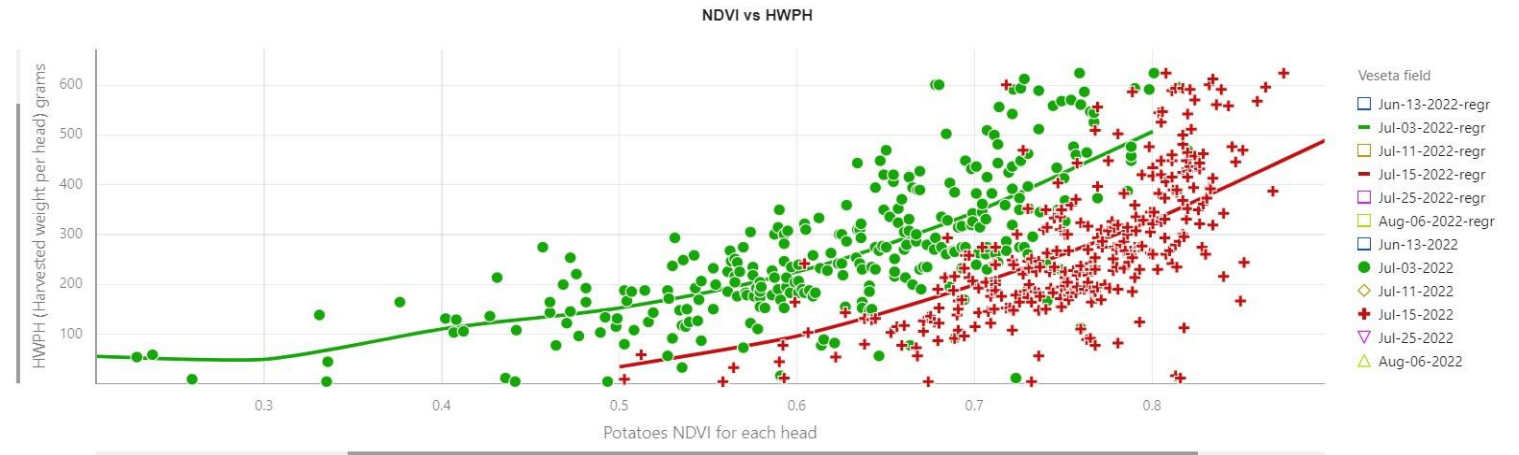


Sun, R., Gregor, S., Fielt, E. (2021). Generativity and the paradox of stability and flexibility in a platform architecture: A case of the oracle cloud platform, Information & Management 58(8), 103548.

<https://www.sciencedirect.com/science/article/pii/S0378720621001221>



# User interface, charts, reports



SG-1

apex\_public\_user

Sākums / Home

QR tests / testing QR

Stāds no QR / Seedling from QR

QR kodi / QR codes

**Novērojumi / Observations**

Stādi / Seedlings

Lauki / Fields

Laučiņi / Plots

Vāgas / Furrows

Šķirnes / Varieties

Stādu kodi / Seedling codes

Laučiņu dati / Plot data

Piezīmes / Notes

Seedlings / Observations

Visi novērojumi / All obs

Home \

**Novērojumi / Observations**

				Attēls/Image	Saite/Link
		08-JUN-21	V01BL10	Dzertē lapas (10%)	
	.56	16-JUN-21	V01BL10	NDVI zonālā statistiskā vērtība	
	.77	12-JUL-21	V01BL10	NDVI zonālā statistiskā vērtība	
		27-JUL-21	V01BL10		07272021-1241_image.jpg
		29-JUL-21	V01BL10		07292021-1648_image.jpg
		29-JUL-21	V01BL10	Priekšlaikus izraksts	
		29-JUL-21	V01BL10	Meinājuma	
		29-JUL-21	V01BL10		07292021-1620_image.jpg
		29-JUL-21	V01BL10		07292021-1624_image.jpg
		29-JUL-21	V01BL10		

1 - 10

Jauns novērojums/New Observation

Rediģēt stādu/Edit seedling

Atpakaļ/Back to Seedling

# What is it, or a container terminal?



Integrated data, available in the database, geospatially correct positions, offered to the user as an easy-to-use product in a GIS environment. Blue containers show harvested



# Novelty

---

- **Flexibility and adaptability, user-oriented design:** Unlike existing solutions, which often provide rigid frameworks for specific problems, this methodology offers a scalable and modular approach, allowing users to **rapidly adjust** systems to evolving data sources, tools, and technologies in agriculture.

Key novel aspects include:

- **Customizable and Dynamic System Design:** The methodology emphasizes the ability to quickly integrate new tools, such as UAV-based multispectral imaging, LiDAR, IoT sensors, and historical data. This flexibility is crucial for addressing the constantly changing technological landscape in precision agriculture.
- **Modular and Service-Oriented Architecture:** It introduces a modular structure that can be adapted to different agricultural tasks with minimal disruption, enhancing the ease of customization for various use cases and tools.
- **Focus on Real-Time Data Integration:** By providing a framework for seamless integration of diverse, multimodal data (e.g., geospatial, sensor, historical data), the methodology oriented to support real-time decision-making and data processing.
- **Cross-Disciplinary Knowledge Transfer:** The research addresses the gap between IT specialists and agricultural professionals, offering methods to enhance collaboration, reduce friction, and promote knowledge sharing across domains.
- **Rapid Customization for Emerging Technologies:** Unlike other systems that may become outdated as new tools are introduced, this methodology allows users to modify and expand the system as new technologies and data sources emerge.
- **AI-ready:** Consolidated data is now accessible through a unified interface, optimized for downstream use with language models (LMs) and deep learning (DL) tools.
- **Agile and DevOPS:** Methodologies not only for system development but as well for data collection and processing methods.

# Development methodology

- Software and systems development
- Roadmap for smart agriculture development
- What innovations could be applied

Decade	Methodology / Trend	Key Innovations
1970s–1980s	Waterfall	Sequential Phases
1990s	Spiral, Iterative	Risk-driven Development, Incremental Delivery
2000s	Agile	Scrum, XP, User Feedback Loops
2010s	DevOps	CI/CD, Infrastructure as Code (IaC), Docker, Kubernetes
2020s	Cloud-Native, SRE	Microservices, GitOps, Observability
2020s–2025	Platform Engineering	Internal Developer Platforms, Developer Experience (DevEx)
2025+	AI-Driven Development, Autonomous Systems	AI Coding, AIOps, Self-Healing Systems

Era	Methodology / Focus	Key Characteristics
Pre-2000s	Traditional Methods	Manual data collection, intuition-based decisions
2000s	Basic Digitization	Introduction of GPS, spreadsheets, simple sensors
2010s	Precision Agriculture	IoT sensors, satellite imagery, variable-rate tech
2020s	Smart Agriculture	AI, ML, cloud platforms, mobile apps, drones
2025+	Autonomous & AI-Guided Farming	Robotics, AI decision systems, edge computing, predictive models, blockchain traceability

# Future innovations in Smart Agriculture development methodologies

- **AI-Powered Soil & Crop Health Diagnostics**
  - **Multi-modal Sensing with Predictive Analytics**
  - **Combining drone imagery, soil sensors, and satellite data analyzed by AI for early disease, nutrient deficiency, or pest detection.**

Area	Potential Innovation	Description / Application in Smart Ag
AI-Driven Adaptive Planning	<i>Real-time AI Optimization of Crop Plans</i>	Systems that dynamically adjust planting, watering, and fertilization schedules based on live sensor and weather data.
Digital Twins of Farms	<i>Full-Farm Simulation Environments</i>	Virtual replicas of entire farms to test interventions, crop rotations, or machinery changes without risking real assets.
Swarm Robotics Coordination	<i>Autonomous Drone and Robot Swarms</i>	Coordinated fleets of drones/robots that collaboratively manage large fields, perform planting, pest control, and harvesting.
Blockchain for Traceability & Incentives	<i>Decentralized Crop Provenance &amp; Carbon Credits</i>	Transparent supply chains and incentivization of sustainable practices using blockchain tokens or smart contracts.
AI-Powered Soil & Crop Health Diagnostics	<i>Multi-modal Sensing with Predictive Analytics</i>	Combining drone imagery, soil sensors, and satellite data analyzed by AI for early disease, nutrient deficiency, or pest detection.
Edge AI with Low Power Sensors	<i>On-Device AI for Real-Time Decision Making</i>	Sensor devices that process data locally to reduce latency and reliance on cloud, enabling instant interventions.
MLOps for Ag Models	<i>Continuous Training and Deployment of Crop Prediction Models</i>	Robust pipelines to update AI models as new data arrives, ensuring accuracy and adaptability.
Human-AI Co-Governance Frameworks	<i>Farmers and AI Systems Collaborate on Decisions</i>	Methodologies that formalize trust, oversight, and feedback between human farmers and AI recommendations.
Augmented Reality (AR) for Field Management	<i>AR Interfaces for Real-Time Field Data Visualization</i>	Allowing farmers to visualize soil moisture, pest presence, or growth metrics overlaid on actual crops through AR glasses or mobile apps.
Sustainability-Focused Dev Methodologies	<i>Incorporating Environmental Impact Metrics into Dev Cycles</i>	Frameworks that mandate measuring water use, emissions, and biodiversity impact during software/technology development.



# Conclusions

## •Respect Legacy, enable transition

Rather than disrupting long-standing practices, focus on *empowering them through structured transformation*. Avoid struggling against entrenched ways of working. Instead, develop and apply a **robust data and knowledge migration methodology**, supported by intuitive tools that make the transition natural, not forced. This approach fosters adoption, preserves valuable expertise, and ensures continuity.

## •Build an Interdisciplinary Core Team

The complexity of modern data systems demands diverse perspectives. Forming an **interdisciplinary team** - blending domain experts, technologists, data scientists, and operations specialists - ensures that solutions are both technically good and practically relevant.

## •Innovate at the intersections

The **future of data collection and processing is interdisciplinary innovation**. True scalability and intelligence emerge when we integrate **sensors, robotics, environmental science, AI, and productivity tools** into unified, adaptive systems. These hybrid solutions enable dynamic monitoring, real-time analysis, and informed decision-making, even in complex environments.

```
-- Main PL/SQL Script for Seedling Processing

DECLARE
    r          VARCHAR2(100);      -- Holds value read from source table
    qry        VARCHAR2(200);      -- Dynamic SQL query
    qryW       VARCHAR2(200);      -- Dynamic SQL query for weight
    w          NUMBER;             -- Seed weight
    nID        NUMBER;             -- Placeholder for row ID
    npID       NUMBER;             -- Not used in current logic
    nF         NUMBER := 0;        -- Furrow counter
    nCn        NUMBER;             -- Column counter within row
    nSeedling  NUMBER;             -- Seedling flag
    vSeedling  VARCHAR2(20);       -- Transformed seedling name
    nWeight    NUMBER;             -- Extracted seed weight
    dSDate     DATE;               -- Germination date
    vInsSQL    VARCHAR2(500);      -- SQL insert statement
BEGIN
    -- Loop through each relevant row in the source table
    FOR i IN (
        SELECT id
        FROM LAUKA_PLANOJUMS_12052023
        WHERE id < 53 AND id > 1
        ORDER BY id
    ) LOOP
        nCn := 1; -- Reset column index for each row

        -- Loop through all columns except excluded ones
        FOR c IN (
            SELECT column_name AS cn
            FROM user_tab_columns
            WHERE table_name = 'LAUKA_PLANOJUMS_12052023'
            AND column_name NOT IN ('ID', 'COLUMN_61', 'COLUMN_62', 'COLUMN_63', 'COLU
        ) LOOP

            -- Dynamically get column value for current row
            qry := 'SELECT ' || c.cn || ' FROM LAUKA_PLANOJUMS_12052023 WHERE id = :1'
            EXECUTE IMMEDIATE qry INTO r USING i.id;

            IF r IS NOT NULL THEN
                -- Check if value is a short string and not a number or date
                IF LENGTH(r) < 10 AND is date(r) = 0 AND is number(r) = 0 THEN
```

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# Phenotypic Variation and Relationships between Grain Yield, Protein Content and Unmanned Aerial Vehicle-Derived Normalized Difference Vegetation Index in Spring Wheat in Nordic–Baltic Environments

by Zaiga Jansone <sup>1,2</sup> , Zigmārs Rendenieks <sup>1</sup> , Andris Lapāns <sup>1</sup> , Ilmar Tamm <sup>3</sup> , Anne Ingvar <sup>3</sup> , Andrii Gorash <sup>4</sup> , Andrius Aleliūnas <sup>4</sup> , Gintaras Brazauskas <sup>4</sup> , Sahameh Shafiee <sup>5</sup> , Tomasz Mróz <sup>5</sup> , Morten Lillemo <sup>5</sup> , Hannes Kollist <sup>6</sup> and Māra Bleidere <sup>1,\*</sup>

<sup>1</sup> Research Department, Institute of Agricultural Resources and Economics, Stende Research Centre, Stende, LV-2009 Dižstende, Latvia

<sup>2</sup> Institute of Life Sciences and Technologies, Lielā Street 2, LV-3001 Jelgava, Latvia

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<sup>4</sup> Lithuanian Research and Forestry, Kadainiai Reg., LT-56344

<sup>5</sup> NO-1433 Ås, Norway

Knowledge transfer, publications

# Current challenges

- Submit publication
- LiDAR data processing workflows (methodology for AREI)
- Literature review

Standard operating procedures for UAV phenotyping. url: [https://excellenceinbreeding.org/sites/default/files/manual/EiB\\_M4\\_%20SOP-UAV-Phenotyping-12-10-20.pdf](https://excellenceinbreeding.org/sites/default/files/manual/EiB_M4_%20SOP-UAV-Phenotyping-12-10-20.pdf).

Biomass Prediction with 3D Point Clouds from LiDAR. url: [https://openaccess.thecvf.com/content/WACV2022/papers/Pan\\_Biomass\\_Prediction\\_With\\_3D\\_Point\\_Clouds\\_From\\_LiDAR\\_WACV\\_2022\\_paper.Pdf](https://openaccess.thecvf.com/content/WACV2022/papers/Pan_Biomass_Prediction_With_3D_Point_Clouds_From_LiDAR_WACV_2022_paper.Pdf).

Soumya Debnath, Manik Paul, and Tanmoy Debnath. “Applications of LiDAR in Agriculture and Future Research Directions”. In: J Imaging 9.3 (Feb. 2023), p. 57. doi: 10.3390/jimaging9030057. url: <https://doi.org/10.3390/jimaging9030057>

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# Publication in process

The screenshot shows a web application interface for manuscript preparation. The top navigation bar includes links for Menu, Upgrade, Review, Share, Submit, History, Layout, and Chat. The main content area is divided into three sections: a left sidebar with a file explorer showing various image and text files, a central map view displaying a geographical area with a blue location pin, and a right panel showing the manuscript title, authors, and abstract. The title is "An in-house solution for the integration of multispectral photogrammetry data and IoT for potato field monitoring". The authors are Andris Lapans<sup>1</sup>, Sandro Bimonte<sup>2</sup>, Jean-Baptiste Pichancourt<sup>3</sup>, and Ginta Majore<sup>4</sup>. The abstract discusses the integration of multispectral photogrammetry data and IoT for potato field monitoring.

The screenshot shows a manuscript submission and review interface. The top navigation bar includes links for JOURNALS, PUBLISH, COMMUNITIES, and HUBS. The main content area displays the manuscript title, authors, and a list of reviewers. The manuscript title is "An in-house solution for the integration of multispectral photogrammetry data and IoT for potato field monitoring". The authors are Andris Lapans, Sandro Bimonte, Jean-Baptiste Pichancourt, and Ginta Majore. The reviewers are listed with their names, dates, and actions. A sidebar on the left shows the manuscript status and a list of reviewers. A sidebar on the right shows the possible payments due, including a 3 authors fee and an Article Processing Charge.

# Questions?

Skrabule, I., Bebre, G. (2013). Development of potato varieties in latvia, Proceedings of the Latvian Academy of Sciences. Section B. Natural, Exact, and Applied Sciences. 67(3), 296– 301. <https://doi.org/10.2478/prolas-2013-0052>

Jansone Z, Rendenieks Z, Lapāns A, Tamm I, Ingver A, Gorash A, Aleliūnas A, Brazauskas G, Shafiee S, Mróz T, et al. Phenotypic Variation and Relationships between Grain Yield, Protein Content and Unmanned Aerial Vehicle-Derived Normalized Difference Vegetation Index in Spring Wheat in Nordic–Baltic Environments. Agronomy. 2024; 14(1):51. <https://doi.org/10.3390/agronomy14010051>



Breeder's notes: Genovefa Timule