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

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Funded by
the European Union

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

21-Oct-2024

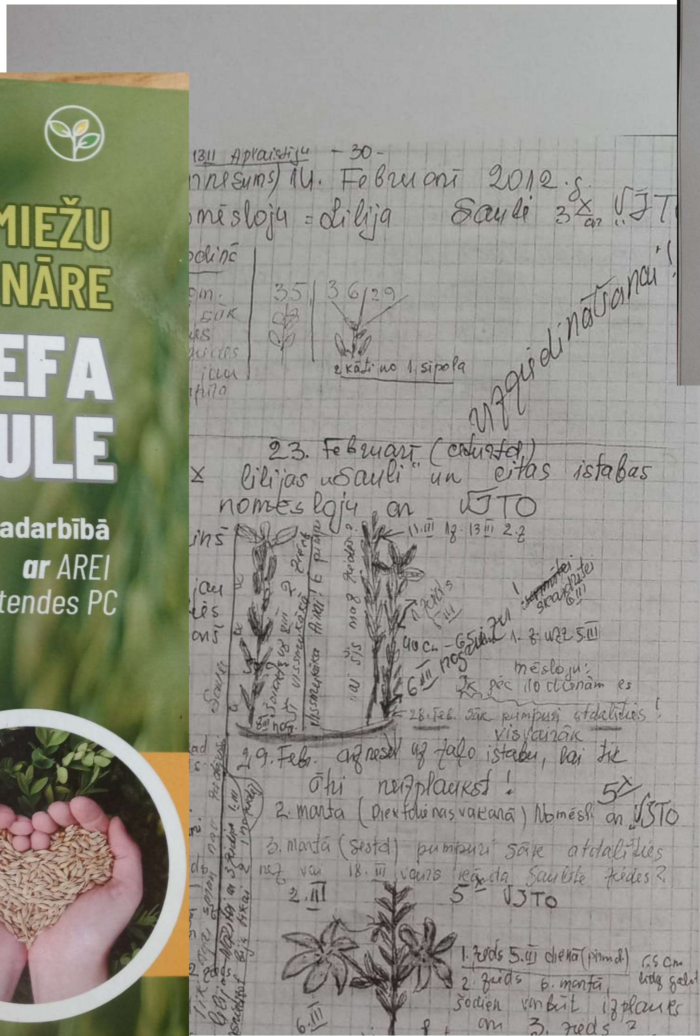
Vidzeme University of Applied Sciences cooperation with Institute of Agricultural Resources and Economics

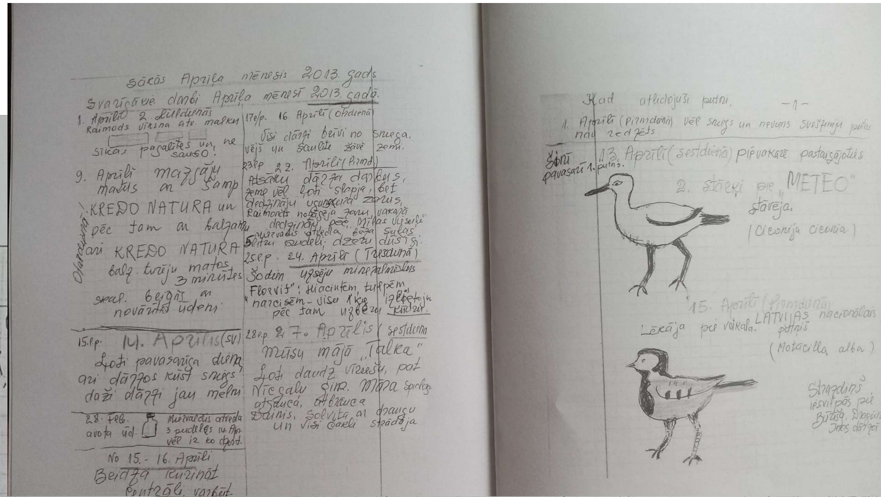
Education institution and an important bioeconomy industry research and leading field plant breeding institute with more than 100 years of history cooperation with high school.

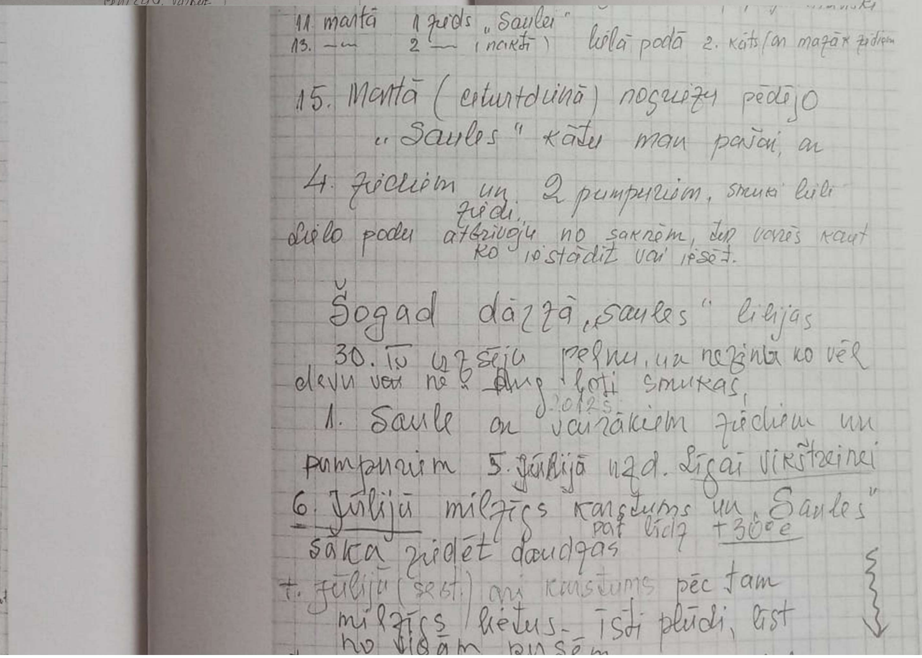
History and operation

- **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**

Historical experience

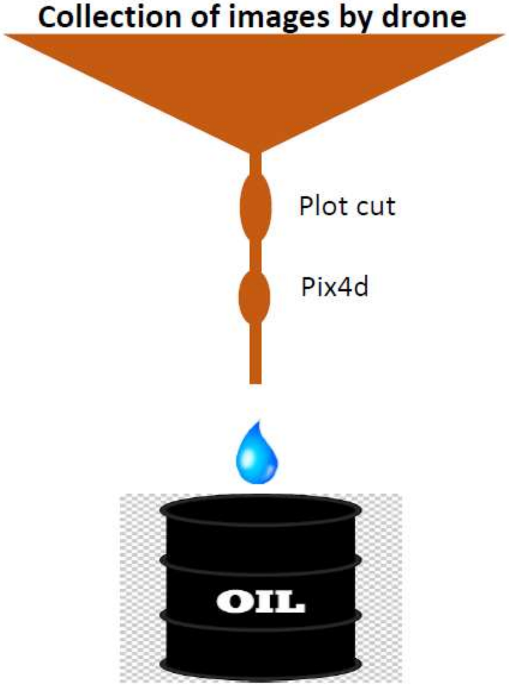






Experience of Norwegian colleagues

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

Graminor

Today's activities

- **Modern technologies, such as precision agriculture**
- **International projects**
- **Standardized work methods, work protocols**
- **New tools and software**
- **Conferences and webinars**
- **...**

LITHUANIAN RESEARCH CENTRE FOR AGRICULTURE AND FORESTRY

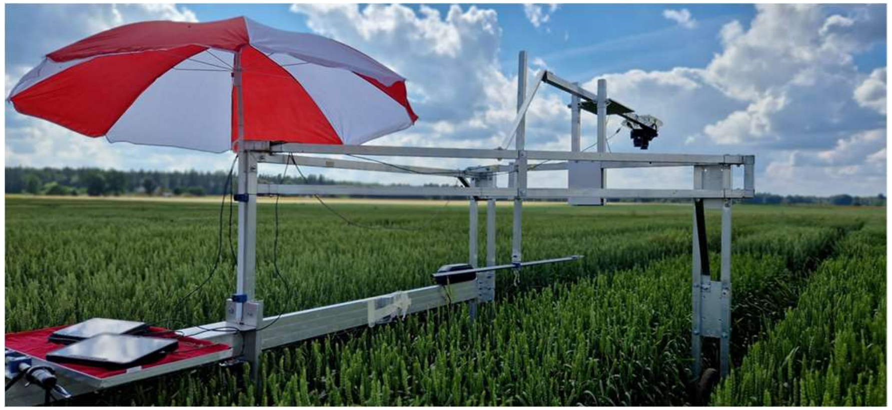
Norwegian University of Life Sciences

AREI

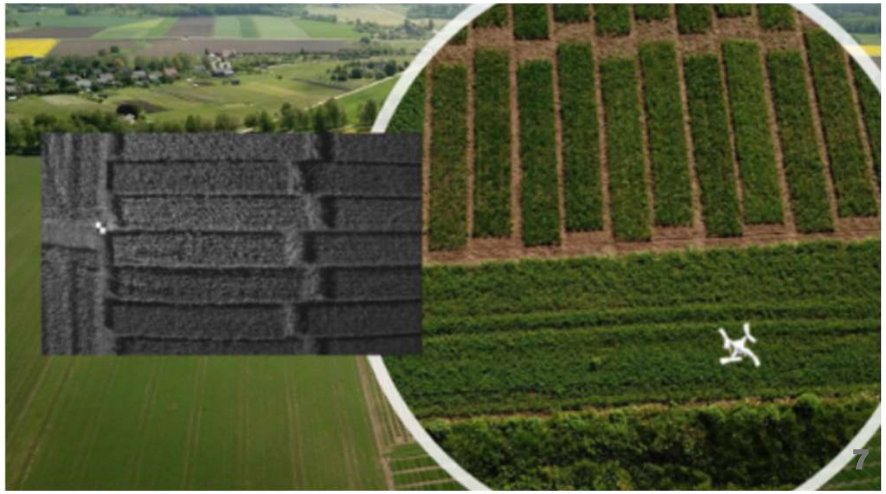
Estonian Crop Research Institute

International NOBAL Wheat Project

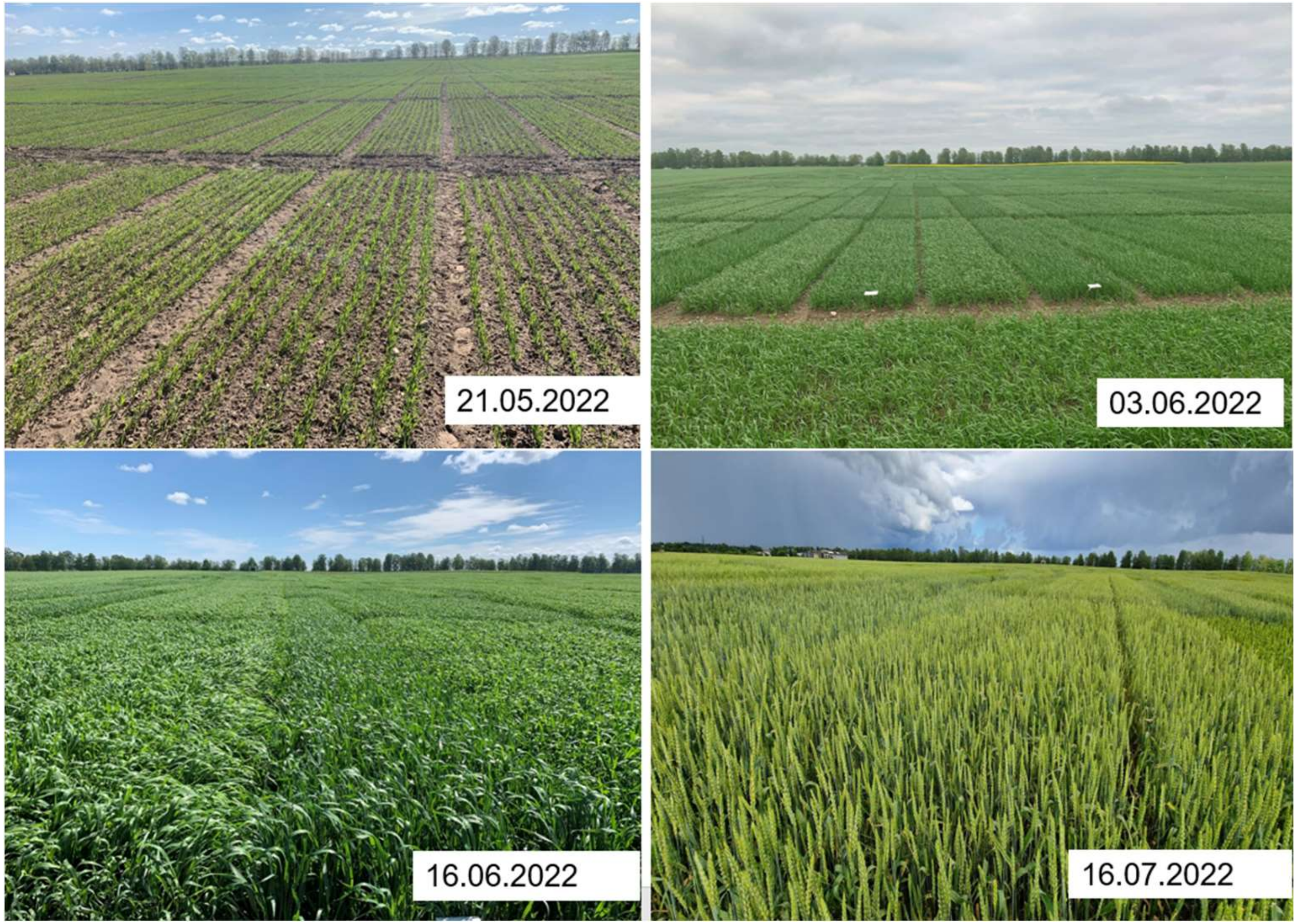
- **A three-year project that gave us stability and confidence in what we do**
  - **Higher work efficiency**
  - **Improved competences**
  - **Better productivity**
  - **Innovative solutions**
  - **Cooperation experience**
  - **Market knowledge**
  - **Strategic thinking**
  - **New data collection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



Phenomobile vs UAV



Data series (3 years x 10 missions) using UAV



Orthophoto map

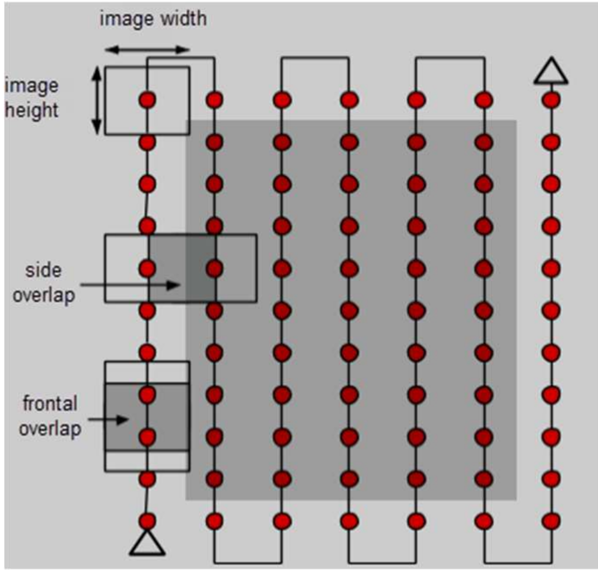
- **Gets data when and where it is needed, with the necessary accuracy and resolution**
- **Compatibility with other resources in the GIS environment**
- **Required GSD* at least 1cm**
- **Shift of images between missions no more than 3cm**

***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

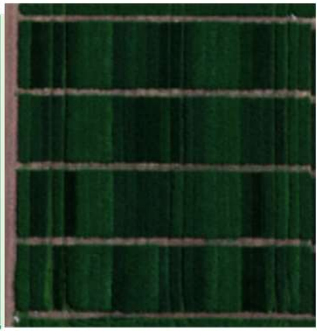


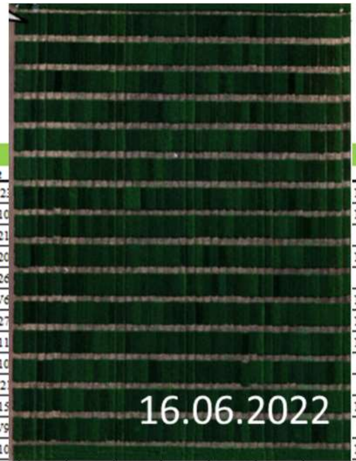
The gray area is the research area.
Image coverage not less than 70% and not more than 85%.
If you want to get a 2D orthophoto, then point the camera vertically down.
If a 3D object or surface model is required, the camera is turned at an angle of approximately 15 degrees from the vertical.

Field planning

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

Replication 2; randomized																			
21	22	23	24	25	26	27	28	29	30	31	32								40
NW117	NW60	NW71	NW263	NW181	NW111	NW261	NW299	NW300	NW256	NW13	[illegible]								NW164
NW86	NW249	NW145	NW69	NW99	NW129	NW34	NW182	NW128	NW19	NW52	[illegible]								NW162
NW253	NW109	NW264	NW283	NW143	NW108	NW17	NW217	NW147	NW169	NW252	[illegible]								NW27
NW56	NW185	NW126	NW243	NW209	NW67	NW2	NW64	NW103	NW206	NW132	[illegible]								NW286
NW231	NW68	NW12	NW110	NW218	NW192	NW237	NW35	NW154	NW31	NW32	[illegible]								NW47
NW149	NW97	NW73	NW239	NW235	NW171	NW130	NW95	NW184	NW11	NW88	[illegible]								NW210
NW223	NW40	NW250	NW138	NW189	NW106	NW33	NW89	NW10	NW83	NW96	[illegible]								NW272
NW93	NW53	NW58	NW279	NW25	NW57	NW196	NW18	NW270	NW240	NW76	[illegible]								NW259
NW208	NW141	NW166	NW172	NW288	NW133	NW16	NW70	NW247	NW43	NW241	[illegible]								NW8
NW55	NW29	NW50	NW287	NW20	NW205	NW257	NW297	NW178	NW148	NW230	[illegible]								NW5
NW163	NW292	NW4	NW105	NW282	NW81	NW41	NW3	NW62	NW298	NW245	[illegible]								NW285
NW160	NW236	NW61	NW48	NW113	NW212	NW91	NW295	NW134	NW293	NW168	[illegible]								NW39
NW227	NW204	NW125	NW120	NW280	NW144	NW84	NW268	NW180	NW215	NW200	[illegible]								NW102
NW72	NW85	NW24	NW244	NW197	NW100	NW284	NW98	NW116	NW38	NW222	NW266	NW114	NW207	NW188	NW37	NW269	NW177	NW51	NW90
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.**

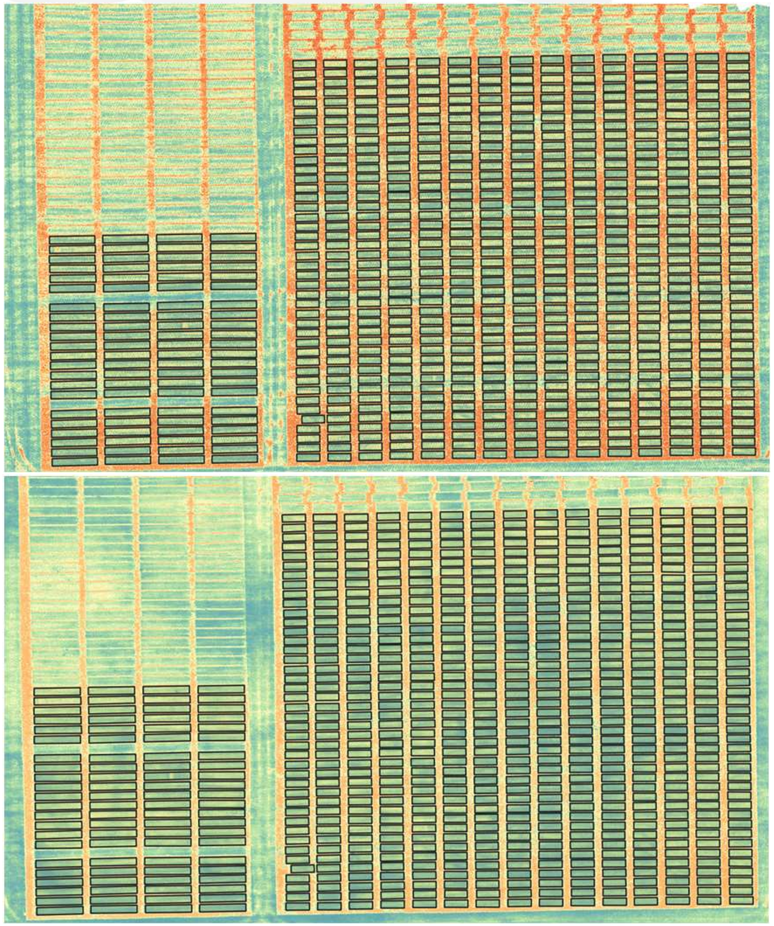
A challenge for an IT specialist, specific knowledge in agriculture is required

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

An example of multispectral data analysis

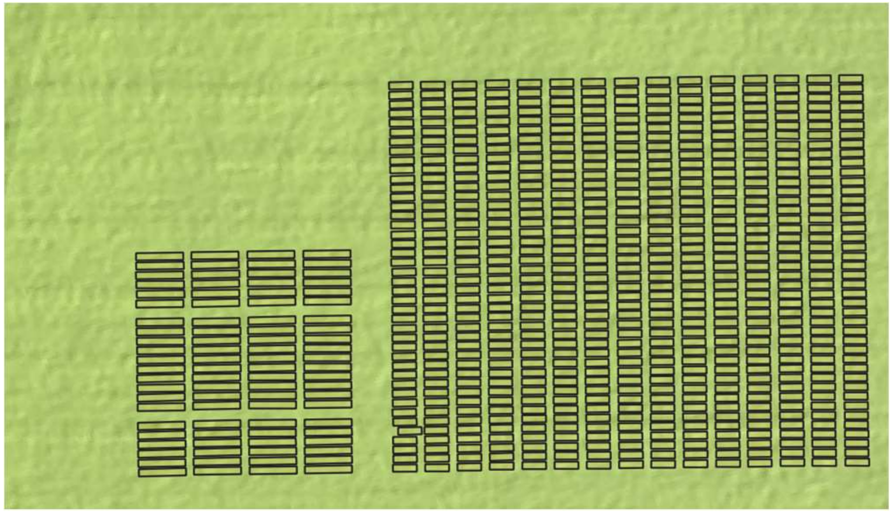
NDVI 30-May-2023
NDVI 03-Jul-2023
We see differences that cannot be seen with the human eye

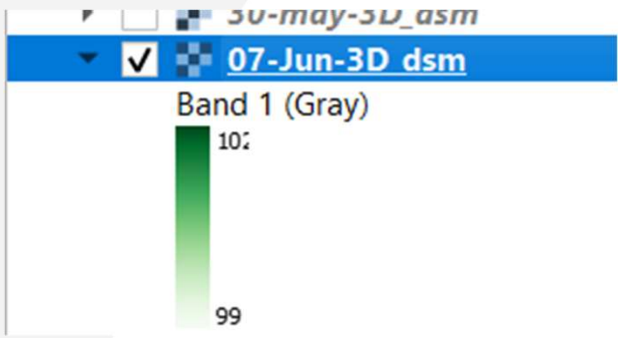


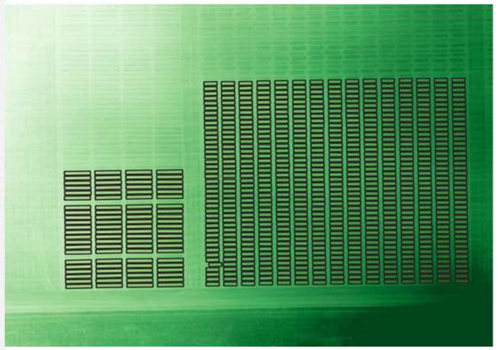
A challenge for an agricultural specialist, specific knowledge in IT, DB, remote sensing and GIS is required

Surface model analysis

- **Open access LiDAR data**
- **Field height model from photographs (99-102m a.s.l.)**

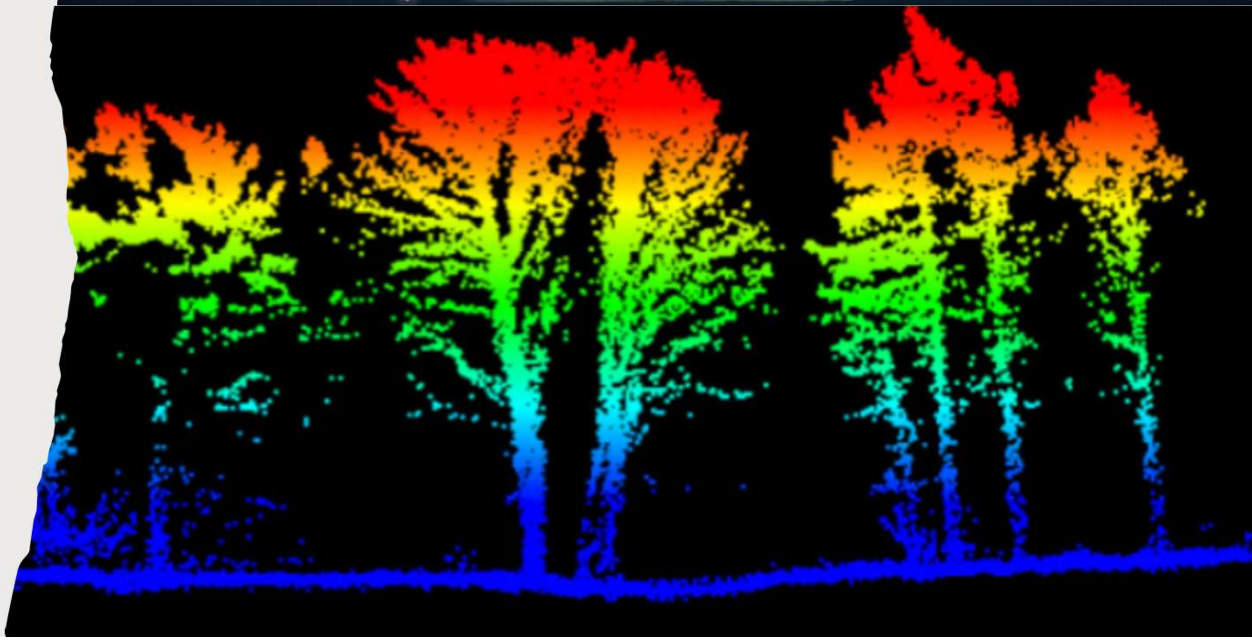






LiDAR capabilities

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



Applicability

- **Surface models (water runoff, depressions, erosion)**
- **Microtopography (analysis of the surface "hidden" under grass, moss, plant remains)**
- **Evaluation of field soil**
- **Analysis of land reclamation and irrigation infrastructure**
- **Plant classification (vertical)**
- **Horizontal distribution of plants**
- **Determination of vegetation density (ratio of vegetation to soil).**
- **Determining the amount of green mass**
- **Identification of contamination**
- **Biodiversity analysis**
- **Assessment of carbon absorption**

Technical resources

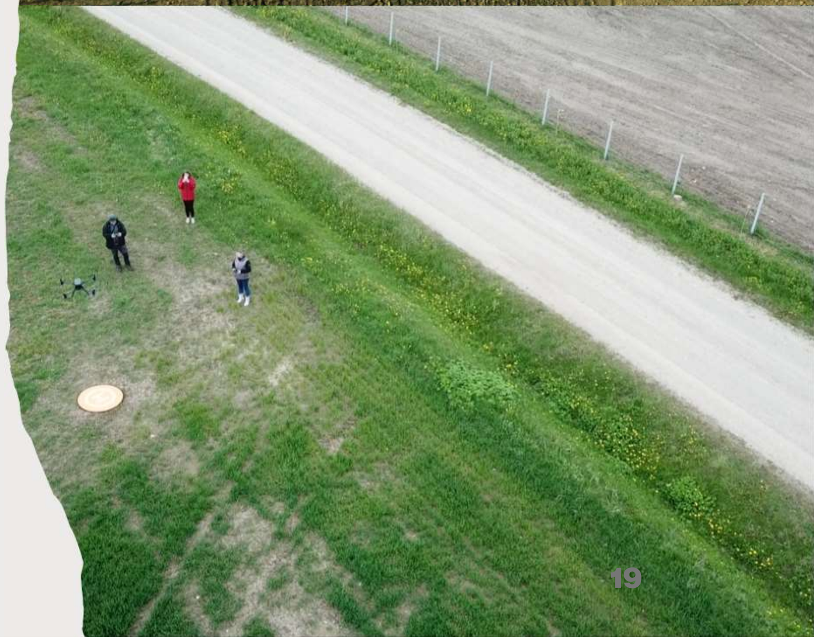
- We have
  - **DJI** Matrice 300
  - **Sentera Multispectral**
  - **Pix4D Mapper**
  - QGIS
- Purchased, but needs to be learned
  - **DJI Zenmuse L2 LiDAR***
- New learning challenges
  - **AI (Artificial Intelligence)**
  - **GIS (Geographic Information Systems)**

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.

Future intentions

- **We must continue to do as we have learned (both historically and now).**
- **New opportunities for cooperation**
- **Improved data integration and analysis (proximal and remote phenotyping)**
- **Use of AI**

•Proximal phenotyping: Uses close-up sensor technologies to obtain data about plants, for example using drones or mobile devices. Example: a drone camera that captures high-resolution images from the field.
•Remote phenotyping (Remote Sensing): Satellites or aircraft are used to observe and analyze large areas from a distance. Example: satellite images analyzing rural health or plant condition over large areas.



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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 [1,2], Zigmārs Rendenieks [1], Andris Lapāns [1], Ilmar Tamm [3], Anne Ingver [3], Andrii Gorash [4], Andrius Aleliūnas [4], Gintaras Brazauskas [4], Sahameh Shafiee [5], Tomasz Mróz [5], Morten Lillemo [5], Hannes Kollist [6] and Māra Bleidere [1,*]

... Research Department, Institute of Agricultural Resources and Economics; Stende Research Centre, ... Dižstende, Latvia

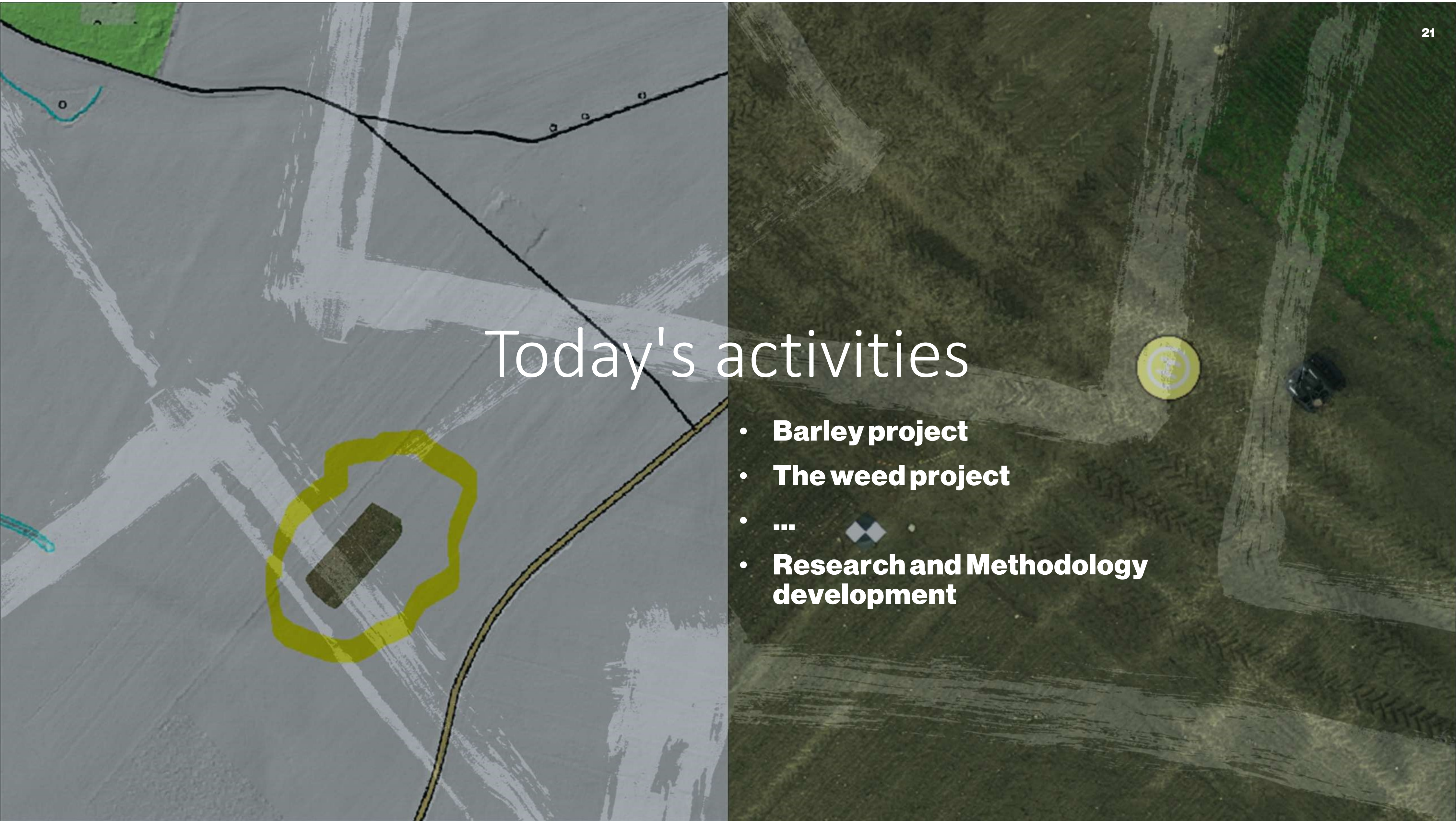
... Life Sciences and Technologies, Liela Street 2, LV-3001 Jelgava, Latvia

... Aamisepa 1, 48309 Jogeva, Estonia

... and Forestry, Kedainiai Reg., LT-58344

... NO-1433 Ås, Norway

Knowledge transfer, publications



Today's activities

- **Barley project**
- **The weed project**
- **...**
- **Research and Methodology development**

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

Aim of this work:
To develop a comprehensive methodology for designing and rapidly adjusting data acquisition, processing, and maintenance systems for data science applications in precision agriculture.

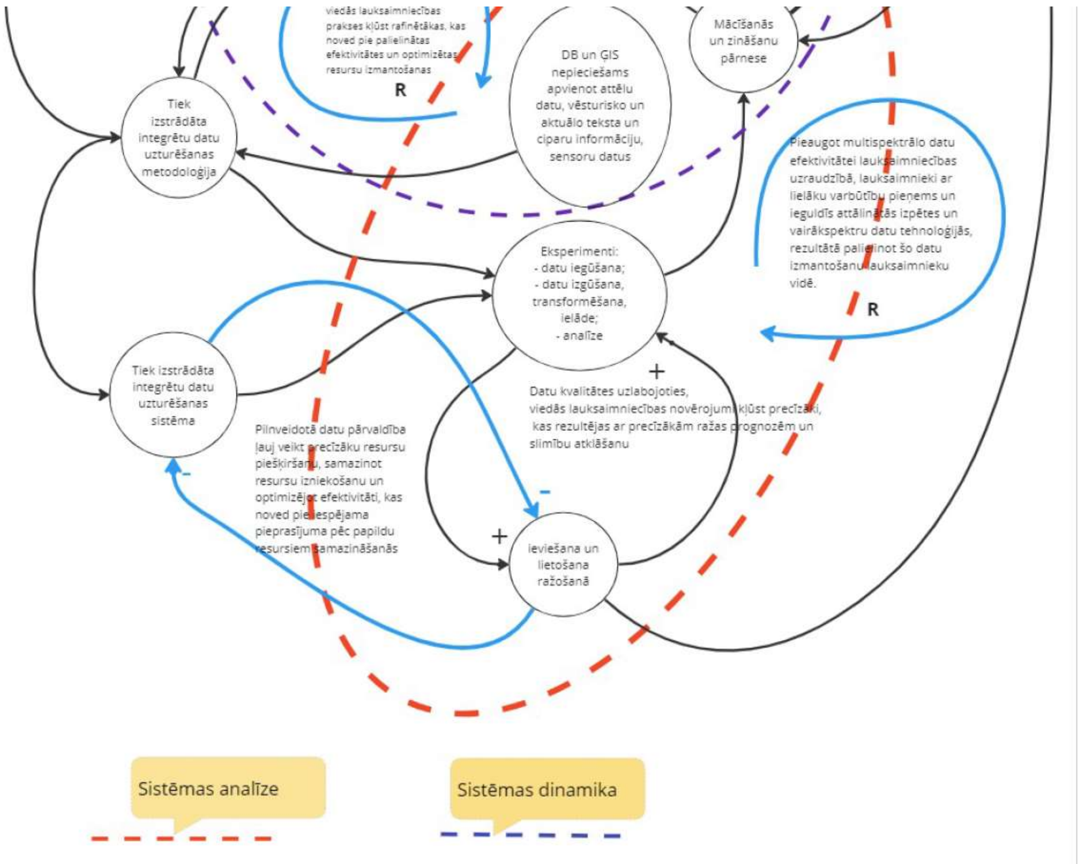
All stakeholders must come to a common understanding

- **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**

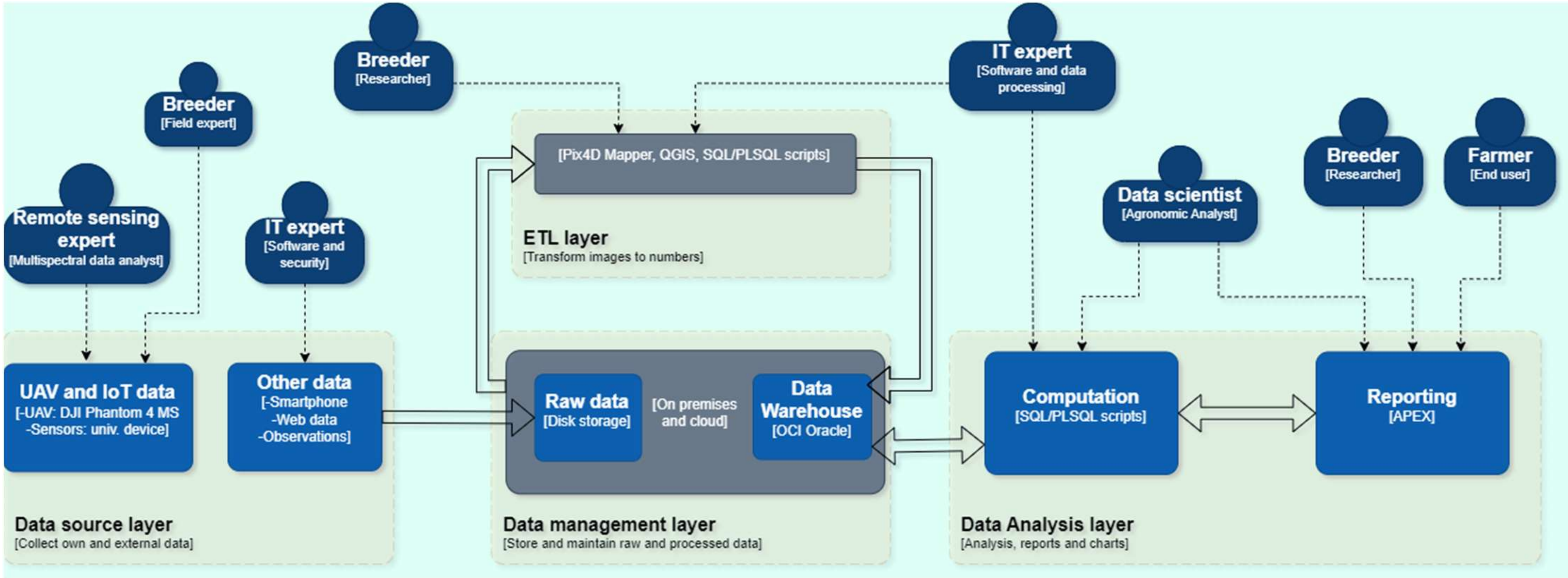
A transparent, universally understandable concept must be validated and verified

How to perform these tasks?

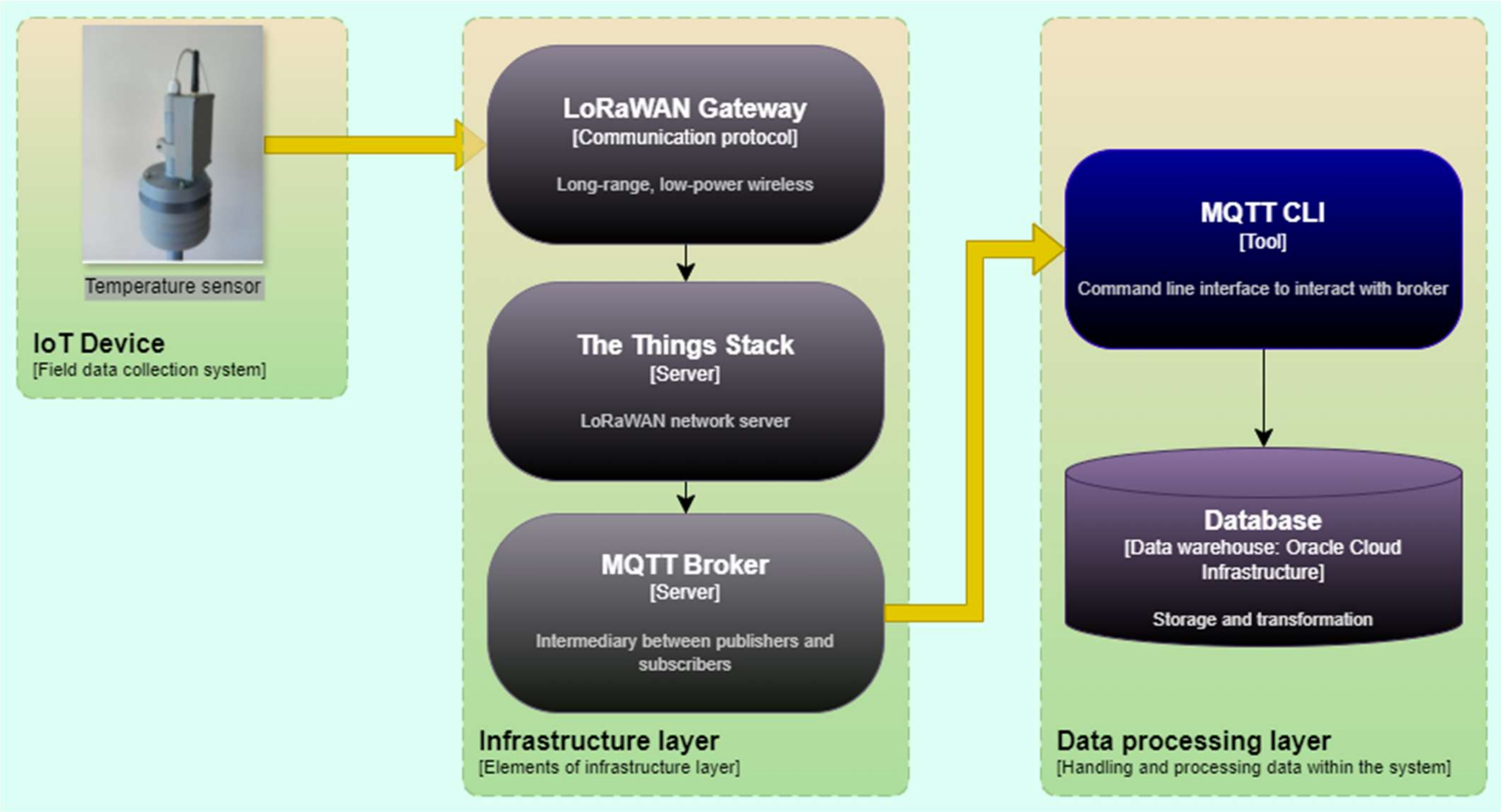
- **Requirements model, the creation of which has several (as many as necessary) iterations**
- **Financing and implementation**



Architecture for multispectral data acquisition, integration and analysis

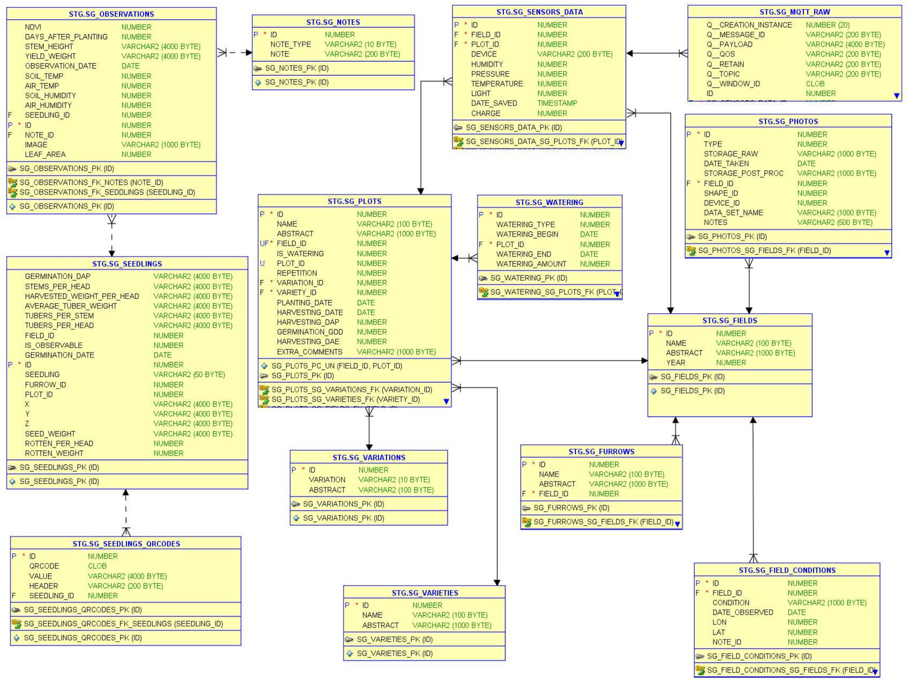


IoT data processing architecture



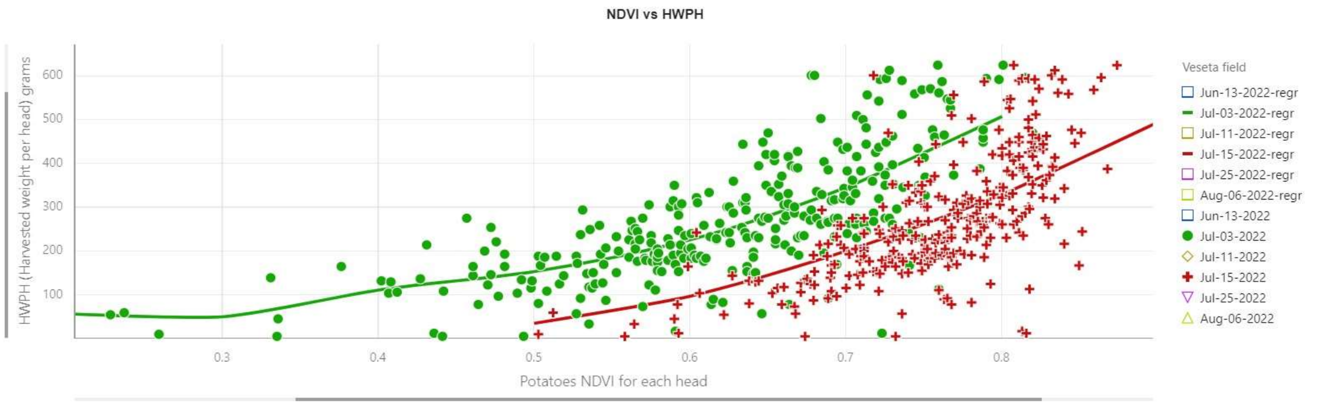
Database: OCI as platform and flexible Data model

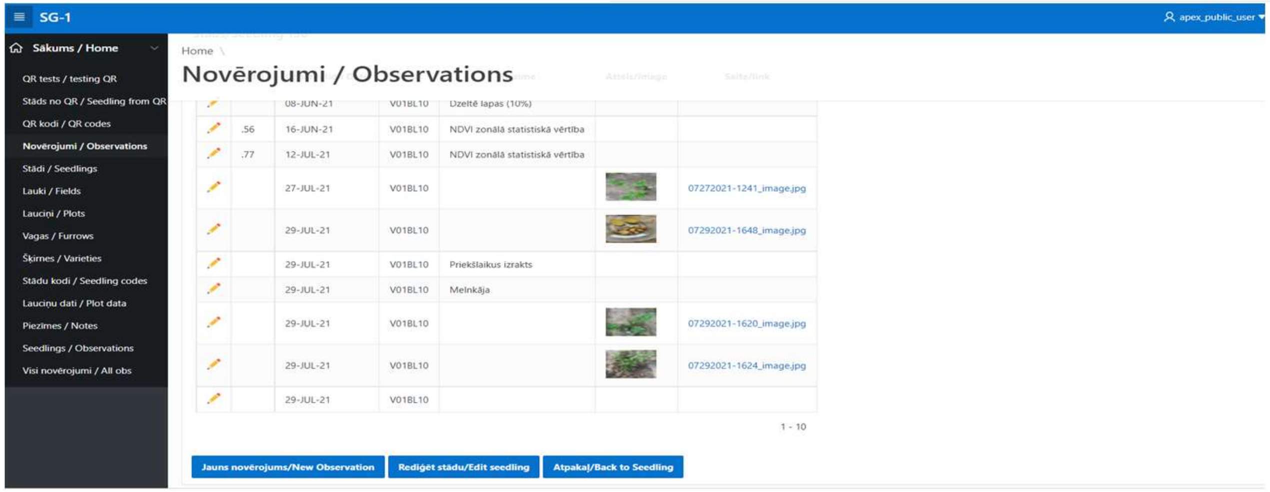
Generativity.
It is a technology's capability of producing new outputs without input from the originator.
Scalability.
Ability to handle growing volumes of data and increasing complexity of processes as precision agriculture advances.
Accesibility.
Easy access for different users, with varying levels 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





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**

Current challenges

- **Submit publication**
- **LiDAR data processing workflows (methodology f**
- **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.
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.
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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Funded by the European Union

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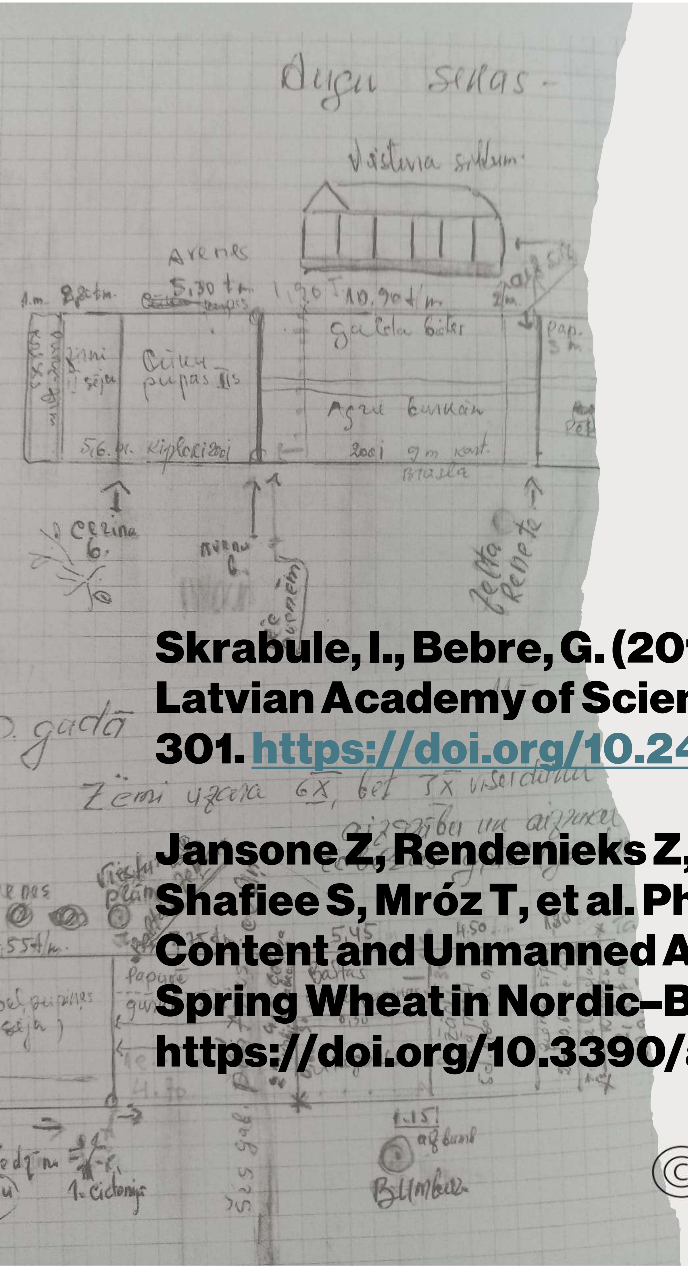

Questions?

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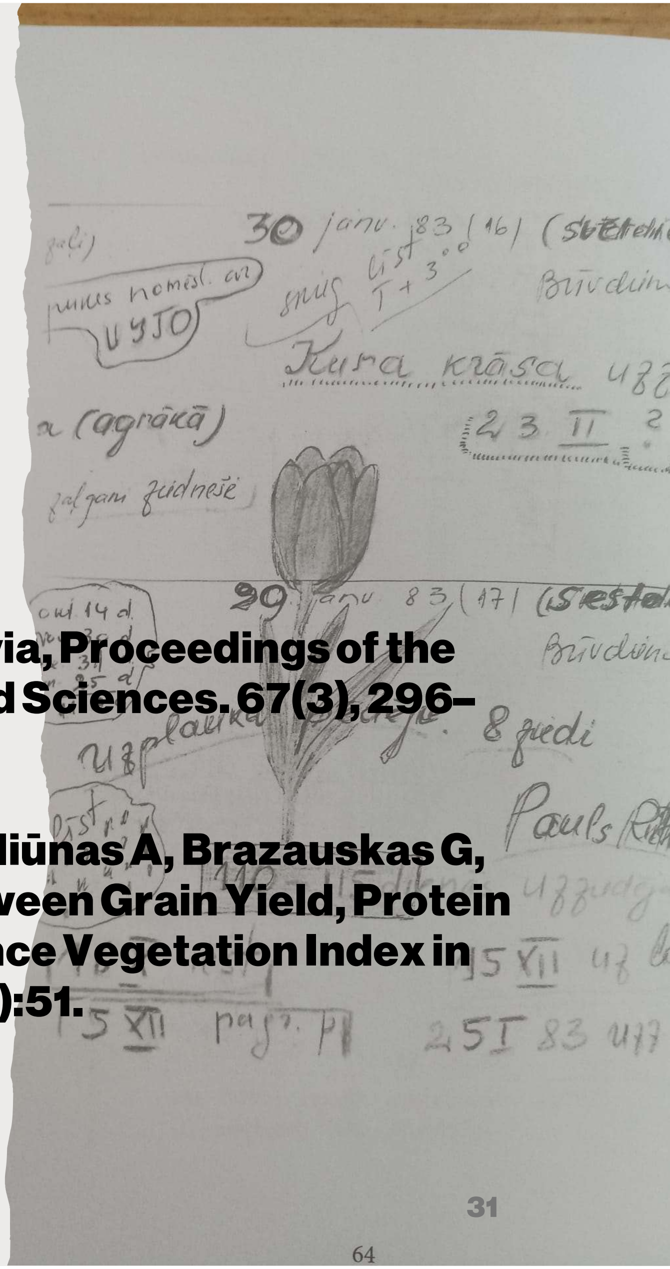

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