

Bioökonomie
REVIER

EVALUATING CARBON-RICH SOIL AMENDMENTS IN A MARGINAL SETTING FOR CROPS IN THE AGROINNOVATIONLABS AT IBG-2

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IBG-2 Bioeconomy – Phenotyping – Bioinformatics - Technology Platforms

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IBG-2: PLANT SCIENCES within Research Centre Juelich GmbH



Efficient plants (growth, harvest, resource utilization, biodiversity)

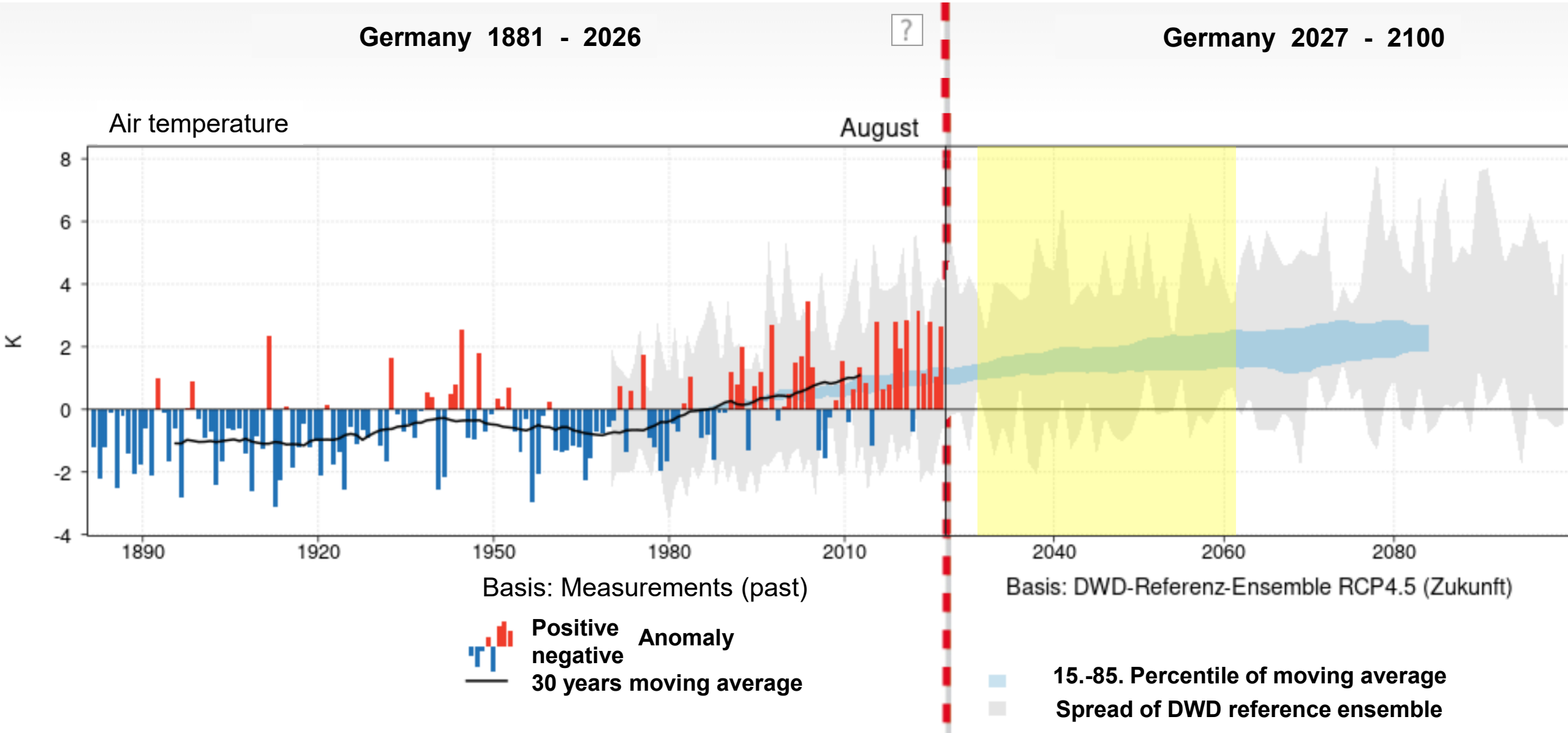
Sustainable plant-based bioeconomy

regionalization, transfer, implementation

CHALLENGE ‚CHANGING ENVIRONMENT‘

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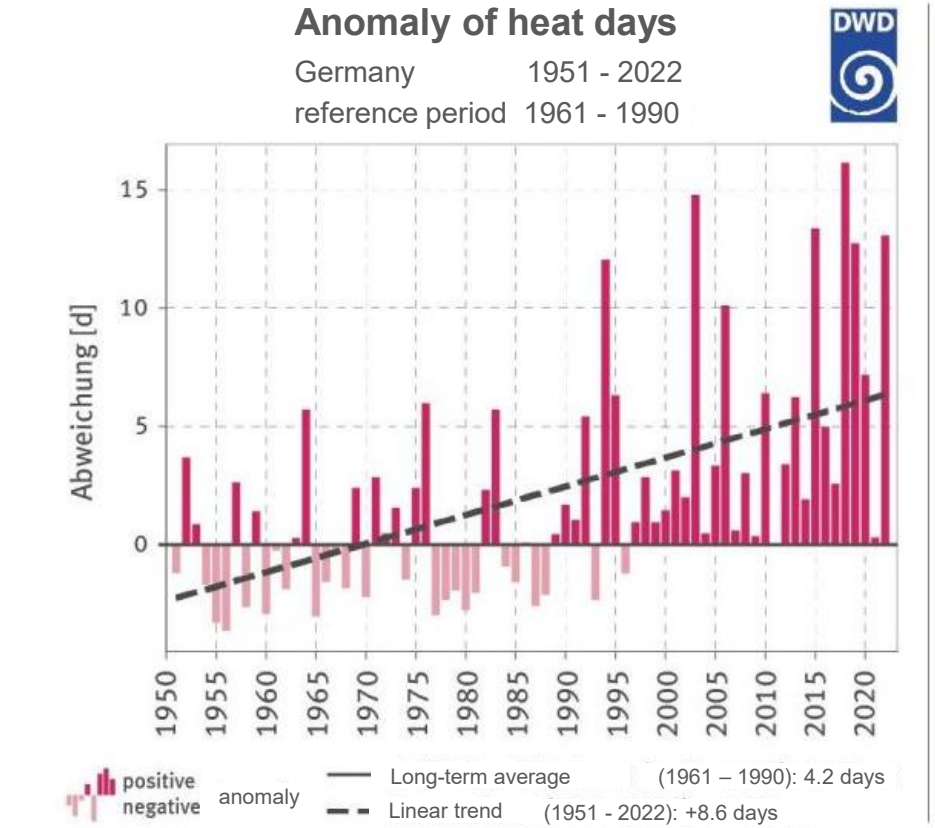
More and more energy in the system…

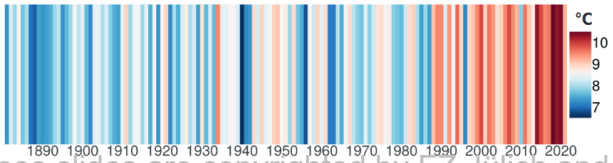


DWD Climate Data Center (CDC)

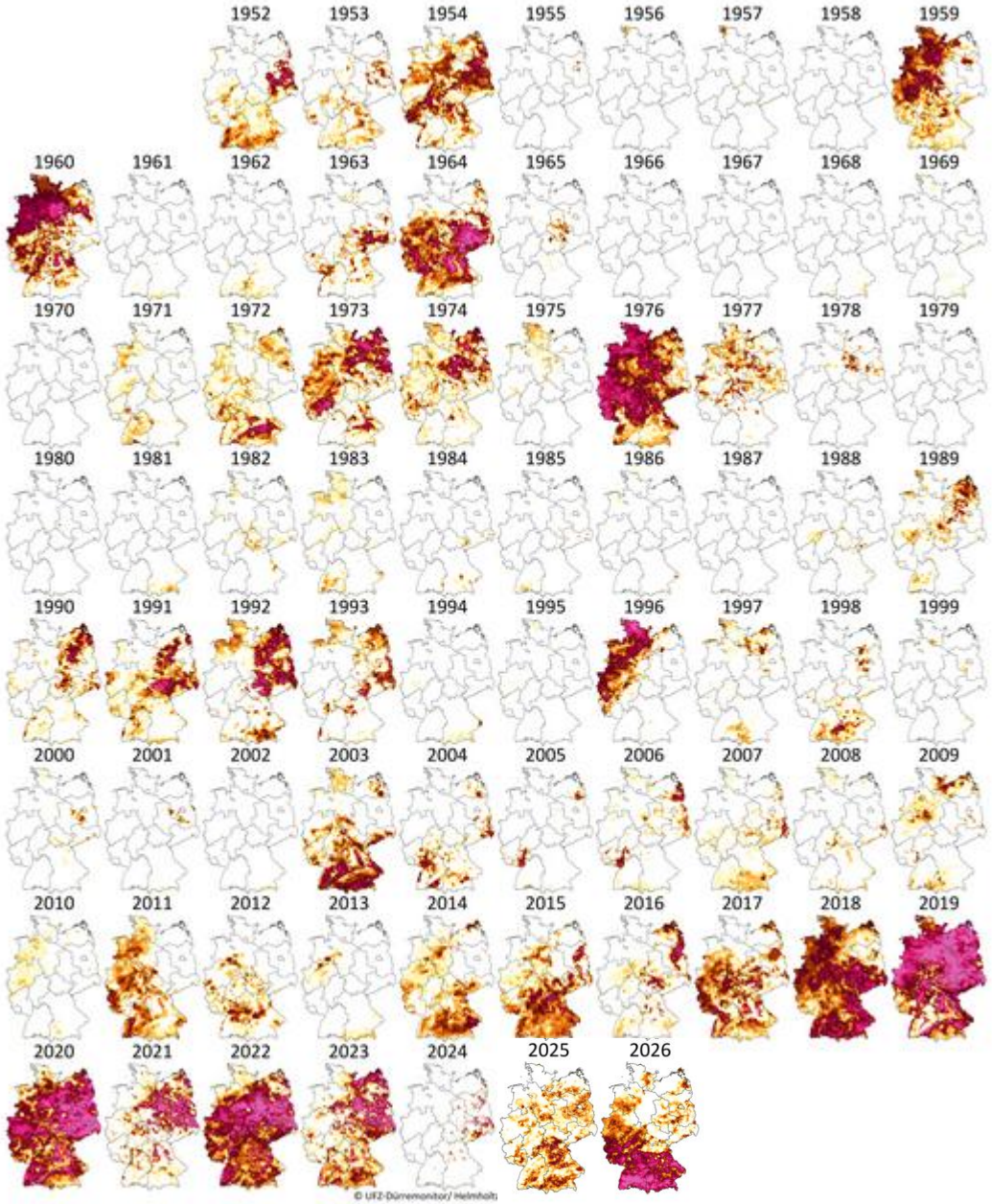
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More and more energy in the system…





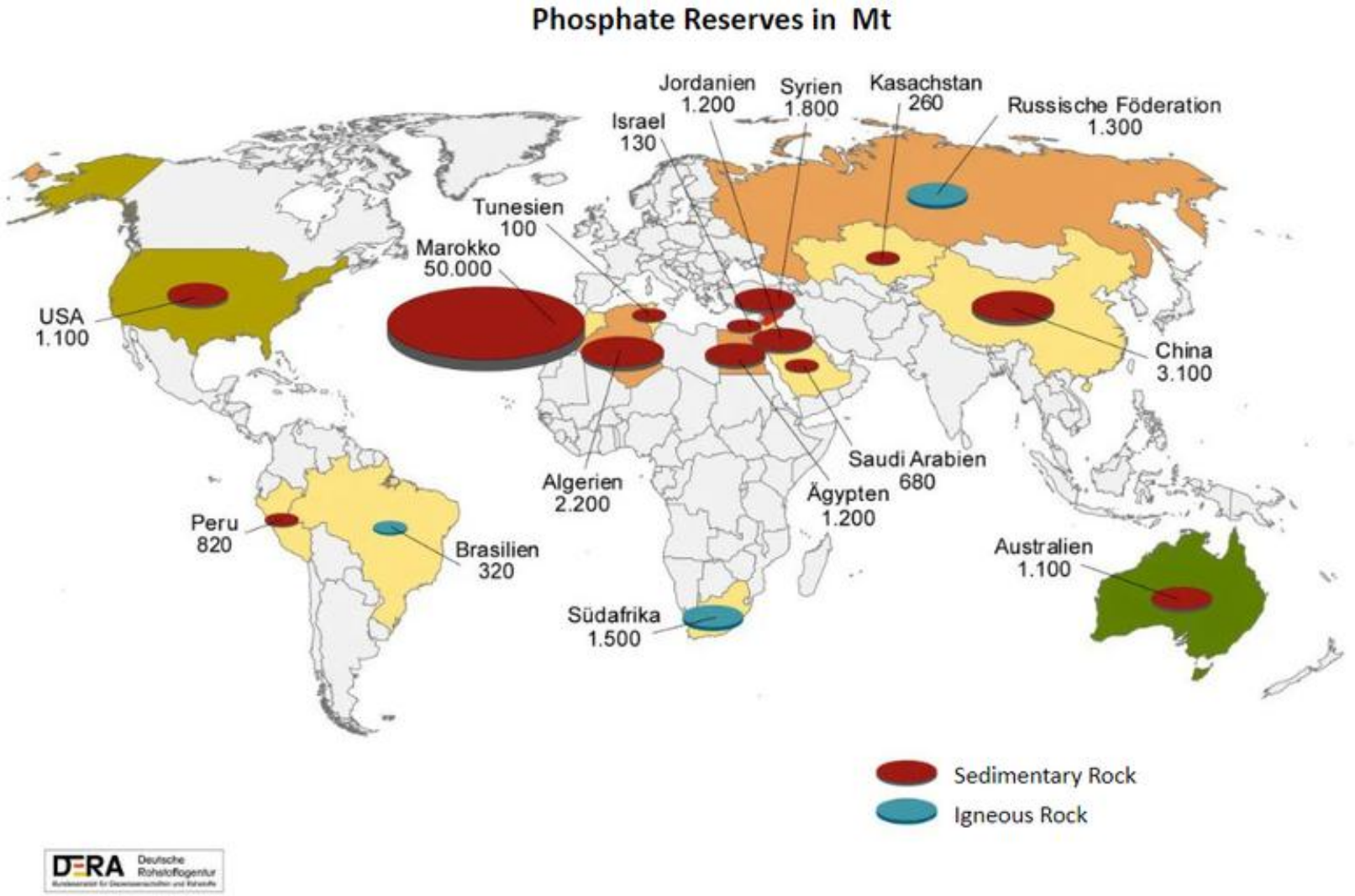
Drought magnitude down to 2m, total soil, Apr-Okt

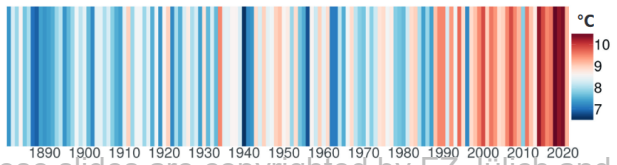


FZ-Drought monitor / Helmholtz-Center Environmental Research

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… and less resources.





P-use (also: N ‚cycling') is coupled to water quality
- eutrophication endangers habitats

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GET MORE LEVERAGE TO REACT







Alternative crop management
more resilient plants
more efficient nutrient supply/utilization even on good soils
Soil supplements/management for poorer soils
even more targeted crop protection
better prediction of environmental influences
or... [...] **...can and must be part of the solution.**

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DÜSSELDORF 🇩🇪 (DUS) | RARE VISUAL APPROACH RUNWAY 23L | REAL AIRBUS A320 | 6 cameras | MCDU VIEWS

Anflug- und Abflugvideos
62.900 Abonnenten

Mitglied werden | Abonniert | 744 | Teilen | Herunterladen | Thanks | Clip | ...

Alle | Von Approach and Departure ... | Ähnlich

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Implementation in the region - BioeconomyREVIER structural change initiative

Triad of economy, ecology, social aspects

- Production and use of biological resources for products, processes and services
- Resource and climate-friendly living and working environment
- Closed material cycle
- waste recycling management



Bundesministerium für Wirtschaft und Energie

Bundesministerium für Forschung, Technologie und Raumfahrt

Die Landesregierung Nordrhein-Westfalen

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RHEINISCHES REVIER

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Production and value creation concepts

Expertise partner in the development of new production clusters and value chains



Agro-Food-Energy systems



Agroforestry systems



Plants for health and cosmetics



Sustainable packaging



Wood substitutes in construction



New raw materials for paper



Reuse of residual materials



bioplastics



Integrated biorefinery

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AGRO-INNOVATION LABS

Importance in general and for structural change in the region:

- Provision of digital infrastructure and modern measurement methods
- Networking of agriculture, science and companies
- Testing new cultivation methods
- Business models for innovative agriculture → e.g. Saflor: oil & fibre, locally used; also Arnica, Nasturtium and others
- Regional value creation - new sustainable jobs and apprenticeships

→ Discussion - Dialogue!



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FELDLABORE FÜR RESSOURCENEFFIZIENTE PFLANZENPRODUKTION.
Ein Projekt des Innovationsclusters BioökonomieREVIER zur Innovativen Landwirtschaft mit Zukunftsideen für die regionale und nachhaltige Lebensmittel- und Rohstoffversorgung. Ein Beitrag zu einer Modellregion für nachhaltige Bioökonomie im Rheinischen Revier nach dem Braunkohleausstieg.

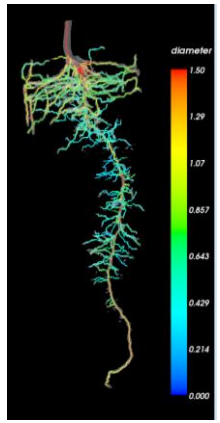
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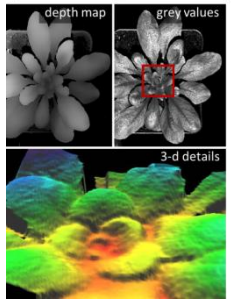
AGRO-INNOVATION LABS toolbox

Photosynthesis

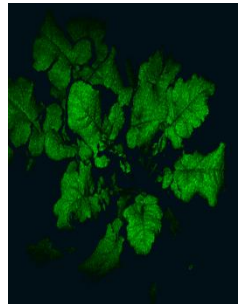


Water balance

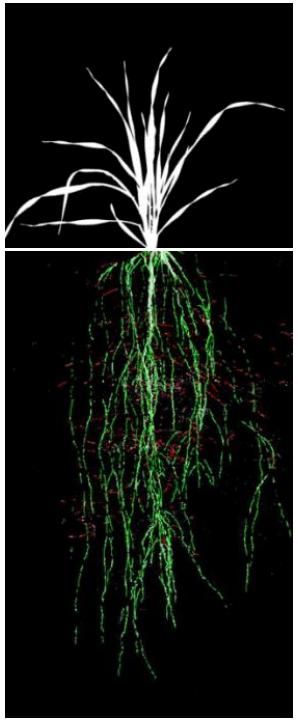




Growth, biomass, architecture below/aboveground







Scaling up







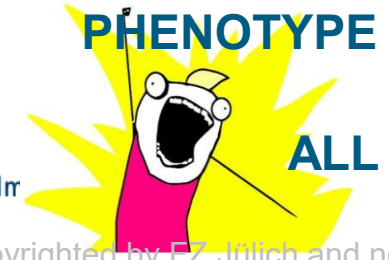


Robotic support



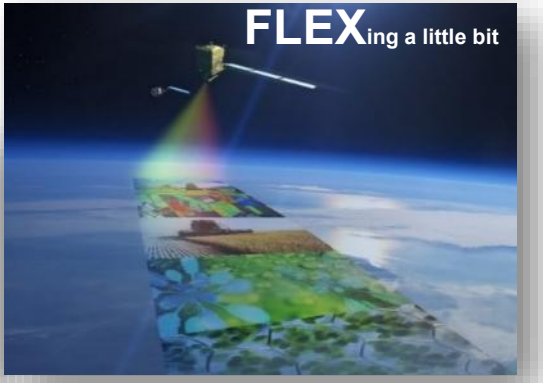
automation

PHENOTYPE



ALL THE THINGS





Aerial survey

Mitglied der Helm

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AGRI FOOD ENERGY





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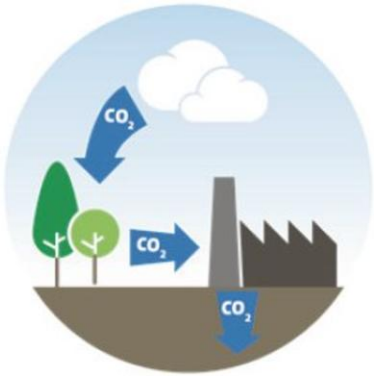
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Motivation Net: Negative Emission Technology
One focus on soil carbon

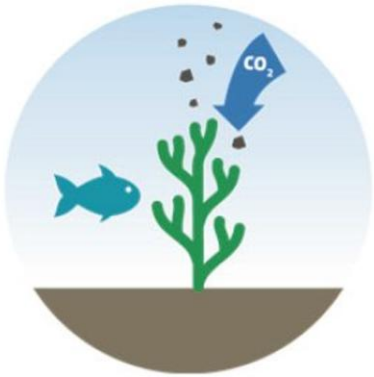
Several carbon dioxide removal options have been proposed:



Afforestation and Reforetation
Tree growth takes up CO_2 from the atmosphere.



Bioenergy with carbon capture and storage
Plants turn CO_2 into biomass that fuel power plants. CO_2 captured and stored underground.



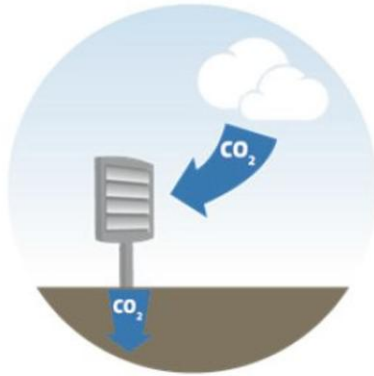
Ocean fertilization
Iron or other nutrients are applied to the ocean increasing CO_2 absorption.



Biochar
Partly burnt biomass is added to soils absorbing additional CO_2.



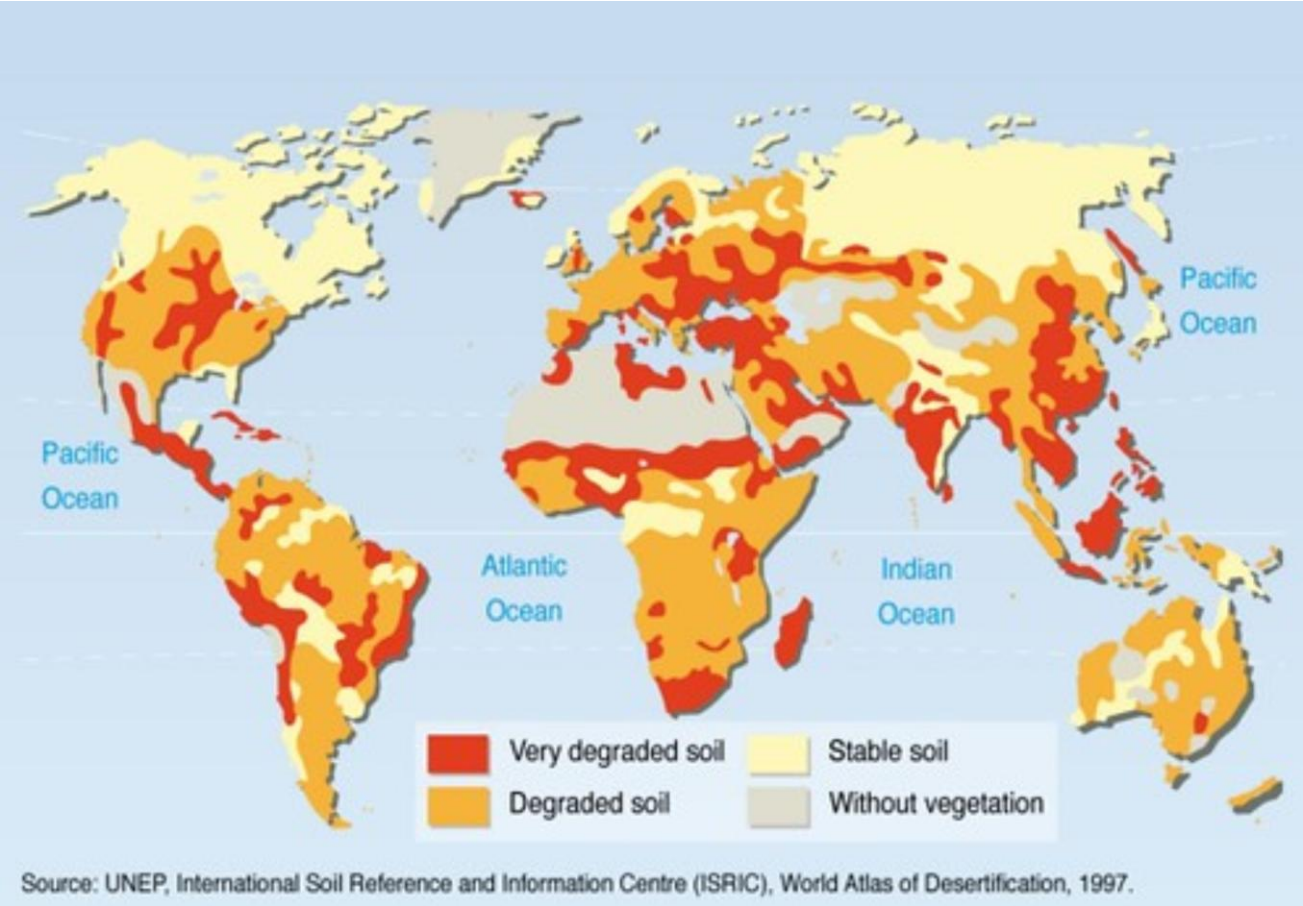
Enhanced weathering
Crushed minerals are applied to soil for chemical CO_2 absorbtion.



Direct Air Capture
CO_2 is removed from ambient air through chemical processes and stored underground.

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Since the soil is literally the basis we exist on, we should care a lot about it.



Global Dimension –

The demands placed on the soil are enormous. It is expexted to

- Save the climate (as potential C-sink)
- Provide healthy food for a growing population
- Withstand Erosion, water scarcity, salinization

The long-term stress on many soils is clearly visible today (graphic is from 1997, and change is slow).

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Approach example: soil additives / amelioration test

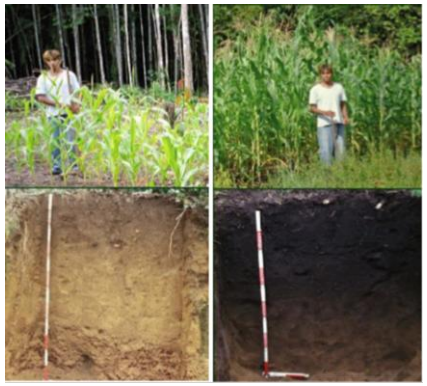
INCREASING SOIL CARBON - INFLUENCE ON GROWTH DYNAMIC AND QUALITY OF CROPS

- Worldwide, the low and decreasing carbon-content of agricultural soils is an obstacle to sustainable plant production.

PGSB-PhD:
Ashwaq Najjar
Saja Salattna
Bachelor projects:
Sarah Milski
Benedict Ohrem
Jens Cohnen
Romeo Polis



Dr. Arnd J. Kuhn



Historical Terra Preta in
the Amazon region as model



Pot experiment under controlled conditions in the IBG-2 greenhouse with carrots: comparison of different biochars

Cooperations:
Palestine-German Science Bridge
IBG-3: R.Bol, N. Brüggeman, N.Sievers
Univers. Bonn: Th. Kraska
AGRIHUMIN: H. Meyrahn
Local Farmer: K.-H. Albersmeier
„Strukurwandel Rheinisches Revier“



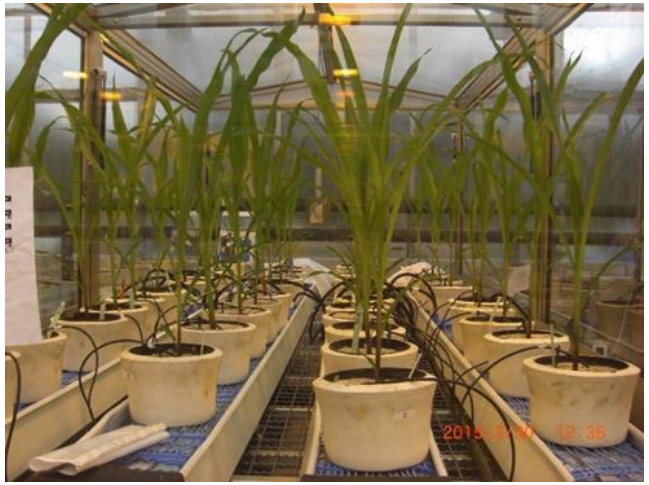
Application of the growing medium (biochar/manure) Oil radish as catch crop on this field in winter 2020/21

Durable carbonisates can be produced by using side chain and waste products - e.g. digestates, sewage sludge, plant biomass, biological waste etc.

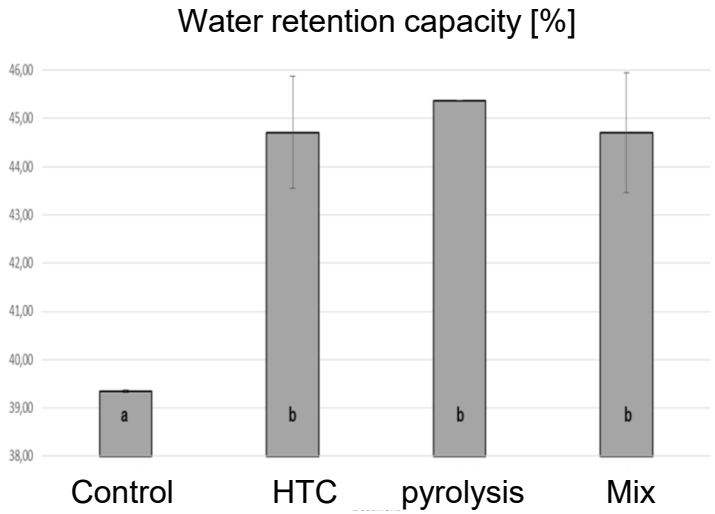
The effect of biochar as a soil additive:
- higher water retention ➔ increasing resilience against drought periods
- higher ion exchange capacity ➔ lower nutrient loss into ground water
- more stable soil structure ➔ better water uptake, microflora increase
- carbon sequestration into soil, long term
- Enable use of marginal soils for sustainable plant production

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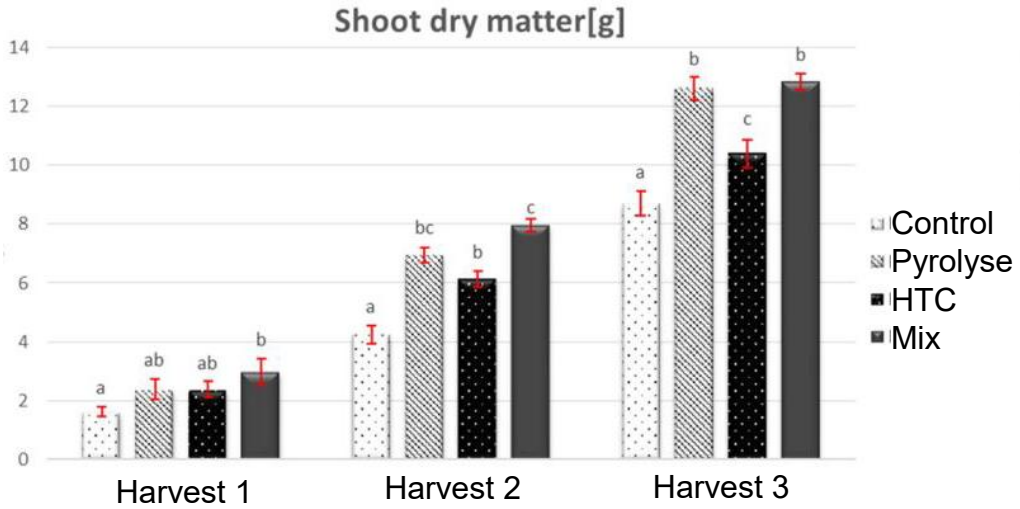
Biochar from pyrolysis and HTC processes as soil additives for sustainable plant production

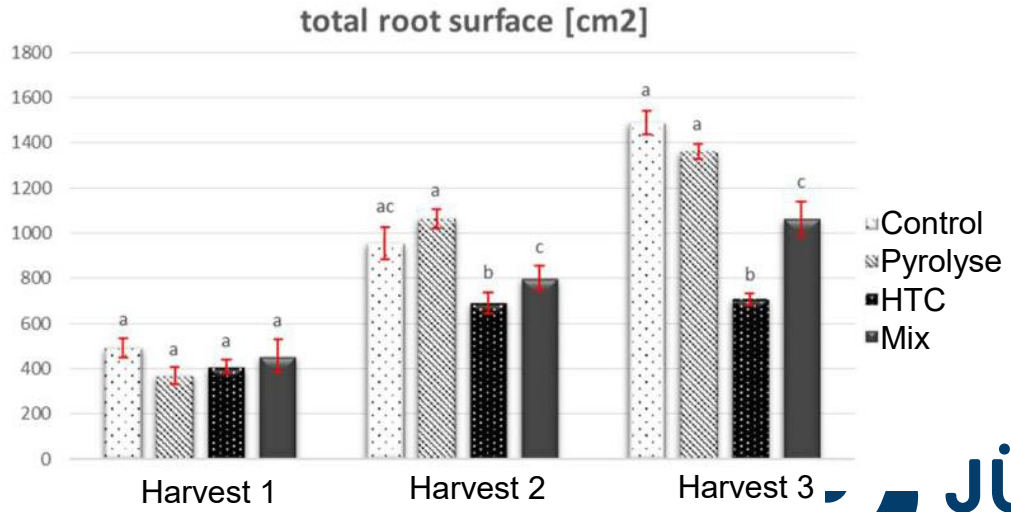


Maize: 23 days after the seedlings have been placed in the **Jülich greenhouse** under controlled conditions.



Maize-shoot dry matter and total root surface at 21, 28 and 35 days (harvest 1/2/3) after insertion of seedlings
[control / pyrolysis / HTC / Mix (50/50)]





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Tomato parameters grown on different biochar formulations (0,1;0.3;0.5% C add. resp.)

Mineral fertilizer control, no biochar added

Mineral fertilizer saturated biochar

Algae biomass fertilizer, no biochar added (but same C content)

Manure saturated biochar

Soil Mix	Shoot height (cm)	Shoot diameter (cm)	Shoot dry weight(g)	Root dry weight(g)	Root/Shoot dry weight	Root Length(cm)	Root AvgDiam (mm)	Root SurfArea (cm^2)
MIN	65.1 ± 9.6	6.9 ± 0.9	16.3 ± 2.9	4.7 ± 0.21	0.29 ± 0.04	1866.8 ± 270.2	0.39 ± 0.02	230.5 ± 31.8
BIO1	72.6 ± 9.3	7.3 ± 0.61	13.8 ± 0.29	3.3 ± 0.01	0.23 ± 0.004	1856.9 ± 508.0	0.37 ± 0.02	183.3 ± 7.9
BIO2	62.2 ± 5.9	7.2 ± 1.02	14.5 ± 0.40	3.6 ± 0.54	0.25 ± 0.05	1882.8 ± 263.6	0.38 ± 0.01	221.6 ± 32.1
BIO3	67.7 ± 6.2	6.9 ± 0.9	13.4 ± 0.79	3.4 ± 0.05	0.25 ± 0.02	2026.7 ± 168.9	0.39 ± 0.01	244.9 ± 19.9
ALG1	60.7 ± 2.4	6.9 ± 1.3	12.7 ± 0.43	2.9 ± 0.36	0.23 ± 0.02	2231.8 ± 118.9	0.39 ± 0.01	280.3 ± 17.5
ALG2	60.1 ± 4.6	7.4 ± 0.75	12.8 ± 0.85	2.8 ± 0.24	0.22 ± 0.03	1717.3 ± 198.1	0.37 ± 0.02	197.4 ± 27.6
ALG3	71.3 ± 9.4	7.3 ± 0.93	14.1 ± 0.31	4.4 ± 0.63	0.31 ± 0.05	2320.8 ± 119.5	0.39 ± 0.02	289.3 ± 18.1
MAN1	65.7 ± 7.9	7.2 ± 0.65	13.6 ± 0.24	4.8 ± 0.53	0.36 ± 0.05	1992.2 ± 328.2	0.40 ± 0.02	229.2 ± 4.6
MAN2	72.4 ± 4.7	7.6 ± 0.34	15.9 ± 0.35	4.33 ± 0.30	0.27 ± 0.01	1621.9 ± 49.6	0.42 ± 0.02	211.6 ± 7.4
MAN3	72.7 ± 10.4	7.5 ± 0.92	16.7 ± 0.69	3.9 ± 0.24	0.23 ± 0.02	2009.8 ± 144.3	0.39 ± 0.01	244.9 ± 16.9
Sig.	**0.036a**	0.936a	**0.000a**	**0.000a**	**0.000a**	**0.002a**	**0.000a**	**0.000b**

Green up arrows (↑) represent values within the upper third (≥ 67%) of the data value span, red down arrows (↓) indicate values in the lower third (< 33%), and yellow right arrows (→) indicate the intermediate range.



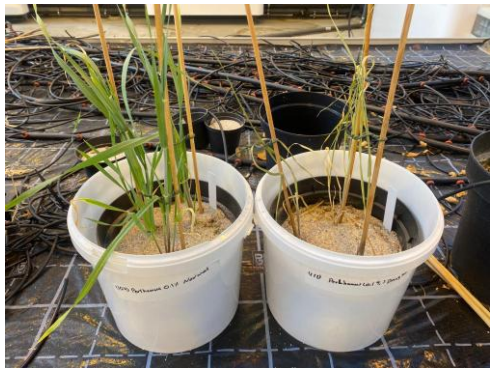
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Greenhouse and garden trials

- **Aim:** show impact of biochar, Terra preta, and leonardite as

up to +1% C-content under greenhouse and scaled-up garden conditions. (Model plant: German barley cultivar).





- **Main findings:**

✓ Biochar improved soil water retention.

✓ Terra preta increased barley yield and dry weight.

✓ Leonardite boosted the plant biochemical content (esp. sugars, starch)

- **New research questions:**

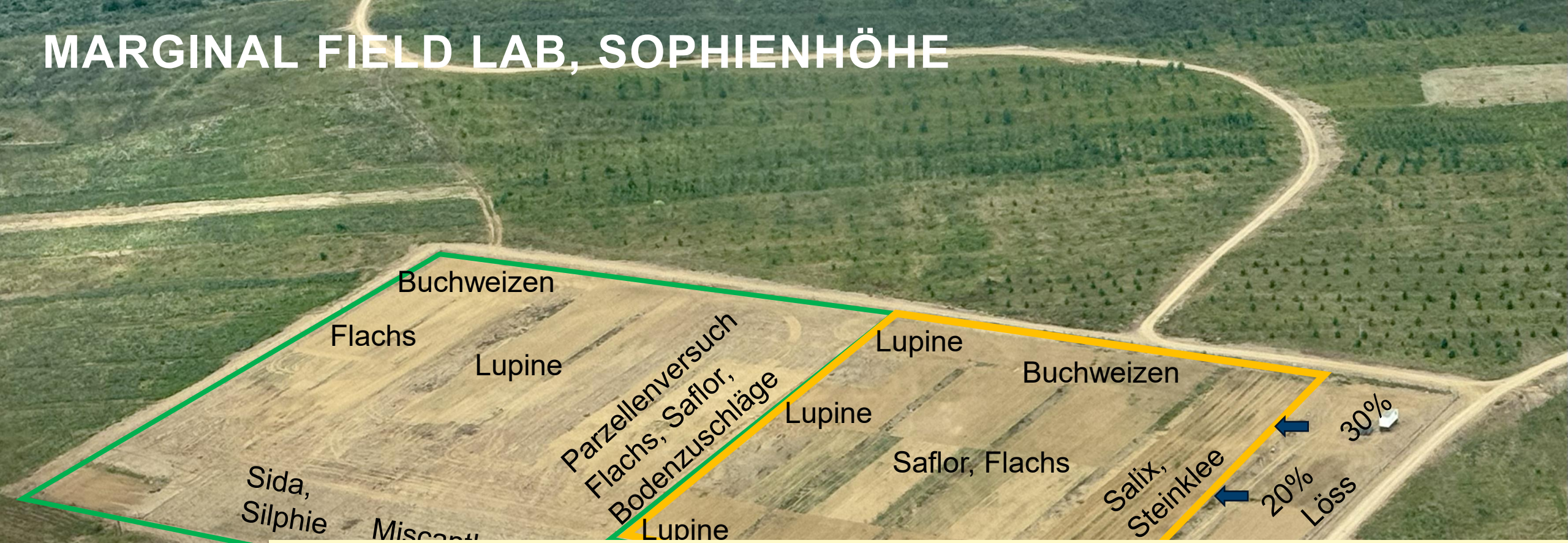
✓ Long-term effect (> 6-months) of the carbon-rich soil amendments for sustainable crop production, improvement on quality of marginal sandy substrates, **upscaling** to see viability with agricultural methods (farmwork)



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MARGINAL FIELD LAB, SOPHIENHÖHE



Sand

Loess

Improving marginal-yield soils for better crop production:
concept of ***Accelerated Pedogenesis****), through combination of:*

Application of organic fertilizers (below the surface or in the soil); addition of other carbon-containing materials for fertilization and soil improvement (humic acid, terra preta, biochar)

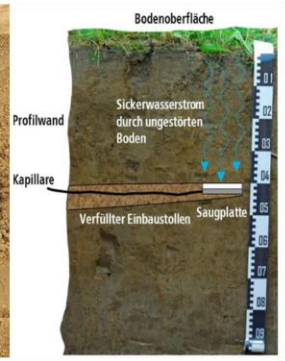
Annual and perennial plants (deep-rooted), including legumes for additional nitrogen fixation; optimisation and selection

No fertilization history. No or minimal tillage and soil treatment.

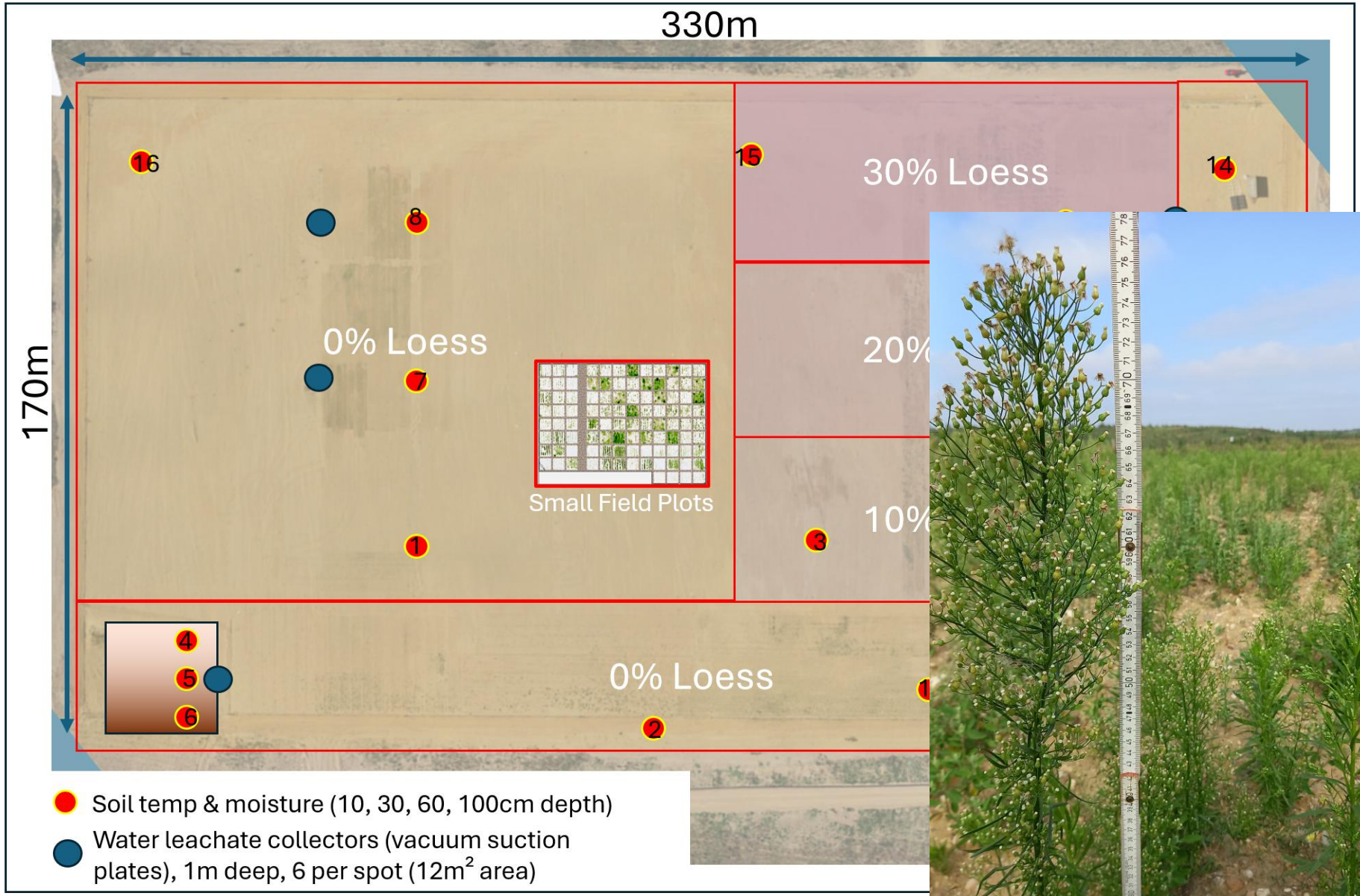
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Digestate strip-till application and sowing

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Digestate strip-till application

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Small field experiments (lots of handiwork)



Manual mini-plot preparation: digestate application

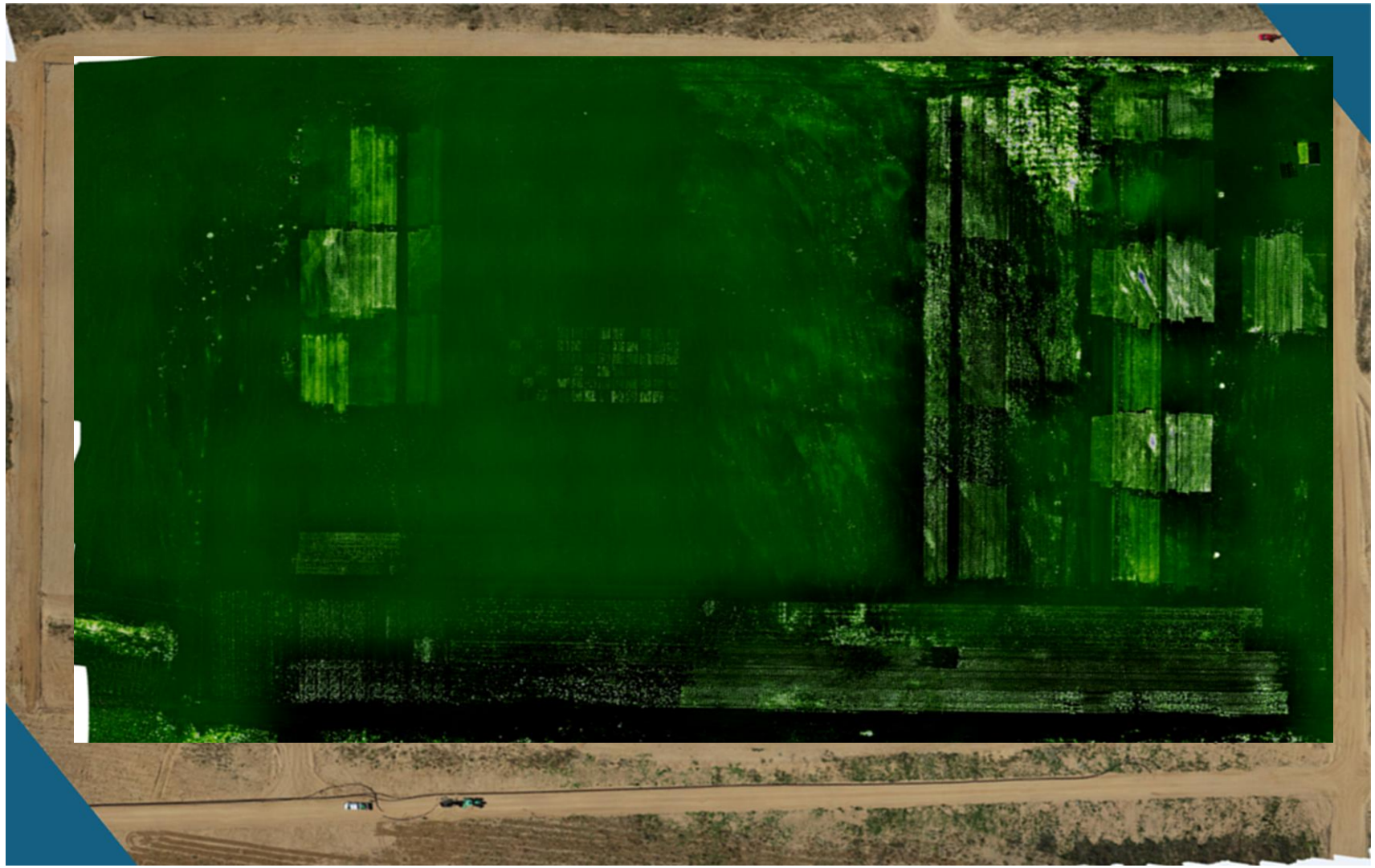
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Aerial data survey & overview



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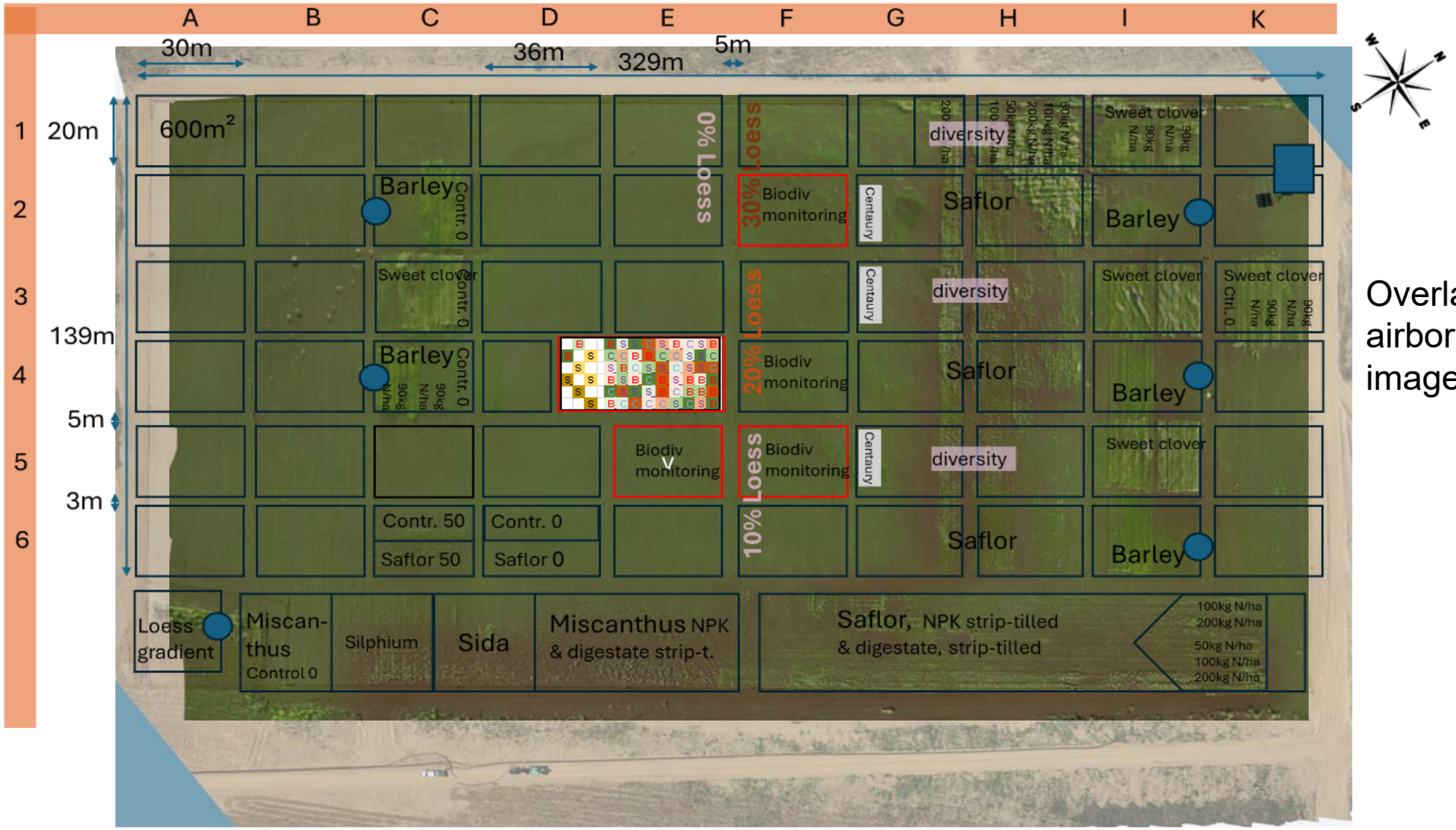
Aerial data survey & overview



Remote sensing of plant growth, coverage, inhomogeneities and invasive neighbours

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Aerial data survey & overview



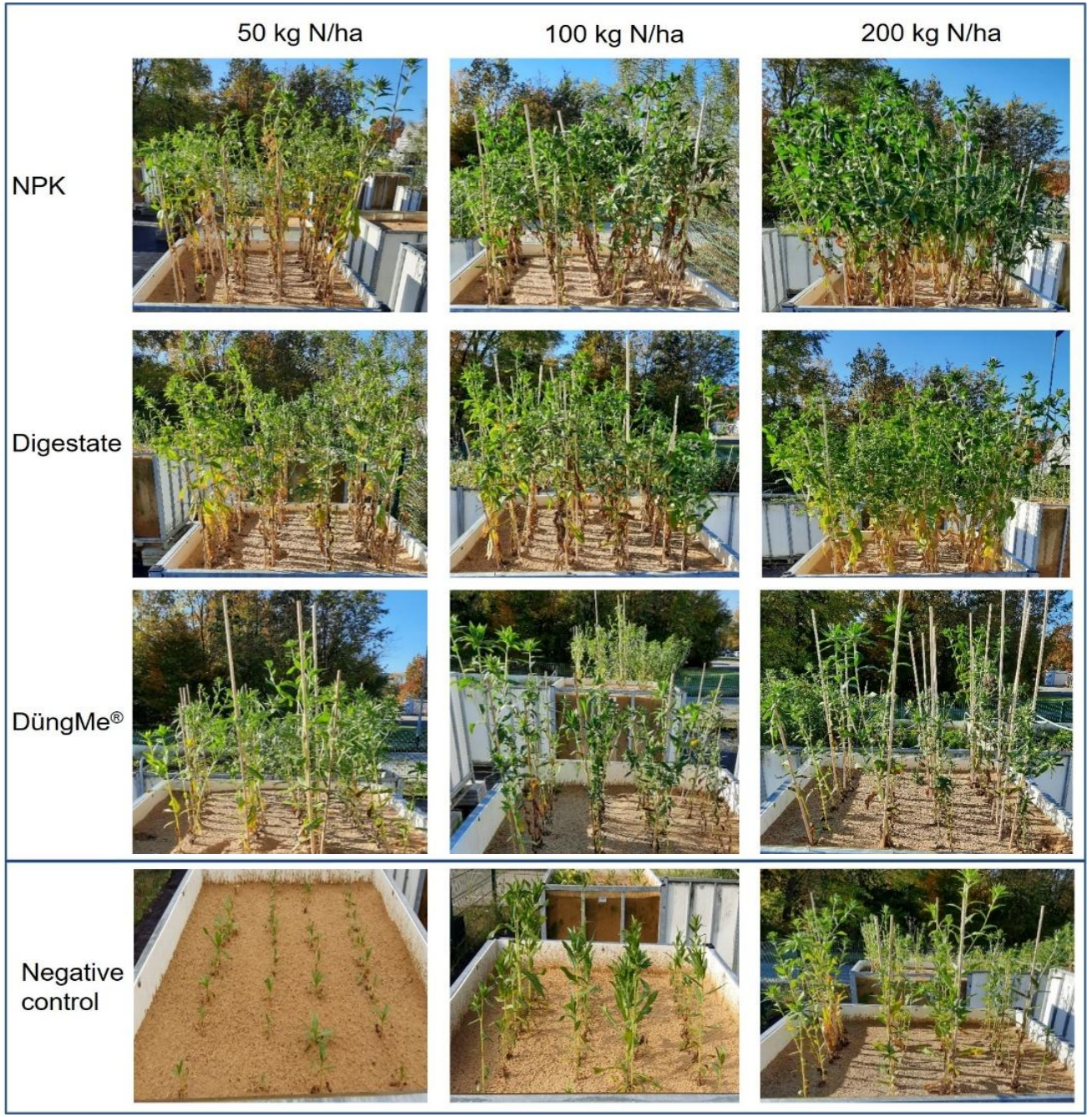
Overlay of NDVI, airborne drone images, and site plan

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Example: Saflor.

Organic fertilizer, biochar and scale-up





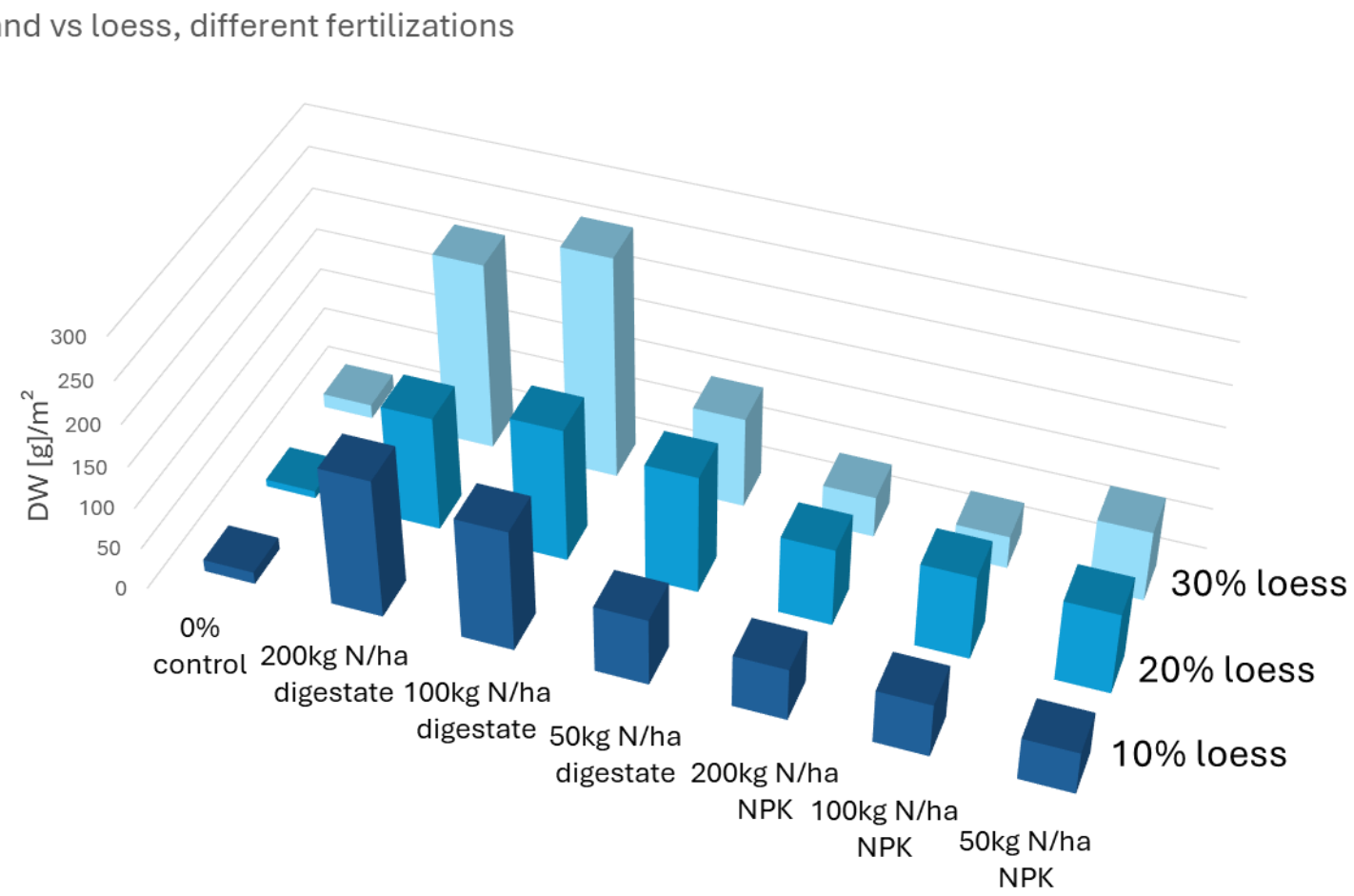
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Mitglied der

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Example: Saflor – 2024 on MFL



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F: Flax
S: Saflor
C: Clover
d: digestate
m: mineral
0p: no leonardite
n: digestate ferment
05: 50kg N/ha
10:: 100kg N/ha
00: Null

	#
With added leonardite	
S0	3
F0	3
S00p	3
F00p	3
Sd05	3
Sd10	3
Fd05	3
Fd10	3
Sm05	3
Sm10	3
Fm05	3
Fm10	3
Sn05	3
Sn10	3
Fn05	3
Fn10	3
Sp05	3
Sp10	3
Fp05	3
Fp10	3
Without added leonardite	
Sn050p	3
Sn100p	3
Fn050p	3
Fn100p	3
Sp050p	3
Sp100p	3
Fp050p	3
Fp100p	3
C0	3
C05	3

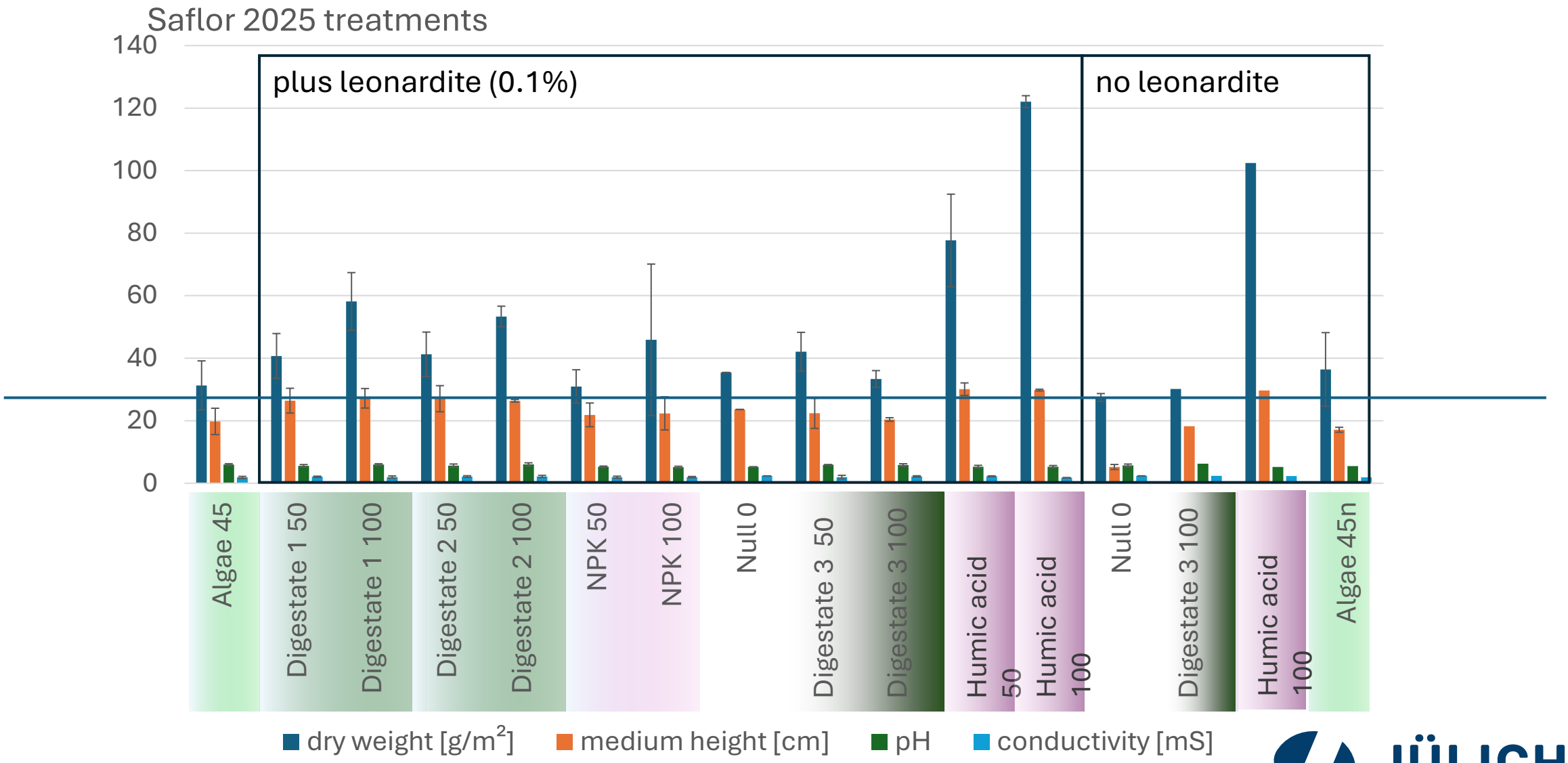
An example of additive application on marginal substrate: small plot setup

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Example: Interim-results of 2025

Saflor on small fields

Last season: digestate 40-60g DW, NPK max. 30g DW.
Comparable; Humic/fulvic acid is better, Leonardite helps!

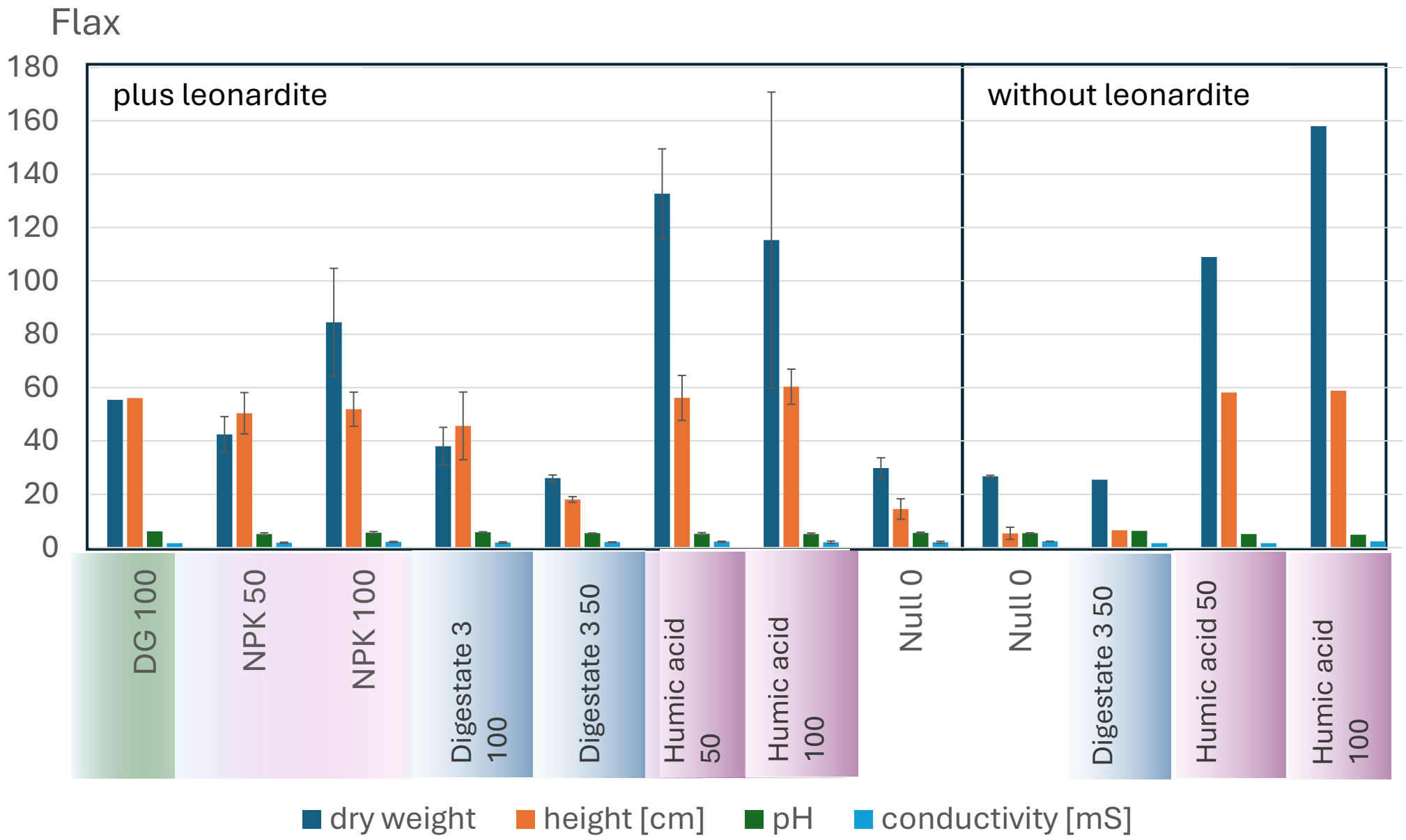


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Example: Interim-results of 2025

Flax on small fields

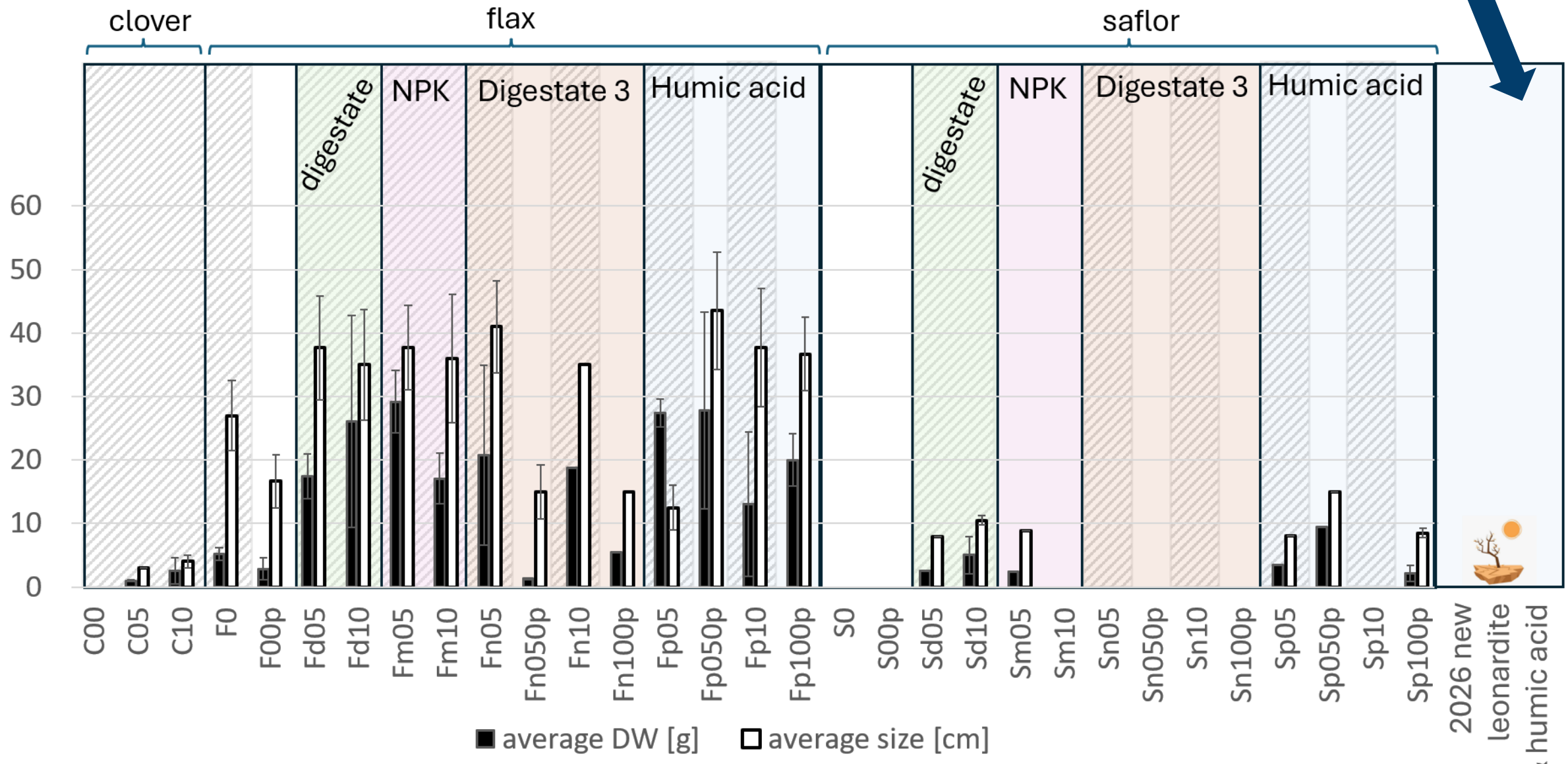


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Example: Interim-results of 2026 (one of the hottest and driest years in history in NRW)

3. Year – diffences btw. several times treated substrate vs. ‚sterile‘ starter substrate‘ under stress (heat)
(3*0.1% C (Leonardite) + respective fertilization)

Similar setup on ‚fresh‘ substrate
3 plots (of 72) with very few flax plants



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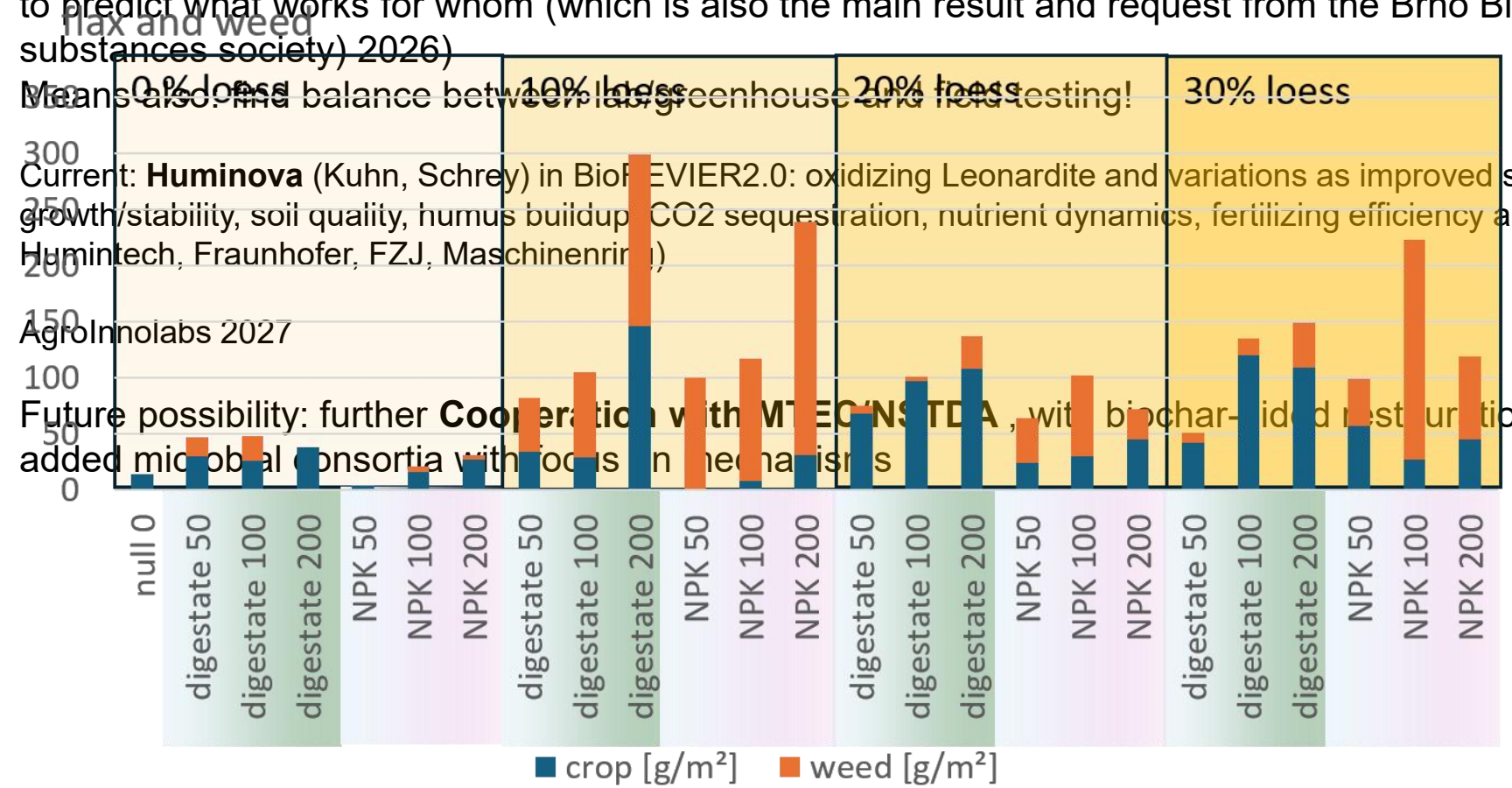
More work with biochar/organic amendments at IBG-2 to come

The observed effects are manifold and depend on target plant, substrate and formulation of C addition – but in general positive.

Some ‚biodiversity' results

Target must now be: **less screening, more process investigation** – substrate-additive-plant-microbe interactions and how to predict what works for whom (which is also the main result and request from the Brno Bio IHSS (international humic substances society) 2026)

Means also: find balance between lab/greenhouse and field testing!



Current: **Huminova** (Kuhn, Schrey) in BioREVIER2.0: oxidizing Leonardite and variations as improved soil growth/stability, soil quality, humus buildup, CO2 sequestration, nutrient dynamics, fertilizing efficiency and Humintech, Fraunhofer, FZJ, Maschinenring)

AgroInnolabs 2027

Future possibility: further **Cooperation with MTECNSTDA**, with biochar-aided restauration added microbial consortia with focus on mechanisms



Mitglied der Helmholtz-Gemeinschaft

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The observed effects are manifold and depend on target plant, substrate and formulation of C addition – but in general positive.

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Current: **Huminova** (Kuhn, Schrey) in BioREVIER2.0: oxidizing Leonardite and variations as improved soil amendments; targets: plant growth/stability, soil quality, humus buildup, CO2 sequestration, nutrient dynamics, fertilizing efficiency and water efficiency (2027-2031; Humintech, Fraunhofer, FZJ, Maschinenring)

AgroInnolabs 2027

Future possibility: further **Cooperation with MTEC/NSTDA** , with biochar-aided restauration of mining areas in Thailand with added microbial consortia with focus on mechanisms







ChatGPT helped here.

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FUTURE PERSPECTIVE – IN GENERAL

- Laboratory-to-field approaches, knowledge creation, knowledge extension
- Regular analysis of plant performance and physiological and biochemical plant properties and soils
- Efficiency of nutrient use: uptake and losses, carbon sink utilization and application of different plant biomasses, soil biodiversity, tailored approaches
- → Material applications, e.g. as paper substitute, energy, medical purposes-Cooperation (inter-/transdisciplinary, national, international)



Many thanks to the colleagues at IBG-2!

Tanapon Glingaysorn

Tobias Wojciechowski

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Thanks for your attention!



Christina Kuchendorf c.kuchendorf@fz-juelich.de

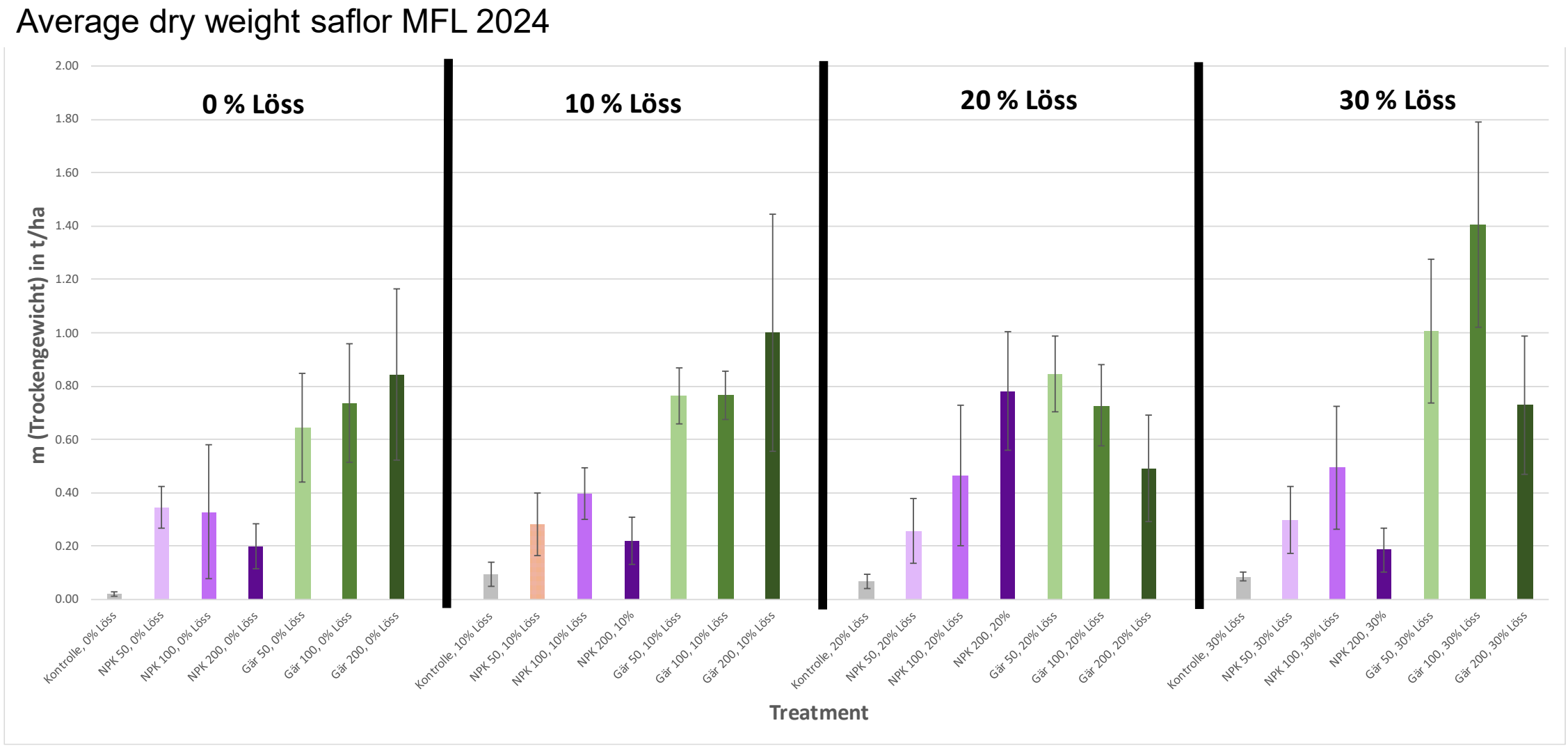
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Bioökonomie REVIER

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Example: Saflor – 2024 on MFL



Experiment: Nachhaltige Biomasseproduktion durch Anbau von *Miscanthus x giganteus* auf Marginalen Böden als Rohstoff zur energetischen und stofflichen Nutzung → MFL (läuft)

Experiment: Gerste als Indikator für Homogenität und Test auf Nährstoffeffizienz in marginalem Boden bei Strip-Tillage (Pflanzenperformance und Sickerwasseranalyse) Done



Experiment: Effekt von Perlhumus als Bodenzusatz auf Marginalen Böden; Vgl mit Terra Preta und reiner Gärrestdüngung sowie anderen C-haltigen Düngern und Nähr- und Huminstoffzuschlägen → MFL Kleinfeld



Experiment: Saflor- und Lein-Anbau auf Marginalen Böden und/oder Tagebaurestflächen → MFL 180m² Felder bis 8ha

Vergleich mit konventionellem Anbau 2026 (1ha, Arnoldsweiler)

sowie am Campus Kleinaltendorf (Saflor auf Kleinflächen, verschiedene Düngestufen) und in einem Ringversuch mit Hohenheim



Experiment: Optimierter Anbau von *Sida hermaphrodita* und *Silphium perfoliatum* auf Marginalen Böden mittels Gärrestunterfußdüngung ~~und Mulchfolieneinsatz~~ → MFL (läuft)

2026-2027: Auswerten, publizieren!

H
rum

Experiment: Biodiversity / Bodenkrusten (Identification of a biodiversity-based early marker for crop productivity on marginal soils) → MFL (läuft)



Experiment: Verhalten von Buchweizen als Vorexperiment zu Buchweizen auf marginalen oder weniger gedüngten Flächen
(mit BIMOTEC Hohenheim (Laura Junker, Samantha J Grimes)

Experiment: Marginale Böden und Lupine (*Lupinus angustifolius*) mit IBG-1 → MFL, done (#2)

Experiment: Aufwertung Marginaler Böden durch den Anbau von Steinklee (*Melilotus albus*) auf Tagebaurandbereichen (→ MFL (läuft) mit M.v.Cosselt, Hohenheim



Experiment: Weiden (Energy-Salix) unter extremen Bedingungen (Mini-coop mit Leonid Melezhyk, Wageningen)
... sie leben noch

2026-2027: Auswerten, publizieren!

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Works with biochar/organic amendments at IBG-2:

Arnd Kuhn (diverse)

Sarah Milski (bachelor): Einfluss von organischer und mineralischer Nährstoffbeladung zweier Pflanzenkohlen als Bodenzuschlagsstoff auf Wachstum und Inhaltsstoffe von Chinakohl (*Brassica rapa subsp. pekinensis*) (organisch aufgesättigte Biokohle trägt signifikant zu erhöhtem Glukose- und Stärkegehalt in Chinakohl bei)

Ashwaq Najjar: comparing effects of Nunos liquid solution (fermented digestate) on Mazie (*Zea Mays Badischer Gelber*) plant with control treatment (Hoagland); (slightly less growth than control, but higher WHC in treated pots) 2026
Further experiments with barley and in PGSB, being submitted
different biochar combinations

Philipp Sowa (IBG-1, PhD-work) an **Lupine**: Lupanine and 13a Hydroxylupanine - Higher content of both alkaloids on the plots treated with fermentation residue and increasing loess content (2025-26)

Kleinfeldversuch MFL mit Perlhumus (Leonardit), Powhumus, mehreren Biogas-Gärresten an Saflor, Steinklee, Flachs (Gerste)

Großer Maßstab MFL: Gärrest (striptill) vs NPK konventionell in marginalem Substrat (Saflor, Flachs, Steinklee, Buchweizen, Lupine, (Gerste))

LW-Maßstab Saflor Tagebaurandbereich mit Gärrest und NPK konventionell, mit/ohne Pflanzenschutz (2023ff)

LW- Maßstab Biokohle/Terra Preta mit Andreas Dering (Luftbildanalyse via Drohne, >20% Einsparung konventioneller Dünger, 2024)

Jablonowski et al.: Digestate und Alternativen an Saflor und Perennials (2020ff), crop garden/minicosms



Jablonowski et al: biofertilizer formulations (e.g. Aspergillus etc.) and entry to soil matrix (Brazil coop 2025)
Barbosa et al: Digestate and soil compaction in Rhizobox-grown Maize (2025)
Borges et al: Cassava and struvite (2025)



Regionale Innovationspartnerschaft
Färberdistelwirtschaft

10.1.2024

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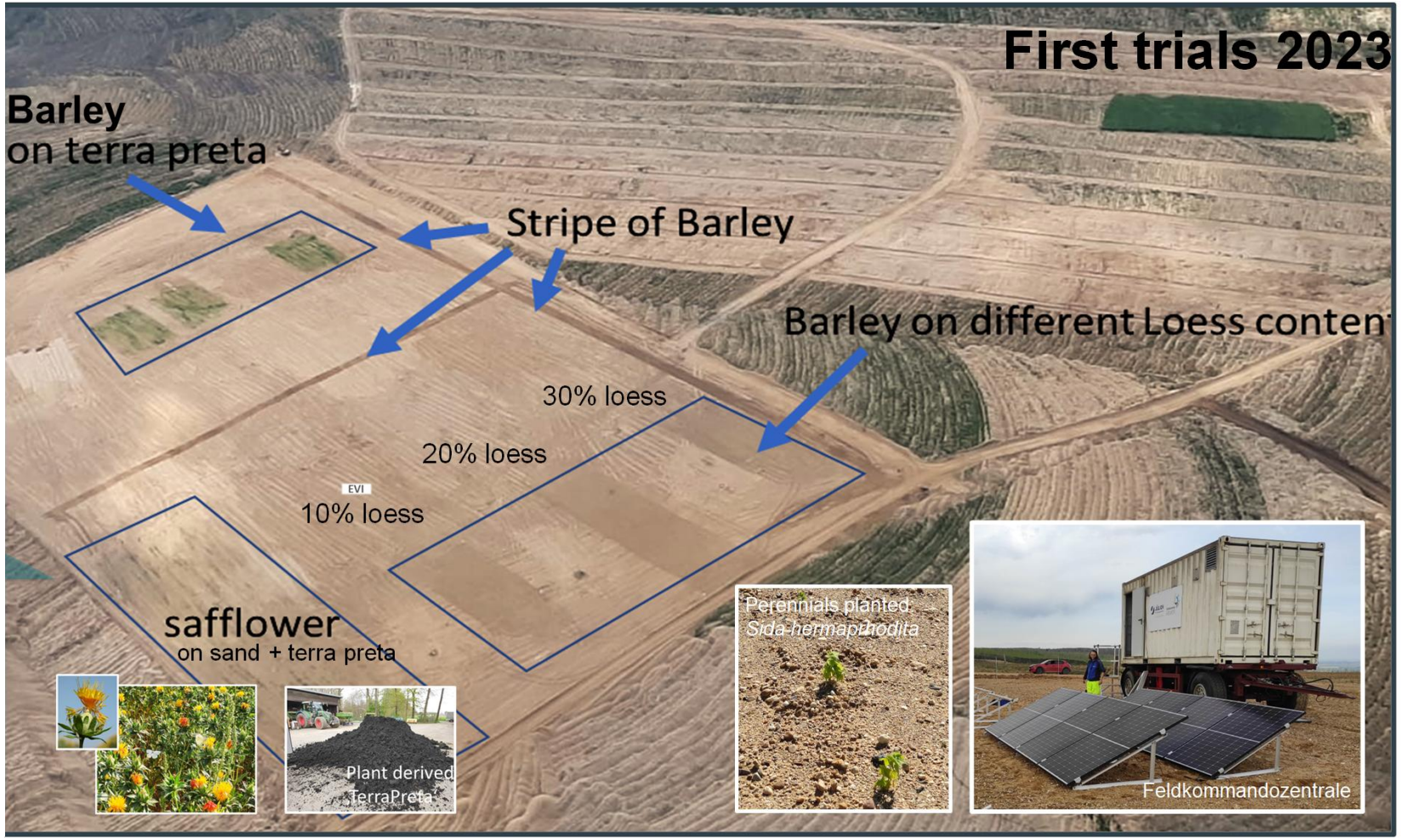
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Bioökonomie
REVIER

Structural change - Bioeconomy REVIERMarginal Field Lab (MFL)

Testing new technologies under real conditions:

- Plant performance under marginal conditions - “blank” substrate with no fertilizer history allows to more clearly visualize the effects of alternative (biochar, digestate, other organic) fertilizers on plant traits to
- better evaluate resource efficiency for nutrients and water and C-fate and
- to be applied in existing and new value chains in cooperation with regional farmers;
- establishment of demonstrators for innovative value creation on a relevant scale (e.g. Saflor)



Campus Klein-Altendorf (Uni Bonn)

CO2/FACE, Perennials, Färberdistel…





The „small scale“ approach



Algae biofilm reactors (TurfScrubber), waste water

PV power

Air after CO_2-usage

Solar-heat

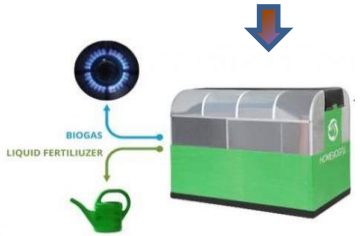
Rain water tanks as level buffers

AlgenAirlift-reactors as heat exchangers



Algae Airliftreactors for CO_2/room climate (compare BiQ Hamburg or FZ Jülich)

WC with yellow/black water separation (compare ARUP):
Yellow water -> Algen Sludge > Biogas (Home use facility)



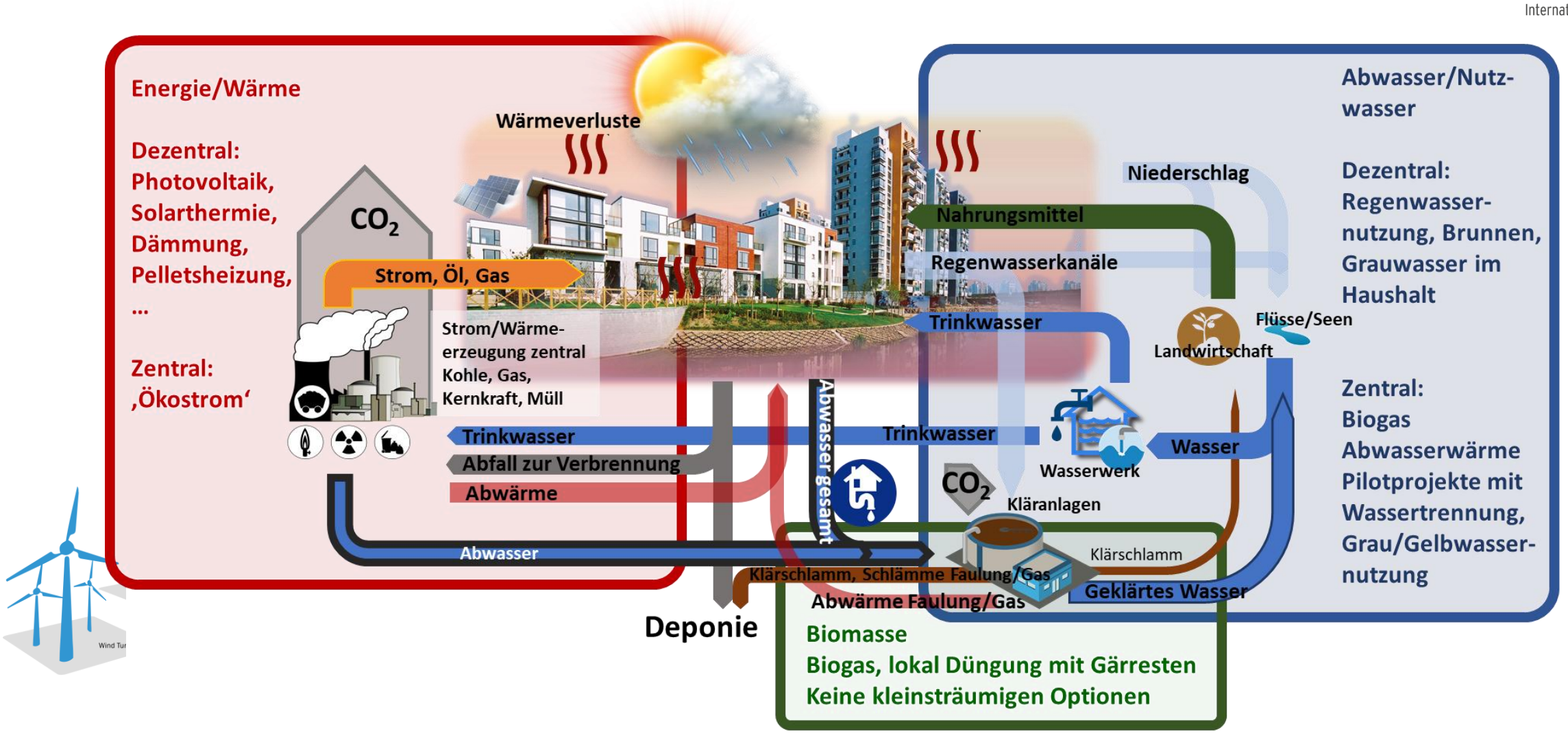
Reduced waste water/waste

Connection to Vertical/Indoor-Farming (upscaling)
Efficient nutrient recyling, especially P, N, C

Optional: connect to **Geothermal/Ice storage for independent heating/cooling**
→ Autonomous living



Siedlungen heute – viele Lösungen! Die ‚eine' Lösung für alle gibt es aber nicht; das Ressourcenproblem muss flexibel, interdisziplinär und nutzerfreundlich gelöst werden…



Ziel: Klärprozesse verbessern

Prozesschema einer Kläranlage, kombiniert mit einem Pond-System

- Die Algenbasierte Abwasserbehandlung erscheint eine energetisch sinnvolle Alternative zu konventionellen Belebtschlammsystemen, auch für Anlagen in der gemäßigten Klimazone
- Die Elektrizitätsproduktion liegt bei ca. 2 Mwha im Vergleich zum vorherigen Verbrauch von 0.68 MWh/a.
- Um dieses Potential voll zu nutzen, muss die Nährstoffzirkulation auch für Stickstoff vollständig erfolgen.
- Diese eher mittelgroße Kläranlage (32,000 PE) hätte einen Flächenbedarf von 29 ha Photobioreaktorfläche, wenn Ganzjahresbetrieb sichergestellt warden soll.
- Das sind etwa 10m² pro Personenäquivalent. Hmmmm….



Field helper for application: Farmdroid FD20

Producer: FARMDROID ApS, Denmark

- Drives autonomously (ca. 1km/h), solar powered
- Simple operation
- Functions: hoeing and sowing in 6 rows, expandable
- In use worldwide: ~ 1.000 devices, especially in organic farming
- Robots could shape agriculture more in future, working in ‚swarms‘



Bild: farmdroid.dk



Safflower / Carthamus



Intercropping Maize & Beans

➢ Agriculture since 2022 with droid support (these are the droids you‘re looking for ;))



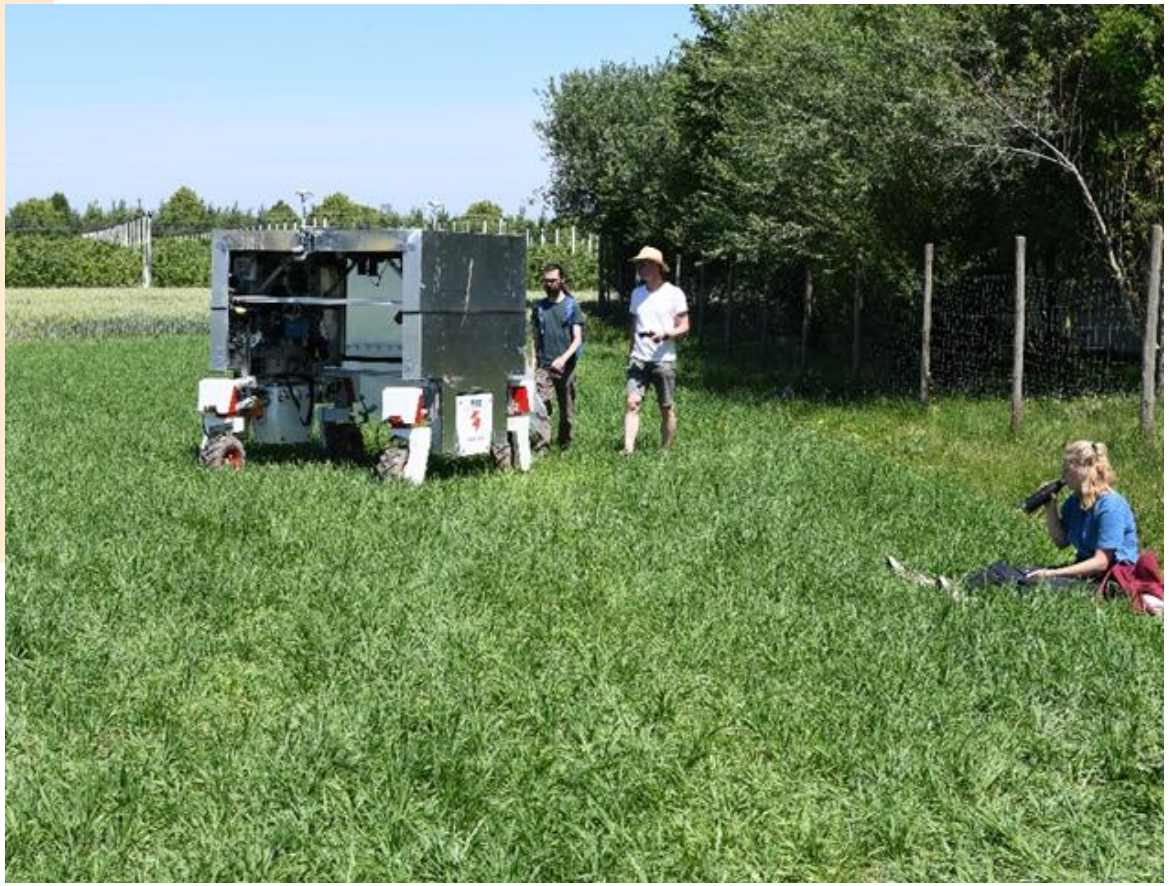
Sensor systems and -carriers in Science



Thorvald Roboter

Hersteller:
Saga Robotics, Norwegen

- Multifunctional robotic system, used at IBG-2 for high-precision plant monitoring with sensors
- Freely programmable: autonomous driving, imaging techniques



➢ Platform that can be used for sensor technology, but also, for example, for targeted fertilization or spraying

Sensor systems and -carriers in Science

Field Weasel

Hersteller: Lommers BV, Niederlande

- GPS-controlled research device for non-invasive plant measurement with high throughput over larger areas
- rotatable sensor platform
- electrically driven (very quiet)
- autonomous or remote-controlled driving





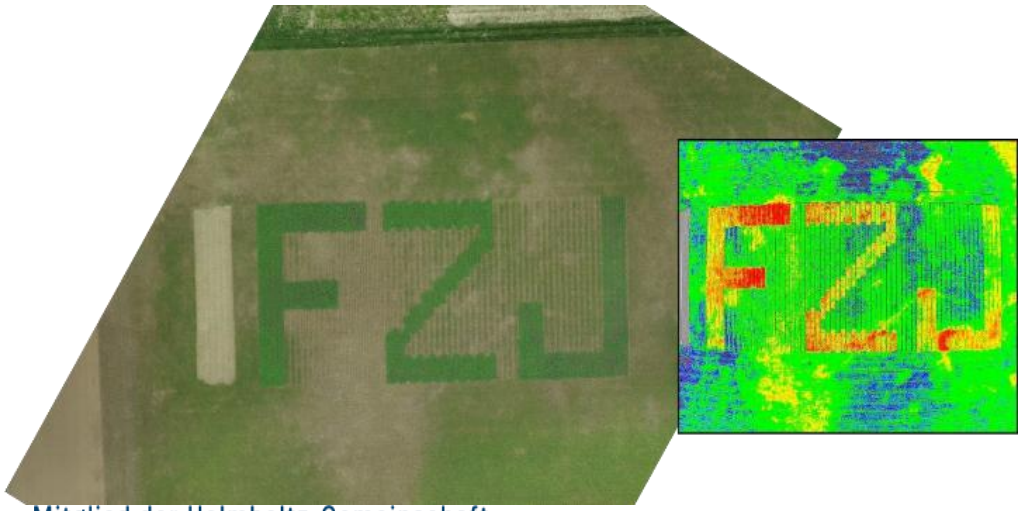


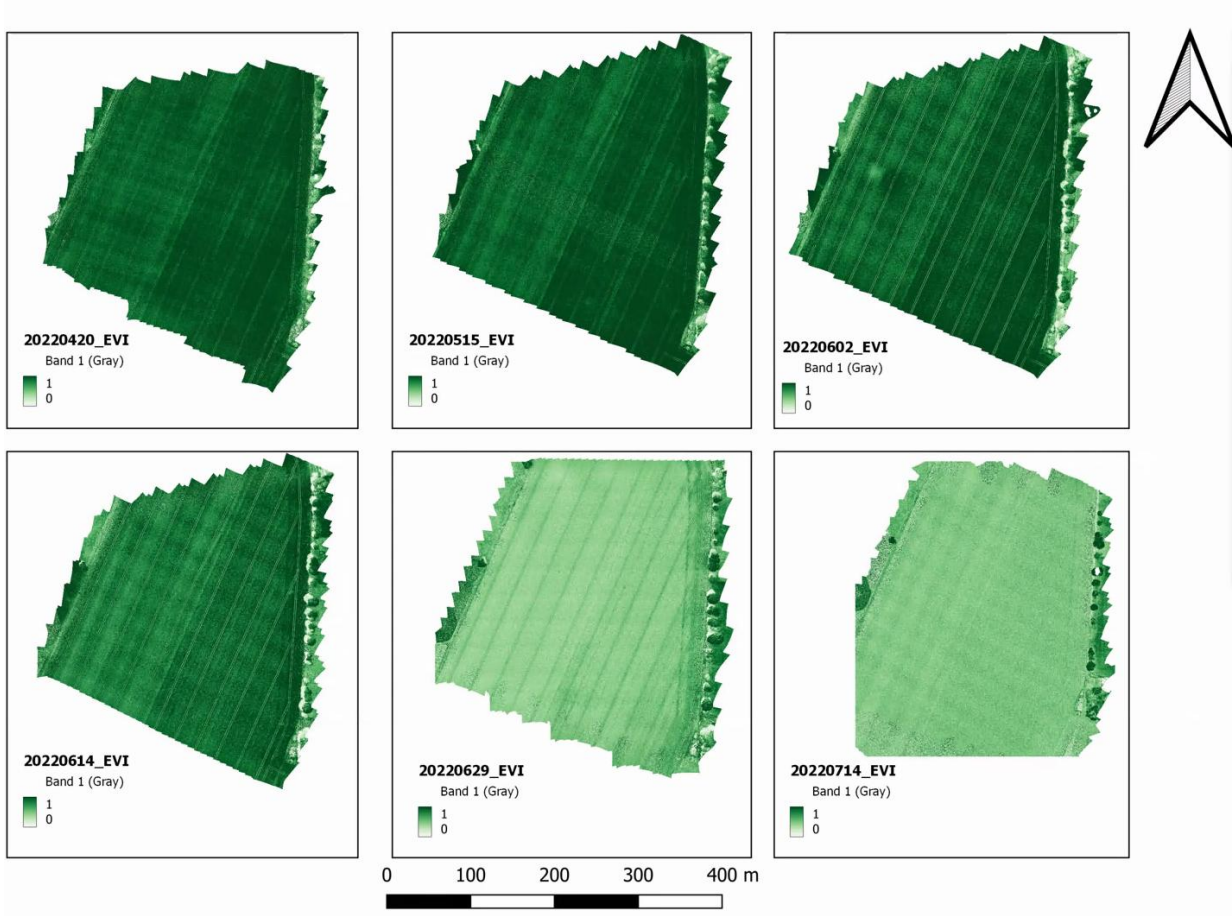
Sensor systems and -carriers in Science



Drones with sensors

- for use in plant breeding, climate adaptation and the investigation of cultivation efficiency
- investigation of plant growth and height, biomass development, chlorophyll content and sowing density
- in addition to measurements taken from aircraft, satellites and on the ground





^^ EVI (enhanced vegetation index), timeline grain ripening (spelt), multispectral camera

<< monitoring (RGB/multispectral) of a test planting with wheat and phacelia

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