AI FOR RESEARCH IN FOOD,
AGRICULTURE AND ENVIRONMENT

KIDA KON

SEPTEMBER 17-18 | 2025

CONFERENCE READER

KIDA
AI for Food and Agriculture

READER

KIDAKON

AI for research in food, agriculture and environment

Conference
17 – 18th September 2025

Johann Heinrich von Thünen Institute
Federal Research Institute for Rural Areas, Forestry and Fisheries

Braunschweig

Gefördert durch
Federal Ministry of Agriculture, Food and Regional Identity
Projektträger
Bundesanstalt für Landwirtschaft und Ernährung
Bundesamt für Verbraucherschutz und Lebensmittelsicherheit
BfR Bundesinstitut für Risikobewertung
JKI Julius Kühn-Institut
DIGITALE PERSPEKTIVEN
DBFZ
MRI Max Rubner-Institut
FRIEDRICH-LOEFFLER-INSTITUT
FLI Bundesforschungsinstitut für Tiergesundheit
Federal Research Institute for Animal Health
THÜNEN

Message of greeting from Alois Rainer, Federal Minister of Agriculture, Food and Regional Identity

Dear readers,
On every step of the path from our fields to our plates, artificial intelligence (AI) and data are progressively changing our agricultural practices and the way our food industry operates. The question of how we can make our agriculture and food systems more competitive, resilient, secure and sustainable increasingly turns into a question of how we can best exploit state-of-the-art technologies. Merely keeping pace with the latest developments is not enough. Instead, we need to take the lead and play a pioneering role. To make this possible, we must develop our key technologies accordingly. Beyond that, we also need to review and update our existing databases to fully exploit the tremendous potential of the data we already have at hand.
We want to give all crucial actors and stakeholders more leeway in their day-to-day work. This applies to farmers, producers, researchers and administrative staff alike. AI is a decisive factor when it comes to providing this kind of leeway and opening up a greater scope for action. It opens up new opportunities and enhances efficiency in resource-intensive processes. In this regard, research in the agricultural and food sector can sow the seeds of tomorrow's key technologies.
Our AI and data accelerator, "KIDA", follows a pragmatic approach to successfully put digitalisation, data and AI into practice. It creates added value that is perceptible and tangible. I am firmly convinced that our desks should no longer be the most labour-intensive field that we need to plough. Neither on our farms nor at our research laboratories, where highly committed colleagues spend days – and sometimes nights – experimenting to find vital solutions for our future! They should not be held back by paperwork or administrative tasks that AI could carry out for them.
A development as complex and dynamic as AI also requires new forms of collaboration – across institutions, branches and disciplines. This means, above all, constructive teamwork, an eagerness to find pragmatic solutions and a shared enthusiasm for exploration and experimentation. With a vast array of topics ranging from remote sensing technologies for land use detection and AI solutions for food waste prevention to efficient techniques for on-farm and underwater monitoring, KIDA and this conference compendium show us what is possible.
This new form of collaboration is exactly what we need to take on a leading role in harnessing AI for the future. Therefore, I am glad that the institutions within my ministry's remit are now taking over and will continue KIDA together in the coming years, so that this successful network of projects, competences and – most importantly – people can carry on its fruitful activities. After all, KIDA has been included in Germany's new High-Tech Agenda for a good reason!
I would like to express my thanks to the entire KIDA team. Your work, your passion and your commitment help to strengthen Germany as a research location where the technologies of tomorrow are born. I wish you an exciting read and insightful exchanges during the conference.

Yours sincerely,
Alois Rainer

Alois Rainer
Federal Minister of Agriculture, Food and Regional Identity

Message of greeting from Dr. Nathalie Gottschalk, KIDA Project Lead

Dear participants at KIDA-KON 2025, dear readers,
It is my great pleasure to present the conference reader for KIDA-KON 2025. Over the past few years, KIDA-KON has successfully established itself as an annual scientific conference on the use of AI in food, agricultural and environmental research. Organized by the KIDA project group and funded by the BMLEH (German Federal Ministry of Agriculture, Food and Regional Identity), the conference sheds light on the emerging and pressing questions of high-tech use in the agri-food and environmental research.
This year's conference offers once again a diverse range of presentations and posters on the practical application of AI by researchers from various disciplines. In this volume, you are invited to dive into their abstracts and gain insights into the latest research in the field. More so, you will also gain insights on how machine and deep learning, computer vision, large language models (LLM), as well as geospatial and time series analysis do already help leading researchers with data analysis for answering current research questions.
Clustered into five inspiring sessions, the KIDA-KON program covers a wide range of topics, such as LLM applications in food and health risk assessment, environmental monitoring, and AI for livestock and marine populations. In addition, we are honoured to feature two outstanding keynote speakers and prominent voices in the research field: First, Paul Devalier from the European Food Safety Authority sketches out what he calls the "Ghost in the machine", thereby challenging our perspectives on LLMs by applying corpus AI to risk assessment. Subsequently, Ina Schiering from Ostfalia University of Applied Sciences shares her experience in data governance and data sovereignty for environmental data.
Beyond the thematic highlights, the conference aims to bring together AI experts, data scientists, and researchers from diverse fields in order to encourage and support hands-on AI application. As KIDA has always been about building and reinforcing a network – both in the technical and social sense, also this KIDA-KON hosted at Thünen Institute in Braunschweig provides a fruitful platform for sharing knowledge, discussing ideas, networking, as well as addressing current challenges in AI application.
I would like to thank all researchers who present their work at KIDA-KON and contributed to this conference reader – on and also behind "the stage". I look forward to captivating presentations and stimulating discussions at KIDA-KON 2025.

Sincerely yours,
Nathalie Gottschalk

Dr. Nathalie Gottschalk
KIDA Project Lead

KIDA Conference 2025 // Brunswick

TALKS

POSTER

KIDA
AI for Food and Agriculture

Wednesday, September 17

9:00 Registration & Thünen Tour

10:00 Opening remarks

10:30 **Keynote I: Ghost in the machine: Applying corpus AI to risk assessment**
Paul Devalier | European Food Safety Authority

11:10 Coffee break

11:40 **Session 1 // LLM applications in food & health risk assessment**
Chair: Jacob Schmieder, M. Sc.

12:20 Lunch break

13:40 Poster session

14:40 Coffee break

15:10 **Session 2 // AI and remote sensing in agriculture**
Chair: Dr. Janis Stiegeler

16.30 Coffee break

17:00 **Podiumsdiskussion // Mit KI gegen Verluste und Abfälle bei Lebensmitteln**
mit Prof. Dr. Birgit Kleinschmit und Prof. Dr. Engel Arkenau

18:00 Get-together

Thursday, September 18

9:00 **Keynote II: Data governance and data sovereignty for environmental data**
Prof. Dr. Ina Schiering | Ostfalia University of Applied Sciences

9:45 **Session 3 // Predictive modeling in economics and trade**
Chair: Dr. Steffen Albrecht

10:25 Coffee break

11:05 **Session 4 // Environmental monitoring**
Chair: Tatjana Manych, M. Sc.

12:25 Lunch break

13:30 **Session 5 // AI for livestock & marine populations**
Chair: Dr. Aileen Bahl

14:30 – 15:00 Conference closing

Talks
Day 1

Session 1 — LLM applications in food & health risk assessment

Chair: Jacob Schmieder, M. Sc.

11:40 **Aileen Bahl**
Information extraction for mechanistic toxicology using LLMs

12:00 **André Friedrich**
Implementation of AI-based support systems in the risk assessment of recipient and donor organisms for genetic engineering operations

Session 2 — AI and remote sensing in agriculture

Chair: Dr. Janis Stiegeler

15:10 **Jennifer McClelland**
Advancing Landscape Monitoring: A Modular and Scalable ML Framework for Woody Vegetation identification with Remote Sensing Data

15:30 **Lukas Blickensdörfer**
Semantic segmentation of multitemporal very high-resolution satellite imagery for nation-wide hedgerow identification

15:50 **Gideon Okpoti Tetteh**
Earth observation and deep learning for area-wide mapping of agricultural land use and habitat diversity in Germany

16:10 **Stefan Paulus**
Challenges of AI-based methods for spot-/site-specific spraying

Talks
Day 2

Session 3 — Predictive modeling in economics and trade

Chair: Dr. Steffen Albrecht

9:45 **Annemarie Kronhardt**
Predicting volatile energy prices

10:05 **Christian Morland**
An evaluation of gravity models and artificial neuronal networks on bilateral trade flows in wood markets

Session 4 — Environmental monitoring

Chair: Tatjana Manych, M. Sc.

11:05 **Teodor Chiaburu**
Towards reliable soil horizon classification: A multimodal approach leveraging hierarchical taxonomy and graph-based representations

11:25 **David Mengen**
Efficient seasonal hydrological prediction with hydracastAI

11:45 **Amelie McKenna**
Ground-truthing of satellite-based forest condition products using precise tree positions

12:05 **Jonathan Wolf**
From study areas to a nationwide forest monitoring: roll-out in Germany in progress

Talks
Day 2

Session 5 AI for livestock & marine populations

Chair: Dr. Aileen Bahl

13:30 **Carsten Meyer**
Detection of common starfish in underwater images from Sylt outer reef using YOLOv8

13:50 **Aseem Tara**
AlphaFold-driven structural optimization of ligninase for enhanced lignocellulose degradation in transgenic livestock

14:10 **Mavis Boimah**
Smart farming in action: Evaluating AI weight sensors for health and profitability in pig production

KIDA KON

SAVE THE DATE

2026

September 23-24

FEDERAL INSTITUTE
FOR RISK ASSESSMENT (BFR)
BERLIN-MARIENFELDE

TALKS

KIDA Konferenz 2024 //
Foto: Matthias Werner (DBFZ)

Day 1, 10:30

Keynote

Paul Devalier

Ghost in the machine: Applying corpus AI to risk assessment

Regulatory risk assessment stands at a crossroads. We've long assumed that AI would enhance evidence-based science—a sharper tool for modelling reality, reducing bias, and accelerating discovery. But large language models (LLMs) don't behave like instruments. They don't follow symbolic logic or controlled method. They simulate people. They generate discourse.

This keynote invites a shift in perspective: from viewing AI as a machine, to recognising it as a *participant* in the scientific process. Not a mind. Not a tool. But an emergent actor embedded in our shared infrastructure of meaning. LLMs do not produce truth—they generate *socially plausible reasoning*. That positions them squarely within a neglected dimension of science: discourse, interpretation, judgment.

We contrast classical epistemology with a dual-helix model of science—discovery and dialogue—better suited to Corpus AI systems that include LLMs which social context co-produces insight. In this light, LLMs become reflection engines, helping us confront the limits of our own reasoning.

For practitioners in food safety, toxicology, and regulatory science, this talk offers a rethinking of trust. We argue for maintaining scientific rigour while expanding our epistemic tools—not just to model the world, but to model how *we model* the world. It's a call to rethink the scientific methods not as an empirical model of reality, but as a model of science which creates a space of dialogue between human and machine.

Paul Devalier
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Day 1, 11:40

Session 1

Talk

Dr. Aileen Bahl

Information extraction for mechanistic toxicology using LLMs

In this work, we use Large Language Models (LLMs) to mine, interpret and enrich toxicological data, with a particular focus on mechanistic toxicity. By integrating omics data, we describe key events in Adverse Outcome Pathways (AOPs), illuminating each step from molecular initiation to observed adverse outcomes. In this context, LLMs can be used for extracting, synthesizing, and contextualizing information from vast and diverse data sources, including scientific literature, public databases, and laboratory reports. By leveraging advanced natural language processing capabilities, LLMs can identify relevant biological entities (e.g., genes, proteins, metabolites) and map them to critical pathways and mechanisms of toxicity, thereby proposing mechanistic hypotheses for further evaluation. By doing so, these models facilitate the systematic construction or refinement of AOPs, where each event from molecular initiation to adverse outcome is supported by structured evidence. This automated information extraction enables researchers to more rapidly uncover novel connections between exposure events and molecular-level perturbations, thereby supporting the discovery of new biomarkers and potential toxicological endpoints triggered by specific substances. Finally, the extracted data can be mapped to existing ontologies and converted to linked data.

Despite their potential, LLM-based approaches also face several challenges. Models can be prone to biases and hallucinations, emphasizing the importance of rigorous validation against domain-specific datasets and expert curation. Additionally, ethical and regulatory considerations remain crucial when applying advanced AI tools for environmental and health risk assessments. Ongoing research aims to refine these approaches to ensure transparency, reliability, and reproducibility. Overall, harnessing LLMs for information extraction in toxicology holds immense potential to accelerate mechanistic understanding, streamline data synthesis, and support a more predictive, evidence-based approach to hazard assessment. Here, we show our current approaches tackeling these issues.

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Dr. André Friedrich

Implementation of AI-based support systems in the risk assessment of recipient and donor organisms for genetic engineering operations

Day 1, 12:00

Session 1

Talk

Basic research often involves the use of genetic engineering methods on microorganisms. In accordance with the German Genetic Engineering Act, the Central Committee on Biological Safety (ZKBS) assigns these organisms to one of four risk groups for their use as recipient or donor organisms, thus enabling the allocation of the corresponding biosafety level to the respective engineering operations. Structural and organisational safety measures are then assigned to the work on the basis of these biosafety levels.

As part of the risk assessment, the administrative office of the ZKBS performs a literature search and analysis, on the basis of which a position statement is drafted and then adopted by the ZKBS. The criteria for risk assessments are formalised and specified by the German Genetic Engineering Safety Ordinance (GenTSV). To shorten the time needed for the literature analysis, an AI-based support tool is being developed (KAPRi).

The KAPRi tool consists of two modules: a text-mining-based module for the extraction of scientific publications from scholarly databases and a large language model (LLM)-based module for the evaluation of publications. A prototype of the latter is already available for valuations. The prototype is built on the parsing and chunking of publications. Based on questions derived from the classification criteria of the GenTSV, each individual chunk is processed by an LLM. Then, the results for each publication are summarised using LLM. The resulting report is intended to facilitate and accelerate identification of relevant literature and facts based on standardised, recurring queries. Initial valuations of already classified sample cases yielded comprehensible, short, concise and, most important, accurate answers without generating any incorrect data.

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Advancing landscape monitoring: A modular and scalable ML framework for woody vegetation identification with remote sensing data

Session 1

Day 1, 15:10

Talk

Woody vegetation such as hedges, brushes, cobs, or single trees are of great importance for the preservation and promotion of species in the ecosystem landscape and thus for the maintenance of ecological processes and ecosystem services. However, achieving this at scale requires integrating diverse and often incomplete data sources, such as reference data from various providers. For example satellite SAR data, satellite multispectral imagery, LiDAR data and weather records. To address these challenges, we developed an open source scalable and modular ML/AI infrastructure designed to unify and standardize reference data for vegetation monitoring, integrating Germany wide open access OGC-WCS data cubes. A central PostgreSQL-based database, enables efficient spatio-temporal querying, ensuring structured access to geo-referenced datasets.

Automated preprocessing pipelines transform heterogeneous data into analysisready formats, allowing consistent data fusion and enabling machine learning applications. The framework supports ML and DL classification using Random Forest, XGBoost, and Multi Layer Perceptrons while allowing comparison with Generalized Linear Models (GLMs), confirming the limitations of linear modeling for early growth stage detection and a high performance with Random Forest and XGBoost. Additionally, the database provides insights into the coverage and usability of optical vs. radar satellite data, particularly regarding cloudrelated gaps in optical imagery. The modular architecture allows for seamless integration of additional AI models, ensures scalability for larger area coverage, and supports the incorporation of diverse data sources such as drone imagery and LiDAR data, improving precision in agricultural analysis. By providing unified access to structured and scalable datasets, this infrastructure enhances the applicability of ML in landscape monitoring and environmental research, supporting sustainable resource management and data-driven decision-making.

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Lukas Blickensdörfer, M. Sc.

Semantic segmentation of multitemporal very high-resolution satellite imagery for nation-wide hedgerow identification

Day 1, 15:30

Session 2

Talk

Hedgerows contribute to carbon storage, protect soil against wind erosion and provide habitat and food for diverse animal species. However, Germany may have lost about 50% of their hedgerows since the 1950s. National estimates of hedgerow coverage are often outdated, inconsistent, and lack standardization across federal states, hampering conservation efforts and accurate carbon accounting. To address this, we developed a national-scale hedgerow mapping workflow that leverages very high-resolution satellite imagery, semantic segmentation, and imperfect reference data. We compare predictors from two different multispectral satellites: 1) PlanetScope mosaics for the months of April, June, August and October at 3 meters resolution, and 2) monotemporal SPOT-Pleaides mosaics at 1.5 meters. The reference data consists of an incomplete inventory of polylines over the Federal State of Schleswig-Holstein. We study the impact of different loss functions and predictors on model performance using a UNet architecture. We propose the Average Surface and Hausdorff distances as metrics to evaluate performance, besides the traditional f1 score. We further validate our predictions at national scale against the Copernicus Small Woody Features (SWF) dataset and other available area-wide datasets.

The models achieve good accuracies (~f1-score 0.64), efficiently separating the vast majority of the hedgerows from the rest of the landscape. Models based on Planet multitemporal imagery from the four available months and the NIR band outperformed models that used single-months or RGB data, as well as models based on SPOT-Pleaides. Flexible loss functions, such as binary cross-entropy, helped mitigate errors produced by sensor artifacts.

We show that using datasets not specifically designed for hedgerows, such as the SWF, can lead to overestimations of up to 130 % in national scale inventories, and significant local underestimations, underscoring the need for target-specific mapping models using deep learning.

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Dr. Gideon Okpoti Tetteh

Earth observation and deep learning for area-wide mapping of agricultural land use and habitat diversity in Germany

Session 2

Day 1, 15:50

Talk

Agricultural biodiversity is critical for ecosystem resilience, food security, and sustainable farming, yet monitoring it at large scales remains challenging. Recent advances in deep learning (DL) and remote sensing (RS) provide powerful tools to efficiently assess and track habitat diversity as a component and proxy of biodiversity in agricultural landscapes. Combining medium-resolution satellite imagery such as Sentinel-2 with DL models such as convolutional neural networks (CNNs) enables the automated delineation of agricultural fields and the area-wide identification of their corresponding land use. In this study, we present the use of two DL methods: one for agricultural field delineation and the other for mapping the crop types on agricultural lands. For the field delineation, we combined the FracTAL ResUNet architecture with hierarchical segmentation and applied it to monthly composites of Sentinel-2 images from March to September per year. Regarding crop-type mapping, we applied an approach that combines a one-dimensional convolutional neural network (1D-CNN), Temporal Encoding (TE), and data augmentation to all clear-sky observations of Sentinel-2 and Landsat images per year. Based on majority voting, the crop type of each agricultural field is identified. With this field-based crop type map, various landscape metrics such as the Shannon Diversity Index and effective mesh size are computed per year and used as proxies to assess habitat diversity on agricultural lands over time. We are currently using these technologies within the MonViA project, which is a German-wide initiative for monitoring biodiversity in agricultural landscapes. By leveraging these technologies, we can achieve scalable, precise, and cost-effective biodiversity assessments, supporting global conservation and sustainable agriculture goals.

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Challenges of AI-based methods for spot-/ site-specific spraying

Day 1, 16:10

Session 2

Talk

Monitoring field experiments is a well-established practice in plant science. It provides crucial information about weed populations, crop plant development, and explicit biotic or abiotic stress conditions. There is a strong emphasis on detecting plant diseases, as society increasingly demands a reduction in fungicide use.

A well-structured data workflow is required to convert UAV images into a reliable plant disease map that can be uploaded to smart sprayers or spraying drones. The necessary algorithms for monitoring, including image calibration, orthomosaic generation, and plant disease detection are readily available. These algorithms are not currently utilized in practical agriculture. One reason is that numerous challenges need to be addressed in this context, which can be categorized into methodological, biological, and agricultural challenges (see Fig. 1). Methodological challenges include issues related to image calibration, labeling, thresholding or the limitations of buffer zones around disease spots. Biological challenges involve the timing of monitoring flights at key periods of epidemiology and disease development, or the emergence of new stress factors in the fields, such as mixed infections. Agricultural challenges encompass, the transfer from one field to another, the sensitivity of classification models, and the risk of disease spread and yield loss if infected plants are overlooked.

This study introduces a comprehensive workflow for converting UAV field images into application maps suitable for modern application devices. It outlines the challenges that must be addressed to integrate this workflow into daily agricultural practices. Focus lies in the critical analysis of the realistic potential of artificial intelligence for monitoring and decision-making in plant protection.

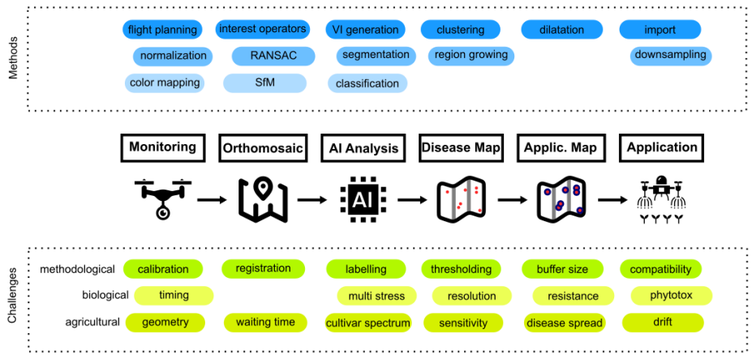

Figure 1: A workflow starting with drone-based monitoring to the generation of orthomosaic images, and disease to the final application is shown together with required methods and rising challenges.

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Prof. Dr. Ina Schiering

Data Governance and data sovereignty for environmental data

Day 2, 9:00

Keynote

Data analysis using machine learning and visualization of environmental data offers significant potential for research. To this end, monitoring data can be provided by sensors integrated into wireless sensor networks and remote sensing utilizing satellites or drones. While remote sensing data from satellites is generally available, data captured via drones or wireless sensor networks needs to be specifically collected as a basis for further investigation. Besides long-term environmental monitoring programs, such as those conducted by the Thünen Institute of Forest Ecosystems on specific areas, most of the data collected in the context of research projects is typically restricted to smaller areas and a limited amount of time. Reasons include the cost of operating wireless sensor networks and periodic drone flights accompanied by operators.

Digital transformation leads to use cases for employing monitoring data in business applications in agriculture and forestry. This long-term monitoring data could be useful as additional input for research. However, since it could also provide insights into business data of farmers and forest owners and could be relevant for taxation in the case of forest owners in Germany, there are concerns about providing this data for other uses, such as research.

To foster data sharing in a trusted and secure manner, the Data Governance Act and the Data Act provide a legal basis. European Data Spaces for the domains of Agriculture and the Green Deal could be relevant in this context. To build up trust, workshops with farmers and forest owners are helpful in determining for which purposes and in what form they are willing to provide access to their monitoring data. Additionally, technical and organizational measures, such as fine-grained access control, aggregation, and secure multi-party computation, can be employed to limit the use of data to the agreed purposes.

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Day 2, 9:45

Session 3

Talk

Annemarie Kronhardt, M. Sc.

Predicting volatile energy prices

A growing share of renewable energies in the power mix adds significantly to price volatility at the German power market due to fluctuating supply of cheap wind and solar energy. What is a challenge to net operators, opens up an opportunity for flexible energy producers to profit from high revenues at times of low supply.

Biogas provides the possibility to generate green electricity irrespective of weather conditions. The project FlexApp puts a model that predicts the gas storage filling level to test on industrial scale. Furthermore, we generate short term predictions of electricity prices at the EPEX Spot Day-Ahead Auctions for the German bidding zone using a model to evaluate added revenues resulting from flexible feeding, and thus, controlled biogas production.
We chose a long-short term memory (LSTM) model that learns to predict prices for the upcoming days with hourly resolution from historical data sequences of past weeks.

As the available amounts of cheap electricity is a result of weather effects and directly affects the hourly market prices, we identified the main influence parameters as wind speed, global radiation, air temperature and use them for model training. Moreover, we take calendar effects into account as well as historical market prices and load data. As we intend to apply the model on operational level, the project stands out by updating and delivering the inference results for revenue optimization on a daily basis as soon as new data is published. Working with the parameters wind speed, air temperature and electricity prices so far, we were able to recreate the so-called ‘double-hump structure’ (German: Doppelhöckerstruktur) of the price curve that results from high electricity demand in the morning and afternoon of working days.

Price forecasts for electricity, heat and synthetic fuels will become increasingly important in the future as the flexible use of biomass for energy becomes more and more common.

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Day 2, 10:05

Session 3

Talk

Dr. Christian Morland

An evaluation of gravity models and artificial neuronal networks on bilateral trade flows in wood markets

International trade in wood products drives economic development through interconnected global markets, yet economic shocks and structural changes frequently disrupt market dynamics. Robust insights into their determinants and accurate predictions of trade flows are critical for policymakers and stakeholders to optimize trade-related decision-making and economic planning. While the deterministic Gravity model provides valuable insights into the determinants of trade and remains widely used due to its intuitive framework and empirical effectiveness, data-driven machine learning approaches – such as artificial neural networks (ANNs) – offer promising alternatives for enhanced predictive accuracy. However, it remains unresolved whether ANNs outperform Gravity models in predicting and forecasting trade flows within forest product markets.

This study systematically compares the predictive and forecasting capabilities of Gravity models and feedforward neural networks (FFNNs) for bilateral trade flows across four major product categories in international wood markets. Key findings reveal that methodological selection must align with both analytical objectives and product-specific characteristics. FFNNs demonstrate superior performance in predicting historical and current trade flows, achieving higher accuracy across all product groups. Regarding forecast accuracy, our results show that FFNNs maintain an advantage in short-term projections (1-5 years), but their efficacy diminishes as the forecast horizon extends beyond this range.

These results provide actionable guidance for selecting context-appropriate methodologies, whether for data validation, short-term operational decisions, or long-term strategic planning. Future research should prioritize integrating exogenous variables and advanced machine learning architectures to further enhance the precision and robustness in analyses of bilateral wood trade.

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Day 2, 11:05

Session 4

Talk

Teodor Chiaburu, M. Sc.

Towards reliable soil horizon classification: A multimodal approach leveraging hierarchical taxonomy and graph-based representations

Accurate prediction of soil characteristics is essential for ecological monitoring, precision agriculture and sustainable land management. Soil horizons, the distinct layers within soil profiles, provide essential information on soil formation processes and properties. However, classifying these horizons is far from a standard classification problem due to the complex and hierarchical nature of German soil horizon classification. Traditional models struggle with the nuanced relationships between horizon labels, which often exhibit dependencies in their definitions and overlap in the multidimensional feature space.

We present preliminary results from baseline models designed to address these challenges. Our approach integrates the graph structure of soil horizon denotation into the classification process through an embedding loss function that preserves label relationships. In addition to image-based features, we incorporate geotemporal metadata, including the timestamp of annotation, geographical location and derived environmental factors such as climate and terrain characteristics. Furthermore, we leverage annotated depth markers and horizon-specific attributes, such as humus and carbonate content classes, to enhance classification performance. The dataset we used for training the models was extensively and laboriously annotated by soil experts.

By incorporating these diverse inputs, our models provide a more informed prediction of soil horizons. Our findings highlight the impact of utilizing structured representations and multi-modal data in improving classification performance. This study serves as an initial step towards more robust soil profile analysis, with implications for both scientific research and practical applications in soil mapping.

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Day 2, 11:25

Session 4

Talk

David Mengen, M. Sc.

Efficient seasonal hydrological prediction with hydracastAI

Climate change is leading to more frequent and intense droughts in Germany and across Europe, affecting agriculture in particular, where dry spells are responsible for more than 50% of yield losses in recent decades. Accurate knowledge of water resource availability and future trends is crucial for adapting to this uncertainty. To address this, Belleflamme et al. (2023) have set up the hydrological model ParFlow/CLM for Germany, which simulates the water cycle at high resolutions and can predict soil water storage and drought risk up to 7 months in advance. Nevertheless, the vast computing capacities required to run the model prevent its cross-industry application and its use for private-sector services. For this purpose, the AI surrogate model HydracastAI was developed and trained on the daily ParFlow/CLM pressure outputs.

HydracastAI is based on the Forced-Spatio-Temporal RNN (FSTR) architecture, originally developed for video prediction and adapted for emulating ParFlow by Bennett et al. (2024). The temporal context is learned by an LSTM, and the meteorological forcings condition the evolution of the hydrologic state as the forecast progresses. The initial hydrologic state and the static parameters inform a memory state. The encoders in FSTR are based on convolutional layers which allows for training the model on smaller patches and applying it later to the full domain.

Once the model is trained, a prediction for one 180-day forecast takes about 10 minutes on a single A100 GPU, including writing the large output dataset. Compared to the numerical Parflow/CLM simulation, HydracastAI offers a speed advantage of more than a factor of 2000, making ensemble predictions and scenario analyses application-oriented and economically feasible. Initial evaluation of HydracastAI shows robust and satisfying results. The predicted groundwater depth remains within a realistic range over the entire prediction period.

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Day 2, 11:45

Session 4

Talk

Amelie McKenna, M. Sc.

Ground-truthing of satellite-based forest condition products using precise tree positions

Forest ecosystems face numerous challenges due to changing climatic conditions which lead to more frequent occurrences of extreme meteorological events, including prolonged dry spells. This increases tree vulnerability to both biotic and abiotic pressures. The European Crown Condition Survey is a response to these changes and aims to adapt and improve methods for assessing tree vitality (Eichhorn et al., 2021). A key development is the integration of modern GNSS technologies to validate remote sensing products of tree vitality at the individual tree level.

During several-months of field campaign, precise RTK GNSS geo-coordinates, diameter at breast height and tree height, were collected, additionally to the annual visual assessment of crown defoliation in the plots of the Crown Condition Survey. The FORCE software (Framework for Operational Radiometric Correction for Environmental monitoring) (Frantz 2019) was utilized to compute a set of 12 different vegetation indices. Random forest regression was employed to find best combination of vegetation indices for predicting crown defoliation. Additionally, different already published satellite-based forest vitality products and vegetation indices were intersected with the tree positions. During the intersection crown extents and their overlap with remote sensing pixels were explicitly considered. All remote sensing products and vegetation indices were derived from the Sentinel-2 satellite mission. Spatial resolutions are either 10 m or 20 m, with temporal coverage starting from 2016.

In 2023 and 2024, 2000 tree positions were collected across Thuringia, Mecklenburg-Western Pomerania, and Baden-Württemberg. An initial point-based analysis revealed only a weak correlation (R^2 = 0.03) between survey-based single-tree defoliation and satellite-derived forest condition indices. This discrepancy is likely due to the limited spatial representation of individual trees within the relatively large Sentinel-2 pixels. To address this, ongoing analyses based at pixel level aim to refine this relationship by explicitly accounting for spectral mixing effects caused by multiple trees within each pixel.

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Day 2, 12:05

Session 4

Talk

Jonathan Wolf, M. Sc.

From study areas to a nationwide forest monitoring: roll-out in Germany in progress

Recent years have seen forests increasingly affected by storms, extreme droughts, and bark beetle infestations, particularly in 2017 and 2018. This prompted the Thuenen Institute of Forest Ecosystems to develop a remote sensing-based detection system for damaged areas. The FNEWs project[1], involving an international consortium from technology, remote sensing, economics, and applied forestry, established a monitoring system and technical infrastructure.

The forest damage monitoring methodology was developed in four study areas covering about 22% of Germany's forests. It involves preprocessing Sentinel-2 satellite imagery, time series filtering, and a statistical model. The annual product identifies damaged areas with a minimum mapping unit of 0.1 ha and a resolution of 10 x 10 m², achieving ≥ 95% accuracy[2]. This largely automated system detects and quantifies biotic and abiotic damage using satellite imagery, with results of the FNEWs project available at the Thuenen Institute's geoportal[3].

Owing to the success of the initial project and an urgent need for information on forest damage, continuous nationwide forest damage monitoring is indispensable. Early in 2024, the implementation phase commenced at the Thuenen Institute of Forest Ecosystems, aiming to scale the successfully tested damage monitoring system to nationwide coverage. The transition towards operational usage brings various challenges, which will be highlighted here. The nationwide rollout, which began at the level of study areas, requires adjustments to the procedure. The workflow was adjusted, resulting in the majority of the preprocessing being eliminated, as the preprocessed data from the FORCE Datacube[4] is now utilized. Furthermore, the classification method has been changed to a vegetation index-based threshold method. We will give an insight into the current status of the rollout process and present first results.

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Day 2, 13:30

Session 5

Talk

Prof. Dr. Carsten Meyer

Detection of common starfish in underwater images from Sylt outer reef using YOLOv8

In 2023, bottom-contacting fishing gears were excluded from German marine NATURA 2000 sites. The exclusion also holds for scientific monitoring where usually traditional, bottom-contacting sampling techniques such as beam trawling were used. However, scientific monitoring will be required to investigate the potential recovery of the areas and thus to assess the effectiveness of the conservation measure. To this end, less invasive monitoring techniques such as underwater videos are increasingly being used. However, they generate large data volumes, which are very time-consuming to analyse if not properly automated e.g. by using computer vision techniques.

Recent advances in artificial intelligence, in particular deep learning, have led to significant performance improvements in numerous tasks in computer vision. Here, we apply a state-of-the-art object detection algorithm, YOLOv8, to automatically detect individuals of the common sea star *Asterias rubens*, a benthic species of Echinodermata, in challenging underwater images from the Natura 2000 site Sylt Outer Reef. Specifically, 1026 distinct common sea stars have been manually annotated in form of bounding boxes by experienced marine biologists in individual, qualitatively different frames of 38 video sequences captured by 38 videosledge stations at the Sylt Outer Reef. The corresponding frames have been extracted from the videos yielding 922 images, which have been organized into a four-fold cross-validation setup on a “split-by-video” basis. The YOLOv8 object detection framework has been configured to a single object class (*Asterias rubens*), fine-tuned to the bounding boxes of three of the four data subsets in each cross-validation iteration („training data“) and then tested on the remaining fourth data subset („test data“). Averaging over the four test sets, we achieved an average precision for 50% intersection over union, AP@0.5, of 0.9660 ± 0.0047 (min: 0.9598, max: 0.9712), while AP@0.50:0.95 was 0.7886 ± 0.0102 (min: 0.7740, max: 0.7971). These first results on the dataset are a promising step towards establishing computer-aided analysis methods for non-invasive marine benthos monitoring.

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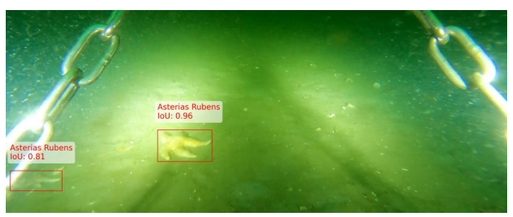

Figure 1: Example image from the test data of the Sylt Outer Reef. The bounding boxes indicate the *automatic* detection results from the fine-tuned YOLOv8 model. „IoU“ refers to the intersection over union between the automatically detected bounding box and the manually annotated ground truth bounding box.

Day 2, 13:50

Session 5

Talk

Aseem Tara, M. Sc.

AlphaFold-driven structural optimization of ligninase for enhanced lignocellulose degradation in transgenic livestock

Livestock production is essential for sustainable food security, but it has hurdles due to its environmental impact, including high land and water consumption, reliance on quality cereals, and greenhouse gas emissions. A potential solution is using agricultural residues like straw, as animal feed, which is otherwise burnt in many Asian countries, resulting in significant environmental consequences. However, since lignin is indigestible to livestock, it limits the availability of polysaccharides for microbial fermentation in the rumen. Engineering goats that express optimized transgenic ligninase enzyme in their saliva can result in efficient lignocellulose breakdown. In this study, we are leveraging Artificial Intelligence (AI)-driven protein structure prediction tool AlphaFold, to optimize the evolutionary procedure for the ligninase gene. It involves analysis of several hundred different fungal and bacterial ligninase genes and their comparison with the functional Dyp1 gene identified previously (Hyder and Kues, 2023), to obtain the essential necessary enzymatic pockets for ligninase activity and identify the most efficient sequence for ligninase expression. The DNA sequence will be carefully optimized with regard to promoter, signal peptide sequences and for codon usage to ensure efficient expression in mammalian salivary gland cells. The interaction between the synthetic ligninase and lignin will be studied with tools like RF Diffusion. The most suitable candidate genes will be transfected into goat salivary gland cells and ligninase expression, its enzymatic activity will be characterized. The two collaborating partners in India involved in this BMGF-funded project will further develop transgenic goats expressing ligninase and conduct physiological studies and straw feeding trials. By combining machine learning with genetic engineering, this work is expected to provide a data-driven approach to improving ruminant nutrition and sustainability in livestock production. The integration of AI in precision livestock farming presents a promising avenue for sustainable agriculture and efficient resource utilization.

Hyder I, Kues WA 2023. Transgenic mammalian salivary cells expressing ligninase as a proof-of-concept model for enhanced lignocellulose degradation to generate future resilient livestock. J Cleaner Production 293, 136226.

Funding:
Bill and Melinda Gates Foundation
Grant to Dharmendra Kumar, Iqbal Hyder, Wilfried A. Kues

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Smart farming in action: Evaluating AI weight sensors for health and profitability in pig production

Day 2, 14:10

Session 5

Talk

Artificial Intelligence (AI) is transforming pig farming by facilitating early disease detection and promoting economic sustainability. This case study is applying the data collection strategy developed within the aWISH project (Thobe, 2025) and investigates the economic implications of deploying AI-powered weight sensor (Weight-Detect, WD) (Banhazi et al. 2025) on a pig farm in Spain in early 2024. The farm implemented AI-based weight monitoring systems that continuously track individual pigs in real time, detecting subtle weight loss patterns that may signal early stages of illness. This early detection enables timely medical interventions, resulting in reduced treatment costs, lower mortality rates, and minimized productivity losses. The system's automation also enhances labor efficiency by reducing the need for manual weighing and health checks while providing more accurate and consistent weight data. In addition to early disease detection, the AI system supports data-driven decision-making, analysing large datasets, allowing the farmer to adopt proactive health and management strategies. Furthermore, it can determine optimal selling times based on weight trends and market conditions, potentially increasing profits. Although the initial investment in AI technology is substantial, the long-term benefits, including enhanced marketing strategies, demonstrate significant economic potential. Preliminary qualitative evaluations indicate that the implementation of weight sensors at the Spanish pig farm can realise cost savings and avoid a reduction in profit and production efficiency. The study assesses the economic impact using the TIPI-CAL model (Chibanda et al., 2020), applying percentage changes observed on the pilot farm to the economic indicators of synthetic Spanish farms. Several scenarios and their potential impacts were tested. This case study illustrates how AI technologies can modernise pig farming by enhancing animal welfare and economic resilience, and serving as a model for broader adoption in livestock.

Figure 1: The WD camera installed above the resting area in the pen on a commercial farm in Spain (Banhazi et al. 2024)

Figure 2: The data processing and communication unit of the WD system before deployment (Banhazi et al. 2024)

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POSTERS

KIDA Konferenz 2024 //
Foto: Matthias Werner (DBFZ)

Niels Lakämper, M. Sc.

AI-Assisted derivation of Agronomically relevant, small-scale soil information using an Integrated soil sensor system, satellite and drone image data, and additional geodata

Poster No. 1

Climate change increasingly affects crop production through heavy rainfall, heat, drought, and prolonged dry periods, particularly in springtime. In the “soil4climate” project a data collection and processing system is being developed to provide farmers and advisors with high-resolution soil data within routine workflows and minimal extra effort to mitigate adverse effects by climate-adapted production methods. For this purpose, data from various platforms and sensor systems as well as external sources (environmental and geodata) are acquired and combined. A key innovation is a low-budget geo-electric sensor system integrated into a cultivator, which records soil electrical conductivity, operation depth, position, and tractor data.

In our study, we set up two modelling approaches to predict soil texture and soil organic carbon. First, a Random Forest model is used to establish a baseline. Second, an approach in with two stages, where the first model is trained on soil samples from Germany and later combined with measurements of the geo-electric sensor and local field data. The goal is to improve generalization in predicting soil organic carbon and texture beyond the study area. The large-scale model training uses soil samples from the LUCAS topsoil dataset and soil surveys from selected German federal states, focussing on Lower Saxony for testing purposes. Ground-based data are augmented with satellite data from Copernicus (Sentinel-1/-2), UAV-based multispectral images (MicaSense RedEdge-MX Dual), a Digital Elevation Model, terrain attributes (e.g., Topographic Wetness Index), and weather data from the German Meteorological Service (DWD). Calibration and validation of generated soil maps are carried out through laboratory analysis of georeferenced soil samples, in close collaboration with agricultural practitioners in Lower Saxony’s Hildesheim region and the Osnabrück area. Presented will be the data collection and preliminary results using artificial intelligence methods for the combined model trained on large-scale soil sample dataset.

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Deliah Tamsyn Winterfeld, M. Sc.

Reinforcement learning in human and veterinary medicine – a systematic review

Poster No. 2

Artificial intelligence has experienced significant advancements in recent years, with Reinforcement Learning (RL) emerging as a promising approach in both human and veterinary epidemiology. RL is a type of machine learning in which an agent learns to optimize decision-making strategies by interacting with its environment, aiming to minimize costs or maximize rewards. This methodology offers significant potential for improving disease surveillance, optimizing intervention strategies, and enhancing overall public and animal health.

This systematic review aims to provide a comprehensive evaluation of the current state of research on RL applications in epidemiology. Specifically, it investigates which RL methods have been applied, the epidemiological questions they address, and the outcomes achieved. By synthesizing existing studies, this review seeks to highlight the potential benefits and challenges associated with RL in this field.

To achieve this, a structured literature search was conducted using the databases Web of Science, PubMed, and Scopus, yielding an initial dataset of 1,160 entries. After removing duplicate and triplicate records, as well as excluding studies without an abstract, 764 manuscripts remained for further analysis. The selection process is currently ongoing, with full-text screening underway. At this stage, no data extraction or synthesis has been completed as it is work in progress. The systematic review process is being conducted and documented using the free web tool CADIMA.
The collected data will provide insights into the application of RL in epidemiology, revealing emerging trends, methodological advancements, and key areas of focus. Additionally, this review will identify existing challenges and potential opportunities for future research, offering a foundation for further development in this interdisciplinary field. In the long term, the integration of RL into epidemiological modelling has the potential to enhance decision-making processes, refine intervention strategies, and improve disease outbreak detection and response, ultimately contributing to both human and veterinary health.

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Alia Spode, M. Sc.

A gamification-based approach for stakeholder engagement using artificial intelligence

Poster

No. 3

Gamification tools are developed to engage stakeholders and promote participation in strategy development (Ingvarsson, Hallin and Kier, 2023). The presented approach combines stakeholder engagement with scenario development and data collection for a PESTEL+I analysis (Blümel et al., 2023). The proposed gamification concept is based on a systematic design process (see Figure 1) and leverages the MDA framework (Hunicke, LeBlanc and Zubeck, 2004) and the Octalysis framework (Chou and Mechelen, 2016). The overarching goals are to increase stakeholder participation, support knowledge transfer, and create inclusive workshop environments. Playful interactions ease stakeholder readiness towards information exchange promoting transparent inclusion of all actor groups and final project success.

The game includes Action Fields that encourage participants to answer open-ended, multiple-choice, or single-choice questions. This creates an integrated survey platform which playfully collects valuable qualitative data on the actors' concerns, expectations, and preferences. Furthermore, the game simulates real-life scenarios and encourages players to make decisions which reflect their priorities and constraints by assuming the roles of relevant stakeholders. The powerful tool provides the option of customization to diverse project specific backgrounds. Theme-specific questions to action fields can be adapted to any topic. The adaptability of contents is at the heart of this gamification concept. However, the adaptation of the tool and the processing of its output records are very time consuming. AI promises the capability to fully exploit (1) the tools adaptative potential, and (2) its output feed into PESTEL+I. Hitherto, qualitative data analysis software (e.g. MAXQDA) is used to prepare data for PESTEL. AI can ease front-end adaptation by drafting content-specific questions of innovation projects to action fields. Similarly, downstream, AI is suited for the task of classifying and coding the PESTEL+I factors (Figure 1). Employing AI for gamification and feeding data into PESTEL+I analysis is seen as the prominent support for processing information about the macro-environment of value chains and networks, and in result enhance stakeholder engagement. Using AI for gamification and feeding collected data into a PESTEL+I analysis is a very promising concept for enhancing stakeholder engagement and collecting information about the macro-environment of a value chain or network.

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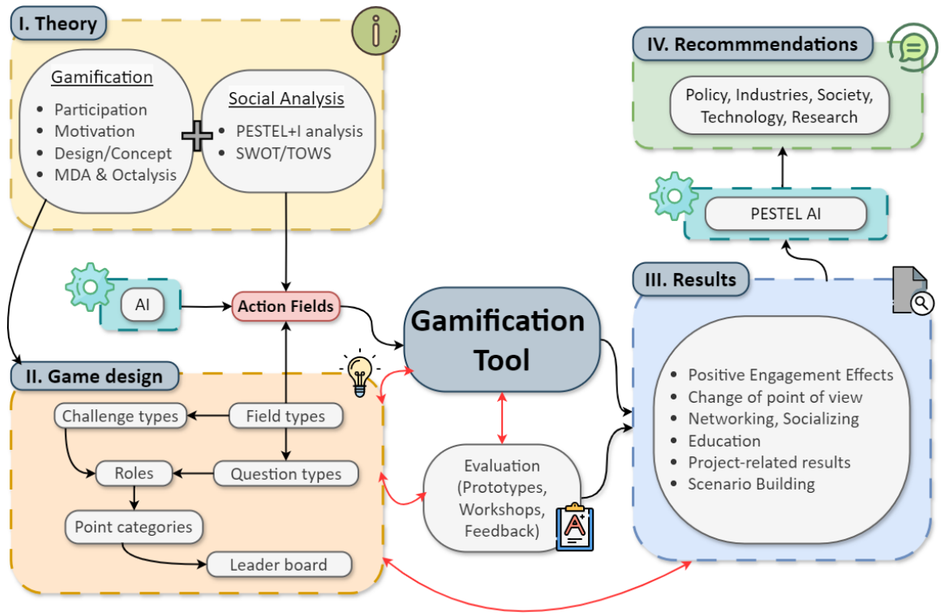

Figure 1: Conceptualization of the gamification tool and further use (arrows in red indicate bi-directional relationships, black one-directional)

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Poster

No. 4

Jacob Schmieder, M. Sc.

Numerical information field theory for acoustic monitoring

Passive acoustic monitoring is widely used in environmental research for continuous, accurate observation of environmental conditions. Machine learning, particularly CNNs, identifies patterns in the time-frequency domain of acoustic signals. However, the dynamic nature of soundscapes and sporadic signal occurrences pose challenges, and expert annotation—though crucial—remains time-consuming and inconsistent.

This study aims to develop a flexible statistical model for identifying time-varying acoustic signals by detecting consistent patterns. To achieve this, Bayesian statistics — specifically Information Field Theory (IFT) — was applied. In the field of animal sound detection, existing Bayesian-based approaches primarily focus on spectrogram denoising to extract detailed information. While effective for analyzing a limited number of sounds, these methods still require expert intervention when signals characteristics shift due to distance or other external factors.

Here, different whale click types were examined to pinpoint stable features — such as overall shape — that remain recognizable even under changing conditions. For feature extraction, the goal of automated click detection (similar to what CNNs aim to achieve) was combined with targeted IFT-based denoising, uniting the strengths of general automated identification and the detailed insights provided by denoised spectrograms. This dual approach enhances robust identification while minimizing the need for expert input, thereby enabling deeper insights into both the spatial and temporal domains of whale clicks and potentially other types of vocalizations.

The Numerical Information Field Theory (NIFTy) framework provides a practical method for implementing probabilistic reasoning in imaging and data analysis. NIFTy was applied to detect and classify sperm whale echolocation and communication clicks recorded from various devices in Norway. Although still in its early stages, this study shows promising initial results. By visually analyzing spectrograms, the original signal, the NIFTy-based signal reconstruction, and the noise part of the data — typically labeled as background noise — are compared.

These statistical models offer a promising alternative for acoustic signal analysis. Future work will refine algorithms, expand datasets, and explore real-time applications.

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Poster

No. 5

Ali Sakhaee, M. Sc.

Harnessing machine learning for multi-scale soil health insights: From national mapping to continental trends

Soil organic carbon (SOC) dynamics as one of the most important soil health indicators is critical for sustainable agriculture and climate resilience, yet its spatial-temporal quantification remains a major challenge. At the KIDA-KON conference, we present a two-stage, data-driven approach to advance soil health monitoring across scales. First, implementing ensemble machine learning on the first German Agricultural Soil Inventory (Poeplau et al., 2020), we generated high-resolution (25 m) maps of SOC fractions—mineral-associated (MAOM) and particulate organic matter (POM)—and C/N ratios for German agricultural topsoils. Our models achieved robust accuracy (MAPE: 8–15%), revealing strong dependencies on soil type, land use, and parent material, with northern Germany's sandy soils showing higher C/N and POM but lower MAOM. These results underscore machine learning capabilities to disentangle complex soil-environment interactions at national scales.

Building on this foundation, our ongoing EU Horizon project *AI4SoilHealth* extends this data-driven framework to a continental scale. By integrating EU-wide spatio-temporal SOC predictions (2000–2021), we quantify decadal trends under varying land management and climate scenarios. Preliminary results highlight regional divergences across Europe where most soils in eastern Europe show accelerated SOC loss, while northern regions demonstrate increase in SOC likely due to sustainable management and cooler climates. Key challenges include harmonizing heterogeneous datasets and addressing scale-dependent uncertainties in trend analysis.

This work exemplifies how machine learning bridges localized soil mapping to continental trend analysis, demonstrates AI's transformative role in agrifood systems, fostering resilience against climate change while balancing productivity and sustainability.

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Poster No. 6

Dr. Florian Schneider

How data-driven space-for-time approaches can help to estimate long-term effects of humans on soil health

The vast majority of our global food, feed and fibre production originates from plants grown in soils. But soils don't only serve as a growing medium for plants, they also act as an important water regulator mitigating flood events after heavy precipitation. Further, soils represent the largest terrestrial carbon pool, storing more carbon than the atmosphere and biosphere combined. These critical soil functions, however, have been subject to ongoing human-induced changes for many millennia. Here, we illustrate how present-day soil survey data can be used to estimate legacy effects and potential future soil health under climate change. For this, we apply data-driven space-for-time approaches on soil data at the German national scale provided by the German Agricultural Soil Inventory (Poeplau et al. 2020) and the European scale by LUCAS-Soil (Orgiazzi et al. 2018). Our results suggest that an average German cropland soil today stores about 39.2 ± 1.7 Mg C ha^{-1} less carbon than what it historically stored before the rise of agriculture. Human-induced traffic has caused the formation of a ploughpan at about 30-50 cm depth which may limit both the ability of crop roots to elongate into the subsoil and water infiltration rates after heavy rain. Global warming will likely decrease soil organic carbon stocks further, depending on the emission pathway. We conclude that such data-driven space-for-time approaches allow the accurate quantification of long-term effects on soil health whenever the human treatment is not unprecedented and the survey data features adequate reference soils without human influence.

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Poster No. 7

Dr. Christoph Manß

Digital twins for the environment – An example for the maschsee

Digital Twins (DTs) are currently used in the industry for fast development purposes and predictive maintenance tasks, reducing costs and resource consumption. Given these advantages, implementing DTs for environmental applications offers significant potential. By enabling real-time monitoring of environmental variables, predicting trends or intervention needs, and generating data-driven insights, DTs can enhance environmental management.

The project DiTAq (Digital Twins for Aquatic environments) investigates how current state-of-the-art models can be connected such that users can query a resulting DT of the environment for monitoring and prediction purposes. Here, the Maschsee, a lake situated in Hanover, serves as an exemplary environmental system. The basis for this project are remote sensing data, deployed sensors, but also data that are gathered in the project HAI-x (Hybrid AI eXplainer), where maintenance operations of a weed harvester for this lake are planned and observed. While in HAI-x the maintenance operations are planned, in DiTAq those operations and environmental impacts can be investigated on a longer time basis. This, on the other hand, benefits the optimization of the maintenance plans in the long term. Thus, the developed DT provides a data backflow and can interact with the environment, which is fundamental to the concept of environmental DTs. Moreover, DiTAq looks at the aspect that models and data might drift over time and how to incorporate this into a DT. Enabling monitoring of the DT's models and incoming data can help detect growing uncertainties in the forecasts. Once detected, the DT's models can be adapted, which increases the long-term reliability of the DT.

Overall, the integration of DTs for the environment offers an effective tool for enhanced environmental monitoring, optimized resource management and informed decision-making.

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Isis Paola Núñez Franco, M. Sc.

Digitalization and automation of technical infrastructure in biorefineries research

Poster

No. 8

The project goal was to fully digitalize technical and experimental data produced during research activities in biorefineries at DBFZ. In order to achieve this, existing systems were systematically upgraded to allow for smooth digital data collection, processing and storage, enabling both real-time monitoring and later analysis.

A central focus was the development of a unified control architecture that ensures unambiguous, standardized, and traceable data handling. This included the standardized labeling of sensors and actuators, the revision and digitalization of technical documentation, and the creation of metadata specifications for experimental records.

17 research systems have been integrated into a centralized process control system. Automation systems now operate with a 1 Hz resolution, with data transferred to aggregators or extracted directly from devices, then stored in an SQL database in a structured and consistent format. The control platform enables 24/7 operation and is supported by mobile and stationary devices for metadata entry and live data displaying.

Specific milestones include the implementation of automation for the hydrotreater, PiloMem, Mini-Meth2.0, and autoclave systems, as well as stable 24/7 data operation of the PilotSBG plant. A new data management server with backup functionality and a revised server infrastructure were introduced to meet evolving IT security standards and future scalability requirements.

Visualization systems have been successfully established to support live and historical data review, both during experimental operations and in results evaluations. In addition, technical drawings were standardized to ensure clarity in sensor identification and data processing pathways.

This integrated approach provides a robust, scalable, and transparent foundation for managing complex experimental data environments. It supports data acceleration and can be seamlessly utilized in AI training pipelines, enabling more intelligent, automated, and adaptive experimentation in biorefinery research.

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Simon Thomsen, M. Sc.

Does implementation of machine learning algorithms in land use modelling enhance allocation accuracy?

Poster

No. 9

Land use and land cover change (LULCC) significantly impacts climate, biodiversity, and ecosystem services, making it a central topic in environmental research and sustainability planning. Land use models are essential tools for projecting such changes and evaluating policy impacts. CLUMondo is an established land use model that is capable to simulate land use change considering competition among multi-functional land uses. However, the model is limited by its technical complexity and lack of transparency. The original implementation of CLUMondo in C++ relies on logistic regression for location suitability calculation, which is a major component of the model's framework.
In our study, we present a Python-based adaptation of the CLUMondo model that integrates machine learning (ML) algorithms into the location suitability calculation process. By leveraging the flexibility and accessibility of Python and the predictive strengths of ML, this approach aims to enhance both usability and modelling performance. Furthermore, we explore the impact of introduction of ML algorithms on the performance of location suitability and in a second step on overall modelling performance. We simulate land cover change in Mato Grosso, Brazil, from 2012 to 2022 using logistic regression and five ML algorithms. Subsequently, we compare validation of location suitability with overall land cover model using different validation approaches. The best-performing ML model is then used to project land cover change until 2050, with results compared to the logistic regression baseline.
Our findings show that ML-based location suitability as input for CLUMondo improves the predictive accuracy of land use allocation in the model. This contribution illustrates how machine learning can enhance traditional environmental models, offering an example of sustainable AI use in land system science. Furthermore, by lowering technical barriers, the Python implementation supports broader interdisciplinary use and transferability in policy and practice.

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Poster

No. 10

Kim Schmidt, M. Sc.

An ontology for classifying biogenic residues in Germany

Climate change is one of the big challenges of our near future. To lower greenhouse emissions, it is getting more important to use renewable resources and, in particular, biogenic waste and residues instead of fossil resources. To identify a suitable residue as admixture or substitute for a production process it is necessary to differentiate them due to their characteristics like fiber length, the concentration of proteins, or fatty acids. At present, there is no general scheme for a detailed characterization of biogenic residues. Additionally, laws and regulations have to be considered when replacing (fossil) resources by biogenic residues. In order to support a climate friendly economy, these regulatory requirements have to be provided in an appropriate way. Thus, we create an ontology that contains all information necessary to (i) clearly identify biomasses (by an unambiguous resource key) and (ii) to facilitate dealing with it in a bioeconomic and industrial context. The first aim is addressed by designing an ontology containing the majority of national available biogenic residues and link them with their most important characteristics for usage in bioeconomy. In addition, the ontology will contain related regulations. This is an early stage work from which we will present suitable tools and current findings.

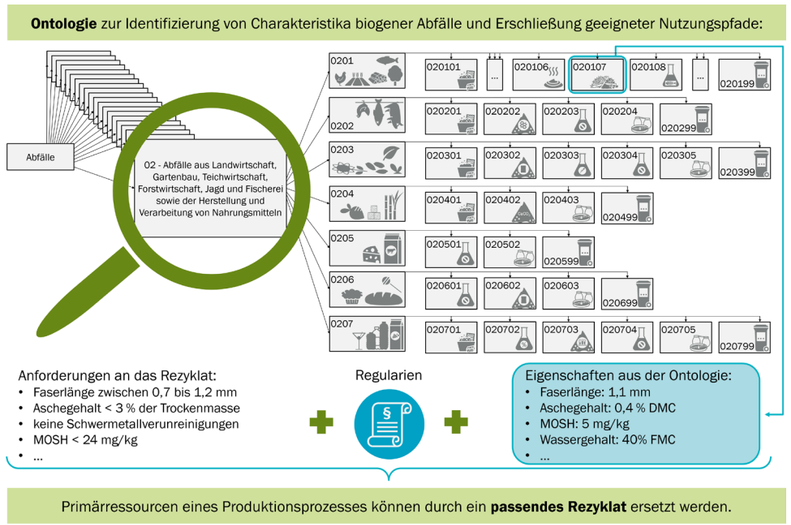

Figure 1: Overview about the project aim: Identifying a biomass (blue circle) in our ontology (aim (i)), which is depicted in a detail view in the upper part. From the identified class in the ontology characteristic of the biomass can be collected (blue field) and compared to requirements of a material to substitute in an industrial context (aim (ii)). In addition with regulations, the perfect substitute can be found.

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Poster

No. 11

Dipl. Tanja Riedel

Leveraging sentinel-1 SAR and AI for high-resolution crop phenology monitoring

In sustainable agriculture, knowledge about the temporal occurrence of certain growth stages of cultivated plants is crucial, particularly for the planning and optimization of fertilization and pesticide applications, or crop yield estimations. In practice, crop growth data are often collected through in-situ field surveys, which are time-consuming, small-scale and do not account for spatial variability. Ontogenesis models, widely used as inputs for prognosis models and decision support systems, often rely on low-resolution weather data, making detailed analyses of individual fields or site-specific assessments impossible. The use of high spatial resolution satellite-data and AI-based approaches can significantly contribute to this challenge by providing powerful tools for frequent and large-scale monitoring of key growth stages.

This study compares the results of two remote sensing-based methodologies for deriving crop growth stages: a dynamic time warping (DTW) approach and initial results from a long-short-term memory (LSTM) model. It highlights the potential of Sentinel-1 SAR data for monitoring the growth of winter cereals (wheat and barley) and winter rapeseed. A key advantage of SAR technology is its all-weather capability, enabling the generation of dense and comprehensive time series. Moreover, SAR data are highly sensitive to structural changes in vegetation, such as stem elongation, flag leaf emergence, and ear development. Depending on the availability of field reference data, 30 or more microstages were identified. For some growth stages, the median time difference between the dates modelled by DTW and those from field surveys was less than four days. Additionally, the poster contrasts remote sensing-derived crop growth stages with outputs from ontogenesis models, providing preliminary insights into how integrating Earth observation data could enhance such models and discusses possible integration pathways.

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Martin Rabe, M. Sc.

Better-Weeds

Poster

No. 12

The BETTER-WEEDS project aims to develop methods for the detection and classification of weeds in agricultural fields. The primary objective is to assess which weeds require intervention and which are either non-harmful or beneficial, and therefore should be preserved. This approach seeks to optimize management efforts, reduce unnecessary interventions, and enhance agricultural productivity while preserving biodiversity.

Our work within this broader framework involves the use of machine learning techniques to detect and classify weeds from aerial images captured by drones. These images are processed to generate distribution maps of the identified plants, which serve as the foundation for informed management decisions. This process follows a two-phase methodology.

In the initial phase, a high-altitude drone flight is conducted to obtain a comprehensive overview of the field. The images collected are processed through a detection pipeline to identify areas with a high concentration of weeds, referred to as hotspots. These hotspots are then utilized to plan a second, low-altitude flight for more detailed image acquisition. The images from this second flight are used to both detect and classify the weeds present in the field.

The advantage of this two-phase approach lies in its ability to efficiently cover a larger area of the field while optimizing drone power consumption. Based on the resulting weed classification, further field management strategies can be devised.

The foundation of our machine learning model is a dataset curated and annotated by our project partners. This dataset includes instances of all relevant weed species, with particular emphasis on the growth stage distribution of the weeds. Early detection of specific weeds is critical for effective management, and this dataset provides the necessary information for such detection.

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Dipl. Jördis Sieburg-Rockel

How can a machine-learning system be trained to distinguish between softwoods even though the characteristics are particularly similar?

Poster

No. 13

To support deforestation-free supply chains, the wood species used in products are determined at the Thünen Institute of Wood Research. In the case of fibrous materials such as paper, isolated cells are examined under a light microscope and analyzed by experts in a time-consuming process. In cooperation with the Fraunhofer Institute ITWM we develop automated image recognition systems to significantly reduce the workload and the time required.

WoodFiberID is our first prototype to analyze microscopic images of fibrous materials. The system already works very well for the trained hardwood genera. However, different genera of softwood are also frequently used for the production of pulp. The challenge with the softwoods is that they have to be identified by a complete other cell type than the hardwoods. These characteristics are very tiny and can overlap in different focal planes in the same image area. Moreover, those cells have a totally different shape. For this reason, it is much more difficult to find a proper method to annotate the cells for a supervised training. The softwood identification is therefore the main topic of the follow-up project funded by the FNR/BMEL. In future, the systems should enable other institutes to check the composition of paper products and facilitate the implementation of EU-wide equal controls of deforestation-free supply chains.

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Poster

No. 14

Dr. Fabian Billenkamp

In the beginning there was complex data...

... or how local deep data annotation enables new perspectives on scientific data use, linked data publication, and large language model integration into workflows

Farm animal research, particularly in animal nutrition, provides insights into animal health, food and feed safety, and the ecological impacts of agriculture. Heterogeneous and highly complex data are acquired throughout an animal nutrition trial. The ethical treatment of animals in experiments is guided by the 3R principle (**Reduce** number of animals in experiments, **Replace** experiments by alternative methods & **Refine** methods to guarantee a minimum required suffering of animals in an experiment).

A contemporary interpretation of the 3R principle emphasizes that data generated in animal experiments adheres to the **FAIR** guidelines (Findable, Accessible, Interoperable, Reusable) to make data usable beyond its original context. The heterogeneity and complexity of animal nutrition data render it unusable without a metadata context, which is larger than the original data. Beyond its primary research use, data from farm animal trials can act as a bridge between research and agricultural practice.

By linking public domain ontologies with local ontologies tailored for scenarios within an animal research institute, detailed annotation of data in linked data formats creates condensed and standardized information. Information can be stored in local databases and, with minimal effort, converted into public domain data via ETL interfaces (Extract, Transform, Load). This approach helps to simplify publishing data in public domain databases according to 3R principles.

Standardized data annotation in local databases enhances reproducibility of analyses when these are stored in a repository. Annotation standards in local ontologies and linked data schemas facilitate the creation of vectors for large language model-augmented querying of data and analyses.

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Poster

No. 15

Marko Henning, M. Sc.

AI consulting for federal institutes with KIDA: Highlighting two projects

KIDA, the "KI- und Daten-Akzelerator", is a BMEL (now BMLEH) initiative that aims to enhance research institutions' AI and data capabilities. Its goals include strengthening AI and data competencies, improving technological infrastructure, and enhancing data usability, to drive innovation in agriculture and food production. As part of KIDA, we have launched several projects to demonstrate the potential of AI and data analytics.

In the project "Baumerkennung", a recurrent neural network was trained on Sentinel-2 satellite image data to classify different tree species with different granularity. The results showed high accuracy in distinguishing between broad categories, as well as in identifying specific tree species. With an accuracy of 97.6% in classifying trees into broad categories and 91.5% in identifying specific species, the model demonstrated its potential for reliable tree species detection. The project's outcomes have implications for forest monitoring, management, and conservation efforts, particularly in the context of climate change and biodiversity conservation.

ScrAIbe is an open-source, automated transcription framework designed for seamless audio and video transcriptions. ScrAIbe-WebUI, built on top of this framework, provides a user-friendly web interface that allows users to transcribe media effortlessly. Supporting both real-time and asynchronous transcription, it can handle a wide range of audio and video file formats. ScrAIbe offers multi-model integration for diverse transcription needs, and with Docker compatibility, users can easily deploy the service locally or on different systems.

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Poster
No. 16

Dipl. Kerstin Wurdinger

Concept and implementation of a mobile data acquisition system for obtaining research data

In its 2030 Agenda, the United Nations (UN) formulated 17 Sustainable Development Goals. This agenda is intended to respond to the most urgent challenges of our time. The Federal Republic of Germany has committed itself to these goals and is endeavoring to achieve them. The aim is not so much to generate fundamentally new scientific knowledge, but rather on the practical implementation of knowledge that is already available. The focus of publicly funded projects is therefore increasingly on the actual market maturity of products. Projects in which the usability of technologies is demonstrated in laboratory setups only are moving out of the focus of funding providers and are only of limited help to society. To transfer successful developments from laboratory (TRL 4) and pilot plant scale (TRL 5) to the market, field measurements (TRL 6 and 7) are essential. Thus, the collection of field data plays an increasingly important role for the implementation of future projects. Furthermore, long-term measurement series under real operating conditions are required to generate simulations and for the development of system components. These data are difficult or impossible to generate under equivalent conditions in pilot plant trials, and if so, only with a high financial and personnel cost.

The options currently available for capturing physical measurement data in the field are cost-intensive or inadequate, lacking the necessary modularity or the possibility of secure remote access. Within the scope of the KIDA project, the intelligent material utilization and energetic use of biomass resources is being considered as a use case; for the prototype developed, it should specifically be possible to collect data from heat sources for buildings (e. g. heat pumps or central heating boilers). However, the technology presented can be used for general purposes in a very wide range of applications as an interface between science and practice.

The figure below shows a connection terminal as midsection of the prototype: it connects a Raspberry Pi via a circuit board on the receiving side with up to 2x4 sensors on additional sensor circuit boards (not shown) with I2C bus and XLR connectors on the field side.

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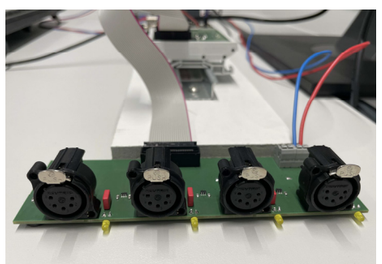

Poster
No. 17

Dr. Arjay Cayetano

Enhancing human-machine interaction towards more effective and practical AI-based otolith analyses

Otolith analyses, primarily the tasks involving fish age determination and stock/species identification, have been a vital component of effective management of fisheries. However, due to the limitations of traditional approaches, there is a growing interest with modern methods that apply the novel techniques from the field of Artificial Intelligence (AI). Consequently, various deep learning algorithms, such as those utilizing Convolutional Neural Networks (CNN), have been widely used to perform otolith analyses and were found to attain satisfactory performance. The main drawback, however, is the lack of explainability of these methods which causes a high degree of hesitation and very slow adoption of the technology amongst the age readers. Recently, we applied an alternative perspective to make the AI-based approach more explainable by utilizing object detection and segmentation algorithms such as U-Net and Mask R-CNN. In addition, we also developed an interactive web-based application that, not only organizes the datasets and models but also provides a way in which the age readers can directly incorporate the necessary corrections for improving the subsequent AI predictions. To further enhance the accessibility of the AI techniques, we conducted workshops with the age readers in order to identify the features to improve or develop according to their specific use cases. Concepts such as transfer learning and continual learning are also made accessible within the toolkit and emphasized during the workshops as they make the AI development more practical and in line with real-world scenarios where data acquisition is done incrementally. The development of a user-friendly interface for AI, coupled with these regular workshops, is hoped to create a more trustworthy and transparent laboratory environment whereby both the human and machine can work closely together to perform the task of analyzing the otoliths more effectively.

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Yukiko Nakamura, M. Sc.

Vegetation indices and wavelengths selection to detect pest symptoms on tomato leaves

Poster

No. 18

The importance of automated pest and pathogen damage monitoring is increasing, as early detection of infestation events can significantly minimize the yield loss and reduce the use of chemical synthetic plant protection products. The approach is aligning with the political goals of the EU and Germany (Farm to Fork strategy) and broader the concept of Integrated Pest Management.

Hyperspectral Imaging (HSI) is one of the key techniques for non-destructive detection of plant stress status and the identification of pest and pathogen damage symptoms. At the leaf level, certain vegetation indices (VIs) have been shown to detect disease symptoms and even early-stage infections. While many studies have used HSI to detect plant diseases, comparatively few have focused on pest detection and classification. In this study, *Aculops lycopersici* and *Trialeurodes vaporariorum* were applied on tomato leaves under laboratory condition. HSI measurement was conducted, covering the VNIR spectrum (404–994 nm) and the SWIR spectrum (954–2511 nm). Images of each individual tomato were taken, with the plant placed horizontally under the camera. Subsequently, all the leaves of an individual plant were dissected and arranged in one image with the top side facing up. The data were processed to obtain the averaged reflectance of plant parts, filtered using the NDVI index, and 120 known VIs were calculated. Machine learning feature selection was applied for 120 VIs to identify the most relevant features for distinguishing between treatments under different measurement conditions. Results show that 40 and 60 VIs out of 120 play a major role in classification (>80%) at the whole-plant and leaf scales, respectively. The implications of these results for the usability of VIs are discussed, partially their potential for symptom detection of pests, even though these VIs were not originally designed for this purpose.

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Stefan Stiller, M. Sc.

Self-supervised learning for European-scale crop classification using the LUCAS dataset

Poster

No. 19

Ground-based datasets such as the European-scale Land Use/Cover Area Frame Survey (LUCAS) are essential for agricultural monitoring, providing high-quality annotations for land use and land cover classification. However, collecting these labels through in-field surveys is time-consuming, expensive, and difficult to scale. To ease this burden, supervised deep learning models have been proposed to automate crop type classification based on LUCAS imagery. Yet, these models still rely on labeled data and often struggle with class imbalance and visual heterogeneity. Self-supervised learning (SSL) offers a promising alternative by learning meaningful visual patterns without the need for manual annotations, but its potential for crop classification at continental scale remains unexplored. In this study, we evaluated SSL using the VICReg algorithm on an agricultural subset of the LUCAS photo dataset, covering ten major crop types across Europe. We pre-trained models using SSL across multiple convolutional neural network architectures and compared their fine-tuned performance to supervised baselines. We show that SSL models can distinguish crop types without using labels and organize them into three semantically meaningful visual groups: Cereal-like & Grassland Crops, Upright Broadleaf Crops, and Low-Growing Broadleaf Crops. After fine-tuning, SSL models consistently outperformed supervised models in classification accuracy on the test set (median accuracy: 0.88 and 0.83, respectively). The best-performing model, ResNeXt-50 with SSL, achieved the highest generalization and robustness across crop types (median ± median absolute deviation: SSL= 0.92 ± 0.06 and supervised = 0.86 ± 0.10). These results demonstrate the capacity of SSL to learn morphology-based crop representations and offer a scalable path toward reducing the reliance on labeled data in large-scale agricultural monitoring.

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Dr. Hamid Mousavi

AI for sustainable agriculture: Improving animal welfare with computer vision and object detection

Poster

No. 20

The use of artificial intelligence (AI) and computer vision in agriculture is becoming increasingly important for improving animal welfare and sustainability. This includes monitoring the behavior of indoor-housed animals, such as their sleeping patterns, feeding habits, and social interactions, which can help farmers detect early signs of disease or stress. In this context, this study focuses on the development of an AI-powered system for detecting and tracking groups of steers in two separate housings. For this, a dataset has been collected and annotated by the Thünen Institute of Organic Farming in conjunction with the InnoRind project, and is being used to train and evaluate the investigated pre-trained deep learning algorithms for object detection. The system utilizes a combination of computer vision and object detection algorithms, including YOLO (You Only Look Once; Redmon et al., 2016), to identify and track the steers. We here present preliminary results from the project, and discuss future steps that are planned for detecting and monitoring the steers.

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KIDA Conference 2025

Johann Heinrich von Thünen Institute, Federal Research Institute for Rural Areas, Forestry and Fisheries, Bundesallee 50, 38116 Braunschweig, Deutschland

Layout

Cover, typesetting, graphics and icons: Joshua Röbisch
Otherwise indicated individually.

For each contribution, the authors are responsible for the correct and legally compliant use of their illustrations, texts and images.

Fonts

Fira Sans by Erik Spiekermann and Ralph du Carrois

ISBN 978-3-949807-31-2
DOI: 10.48480/kida-2025

kida-bmel.de

Gefördert durch

Federal Ministry of Agriculture, Food and Regional Identity

Projektträger

Bundesanstalt für Landwirtschaft und Ernährung

DIGITALE PERSPEKTIVEN

JKI Julius Kühn-Institut

BfR Bundesinstitut für Risikobewertung

DBFZ

Bundesamt für Verbraucherschutz und Lebensmittelsicherheit

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