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Long-Term Field Experiments: Lift the Agricultural Data Treasure (8-9 November 2022)

Highlights and Abstracts

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Title Highlights and Abstracts of the International BonaRes Workshop: Long-Term Field Experiments

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Date January 2023

Abstract

Long-term field experiments (LTEs) are agricultural experiments for monitoring soil and crop properties under changing climate conditions and different management practices. Within the framework of the BonaRes (www.bonares.de) program, a data infrastructure has been developed to collect, process and curate the metadata and research data of LTEs with a minimum duration of 20 years in Germany and Europe. In November 2022, researchers on LTEs from six European countries met in a workshop to exchange experiences with LTE management, data analysis, and modelling. The presentations and discussions focused on understanding the activities and advantages in publishing and using LTE data, including, i) LTE data management and reuse through the LTE overview map (lte.bonares.de) and the BonaRes Repository in which an increasingly large number of LTE research data are offered for free reuse, ii) use of structured LTE data for model applications, iii) research on soil management with LTE. The importance of up-to-date LTE standards, the requirements for data acquisition and the statistical analysis of LTEs were concluded. The outcomes emphasized the paramount importance of LTE in understanding management and climate change impacts in agriculture. A close collaboration between leading LTE groups (BonaRes, EJP SOIL, GLTEN) was concluded as relevant to increase the visibility of LTEs for boosting European research initiatives in soil research. A position document about the future need for LTE sites, management, and data analysis is envisaged as the next step.

Keywords

BonaRes, soil research, long-term experiments, experimental design, soil parameters, plant parameters, modelling, research data management, reuse

Acknowledgement

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Long-Term Field Experiments-Lift the agricultural data treasure: Highlights and Abstracts

Müncheberg, Germany 8-9 November 2022

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Session 1: LTE data management and reuse *Chair: Janna Macholdt*		
13:10 – 13:25	Long-Term Field Experiments (LTEs) data publication remarks in the BonaRes Repository	Carsten Hoffmann (ZALF)
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13:40 – 14:00	Realising the potential of the Rothamsted Long-Term Agricultural Experiments	Richard Ostler (Rothamsted Research, UK)
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Day 2: 9th November 2022

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1.INTRODUCTION

Long-term field experiments (LTEs) are agricultural experiments for monitoring soil and crop properties under changing climate conditions and different management practices. Within the framework of the BonaRes (www.bonares.de) program, a data infrastructure has been developed to collect and process the metadata and research data of LTEs. In this regard, LTEs with a minimum duration of 20 years in Germany and Europe have been continuously identified and processed since 2015. The BonaRes initiative aims to improve the reuse of LTE data and facilitate scientific collaborations through the networking of researchers. With the International BonaRes workshop "Lift the agricultural data treasure!" which was organized on 8-9 November 2022 at the Leibniz Centre for Agricultural Research (ZALF) in Müncheberg, Germany we wanted to foster knowledge and idea exchange among LTE owners and past and future users of LTE data with the goal of lifting the LTE data treasures.

The workshop was held in English and German upon demand; a total of 45 registered participants, including researchers (BonaRes, Module A projects), LTE owners and decision-makers from six different countries (Germany, Poland, United Kingdom, Hungary, Netherlands, Belgium, Switzerland), attended the event.

Workshop themes and the scope helped to understand and exploit the stimulating progress presenting the activities and advantages in publishing and using LTE data, including i) demonstration of the BonaRes Centre's LTE activities, including the LTE overview map, ii) practical showcasing for reusing LTE data, iii) assisting LTE owners with data curation and publishing, iv) initiation of corporations. The workshop activities comprised the exchange of experiences of LTE owners and selected data users (i.e., modellers), including the process for publishing LTE data in the BonaRes Repository and data analysis.

The workshop allowed the participants to discuss the application of up-to-date LTE standards, the requirements for data acquisition and the statistical evaluation of LTEs. The outcomes emphasized the paramount importance of LTE in understanding management and climate change impacts in agriculture. A position document about the future need for LTE sites, management, and data analysis is envisaged as the next step.

Highlights based on the presentations, group work and discussions are outlined below.

2.HIGHLIGHTS

The research outputs and applications of different LTEs in Europe were presented by various researchers and LTE holders at the workshop. Fourteen studies about the research themes and activities of running LTEs and networking initiatives in Germany, United Kingdom, Belgium, Switzerland, Hungary and Poland were presented, and the potential of international networking was emphasized. The presentations were held in three main sessions, including, i) LTE data management and reuse, ii) use of LTE data for model applications, and iii) research on soil management with LTE. Following the presentations, parallel-group work was conducted in four complementary groups.

2.1 LTE data management and reuse

LTEs are critical agricultural research infrastructures for monitoring long-term changes in plant and soil variables (e.g., yield) under various environmental conditions and management themes. Since LTEs were set up on different (and mostly representative of a particular region) soil textures, soil types, management practices, crop production, and climatic situations, they comprised a broad and complex variety of data sets that are often not well described with metadata and disseminated. To utilize the full potential of LTEs worldwide, it is relevant to harmonize their data and publish them to enhance their visibility.

An extensive metadata collection on LTEs has been compiled within the BonaRes project to identify LTEs and make their data visible. In this context, as the leading research initiatives, the BonaRes and EJP SOIL research groups have merged their LTE metadata databases of the European LTEs (Grosse et al., 2021; Blanchy et al., 2022; Donmez et al., 2022). The complete dataset (10.20387/bonares-40kc-2661) consists of metadata for 616 LTEs from 30 countries in Europe including many LTE features for a time span of more than 175 yrs (1843–2022). The complete data set was published in an online LTE overview map (lte.bonares.de) running under the BonaRes Repository. The dataset offers a comprehensive set of LTE locations, research themes, and observed variables allowing scientists and decision-makers to identify LTEs for possible collaborations and research activities efficiently. The LTE data collection was complementary to emphasize different LTE definitions of different groups[1]. The dissemination of the collected data set through an online geodata infrastructure established an innovative framework to make data from different LTEs findable and appraisable, even though there are no standard procedures for LTE design, treatment set-up, minimum data requirement and management.

Besides the BonaRes and EJP SOIL initiatives, GLTEN provides the global coverage of LTEs. GLTEN and BonaRes have differing underlying schemes, but these are broadly compatible for minimal information exchange (i.e., location, crops, treatment, etc.). The Rothamsted Sample Archive can also be used for new analyses and for creating new data from the past. However, while these data can add to the value of the experiment, there are challenges integrating them; the data are frequently patchy in time and space and confounded by different surveying and analytical methods. To ensure Rothamsted LTEs can continue to have an impact, their data and metadata must be curated manually over the long term. The LTE data stewards must ensure the data remain findable, accessible, interoperable, and reusable over time.

2.2 Use of LTE data for model applications

Process-based modelling is essential to quantify the influence of agricultural soil management on soil processes and functions. LTEs, as long-term infrastructures, play an essential role in studying long-term trends of different management operations and provide valuable inputs for environmental and agricultural research. Although LTEs were mainly established long before the development of process-based modelling, they have vast importance for developing systemic soil-crop-atmosphere models capable of simulating the dynamics of soil functions and the interactions and feedback between soil and crop growth processes. However, their design and observed variables do not always meet the requirements for process-based modelling, especially soil information and time series of soil state variables are rarely available.

Moreover, for long-term modelling, the classical design and treatment schemes of LTEs might be significant limiting factors to fully reflect feedback interactions, e.g., between soil

[1] The BonaRes LTE definition is as follows: "field experiments with a minimum duration of 20 years and a static design," while the EJP SOIL applies "with a minimum duration of 5 years".

organic matter, soil physical properties, and crop growth. To make agriculture more sustainable, integrating model approaches and knowledge about the long-term changes in soil functions through LTE data is essential. Such integration is highly valuable to gain a systemic understanding of soil and crop processes. It is required to evaluate the impact of soil management on soil functions and their effects on crop production and environmental impacts through various research themes. For developing new systemic modelling approaches, highlighting how additional measures of soil properties in LTEs with a well-known land management history can provide valuable input toward a future perspective.

Projected climate change is expected to modify the intrinsic LTE conditions in many cases. . Since agricultural productivity depends on climatic variables, rising temperatures and changes in precipitation regimes are expected to significantly affect crop growth in Europe through prolonged droughts and water shortages. Quantifying the potential changes of agroclimatic conditions and their spatial differentiation in multiple LTE sites is essential for conceiving spatially differentiated yields and soil-crop interactions under different climatic conditions. Integrated modelling frameworks through Geographical Information Systems (GIS), remote sensing data/techniques, and LTE information can be helpful in analyzing the potential effects of past and expected climatic changes on LTE sites to support experimental research on climate change mitigation.

2.3. Research on soil management with LTE

For ensuring global food security and stable cereal production, the design of climate-resilient cereal cropping systems is of significant importance. However, maintaining productivity while minimizing temporal yield variability of cereal cropping systems is expected to be challenging due to the projected climate change and increasing abiotic stresses. Evaluating the yield variability of different cereal crops over the past decades under different soil conditions and agronomic management practices is a relevant approach (Macholdt et al., 2021). In this context, for investigating this complex climate, soil, and agronomic management system, LTEs are valuable infrastructures for accurately estimating yield variability and its trend over the years.

Another important factor for agricultural systems to achieve a higher yield and adapt to various environmental conditions is diversification, which can support ecosystem services and biodiversity. However, there is little evidence on the type of temporal field arrangement to affect the productivity and stability of crop yields. It is mainly due to a lack of long-term data and suitable indicators. Reckling et al. (2021) indicated that diverse cropping systems could increase cereal productivity and environmental adaptability and that they are more likely to outperform less varied systems, especially when introducing perennial forage legumes into arable systems. Effects of diversification on cereal yield stability were inconsistent, indicating that higher productivity is achievable without reducing yield variability. MacLaren et al. (2022) conducted a multi-LTE analysis of 30 LTEs from Europe and Africa to investigate how field-scale ecological investigation practices interact with different research themes (N fertilizer and tillage) and their effects on long-term crop yields. They concluded that intensification practices, such as increasing crop diversity, showed positive effects on the yield of staple crops.

LTEs are also crucial for analyzing soil organic carbon (SOC) stocks as direct indicators for contributing to carbon sequestration and climate change mitigation. LTEs were proven to be beneficial for studying SOC processes; however, distinguishing the actual management effects in the subsoil from the background noise of non-management-related changes in SOC stocks were constraining factors in LTE-based SOC measurements. A purposive sampling with sufficient sites and replicates was conducted in ten German LTEs with varying experimental designs and duration. A soil sampling to be extended to 50 cm soil depth is recommended to fully capture agricultural management effects on SOC. Moreover, additional measurements of N emissions related to SOC sequestration are required to get a better picture of the real mitigation effect, which might be negated by increased N_2O emissions (Powlson et al. 2011, van Groeningen et al. 2017)

2.4. Parallel group work

In the workshop's final session, parallel group work was conducted. Four groups were set up to discuss i) opportunities for international cooperation, ii) research and modelling with LTE, iii) exchange of experience between LTE holders, and iv) data publication.

Since the LTEs are essential infrastructures for sustainable soil use and yield, information produced from this LTEs-based information attracted the attention of many different research institutions and organizations. The first group was moderated by Richard Ostler (Rothamsted Research, UK) to discuss the activities and contributions of different research initiatives to LTE data collection and dissemination. LTE-based data were acquired and managed by various national, international, or global initiatives and networks, including GLTEN (Global Long-Term Experiment Network), ILTER (International Long Term Ecological Research), IOSDV (International Organic Nitrogen Fertilization Experiments), NLFT (National Long-term Fertilization Trials, Hungary), RetiBio 2 (Italy), and the projects BonaRes and EJP SOIL. The importance of concretizing international cooperation between leading data organizations was emphasized to develop a community of LTE practitioners and users, an original objective of GLTEN, and help understand the obstacles to data sharing across different groups and their databases. The lack of widely adopted community data repositories and data standards for describing, formatting, publishing, accessing, and reusing LTE datasets is a significant limitation of their reuse. Standardizing LTE metadata sets and research data templates is an important but challenging activity requiring collective agreement from multiple stakeholders.

Group 2 focused on research and modelling with LTE and was moderated by K. Christian Kersebaum (ZALF). One of the main problems with modelling and LTE data integration is the limited access to data due to the hesitant data provision of LTE holders. Existing networks and databases (e.g., BonaRes, EJP SOIL, GLTEN) provide a remarkable advantage to increase the visibility of LTEs that might boost the networking of LTE owners and modellers, leading to continuous data provision. Building confidence among modellers and data providers through shared publications may increase the exchange of experience and knowledge among LTE owners and modelling groups with an increasing learning effect, identification of data gaps, enhanced efficiency, upscaling, and extrapolation of results and co-evolution of ideas for measuring additional research parameters/variables. Publication of LTE data in repositories (such as BonaRes) is necessary to increase the visibility of an LTE and receive feedback to improve existing LTE datasets and future research direction of these experiments. Constraints in data availability and standardized methods (e.g., restrictions due to institutional policies, national data restrictions, and different LTE definitions) must be overcome, e.g., by running own met stations on site, which are not under public restrictions. Crop growth and its relation to climatic conditions are highly related; therefore, it is essential to provide specific information by LTE owners to modellers on the conditions (soil, crop type, climate data) of the experimental site. To ensure the compatibility of modeling approaches and LTE data availability, potential deviations between the objectives of LTE owners and modellers should be clarified, and benchmark tools to estimate the suitability of data sets for modelling (Kersebaum et al. 2015) may be applied. In this context, a basis can be set up on crop yield trend modelling, soil functions (e.g., SOC), and agroclimatic indicators on crop growth/yields (e.g., drought, dry spells, frost days, growing degree days). Additional measurements should be obtained either by proximal sensing or, if destructive, require enough plot space of the LTE, which has to be considered when a new LTE is established.

In Group 3, moderated by Carsten Hoffmann, experiences between LTE holders were exchanged, and possible solutions were discussed. Unstable financing of LTEs causes a lack of planning stability and security since LTEs are often financed by fixed-term projects. This often leads to a high turnover of LTE staff, thus, poor documentation or loss of long-term data. There is a need for action to convey the tremendous scientific and social value of LTE both to the holding facilities/research institutes and to the public (authorities). A permanent financial commitment from the holding institute is needed to ensure data availability and a continuum of treatments with a broader perspective. Data management of LTE-based information is another problem since the majority of measured LTE data are stored in individual computers or external hard drives of LTE owners. Sharing data with repositories could ensure data protection and lead to increased visibility and networking/research outputs of LTE owners.

Group 4 was moderated by Nikolai Svoboda. Representatives from universities and non-university institutions with different experiences in data management participated. There were both infrastructure operators and beginners in the field of data use in the group. In the fruitful discussion, it was noted that some data and metadata are already available for reuse, but there are significantly more "data silos." Many data are published as appendices to papers, limiting their reuse. For many LTE sites, no metadata is available, and the data is challenging to find. The benefits of publishing LTE data were identified as increased visibility, collaboration creation, and long-term financing of LTE.

There are also the following benefits for reusers: Availability of data for modellers and other scientists; easy referencing by DOI; described methods, data linked and standardized. For the authors of the data publication, the following advantages arise: increased impact and collaborations; community contribution; improving data quality by peer and community review; secure storage, and permanent availability.

In addition to institutional restrictions, participants discussed that authors often do not know how to publish data, how to deal with old data from "predecessors", and whether there is a culture of error. It was discussed that in the case of the BonaRes repository, it is possible to easily withdraw erroneous datasets and replace them with corrected ones (versioning and updates). Authors fear a loss of authority over "their" data. This fear could be defused by an appropriate licensing model. To encourage data publication, participants think credits should be given to the dataset published as it is done with full-length articles or reviews.

In conclusion, it was stated that much has already been achieved; however, there are still some steps to be taken to make LTE data become FAIR, especially in the research data management (RDM) of LTE data: RDM needs financial and human resources, publications must be legally secure, and the community must be sufficiently qualified. In addition to a user-friendly infrastructure, we need a culture of data publication.

3.ABSTRACTS

Simulating soil carbon turnover with the MONICA model using long-term experimental data from Germany

Konstantin Aiteew[1], Rene Dechow[1]

Abstract:

Biogeochemical models are common tools that are used to predict future developments of soil carbon stocks. However, a preceding validation is essential for determining the reliability and applicability of model results. In this study, we evaluated the process-based, simulation model MONICA (Model of Nitrogen and Carbon dynamics on Agro-ecosystems, release 3.2.12) with respect to soil organic carbon (SOC) dynamics using long-term experimental data from 48 German agricultural sites. We found a systematic overestimation of modelled SOC decomposition rates. A revision and parametrization of the representative equations, involving the abiotic factors soil temperature, soil water and clay content, based on current scientific findings was realized and included in the model. The modified version was further used for a Morris elementary effects screening method confirming the importance of environmental factors for the model performance. Subsequently, we calibrated the model by means of Bayesian inference using the Metropolis-Hastings algorithm. The calibration improved the model performance significantly, reducing the mean absolute error by 30 %. The following validation confirmed the results. The calibrated MONICA model performed comparable with the popular and acclaimed RothC model. Using the modified and calibrated MONICA model allows mostly adequate reproduction regarding site specific SOC turnover rates.

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How FAIR are Agricultural Data Repositories? An Evaluation FAIR-based evaluation of Agricultural Data Repositories

Alsayed Algergawy[1], Karl Allgäuer, Ouamba Fedjo Jonhson, Soha Elfarsy, Birgitta König-Ries[1]

Abstract:

In the context of the AgriSem project, Semantic Web Technologies for Agricultural Data Interoperability, a collaboration between Friedrich-Schiller-Universität Jena, Germany and Nile University in Egypt, we have carried out a study to evaluate and analyze agricultural data repositories in Germany and Egypt against the FAIR principles. In this study, we consider two agricultural data repositories, namely BonaRes and OpenAgrar. The initial results show that both data repositories achieve a moderate FAIR level with respect to the Findability aspect, however, they have initial FAIR level, only, with respect to the other aspects, i.e. Accessibility, Interoperability and Reusability. We recommend using semantic web techniques in modeling and describing datasets and providing services to the end user to increase the FAIR levels.

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An open-source database of European long-term field experiments

Tommy D'Hose[1], Guillaume Blanchy[1], Katja Klumpp[2], Lisa Makoschitz[3], Adelheid Spiegel[4], Rajasekaran Murugan[4], Taru Sanden[3], Lilian O'Sullivan[5], Cenk Dönmez[6], Carsten Hoffmann[7], Nikolai Svoboda[7]

Abstract:

Long-term field experiments (LTEs) are crucial sources of knowledge on agricultural soil management and are vitally important in monitoring, understanding and modeling the changes in soil properties and crop production occurring as a result of different agricultural management practices. Besides, they are an indispensable basis for the calibration and validation of new analytical techniques or models. Within the European Joint Program SOIL (EJP SOIL), a database containing metadata from 226 LTEs across Europe was built. A specifically designed template that used the keywords tree of the Knowledge Library of the Bonares project, was sent to the LTE-owners to collect the metadata. Precise descriptions of the treatments (combination of factors) related to tillage, crops, amendments/fertilizers, grazing and pest/weed management as well as soil and crop measurements and pedo-climatic information were gathered. Using several maps and dashboards, a European overview of the LTEs is presented and specific research themes (tillage systems, residue management, amendment type and cover crops) are detailed within their pedo-climatic context. The analysis enabled us to identify knowledge gaps in terms of practices (e.g. grazing, pest/weed management) but also pedo-climatic context (e.g. Western Europe, coarse texture soil) rarely investigated within LTEs. An interactive web portal developed in collaboration with the Bonares project (https://lte.bonares.de/experiments), enables users to explore the database and find relevant LTEs for specific combinations of practices. Finally, a SWOT (Strength, Weakness, Opportunities, Threats) analysis of the database was carried out to highlight the potential contribution of LTEs to harmonized European soil observation and monitoring.

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Overview of LTEs in the BonaRes project: achievements, prospects and activities

Cenk Dönmez[1,2]**,** Carsten Hoffmann[2], Nikolai Svoboda[1], Wilfried Hierold[1], Xenia Specka[1]

Abstract:

Long-Term Field Experiments (LTEs) are significant infrastructures for monitoring soil and crop properties in various management practices and climate conditions. They are essential trials to reveal the effects of management and environment on soil resources on various soil textures and types. However, LTE-related information was scattered and often difficult to find. Within the BonaRes Project (www.bonares.de), we compiled and analyzed the meta-information of the LTEs across Europe and their spatial representation in a geospatial data infrastructure to close this research gap. A data repository and an LTE overview map were developed and integrated with a comprehensive geospatial data infrastructure. For LTE data management, the meta-information was collected by extensive literature review and factsheets from LTEs with a minimum duration of 20 years. In total, 500 LTEs from 26 countries in Europe were identified in the overview map and clustered in different research themes (management operations, land use, duration, status, etc.). We analyzed these clusters geospatially to provide inputs for the agricultural sector, researchers, and decision-makers regarding the relevance of these trials. The results will be helpful in revealing the LTE potential for developing a mutual agricultural management framework internationally. The LTE overview map is expected to contribute to the increasing adaptation of agricultural systems to climate change and the visibility of LTEs for networking.

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Modelling climate change impacts in German LTEs through an integrated modelling framework

Cenk Dönmez[1,2], Ahmet Cilek[2,3], Marcus Schmidt[1], Carsten Paul[1], Katharina Helming[1]

Abstract:

Projected climate change is expected to change the stable conditions LTEs are based on. Since agricultural productivity depends on climatic variables, rising temperatures and changes in precipitation regimes will significantly affect crop growth in Europe through prolonged droughts and water shortages. For conceiving spatially differentiated yields and soil-crop interactions under different climatic conditions, LTEs are essential infrastructures that enable the assessment of long-term change effects on agricultural variables. Using Germany as a test case, we quantified the potential changes of agroclimatic conditions and their spatial differentiation in the German LTE sites. We set up a GIS-based modelling framework to compare the baseline (1971-2000) the future conditions (by 2100) under the Shared Social Pathways (SSP) scenarios through climatic indicators (aridity index, frost days, growing degree days in growing season length, etc.) for 247 LTE sites. Under the most extreme scenario (SSP585), over 100 LTEs are expected to shift from different climatic conditions (humid and dry sub-humid to semi-arid). The framework developed in the study can be implemented in different agricultural regions and LTEs worldwide to support experimental research on climate change mitigation.

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Reduced tillage in two long-term experiments of FiBL, Switzerland

Meike Grosse[1], Maike Krauss[1], Frédéric Perrochet[1], Paul Mäder[1]

Abstract:

Reduced tillage has proven positive effects on topsoil carbon storage (Krauss et al. 2022) and consequently for topsoil structure compared to conventional ploughing. However, in organic farming, many farmers use the plough because it is considered as a reliable method of reducing weeds and stimulating mineralization in spring (Peigne et al. 2015). A field trial was set up 2002 on the biodynamic FiBL Farm Linde, Frick AG, and 2010 on the organic farm Schlatthof, Aesch BL, both Switzerland, for the further development of organic arable farming in the area of reduced tillage. The experiments are still ongoing. The tillage treatments are conventional tillage (annual ploughing, approx. 20 cm deep, CT) versus reduced tillage (chisel ploughing with occasional use of a skim plough for ley termination, approx. 10 cm deep, RT). Further factors are fertilization (Aesch and Frick) and biodynamic preparations (Frick; FiBL 2019 and 2022). Among other parameters, crop yields, soil organic carbon (SOC), and soil microbial biomass were measured in three-year intervals in 0-10 cm and 10-20 cm depth. The mean yield reduction with RT compared to CT was approx. 4% in both experiments over all years. For SOC, there was an increase of 25% in the clay loam in Frick, and 14% in the silty loam in Aesch under RT in the 0-10 cm layer, and no significant differences were measured in the layer 10-20 cm on both sites. 2021 soil microbial biomass was significantly higher in 0-10 cm and 10-20 cm in RT compared to CT in Frick and in 0-10 cm layer in Aesch. Weed pressure was higher in RT compared to CT on both sites. In conclusion, RT enhanced SOC and microbial biomass on both sites and acceptable yield were achieved, but weeds should be monitored further to avoid future problems. For improved weed control, hoeing will be introduced as a new factor in Aesch and the efficiency of hoeing intensity on N-mineralisation, C-depletion and contribution margin will be assessed.

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LTFEs in Thyrow - new insights into the potential for carbon sequestration by organic manure

Timo Kautz[1]

Abstract:

The agricultural research station Thyrow of the Berlin Humboldt University is located 30 km southwest of Berlin. The dominant soil type at the site is a pallid brown earth of sand over deep loam with low humus contents and a usable field capacity in the effective root zone (60–80 cm depth) between 60 and 150 mm. The sandy soil is characterized by limited nutrient and water supply, related to low average annual precipitation and a high probability of dry spells during growing season.

Today, five long term field experiments in Thyrow are still active. They were established between 1937 and 1998, covering a wide range of agronomical questions and factors including organic manure and mineral fertilization, liming, crop rotation design, irrigation, tillage, and even soil texture. Since 1965 annual values of soil organic carbon contents are available without interruption for each of the approximately 400 plots.

In one of the field trials called „Static Nutrient Deficiency Experiment“, different levels of mineral N-fertilization are tested with or without application of cattle manure. Although the experiment was first established in 1937 and the fertilization treatments were not changed since 1971, the field trial is not in a steady-state condition regarding soil carbon contents. Instead, a study of a 12-year period from 2007 to 2018 revealed increases of SOC contents by 6% to 28%, with treatments receiving manure having both the highest overall SOC contents and the highest overall C-sequestration over the investigation period. Moreover, our results indicate that manure application stabilized grain yield of winter rye in years with drought and heat stress. On the other hand, winter rye grain yield tended to decrease in all treatments with mineral nitrogen fertilization during the investigated period.

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Modelling long term effects in agriculture - data requirements for long term field experiments

Kurt-Christian Kersebaum[1]

Abstract:

Long term field experiments were mostly established at a time, when process based modelling was not yet existing or at its beginning. Although such experiments play an important role to monitor long term trends of different management schemes and provide valuable data for modelling long term effects, their design and measurement schemes often don´t fit to model requirements regarding input data and observed variables. Moreover, the research question behind the experiments was mainly agronomically driven, while today the focus is often more on environmental issues. Examples are shown, where this has been addressed, but also experiments, where data gaps and the specific experimental design limit their suitability for modelling.

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Realising the Potential of the Rothamsted Long-Term Agricultural Experiments

Richard Ostler[1]

Abstract:

Rothamsted's Long-term agricultural experiments (LTEs) were established to test the effects of different organic and inorganic fertilisers on yields for cereal and root crops and hay. Since then, other LTEs have been established to test treatment factors including crop rotations, cultivation, pest and disease control, and liming. Today we know LTEs can address research questions beyond their original purpose, notably studying soil health and the effects of climate change, and this is realised by re-using LTE data and integrating it with other data from other experiments. This is possible because throughout their history the LTEs have accumulated unique time series data, with a core collection of routine datasets for yields, yield and grain quality traits, soil chemistry, and for Park Grass botanical diversity, alongside agronomic management records and documented experiment modifications. Overtime, cumulative additions, or omissions of treatment factors have given rise to contrasting soil properties between experiment plots, making the LTEs valuable as research infrastructures allowing researchers to generate new datasets for non-routine LTE variables. Rothamsted's sample archive can also be used for new analyses and creation of new data from the past. However, while these data can add to the value of the experiment, there are challenges integrating it; the data are frequently patchy in time and space and confounded by different surveying and analytical methods. To ensure Rothamsted LTEs can continue to have impact their data and metadata must be actively curated, and it is the responsibility of the LTE data stewards to ensure the data remain findable, accessible, interoperable, and re-usable over time. In this presentation I will examine some of the data management challenges facing LTE data stewards, how FAIR Data Principles have stimulated a reappraisal of LTE data provision, and work within GLTEN to bring standardisation to LTE (meta)data.

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Yield variability in cereal production: LTE-analyses based on a system perspective "climate x soil x agronomic management

Janna Macholdt[1], Hans-Peter Piepho[2]

Abstract:

The design of climate-resilient cereal cropping systems is important for global food security and stable cereal production over time. However, in the face of climate change and the associated increases in abiotic stresses, maintaining productivity while minimizing temporal yield variability of cereal cropping systems will become increasingly challenging. Consequently, it is essential to evaluate the yield variability of different cereal crops over the past decades under different soil conditions and agronomic management practices. Long-term experiments are a valuable resource for investigating this complex system of climate, soil and agronomic management, as they provide enough time to accurately estimate yield variability and its trend over years. In the presentation, we report our analyses results based on different long-term experiments across Europe (Germany, Denmark, England, Poland). For yield variability estimations of wheat, barley and rye, we analysed the data sets using individually adapted mixed model approaches with REML (restricted maximum likelihood) based and refined Shukla`s stability variance. We implemented statistical models that allowed yield variability to be determined independently of yield level in order to avoid any misinterpreting. In addition, we present findings based on yield risk analyses (Eskridge) and environmental adaptability estimations (Eberhart-Wilkinson regression). We identified diversified crop rotations, especially by introduction legumes and winter catch crops, moderate mineral fertilisation, sufficient liming and additional organic matter input (e.g. manure) as important agronomic management practices for reducing temporal yield variability of cereal crops. The results can help improve the climate resilience in cereal production by optimizing their agronomic management, which are associated with benefitting soil fertility over time.

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Planting date maize long-term experiment at Martonvásár, Hungary (1991-2021): Developing a mixed model for analysis

K. Pokovai[1], N. Fodor[2], T. Árendás[2], H.P. Piepho[3]

Abstract:

The experiment was set up in 1991 and involved three factors of interest: planting date, genotype and fertilizer treatment. As fertilizer effects experienced in the first year probably are result of original soil supply instead of the treatment itself, first year data were excluded from the analysis, hence a 30-year long time period will be analysed. The soil of the experimental area has a slightly alkaline chemistry in the plowed layer humus content 3.3–3.6%, humus loam well supplied with phosphorus and potassium, type forest residue Chernozem. Meteorologically, the area corresponds to the continental climate of the country.

The planting date (PD) manipulations consisted of a ten days earlier than the optimal time (early), the optimal time (around April 24), ten days after the optimal time (late) and 20 days after the optimal time (very late). Genotype selection of five maize hybrids were selected so that represent different growing season groups (FAO 200–299, FAO 300–399 and FAO 400–499). The examined hybrids are primarily bred in Martonvásár, for their partial exchange took place every 4-5 years. In order to study distinct genotype groups only data of the first, third and fifth groups were selected for further analysis.
Fertilizer treatments are 60 (designates as extensive treatment), 120, 180 and 240 kg ha^{-1} N (the latter two designated as intensive treatments) amount active ingredient applied in the form of ammonium nitrate and a non-fertilized one for control. The dose of P and K fertilizers are the same in all treatments, 120 kg ha^{-1}. In order to study distinct fertilizer treatments only data of the control, extensive and intensive treatments were selected for further analysis. Yield harvests were conducted in late October - early November.

The purpose of the current study is to analyze a 30-year period of the PD LTAE to see if climate change modified the effect of given treatment factors, i.e. planting date, genotype and fertilization, on yield of maize crops. Furthermore, the purpose is to determine whether trends emerge over time under the influence of these factors and whether they are statistically different, hence assessing if climate change has had differential impact on the treatments.

The experimental design is Latin square for planting dates with four replications. Within a main plot for a planting date, the five genotypes are also randomly allocated to columns. The fertilizer levels were allocated to long rows spanning across four main plots of a super-row of the Latin square. In this talk, we will develop mixed models for this experiment that represent the randomization layout of the trial and allows assessing trend as specified in the objectives of this study. Some initial results will be presented and discussed.

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Can diversification improve the performance of cereals in cropping systems? Diverging evidence from five LTEs across Europe

Moritz Reckling[1]

Abstract:

In the face of climate change, cropping systems need to achieve a high performance, providing food and feed, and adapting to variable environmental conditions. Diversification of cropping systems can support ecosystem services and associated biodiversity, but there is little evidence on which temporal field arrangement affect the performance of crop yields (productivity and stability), partly due to a lack of long-term data and appropriate indicators. The objectives of this study were to quantify the effect of cropping system diversification on yield stability, environmental adaptability and the probability of diversified systems to outperform less diverse cereal-based systems in Europe. Spring and winter cereal yields were analysed from long-term field experiments from Sweden, Scotland and France. We investigated diversification through (i) introduction of perennial leys, (ii) increasing the proportion of ley in the rotation, (iii) varying the order in which crops are positioned in the rotation, (iv) introduction of grain legumes and (v) introduction of cover crops. The results showed that cereal crops within cropping systems incorporating perennial leys outperformed systems without leys in 60-94% of the comparisons with higher probabilities at low fertilizer intensities. The yield stability of oat did not differ, but mean yields were 33% higher, when grown directly after the ley compared to oat grown two years later in the crop sequence under similar management. Durum wheat grown in a cropping system with grain legumes had higher yields in lower-yielding environmental conditions compared to rotations without legumes. Diversification with cover crops did not significantly affect yield stability. We conclude that diverse cropping systems can increase cereal productivity, environmental adaptability and are more likely to outperform less diverse systems especially when introducing perennial forage legumes into arable systems. Effects of diversification on cereal yield stability were inconsistent indicating that higher productivity is achievable without reducing yield variability. These novel findings can support the design of more diverse and high-performing cropping systems.

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Subsoil organic carbon stocks are influenced by agricultural management – Results from ten German long-term field experiments

Laura E. Skadell[1], Florian Schneider[1], Martina I. Gocke[2], Julien Guigue[3], Wulf Amelung[4], Sara L. Bauke[4], Eleanor U. Hobley[5], Dietmar Barkusky[6], Bernd Honermeier[7], Ingrid Kögel-Knabner[3,5], Urs Schmidhalter[8], Kathlin Schweitzer[9], Sabine J. Seidel[3], Stefan Siebert[10], Michael Sommer[11], Yavar Vaziritabar[7], Axel Don[1]

Abstract:

Agricultural management can influence soil organic carbon (SOC) stocks, contributing to carbon sequestration and climate change mitigation. However, it is uncertain to which depth agricultural management affects SOC. Therefore, we sampled and analysed the upper metre of soil from ten German long-term field experiments (LTFE) in order to quantify the effects of agricultural management practices (e.g. mineral and organic fertilisation, irrigation, liming, reduced tillage) on SOC stocks down to a depth of 100 cm. Since changes in SOC stocks are usually slow, LTFE prove to be beneficial for studying these processes. The main problem in analysing LTFE data was to distinguish the actual management effects in the subsoil from the background noise of non-management related changes in SOC stocks. Therefore, we conducted purposive sampling with a sufficient number of sites and replicates. However, the experimental designs and duration of the trials varied widely. For more general, no longer site-specific conclusions about the effects of agricultural management on SOC stocks in 0-100 cm, suitable statistical methods had to be found. Linear mixed-effects models proved to be suitable for this purpose. Results showed that 19 ± 3 % of the net management effects were found in the upper subsoil (30-50 cm) and 3 ± 4 % in the lower subsoil (50-100 cm), including all agricultural managed options with significant topsoil SOC effects. 79 ± 7 % of management effects were found in the topsoil (0-30 cm). Mineral fertilisation was the most subsoil-effective treatment, followed by irrigation and organic fertilisation. Sampling down to a depth of 50 cm resulted in significantly higher SOC effects compared to considering topsoil only. Liming and reduced tillage revealed no evidence for significantly affecting SOC stocks in any depth increment. We recommend soil sampling to be extended to 50 cm soil depth to fully capture agricultural management effects on SOC.

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Austrian LTE data enabling international cooperations

Heide Spiegel[1], Georg Dersch[1], Julia Miloczki[1], Lisa Makoschitz[1], Andreas Baumgarten[1], and Taru Sandén[1]

Abstract:

Food security and the production of biomass for material and energy use on the limited resource soil under climate change are among the greatest current challenges. Agricultural management practices such as different organic and mineral fertilization, tillage and crop rotations influence the development of soil and crop parameters. Long-term field experiments are indispensable to quantify the effects of changes. The shift of those parameters in time and at different sites may tell us, if certain agricultural practices are sustainable in the long-term. The Austrian Agency for Health and Food Safety (AGES) runs field experiments since the mid-1950s. Selected arable practices under study are:

- different tillage systems ("conventional", "reduced", minimum), Spiegel et al. (2007), Franko, Spiegel 2016)
- different amounts and forms of nitrogen (N) and phosphorus (P) fertilization (Spiegel et al., 2001, 2010, 2020)
- application of different composts (biowaste compost, green waste compost, cattle manure compost and sewage sludge compost), Kurzemann et al. (2020); Lehtinen et al. (2017)
- management of crop residues (incorporation, removal), Spiegel et al. (2018)

LTE data from Austrian P experiments were recently used in cross national evaluations (Steinfurth et al., 2022; Buczko et al., 2018) to improve P target values and fertilization recommendations. Hendricks et al. (2022) analysed soil organic matter (SOM) parameters from the above mentioned LTEs to derive how sensitively the parameters active carbon (AC) and nitrogen mineralisation potential (NMP) react to different agricultural management practices compared to total soil organic carbon (SOC) and total nitrogen (Nt).
Furthermore, Austrian LTE data were/are included in international research projects such as LANDMARK (e.g. Trajanov et al., 2019) and EJP soil (www.ejpsoil.org), where metadata of the Austrian LTEs are stored in a database connected with the BONARES database. In the EJP Soil internal project CarboSeq, we use SOC data of the crop residue trial to derive carbon emission factors. These cooperations enable Austrian LTE data to feed into the evaluation of sustainable management practices and to assess future opportunities for sustainable soil management.

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Long-term agricultural experiments of the Institute of Agriculture, Warsaw University of Life Sciences – SGGW, Poland

Łukasz Uzarowicz[1], Wojciech Stępień[2], Tomasz Niedziński[2], Irena Suwara[3], Aneta Perzanowska[3], Zdzisław Wyszyński[3], Krzysztof Pągowski[3], Paweł Szacki[4], Przemysław Chłopek[4], Stanisław Samborski[3]

Abstract:

Long-term agricultural experiments of the Institute of Agriculture, Warsaw University of Life Sciences – SGGW, Poland operate in central Poland. The experiments includes fields in three locations: Skierniewice, Miedniewice and Chylice.

The fertilization experiments in Skierniewice were established in 1921 on Luvisols. These experiments are the oldest existing experiments in Poland, 5th in Europe and 7th in the world. The experiments have been carried out in various fertilization combinations (Ca, CaNPK, NPK, CaPK, CaPN, CaNK, PK, PN, KN, farmyard manure) including control plots with no fertilization. The four crop rotation are applied: 1) 5-field crop rotation, 2) rotation without manure and legumes, 3) rotation without manure with legumes and 4) 3 long-term monocultures (rye, potatoes and triticale).

The fertilization and tillage experiments in Chylice were established on Phaeozems. The fertilization experiments were established in 1955. The effects of organic and mineral fertilization in a four-field crop rotation with and without fine-seed bean is compered. The tillage experiments were set up in 1975 to investigate the effect traditional moldboard plough and conservation zero-tillage on soil properties and crop yield. In 2011, some plots with direct sowing were replaced into plots with no-till cultivator.

Experiments in Miedniewice were established in 2011 on Luvisols. Plant cultivation is carried out in a constant 3-field intensive rotation with a predominance of cereals. Also, permanent 4-field integrated rotation is carried out with the root crop, beans and cereals. For part of the field, the organic farming certificate has also been obtained. In the part of intensive and integrated production system tillage, experiment was also established with three tillage systems: conventional moldboard plow, ploughless tillage with a cultivator and strip-till (introduced in 2020 instead of direct sowing). There is also a permanent meadow in Miedniewice (0,2 ha is conventionally and 1,6 ha is organically managed).

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Modelling long-term dynamics of soil functions under agricultural management

Ulrich Weller[1,4], Sara König[1,4] , Birgit Lang[2,4], Bibiana Betancur-Corredor[2, 4], Thomas Reitz[5], Hans-Jörg Vogel[1,4], Martin Wiesmeier[3,4], Ute Wollschläger[1,4]

Abstract:

Mechanistic simulation models are an essential tool for predicting the influence of changing external factors on ecosystem functions. To render agriculture more sustainable, knowledge about the long-term effects of different land management activities on the various soil functions is mandatory.

In this contribution, we will discuss the importance of long-term field experiments for the development of systemic soil models capable to simulate the dynamics of soil functions. This is demonstrated for the *Bodium* model which integrates biological, physical and chemical processes to predict the effect of management activities on soil functions. For validating the simulated outcomes, data of long-term field experiments are essential.

Here, we simulated the Static Fertilization Experiment in Bad Lauchstädt and compared measured data of the last 40 years on yield, soil carbon, nitrogen, and microbial biomass with our simulation results. In this respect, we emphasize the enormous value of the various long-term experiments in Bad Lauchstädt. Such data are indispensable to gain a systemic understanding of soil processes which is highly required to evaluate the impact of soil management on soil functions. Towards a future perspective we want to highlight how additional measures of soil properties in long-term field experiments with a well-known land management history can provide valuable input for the development of new systemic modelling approaches.

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4.SUMMARY

Long-term field experiments (LTEs) are agricultural experiments for monitoring soil and crop properties in changing climate conditions and different management practices. Within the framework of the BonaRes (www.bonares.de) program, a data infrastructure has been developed to collect and process the meta-information and research data of LTEs with a minimum duration of 20 years in Germany and Europe. In November 2022, researchers on LTEs from six different European countries met in a workshop to exchange experiences with LTE management, data analysis and modelling. The presentations and discussions focused on understanding and exploiting the stimulating progress presenting the activities and advantages in publishing and using LTE data, including, i) LTE data management and reuse through the LTE overview map (lte.bonares.de) and the BonaRes Repository, ii) use of LTE data for model applications, iii) research on soil management with LTE. The importance of up-to-date LTE standards, the requirements for data acquisition and the statistical evaluation of LTEs were concluded. The outcomes emphasized the paramount importance of LTE in understanding management and climate change impacts in agriculture. A close collaboration between leading LTE groups (e.g., BonaRes, EJP SOIL, GLTEN) was concluded as relevant to increase the visibility of LTEs for boosting research initiatives in soil research.

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