BONARES newsletter

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Soil compaction on farmland (pascvii/pixabay.com)

Editorial

Research field soil compaction

Compacted soils store less water, they are less aerated and rain cannot percolate freely. As a result, more surface runoff leads to erosion of the most valuable upper soil layer. In addition, compacted soils hamper root growth and provide fewer habitats for soil organisms. All in all, the diverse soil functions can no longer or only insufficiently be fulfilled, and soil fertility in particular is also severely impaired. For agriculture, this means reduced or even lost harvests.

A major cause of harmful soil compaction is the use of heavy machinery on arable land. Especially when the bearing capacity of the soil is low due to high soil water content and poor soil structure. To enable farmers to better assess the actual compaction risk of their sites and to act accordingly, new practice-oriented technologies and site-specific instructions for soil conservation tillage are needed.

In addition, new cost-effective methods are needed to enable farmers to identify compacted soil areas on their land so that they can take specific measures to remedy the damage.

The development of such strategies and technologies is the central task of the BonaRes joint project SOILAssist. The scientists place great emphasis on close cooperation with farmers and companies involved in agricultural engineering. Read more about the project, current research questions on soil compaction, past results and future challenges in this issue of the BonaRes newsletter.

We wish you a pleasant reading!

Hans-Jörg Vogel

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Hans-Jörg Vogel coordinates the BonaRes Centre for Soil Research. He studied agricultural sciences at the University of Hohenheim. Since 2005 he is head of the Department of Soil System Science at the Helmholtz Centre for Environmental Research - UFZ in Halle-Leipzig. His work focuses on the modelling of soils as complex systems and the influence of agricultural land use on soil functions.

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Soil compaction in lanes on a wet field (Maike Siekmann/Thünen-Institute)

In focus

Soils under Pressure - Soil Compaction in Agriculture

Soil compaction is of great relevance for agricultural soils worldwide. It leads to soil degradation and is one of the eight main threats to soils in Europe. Compacted soils can no longer fulfil important functions such as water and air transport, both parameters are directly related to the habitat function of soils. This results in lower yields due to a reduced production function. To prevent soil compaction and provide farmers with valuable recommendations for action in the future, scientists of the BonaRes joint project SOILAssist develop practical solutions for agricultural soil protection during field traffic on arable land.

Soil compaction and soil degradation in agriculture

In recent years and decades, the trend towards greater productivity and area output has resulted in larger and heavier agricultural machinery. Moreover, specialized machines are expensive and have to be used to full capacity. However, the time windows of soil-conserving field traffic of these machines are sometimes very short, because especially in spring and autumn extensive precipitation often leads to very wet soil conditions, resulting in a high susceptibility of the soil to compaction. In these cases, the machinery often reach the limits of a soil-conserving trafficability. If the field traffic cannot be waived or postponed, soil damage can result.

However, a look into practice also shows that agricultural soils are deliberately loosened and compacted. Therefore, it is important to distinguish between consciously induced soil compaction or reconsolidation and harmful soil compaction. In wheat sowing, for example, the soil surface is specifically compacted ("reconsolidated") to ensure optimum field emergence of the crop. First of all, soil compaction is an increase in mass per unit volume. It becomes critical when the soil is compacted beyond its load-bearing capacity. This reduces the pore volume in the soil and limits the water and air balance or the rooting of the soil for plant growth. In the Federal Soil Protection Act (BBodSchG), it is called soil damage.

Causes and control variables of soil compaction

Pressure and shear forces, occurring under tyres during field traffic, affect the soil and lead to an increase in density. The extent of soil compaction depends on many factors. The soil water content and the load-bearing capacity of the soil at the time of pressure application as well as the force exerted by the machine itself are of great importance. Soil can be compacted because of cultivation and field traffic. If water and air permeability are disturbed, soil compaction can be considered as harmful. Consequentially, crops do

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not develop optimally and precipitation cannot drain into the soil, leading to surface runoff. Harmful soil compaction also has a negative impact on the habitat function of the soil and on various soil organisms, such as earthworms.

Types of harmful soil compaction

Soil compaction can occur in many areas of the soil. One type, for example, is in the topsoil at a working depth between 15 and 30 centimetres. Topsoil compaction can result from field traffic or cultivation under excessively humid soil conditions. Above all, it reduces nutrient uptake and leads to water accumulation on the soil surface. A topsoil base compaction, better known as plough pan compaction, is caused by the pressure of the plough blades and the furrow wheels below the working depth at 30 to 40 centimetres below the soil surface. As a result, the exchange of water and gas is inhibited and root penetration is reduced. Another form of soil compaction is subsoil compaction. Harmful soil compaction in the subsoil below 40 centimetres depth is particularly devastating. It can be caused by harvest campaigns and transport work on the field. Loosening measures, such as ploughing, hardly reach this depth. If subsoil compaction already occurred, it is very difficult to remove and requires considerable time and money.

Affected areas

Nationwide measurements on the extent and distribution of soil compaction in Germany are not available, so general statements cannot be made. However, individual measurements and structural investigations are available for some federal states and regions. The results indicate that above 10 to 20 percent of arable land is affected by cultivation-related compaction. In northern Germany, tilly soils and in southern Germany clayey soils are particularly affected.

Technical developments and soil-conserving field traffic

Developments in agricultural engineering have resulted in new chassis such as caterpillars, crab steering function or tricycles. Caterpillars have larger contact areas on the soil and can therefore support higher wheel loads without damaging the soil. During crab steering, the rear axle drives with a track offset, which minimises multiple wheel passes and the use of trikes reduces the share of trafficked field area. Continuous development of the tyres (wide tyres and terra tyres) has also resulted in tyres with large contact areas due to low tyre inflation pressure. These tyres can support high wheel loads optimally and soil-conserving. With a tyre pressure control system, the tyre inflation pressure can be adjusted to switch from road to field operation. Other measures, such as combined working operations, permanent tramlines or increased working width, reduce the number of wheel passes in the field and the trafficked area. To improve soil stability, the working depth and intensity can be reduced. In so-called conservation tillage systems, the soil is loosened without a plough. This has a positive effect on the soil organisms and preserves the intact soil structure.

Relevant machine parameters

To understand the issue of soil compaction better and to find practical solutions, it is important to understand the relationships between machinery applied load, the resulting soil pressure, the pressure propagation in the soil and the resulting soil structural changes. Different machine parameters are relevant for field operation. Due to its weight, the machine causes a mechanical load on the soil (load

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input). The contact area pressure results from the wheel load and the contact area between tyre and soil: the larger the contact area, the lower the contact area pressure, since the weight is distributed over a larger area. Another important factor is the rollover frequency in the track. On the one hand, it gives information about the number of wheel passes at one point in the field. On the other hand, we get information about the spatial distribution of wheel passes (hotspots in the field). With the number of wheel passes, the risk of subsoil compaction also increases. If, for example, a slurry tank with a tandem axle is used, wheel load and contact area pressure are reduced for each wheel. At the same time, however, the rollover frequency increases. Tandem axles are therefore not as suitable for protecting topsoil as vehicles with wide or twin tyres. By providing a larger contact area and a lower rollover frequency, they can distribute the pressure over a larger area.

Tyre-soil contact area

The contact area pressure directly depends on the wheel load of the agricultural machine. The wheel load can be determined using mobile scales. However, since the machine stops when weighing, only a static value is obtained. Yet, the dynamic wheel load is important for field operation. This can be several times higher than the static wheel load, as it depends on the slip of the tyres or the slope inclination. The difficult part is that the wheel load is constantly changing - it is dynamic. In harvest vehicles, for example, it increases continuously until the bunker is full. In the case of a slurry tank, it is the other way round and the wheel load decreases accordingly during slurry application. To reduce the contact area pressure, a soil-conserving tyre pressure control system can be used. The driver of the machine can adjust the tyre inflation pressure manually. Even though some farmers and contractors already use such a system, only a few agricultural machines are equipped with a tyre pressure control system. Until now, the driver of the machine has been the decisive factor, as he has to adjust the tyre inflation pressure manually. He has to take into account the current soil properties and he has to find the optimum inflation pressure for his tyres in complicated tyre tables of the manufacturer. One of SoilAssist's aims is to develop sensors that turn a manual tyre pressure control system into an automatic tyre pressure control system.

Future developments in agricultural engineering

The deflection of a tyre is closely related to the wheel load and tyre inflation pressure. SoilAssist developed a sensor system that is equipped with several different sensors to determine the dynamic wheel load during field traffic. For example, an ultrasonic sensor is located in the rim of each tyre of our agricultural measurement vehicles and measures the distance between the tyre rim and the inside of the tyre, i.e. the deflection of the tyre. By tyre deflection, the dynamic wheel load during field traffic can be determined for each tyre. The values for the deflection and the dynamic wheel load can be used to determine the optimum and thus soil-conserving tyre inflation pressure. Using these parameters, a manual tyre pressure control system can be turned into an automatic tyre pressure control system that dynamically adjusts the tyre inflation pressure to the optimum pressure while driving in the field. Together with the agricultural companies Grasdorf Rad, Steyr and TerraCare, we developed the first prototype of this system. This prototype was integrated in a tractor and presented at Agritechnica 2019 at the booth of our partner Steyr. This technology allows, for example, achieving the lowest possible soil pressure during field traffic. Our sensor system provides continuous data during field operation. These data are relevant for adjusting the tyre inflation pressure to the soil conditions. In addition, an important task of SoilAssist is to find out whether soil compaction effects can be predicted by these machine-supported data.

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Furthermore, we are looking for optimized tracks and process chains in the field that specifically contribute to maintaining and improving soil functions for the respective location.

Putting research results into practice

However, a large part of SoilAssist's research work is also dealing with the answering of practical questions: How much does sustainable field traffic cost the farmer? Which economic effects can be expected on the field and which factors determine whether soil-conserving field traffic is implemented? To answer these and other practical questions, SoilAssist scientists work closely with farmers, agricultural contractors, and machine manufacturers. These cooperations ensure the transfer of the results into practice.

Maike Siekmann, Marco Lorenz, Joachim Brunotte (Thünen-Institut)

Maike Siekmann studied geoecology at the University of Braunschweig and specialized in the fields of climatology and soil science. Since 2016 she works as a scientist in the SOILAssist project, where she is researching the influence of heavy agricultural machinery on the soil.

Marco Lorenz is coordinating the Bonares joint project SOILAssist at the Thünen-Institute for Agricultural Technology in Braunschweig since 2015. He studied environmental technology with a focus on soil science at the Technical University of Berlin and specialised in soil degradation and soil protection in his doctorate. His research focuses on physical soil protection in the agricultural use of soils, the effects of management measures on soil functional parameters and the technical options to reduce harmful soil impacts.

Joachim Brunotte is a trained farmer and head of the Department of Environmental Technology Soil/Plant of the Thünen-Institute (formerly Federal Research Centre for Agriculture - FAL). There, he has been researching the topic of soil protection in agriculture since 1993. Since 2015 he is leading the project SOILAssist.

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Joachim Brunotte at work (Vosshenrich/Thünen-Institute)

Point of view

Challenges and solutions for avoiding soil compaction

PD Dr. Joachim Brunotte studied agriculture and has been researching on soil protection in agriculture at the Thünen-Institute (formerly Federal Research Centre for Agriculture - FAL) since 1993. He is in charge of the " Soil Assist" project since 2015. Sandra Ledermüller asked him about the reasons why he started studying soil compaction, what the greatest achievements have been in recent decades and where developments are heading.

Mr Brunotte, as a farmer and scientist, you have been concerned with the interaction between machinery and soil for many years - from both a practical and a scientific point of view. Do you still remember what prompted you to deal intensively with the subject of soil compaction?

Soil erosion on agricultural land was a major topic in the 1980s. At that time, we were able to provide clear recommendations for action to prevent soil erosion within a short period of time, which were implemented in practice within a few years. Since the effectiveness of the proposed measures, in particular conservation tillage, was visible directly on the soil surface, they were quickly accepted by farmers. Additional support programs convinced the last skeptics. The issue of soil compaction is indirectly related to soil erosion: Compacted soil, for example, allows less water to infiltrate in the soil and, non-turning tillage, like mulch seeding strengthens the soil structure and thus the ability of the soil to carry high loads. But the problem is that compaction occurs within the soil and is, unlike soil erosion, more or less invisible. Even if you search specifically for certain soil parameters, it is very difficult to estimate soil compaction – this is of course even more difficult for the farmer than for the scientist.

In your opinion, what have been the most significant advances or achievements concerning soil compaction over the last 25 years?

Because of a time series of soil investigations, research came to an important conclusion: we can quantify the problem of soil compaction in the crumb and subsoil. The status surveys carried out in 1952 and 1982 by Eduard Ruhm at the Federal Research Centre for Agriculture (FAL) which were repeated by myself and my colleagues in 2002 in southern Lower Saxony showed that from 1952 to 1982 a crumb deepening had taken place to increase yields. Because the technical development at that time was not yet geared to soil protection and the soil was often ploughed at high soil moistures with a lot of slip, a massive ploughing pan was formed. The compacted soil areas exhibit reduced air and water conductivity and increased bulk density. From 1982 to 2002 we noted a relaxation in the area of the ploughing pan. Due to high energy costs, soil cultivation was less deep and the proportion of conservation soil tillage with driving on the soil surface increased to 50 percent.

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But there was also decisive progress in technology. Although the machines became larger and heavier, new tire technologies have made it possible that today a tire inflation pressure of 2 bar are sufficient to carry 12 tons of wheel load. Additionally, chassis developments such as 3 wheels and crab steering reduced wheel pass frequencies. High machine performance also allows to work in favourable soil conditions. The most groundbreaking technological achievement was the adaptation of an ultrasonic sensor in the rim of a tyre by my electrical engineer colleague Klaus Nolting, which allows to measure current tire deflection. This made it possible to measure the dynamic wheel load while driving. From this, the current wheel load can be determined. So, the potential of a tyre for soil protection can be exploited without damaging the tyre.

It appears that practical implementation still needs to be driven forward. Where is the problem?

In the latter development, the control parameter "tyre deflection" still has to be linked to the tyre pressure control system to be able to supply the farmer with a fully automatic system for maximum soil protection at any time. The agricultural machinery industry should take up the prototype of a "fully automatic tyre pressure control system" developed by us, produce it in series and offer it on the market. At Agritechnica 2019 some cooperating manufacturers showed how this innovation can be implemented. In process chains, the challenge is to compare the costs of soil-protecting technology with the monetarized benefits. An example: In the silage maize harvest, reloading the crop from field to road transport vehicles makes an enormous contribution to soil protection. The costs for this are 1 to 1.50 euros per ton or 60 to 80 euros per hectare. Since farmers cannot judge whether the higher costs for soil protection will pay off through positive effects on the field, they are hardly willing to carry out the expensive soil protection measure.

How do you think this economic hurdle can be overcome?

In this topic further research is needed. We must succeed in evaluating the monetary benefits of soil protection measures for the field - and thus for the farmer. Possible parameters are, for example, the effort involved in subsequent soil tillage using ploughs or cultivators or the increased yield of the following crop due to soil-conserving traffic.

You have pointed out that the higher costs often discourage farmers from taking tillage measures that protect the soil. Must financial incentives be created so that recommendations for action can be implemented more consistently?

Of course, a partial subsidy of 50 percent for automatic tyre pressure control systems would enormously increase the willingness of farmers and contractors to invest. We know that this works, for example, from the successful promotion of mulch seeding tillage combinations in the past. It is also conceivable to make money available under the second pillar of the Common Agricultural Policy (CAP) for the overloading of silage maize at the edge of the field so that this measure can be accepted and implemented with a view to protecting the soil.

When you think about the future, how do you envisage a system that takes into account both soil protection and economic aspects of land management?

Soil protection is not feasible if specialized harvesters are operated at the limit of their capacity without considering critical soil conditions. Every soil reacts differently to mechanical stress. To correctly assess

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the risk potential throughout Germany, a region-specific online application is needed that describes the compaction risk of the soil. Data from the German Weather Service (DWD) and soil moisture modelling help here. This data is combined with the mechanical load of the planned machine investment. The combination of these parameters results in a very site-specific number of days of soil conserving field traffic. The functionality of the machines is, of course, guaranteed on many more days. The utilization rates of machines would have to be reduced and the additional costs arising from the 2nd pillar of the CAP would have to be compensated.

Sandra Ledermüller (Thünen-Institute)

Sandra Ledermüller studied geography with the subsidiary subjects soil science and meteorology at the University of Cologne. After her diploma thesis in the field of integrated water resources planning at the Helmholtz Centre for Environmental Research in Leipzig, she joined the SOILAssist project at the Thünen-Institute in Braunschweig in 2015. Here, she focuses on socio-economic issues in the prevention of soil compaction in agriculture.

The contractor provides the project with agricultural machinery (Joachim Brunotte/Thünen-Institute)

Interview

"I consider it as my duty to support a governmental funded research project"

As a trained farmer, Thorsten Illers works on the family farm in the Hildesheim region and has been running the Ährensache agricultural contracting company since 2013. He has supported the SoilAssist project right from the start with his fleet of agricultural vehicles. Sandra Ledermüller asked him about his motivation for cooperating with scientists.

Mr Illers, please explain why you decided to start your own contracting business.

Already in my childhood, it was clear to me that I wanted to work in agriculture. Unfortunately, our farm does not allow us to carry two people full-time. So I thought to myself: If we don't have the work ourselves, then I'll do the work for others!

You are interested in soil protection both privately and professionally. Where does this interest come from?

During my high school graduation at a grammar school with a focus on agricultural economics, I wrote a technical paper on the subject of "Soil protection - comparing tyres against caterpillars". Through a friend, I got in touch with Joachim Brunotte from the Thünen Institute, who supported me quite well in this project. This has sparked my first interest and over the years the subject of soil protection has also become a guiding principle in my contracting company. When we buy new machines, for example, we make sure that they are fitted with the appropriate tyres. Soil protection is taken into account in everything we do in the contracting business.

How did your cooperation with the BonaRes joint project SoilAssist come about? And what exactly does it look like?

On the one hand, my contracting company is located close to the experimental fields of the project and since the project for school, I maintained a good cooperation with Mr. Brunotte. He asked me if I was interested and I immediately got involved. Since the start of the project in 2015, we have provided various process variants for liquid manure application for the wheeling experiments to investigate soil compaction. At the beginning, we came with the umbilical cord slurry spreading and the following year we were on the test plots with our self-propelled vehicle. We also provided our technology for the direct incorporation of liquid manure for emission protection for the field tests.

So the cooperation with SoilAssist has no monetary advantages for you. Why do you do it anyway? Which benefits do you have?

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On the one hand, I am personally very interested in news and new developments within agriculture. If I have the chance to participate actively in research through cooperation, this also enriches the work with my customers. This enables me not only to provide them with theoretical information but also with new findings, information and data. On the other hand, a scientifically sound basis in this field is also in my own interest, for example as a basis for new technological advances or for political developments. I consider it my duty to support a governmental funded research project that does not have these expensive machines at its disposal. After all, I expect important information from research that help me and my colleagues in our everyday work and support us in our planning. I simply want to make my contribution.

If you had a wish for research or politics, what would it be?

I wish our politicians would pay more attention to scientific results and not so much to opinion-making. If we could achieve that, we would be much further along. It is important that we do research, that we have reliable data for both sides: For farmers and for politicians. I would also like to see research results processed in the media in a way that is free of valuation and based on facts.

Sandra Ledermüller (Thünen-Institute)

We would like to thank Mr Illers for this interview and also for providing the agricultural machinery for our trials, especially for the application of fermentation residues.

Sandra Ledermüller studied geography with the subsidiary subjects soil science and meteorology at the University of Cologne. After her diploma thesis in the field of integrated water resources planning at the Helmholtz Centre for Environmental Research in Leipzig, she joined the SOILAssist project at the Thünen-Institute in Braunschweig in 2015. Here, she focuses on socio-economic issues in the prevention of soil compaction in agriculture.

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Michael Kuhwald (Katja Kuhwald/CAU Kiel)

Portrait

Michael Kuhwald - environmental researcher and soil scientist by passion

Since 2015, geographer and soil scientist Michael Kuhwald has been working on the topic of soil compaction in the SOILAssist project. And this despite the fact that he has rather bad memories of soil from school. In spring 2019 he finished his doctorate and wants to continue working as a scientist in the future. In a short portrait, you can learn more about his professional career and find out what inspires him about his work.

Michael Kuhwald is a research assistant at the Department of Geography at the University of Kiel and part of the SoilAssist team. Since the beginning of the project in summer 2015 he has been working on the spatio-temporal dynamics of soil compaction and analyzes them on different spatial scales. It has long been known that soil compaction is a global problem and contributes significantly to soil degradation and loss of soil fertility worldwide. Nevertheless, attention must be drawn to this problem again and again, and further research must be carried out on the effects of soil compaction and on strategies to avoid them. In the SoilAssist project, Michael Kuhwald does just that.

At school, soils were boring

He could not have imagined earlier that one day soils would become an important part of his work. He still remembers well when soils were on the curriculum in geography lessons: Memorizing different types of soil and passing a test. At the time, this was so boring to him that he didn't really want to have anything to do with "soil" again. He decided to study geography because of his interest in geopolitics and economic geography. But the first semesters at university finally changed his opinion about soil. His fellow students were also to blame for this, who, friendly but determined, convinced him to join them in soil science as well. Thereupon he changed to the physical-geographical field and started to study environmental protection and hydrology in the minor subjects besides soil science. During his time as a student assistant and later as a research assistant, he discovered his enthusiasm for scientific work and decided to pursue a doctorate and a career in science.

With patience and determination towards a doctorate

The path to his PhD was not always easy and required a lot of patience. For his doctorate, he needed firstly funding and secondly a topic. After his Master's thesis, he bypassed the time until project approval with various short employment contracts at the university. Short contract periods and constantly changing work tasks made it impossible for him to pursue his PhD topic. But he did not give up on his project so easily and his patience finally paid off. Thanks to the BonaRes initiative and the SoilAssist project, he finally had a project position for several years starting in the summer of 2015.

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His job in the SoilAssist team enabled him to concentrate on one topic - the spatio-temporal dynamics of soil compaction - and to return to his dream of a PhD. The spatial estimates of soil compaction, which are so interesting for him as a geographer, were previously based on rigid assumptions that only imprecisely reflect reality. Due to the lack of spatially and temporally highly resolved information on soil compaction risk, he decided to develop a new approach to its evaluation in the form of a dynamic model. Extensive field and laboratory work provided a reliable data basis for his model and he was involved in data preparation and statistical analysis. Because a model is only as good as the underlying data.

The result of his efforts is called "SaSCiA" (Spatially explicit Soil Compaction risk Assessment): a model with which the risk of soil compaction for entire regions can be estimated on a daily basis. Currently, the model is mainly used for research purposes, but in the coming years, SaSCiA will be made available to farmers and contractors via a website or app.

Inspiring others for the soil and the project

Since obtaining his PhD, Michael Kuhwald has been taking on more and more coordinating tasks in addition to his scientific work and now supervises PhD students himself. In addition, his work as a lecturer at the university is important to him because it enables him to pass on the latest scientific findings and at the same time he benefits greatly from the exchange with students. "Every now and then I manage to convince students of the subject matter in such a way that they want to join the project as student assistant. And who knows, maybe a new scientific path will begin, as I did myself at that time."

Dream job scientist

For Michael Kuhwald, working as a scientist is one of the best professions he can imagine, despite all the imponderables and an uncertain perspective. And he knows that there is still a lot to do - in research, but also in terms of public awareness of the environmental problem of soil compaction.

There are still many unanswered questions that he would like to solve together with his colleagues. These include, for example, the assessment of the regenerative capacity of compacted soils or the search for practical prevention strategies. In this context, the link with other research areas such as water erosion will become increasingly important. Research must also be conducted into how climate change will affect soil compaction: For example, a decrease in the number of frost days could have a negative effect on the natural regeneration of compacted soils, while summer drought could reduce the risk of compaction during rape or cereal harvesting.

Raising awareness

In addition to these scientific challenges, scientists must also succeed in raising public awareness of the topic of soil compaction. "Soil compaction is a problem for all of society and can only be solved by society as a whole. No farmer deliberately compacts his or her own land. Time and above all cost pressure, however, force them to drive their areas even under unfavourable soil conditions or to have them driven by contractors and to use heavy machinery. Two factors stand in the way of sustainable soil management: Consumer behaviour - agricultural products cannot be sustainably produced at discount prices - and at least questionable political control. The German Renewable Energy Sources Act (EEG), for example, led to a considerable expansion of maize cultivation, which is associated with a very high risk of soil compaction.

The EEG has therefore led to an expansion of areas affected by soil compaction. Politicians and consumers therefore also have a responsibility to create a suitable framework for farmers to manage their soils sustainably and make a living out of their work".

Michael Kuhwald, therefore, devotes himself specifically to the dissemination of his research results and the findings of his project colleagues. His main concern is to raise awareness of the environmental problem of soil compaction in agriculture and in society. "Scientists are laying the foundations for this. By compiling objectively reliable facts, they help to develop sustainable strategies and solutions to reduce or avoid harmful soil compaction in agriculture.

Susanne Döhler (UFZ)

Susanne Döhler is a geographer and soil scientist. Since 2017 she is responsible for public relations in the BonaRes Centre for Soil Research. Her responsibilities include editing the BonaRes newsletter.

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Demonstration of a soil deformation measurement (Susanne Döhler/UFZ)

Network

Interest in soil protection grows, but measures are too expensive

Since 2015, scientists of the BonaRes project SOILAssist have been working together with partners from industry, consulting and agriculture to develop future strategies for soil conserving traffic on arable land. In the workshop of the same name, which took place in spring 2019 at the Thünen Institute for Agricultural Technology in Braunschweig, the SoilAssist research team presented previous results and exchanged ideas with their cooperation partners on open research fields, technical and practical hurdles and the next steps on the way to minimizing harmful soil compaction.

The central questions were: How does the contact between machine and soil affect the soil? How can harmful soil changes be avoided and which technological developments can best support farmers? Dr. Joachim Brunotte from the Soil/Plant Environmental Technology Soil/Plant Department at the Thünen Institute emphasised right at the start of the event that his team "is directly working on the ground". SoilAssist focuses on large machines such as sugar beet harvesters, maize choppers and combine harvesters. Although farmers in Germany also think about smaller self-propelled machines, the demand for larger agricultural machines is still increasing worldwide, according to the cooperation partners.

The compaction risk is determined by key variables

Wheel load, contact area pressure, and tyre inflation pressure are important technical parameters and control factors for avoiding harmful soil compaction. The number of wheel passes is another important factor: Many wheel passes with a lighter machine can have the same effect as few wheel passes with a heavy machine. In principle, however, the heavier the machine and the more frequently it is used on arable land, the greater the risk of soil compaction. The headland is, therefore, particularly at high risk. However, the actual risk of soil compaction also depends on the soil properties, soil and weather conditions. Heavy clayey soils are more sensitive to compaction than sandy soils and high soil water contents increase the risk of soil compaction in general.

On-board assistance systems to better support farmers in the future

New technologies should enable farmers to adapt the load of the machines to the soil condition - in real time. However, this is not an easy task because the soil properties of arable land are continuously changing. While the soil texture only varies spatially, the soil moisture changes over time depending on the weather. And the machine parameters also change continuously: the wheel load increases continuously during harvesting, e.g. for bunker machines during sugar beet and maize harvesting. The

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additional loads, on the other hand, decrease with the spreading of liquid manure or sowing. The risk of compaction on the field is therefore subject to constant fluctuations.

In the future, on-board assistance systems will help farmers to better assess the trafficability of the soil. These systems will show, on the basis of the current soil condition, at which bunker filling level the critical wheel load is exceeded. The automatic adjustment of the tyre inflation pressure will also help to ensure that large machines can be used without damaging the soil. A suitable model for calculating compaction sensitivity is currently being developed by scientists from the University of Kiel and the Thünen Institute for Agricultural Technology. In the coming years, it will be important to further develop such systems in cooperation with partners from industry in such a way that they can be transferred into practice. Until then, the experts recommend, for example, the separation of field and road transport during silage maize harvesting as a useful but more expensive way of avoiding soil compaction.

Sensitising and better training for farmers

Contractor Thorsten Illers pointed out that one of the main sources of error when driving on arable land sits "between the seat and the steering wheel". Good training, awareness-raising, and advice for farmers and contractors are therefore of fundamental importance when it comes to avoiding soil damage.

Soil protection is a question of money

New machines and processes that protect the soil are usually cost-intensive. Scientists and cooperation partners report that farmers always ask about the added financial value of extra measures: What is my financial benefit if I switch to soil conserving farming? It is true that farmers have an interest in managing their soils sustainably. But in the end farmers have to be able to afford it. Economic efficiency is therefore currently the most important condition and at the same time the greatest obstacle when it comes to putting new methods and technologies into agricultural practice. Research is therefore required to monetize the benefits of soil protection for soil structure and yield. This is the only way to improve acceptance in practice.

Financial support for new soil-protecting methods conceivable

Long-term studies on land management show that conservation tillage and technical developments on agricultural machinery (e.g. radial tyres and internal tyre inflation pressure adjustment) have led to a relaxation of compaction in the topsoil. The workshop participants doubt, however, that new technologies will be used on a large scale voluntarily because they are always associated with high investment costs. In one case or another, regulations combined with government support measures will certainly be necessary to introduce soil protection measures on a large scale.

Germany is an international pioneer in the agricultural sector

In the opinion of agricultural machinery manufacturers, Germany continues to be a role model for new developments in agricultural technology and is thus playing an important pioneering role. Many new technologies have quickly spread internationally following their market launch in Germany. Despite low international demand, the industry is therefore very interested in soil conserving, sustainable processes.

Susanne Döhler (UFZ)

Susanne Döhler is a geographer and soil scientist. Since 2017 she is responsible for public relations in the BonaRes Centre for Soil Research. Her responsibilities include editing the BonaRes newsletter.

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Field measurements with RGB and multispectral cameras (Fritjof Busche/CAU Kiel)

News from the field

Detecting soil compaction from a distance with high-tech

To investigate soil compaction, time-consuming and costly field and laboratory methods are usually used to determine important soil properties such as bulk density, air conductivity and saturated hydraulic conductivity. Thanks to modern remote sensing technology, it could become easier and cheaper in the future to identify compacted areas on agricultural land and to take them into account in soil tillage.

As part of the SoilAssist project, scientists at the University of Kiel are currently working on a method for detecting soil compaction from above. Therefore, they make use of the close relationship between plant growth and soil properties: When soil is compacted, roots and leaves cannot grow ideally and where crops have less foliage, the soil may be compacted. By using a multi-spectral camera attached to a UAV, the researchers are able to locate suspicious sites. The multi-spectral camera can record the spectrum visible to humans as well as wavelengths in the near infrared range. Because the chlorophyll in plants reflects a particularly large amount of infrared radiation, differences in plant growth become visible. The images are then used to detect patterns in growth height and biomass production to identify potentially compacted areas.

However, growth depressions can also have numerous other causes, e.g. differences in soil type or nutrient availability. To detect where reduced plant growth is actually a consequence of soil compaction, the sites identified with the multispectral camera are sampled and investigated with classical soil science methods.

Based on these investigations, we are developing an algorithm that can reliably detect soil compaction and distinguish it from other forms of soil degradation such as nutrient deficiency. At present, we are still searching for patterns in plant growth by hand. However, we are confident that an automated recognition of plant growth patterns will be possible after only two growth periods.

Special camera makes differences in plant growth visible

In addition, scientists at the University of Osnabrück are using a 3D laser scanner. 3D laser scanners capture the environment very precisely and generate so-called 3D scatter plots from a large number of three-dimensional measuring points. Using a hyperspectral camera, additional data can be assigned to each measuring point. In contrast to a multispectral camera, a hyperspectral camera can capture the entire spectrum of incoming sunlight from the near infrared to the violet range. The system used in SoilAssist is currently unique in Germany. It allows to precisely locate the captured hyperspectral signals in space.

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SoilAssist scientists use a unique system of 3D laser scanner and hyperspectral camera

To improve plant monitoring, the data recorded with the hyperspectral camera can be combined with the airborne data of our colleagues in Kiel. In addition, the hyperspectral 3D scans form the basis of the SoilAssist planning and assistance system. The high information content of the data makes it possible to divide the environment into different categories. Field crops, fallow arable land or access roads can easily be distinguished and processed with the help of artificial intelligence. For example, different soil properties can be assigned to specific locations.

This information is processed in the SoilAssist planning system in order to provide the farmer with the best possible support in planning the cultivation of his land. Once the planning system is fully developed, it should be possible to automatically simulate and evaluate different types of field traffic on the basis of the collected environmental data, and to generate recommendations for action to ensure that cultivation is as soil conserving as possible.

Frauke Lindenstruth (CAU Kiel) and Thomas Wiemann (Uni Osnabrück)

Frauke Lindenstruth studied environmental geography and environmental management at the Christian-Albrechts-University of Kiel and has been employed at the Chair of Landscape Ecology and Geoinformation since her graduation. Since 2019 she has been working as a research assistant in the SOILAssist project and is doing her PhD on the recording of spatio-temporal patterns of soil degradation using UAV images.

Thomas Wiemann studied physics with computer science at the University of Osnabrück. There he received his PhD in computer science in 2013 and since then he has been researching the semantic interpretation of multimodal 3D sensor data as a postdoc in the Knowledge-Based Systems group. In SOILAssist he leads the subproject for the creation of a semantic 3D environment model.

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Separation of field and road transport during maize harvest (Maike Siekmann/Thünen-Institute)

Videos

Separation of field and road transport during maize harvest

The video shows a loading mouse at the edge of the field, which loads chaff from the silo wagons onto waiting transport vehicles.

For silage maize harvesting, we examine the entire chopping chain. It consists of a chopper, tractors with silo wagons and a tractor with mounted mulchers. The chopper chops the maize plants into small pieces and transfers them to the tractor with transfer wagons driving in parallel. The tractor with mulcher drives behind the chopper and chops the maize stalks in the field. This chopping is important to prevent the corn borer insect from overwintering in the corn stalk.

At the edge of the field, there is a loading device that transfers the chopped material from the silo trucks to waiting transport vehicles. This makes it possible to separate road and field transport. The vehicles that only drive on the field for harvesting can set a low tyre inflation pressure that is gentle on the soil. The vehicles that transport the chopped material to the biogas plant can drive with a higher Tyre inflation pressure.

See the video here: https://vimeo.com/365012901

We would like to thank the contractor Uwe Probst for providing the chopping chain for the silage maize harvest and our field trials.

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Measuring soil deformation during silage maize harvest (Maike Siekmann/Thünen-Institute)

Videos

Measuring soil deformation during silage maize harvest 2019

In this short video you can see a field test for measurement of soil pressure and deformation during silage maize harvesting with a chopper chain.

During last year's silage maize harvest, we carried out a field test with the harvesting chain. During these tests, we measured the soil pressure and the corresponding soil deformation under each tyre at three different depths in the soil. To do this, the vehicles of the chopper chain roll over the measuring plot one after the other. The sensors are installed in the soil in such a way that the measurement is made just below the centre of the vehicle tyres. Soil samples are taken before and after wheeling to detect changes in soil structure as a result of field traffic.

See the video here: https://vimeo.com/364991728

We would like to thank the contractor Uwe Probst for providing the cutter chain for the silage maize harvest and our trials.

Sugar beet harvest with crab steering (Sebastian Skupski/Thünen-Institute)

Videos

Sugarbeet harvesting with crab steering

The video shows the sugar beet harvest with a 3-axle harvester with soil-conserving crab steering.

For the sugar beet harvest we use a 6-row 3-axle sugar beet harvester with bunker and soil conserving crab steering function. When harvesting the beets, the wheels of the two rear axles are deflected in the same direction so that all wheels run offset when driving straight ahead. This reduces the wheel pass frequency. Because in addition to the wheel load of the vehicles the number of wheel passes in the same track are decisive parameters for avoiding soil compaction.

See the video here: https://vimeo.com/374636871

Many thanks also go to the Maschinengenossenschaft Ambergau and GRIMME Landmaschinenfabrik for providing the sugar beet harvester for the sugar beet harvest campaign and our field tests.

BonaRes Events

"Ohne Boden nix los!" Warum Böden für uns alle wichtig sind

Public panel discussion at KUBUS Leipzig – February 17 2020 (in German)

Healthy soils are true all-rounders. They store and filter water, are a habitat for plants and countless soil organisms and play an important role in climate protection as carbon stores. But the soil under our feet is in danger. Unfortunately, very few people are aware of this.

The event "Ohne Boden nix los!" therefore puts soil, its sustainable use and its significance for mankind and the environment at the centre of current social and environmental policy issues and developments.

Guests:

- Prof. Dr. Ingrid Kögel-Knabner, Technical University Munich (Winner of German Environmental Prize 2019)
- Prof. Dr. Nicolas Brüggemann, Research Centre Jülich
- Prof. Dr. Bärbel Gerowitt, University of Rostock
- Dr. David Russell, Senckenberg Museum of Natural History Görlitz
- Florian Schwinn, journalist and author ("Save the ground")
- Dr. Susanne Dohrn, journalist and author ("The Soil. Threatened helper against climate change")

Moderation by Hanna Gersmann

Venue:

Leipzig KUBUS of the Helmholtz Centre for Environmental Research - UFZ, Permoserstraße 15, 04318 Leipzig

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The event is part of the Science Year 2020 - Bioeconomy and is open to all interested citizens. Prior registration is not necessary.

For further information pleas contact Susanne Döhler (UFZ).

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