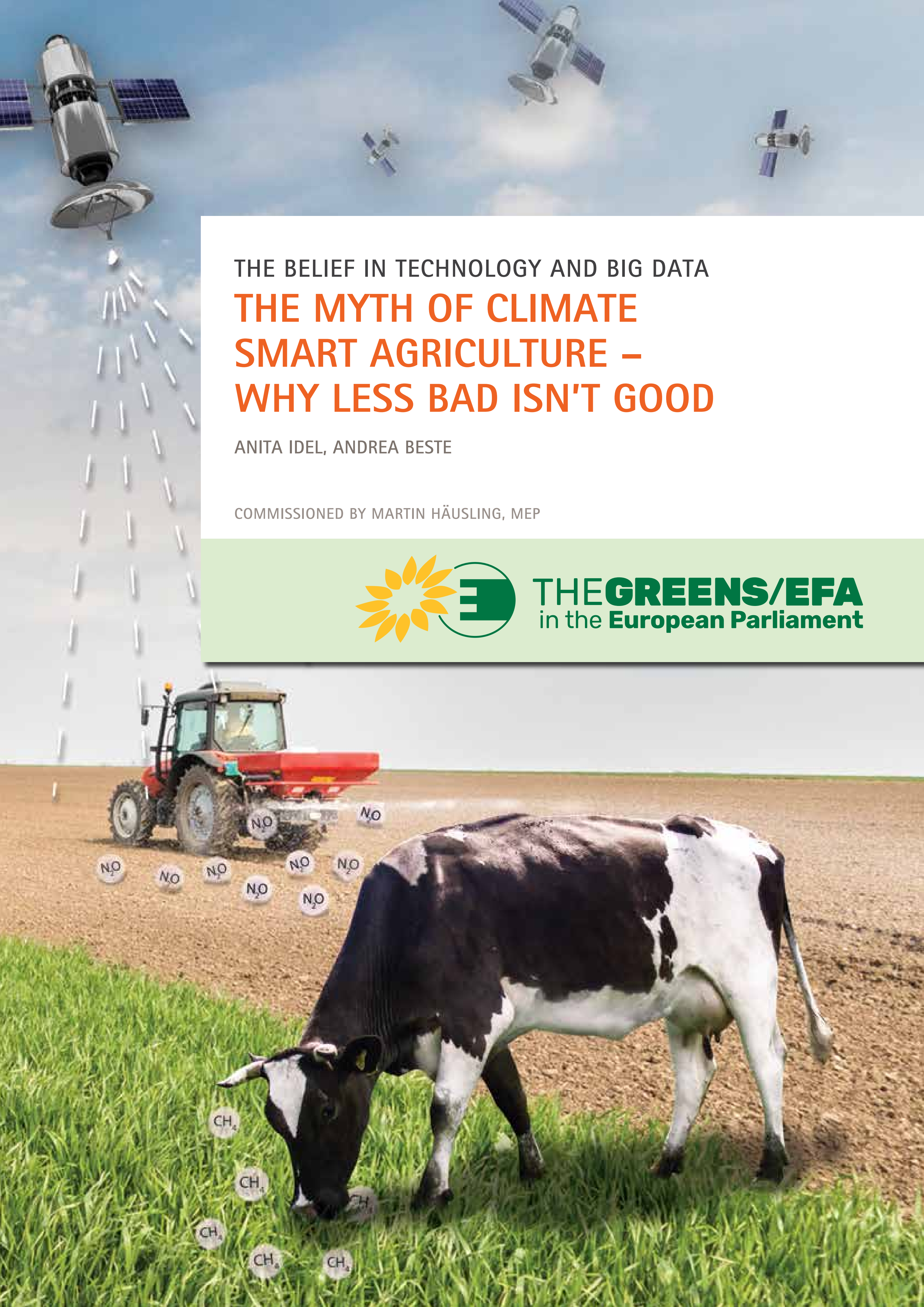
THE BELIEF IN TECHNOLOGY AND BIG DATA

THE MYTH OF CLIMATE SMART AGRICULTURE – WHY LESS BAD ISN'T GOOD

ANITA IDEL, ANDREA BESTE

COMMISSIONED BY MARTIN HÄUSLING, MEP

THE GREENS/EFA
in the European Parliament



IMPRINT

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LAST UPDATED
April 2020, 3rd edition

COVER
depositphotos.com, Tractor fertilizing in field © fotokostic / Satellite © mmaxer / Kuh © Michaela Braun

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PREFACE
MARTIN HÄUSLING

With the 2015 Paris Climate Agreement the international community reinforced its common goal to limit global warming to significantly below 2°C compared to the pre-industrial era. Climate protection as well as the adaptation to the increasingly noticeable climatic changes have to be inseparable, equal goals on our to do list.

According to the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) Report, agriculture is causing climate change as well as suffering from it and, what's more, it has the potential to limit it. For practical agriculture it will be very important, even essential, to develop or rediscover adaptation systems which minimise the risks brought about by climate change. Agricultural systems have to be geared first and foremost towards resilience rather than highest yields. That goes for torrential rains as well as drought and increasing pest pressure. Almost all measures that increase resilience are at the same time climate-friendly, organic agriculture being the best example. Grassland offers a special potential in regard to climate-, soil- and flood-protection as well the promotion of biodiversity – not least because it constitutes a considerable share of agricultural land. Add to that the importance of sustainable grazing for animal welfare and the supply of proteins for humans.

It is essential to optimise agricultural systems. Agriculture should reject any unilateral maximisation of CO_2 sequestration for emission trading which just aims to relieve the pressure on other sectors. Soil fertility should not be regarded as an underground CO_2 savings account. It is crucial to shift the balance from soil degrading to soil building biological processes.

On the whole there is a danger of eventually creating negative environmental effects through a one-dimensional approach to research and blinkered climate protection methods. As is the case with agro-energy. This needs to be avoided.

Apart from climate protection goals, the European nitrate- and water framework directive, the directive for air pollution control and the biodiversity strategy all demand a systemic approach in order to satisfy all environmental goals and not pit one against the other.

Happy reading!

INTRODUCTION

LAND USE AND CLIMATE CHANGE – CHALLENGES AND POTENTIAL

Anita Idel and Andrea Beste

THE BIGGER PICTURE

The facts: The exploitation of fossil fuel repositories, both stable and gaseous, (energy for industry, transport, heating, cooling etc.) is responsible for the main share of greenhouse gas accumulation in the atmosphere.

The fact that the agricultural use of arable and grassland played and still plays an important role in climate change is significant, too: according to the IAASTD[1] report and depending on one's stance agriculture is a main driver as well as a dramatic victim of climate change, while simultaneously holding the crucial potential to limit it. The production and field application of synthetic nitrate fertiliser causes agriculture's largest contribution to climate change[2]. But in almost all calculations and models these emissions are not attributed to agriculture.

As for forests, grass and grazing land or arable use: To reduce emissions does not (!) mean storing carbon in soils long term, but, through prudent management, to shift the balance between carbon releasing and carbon storing biological processes in favour of the latter.

The authors would like to state clearly: Agriculture's purpose is to maintain its ability to produce enough food on planet earth and continue to do so in the future. This will only be possible if the basic resources – soil, watercourses, biodiversity – can be maintained. It is not the purpose of agriculture to "sequester" or compensate for greenhouse gasses released through industrial production. The latter would equate to an irresponsible climate "sale of indulgences".

Soil can be a carbon source (CO_2 emissions) and/or it can be a carbon sink (C sequestration). At present the world's soils store 1,460 billion tons of organic carbon, that is more than twice the amount of CO_2 in the atmosphere[3]. The largest amount of the carbon (25 %) is stored in the soils of permafrost regions which amount to a quarter of the land surface (Arctica, Antarctica, Alps)[4], but only as long as permafrost conditions continue.

As for forests, grass and grazing land or arable use: To reduce emissions does not (!) mean storing carbon in soils long term, but to shift the balance between carbon releasing and carbon storing biological processes through prudent management in favour of the latter.

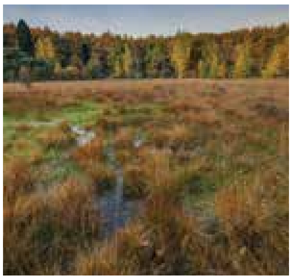
Whether emissions or storage of carbon dominate on agricultural land depends on the type of land use as well as on how and with what dynamic vegetative cover and vegetation are being changed.

For the climate a change in land use from more C storing systems to more CO_2 emitting systems is extremely relevant – in particular if mixed forests are cut down or grassland is ploughed up. As is the case at present in particular in Asia and Latin America where rainforests and woodlands are being cleared and savannahs (grassland) are ploughed up on a dramatic scale to make way for plantations (palm oil) and intensive agriculture (soy/corn)[5].

Apart from soils in permafrost regions moors and grasslands contain the majority of carbon stored in soils. If they are converted into arable land or (short) rotation plantations or if peat is extracted, large amounts of greenhouse gasses are set free, biodiversity is destroyed and soil fertility and water storage capacity decrease considerably[6]. The conversion of European mixed forests and grassland into arable land is linked with very high CO_2 emissions, too.

Forest

Grassland



Moor

The overproduction of animal products within the European Union is mainly based on imported feed. It's the reason why the change in land use is less dramatic and not as obvious in the EU as it is for example in Brazil's Cerrado. Nevertheless, between 1967 and 2007 over 7 million hectares of permanent grassland, equalling over 30 %[7], were converted in the EU founding nations (Belgium, Germany, France, Italy, Luxemburg and Netherlands), and with EU enlargement an additional 4 million hectares during the past 20 years[8]. The climate balance in European agriculture hinges on whether animal production will be lowered massively in order to reduce the pressure on soils. It necessitates an orientation towards species and intensities of use which are based on grassland rather than on concentrated feed.

What's more, in Europe it is of particular relevance how arable and grassland systems will be designed in future. It will be decisive as to whether in future they will become CO_2 sources or C-sinks. It will also decide whether we will be able to meet the challenges of climate change in Europe and continue arable farming and the use of grasslands in a productive manner.

DON'T COMPARE APPLES AND ORGANGES

Yet, one-sided research questions and the narrow design of studies - like the evaluation of nitrogen efficiency or the calculation of methane/kg milk instead of the assessment of the overall relevance of milk production systems for climate change - suggest conclusions which actually are counterproductive to the conservation of resources and climate protection. The short-term focus of political measures on high-tech methods and end-of-pipe measures ignore the system-based character which solutions to climate protection and adaptation to climate change absolutely need to include.

THE 'HOW' IS ALL IMPORTANT

Challenges and potential for future food supplies on our planet thereby rest on how we develop our systems of land use in combination with resilient plant- and animal breeding and how we adapt them to climate change accordingly.

The climate balance in European agriculture hinges on whether animal production will be lowered massively. We need an orientation towards species and intensities of use which are based primarily on grassland rather than on concentrated feed.

The production of synthetic fertilisers and pesticides leads to emissions. External emissions are defined as emissions which do not develop directly in the field or through farming activities but nevertheless have to be attributed to agriculture.

If the production of synthetically manufactured nitrogen fertilisers and pesticides is included, agriculture's share of greenhouse gas emissions in Germany in 2011 does not amount to 6.3 % but to 16 %.

THE MYTH OF CLIMATE SMART AGRICULTURE – WHY LESS BAD ISN'T GOOD

1. IN THE FIELD: DIFFERENT SYSTEMS INSTEAD OF DIGITAL COSMETICS!

By Andrea Beste

ARABLE FARMING – AT PRESENT THE TRUE EMISSIONS ARE COVERT

The conversion of different land use systems to others – like from forest to arable farming – causes major changes in regard to the emission of greenhouse gasses. The farming system has significantly different effects on the climate, too, but to a much lesser degree than is the case with land use change. One should keep that relation in mind when discussing the climate relevance of different techniques within an arable farming system. In comparison to the damage done to the climate by ploughing up grassland, the variation of possible short-term storage or emission of greenhouse gasses through different arable farming practices is much smaller. But only when remaining within the agricultural cycle – without external input[1].

The production of synthetic fertilisers and pesticides leads to emissions. External emissions are defined as emissions which do not develop directly in the field or through farming activities but nevertheless have to be attributed to agriculture. Current farming practices manage their productivity to a large degree via mineral fertilisers and the use of synthetic pesticides and therefore not from within the agricultural cycle but through the industrial sector. However, the external emissions of greenhouse gasses arising during the production of these external inputs have to be added. At present the CO_2 emissions occurring during the production of mineral fertilisers and pesticides are not attributed to agriculture but to the industrial sector.

Roughly 1.2 % of the world energy consumption is needed for the Haber-Bosch synthesis and the production of ammonia from atmospheric nitrogen[2]. More than 90 % of the energy needs within the fertiliser industry are required for the production of mineral nitrogen[3]. With many field crops as well as with fruit and vegetables more than a third of the energy usage in agriculture must be attributed to the production of agrochemicals (fertilisers and pesticides)[4]. If the production of synthetic nitrogen fertilisers and pesticides is included, agriculture's share of greenhouse gas emissions for example in Germany in 2011 does not amount to 6.3 % but to 16 %[5].

Because external inputs are so energy intensive, the emission of greenhouse gasses for non-closed agricultural systems reaches a new dimension. It is therefore necessary to distinguish sharply between these farming practices and those which mostly work within the agricultural cycle. In comparison and in particular in the long-term it is relevant whether a farming system implicates the storage of carbon or the emission of carbon and other greenhouse gasses. Or in short: whether soil fertility is built or degraded.

Particularly in the tropics there are "farming" systems that hardly need any external inputs and look more like forest use (agroforests, permaculture, agro- silvo- pastural systems). These systems are not necessarily "extensive" or less productive, on the contrary: often they are quite intensive, at times they have a significantly higher productivity and - compared to the prevalent farming systems in Europe – a higher potential for CO_2 storage.

A narrow focus on aspects of climate protection in agriculture can actually undermine other environment media (see chapter 3). Aspects of soil fertility, biodiversity, water and soil protection as well as animal welfare are at least as important. The focus on climate aspects should not thwart the appropriate consideration of other aspects of sustainability.

The federal research institute for rural areas, forestry and fisheries (Thünen) in Germany in 2012 wrote:

„Climate change measures in agriculture should be implemented first in areas where large synergies with other environmental goals and environmental policies exist[6]."

In this respect we have to look at the effects of whole systems rather than focus on small changes in favour of some environment medium that just happens to be in the lime light.

Permaculture: Intensive – but still with carbon storage!

Photo: Beste

A narrow focus on aspects of climate protection in agriculture can actually undermine other environment media.

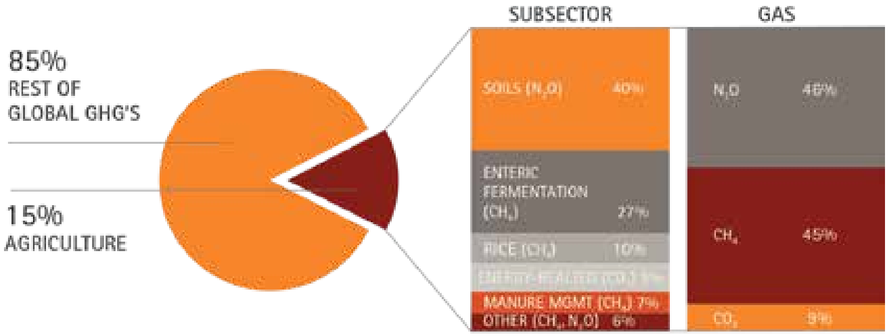
2. CLIMATE SMART AGRICULTURE AND PRECISION FARMING – WHY LESS BAD ISN'T GOOD

TOO MUCH NITRATE AND FAR TOO LITTLE CARBON

The production of mineral fertiliser needs a lot of energy – see above. In intensive agricultural systems with external fertiliser input this accounts for up to 50 % of energy use per hectare[7]. The energy use for pesticide production still has to be added to this. But the indirect climate damaging effects through these external inputs have to be taken even more seriously because they also harm the environment in other ways. Soils under conventional intensive production show significantly faster humus depletion and can store nutrients and carbon less well[8]. This is linked to high emissions of CO_2 and nitrous oxide (N_2O) in particular, which has 300 times the climate impact of CO_2. It also makes up the biggest part of climate relevant emissions in agriculture, considerably more than CO_2.

The World Research Institute (WRI) and the UN Environmental Programme (UNEP) calculate the share of nitrous oxide emissions worldwide to be the highest among the climate relevant gasses in the agricultural sector, i.e. 46 %

The World Research Institute (WRI) and the UN Environmental Programme (UNEP) calculate the share of nitrous oxide emissions worldwide to be the highest among the climate relevant gasses in the agricultural sector, i.e. 46 % (see fig.)[9]. For Europe the figure quoted is 43 %[10]. In general, calculations estimate nitrous oxide emissions to be higher than methane emissions (CH_4), but strangely enough there is much less debate about them (for an evaluation of (methane) emissions from livestock see the chapter by Anita Idel).



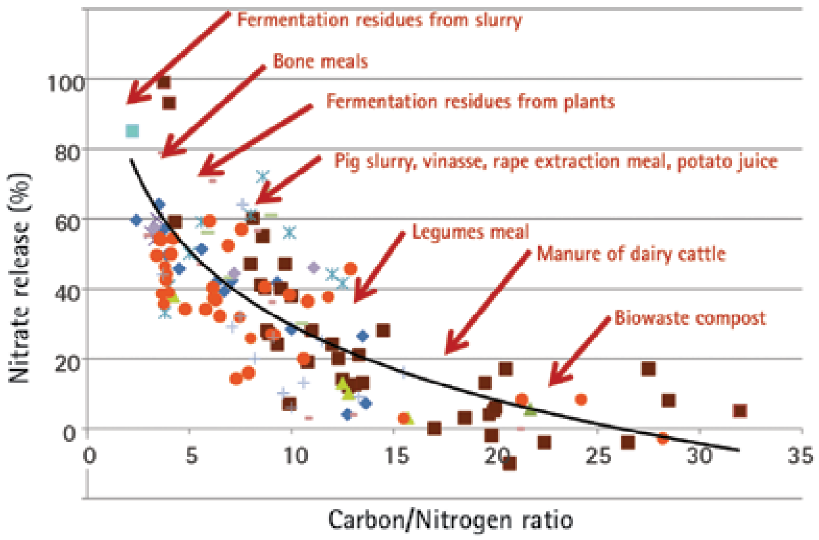
Source: WRI, 2005

The carbon content of agricultural land is declining worldwide[11], this applies to Europe as well[12]. Results from the CAPRESE pilot project and the German federal research institute for rural areas, forestry and fisheries (Thünen) show that previous estimates and measurements have overestimated the content of organic matter in European soils by 25 %[13].

Eleven research institutions participated in the SOILSERVICE-PROJECT, which investigated the effects of intensive agriculture on the soil ecosystem services throughout Europe. The results show that intensive agriculture primarily leads to a loss of biodiversity in the soil. Short rotations, intensive mineral and high-on-nitrate organic fertilisation and the use of large quantities of pesticides as well as the lack of organic matter lead to a decrease in biological diversity in the soil and to humus depletion. As a result, less carbon is stored in the soil[14]. Crop residue is often used for other purposes and is not available for returning carbon to the cycle. Short rotations don't deliver enough diversity and sufficient quantities of root substance to the soils. In comparison to manure or compost, organic fertilisers like slurry or digestates contribute little or nothing to humus building because they contain little carbon[15]. In intensive production their nitrate content, too, comes from external, emission causing sources (feed imports).

Too little carbon – in slurry, too.

Statistical relationship between the C/N ratio of organic fertilisers and N release over a year, as revealed by field, pot and incubation experiments for estimating nitrogen availability

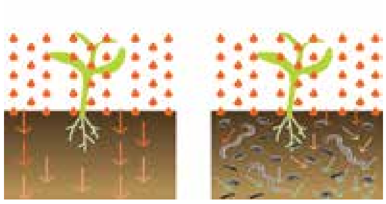


Source: Association for Technology and Structures in Agriculture (KTBL) expert discussion, 2014

Conventionally produced organic fertilisers are contaminated with medications which negatively affects soil organisms[16]. Slurry is a quickly convertible plant fertiliser. Because of the close C/N ratio (carbon content in relation to nitrate) there is a danger of rapid N-leaching and gas emissions (N_2O)[17].

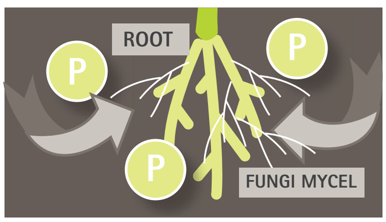
With the decline of soil life due to the lack of carbon feeding material soil organisms cease to contribute to the maintenance of soil functions like nutrient exchange, water filtration and water storage. Fungi based soil nutrition networks for example show significantly fewer nitrogen losses through leaching or nitrous oxide emissions than fungi deficient ones[18]. They can also store more carbon in the soil[19]. This shows how important an even balance of soil organism diversity is.

Mycorrhiza are of particular importance for the phosphor supply to crops because they can free phosphor from the bedrock and make it available to the plants. But, mineral fertiliser has a negative impact on mycorrhizal fungi[20]. If they cease to function – which is the case in most intensively managed soils, plants have to be supplied with energy intensive, externally produced, phosphor which again causes emissions. While introducing manure fertiliser into the cycle is beneficial for a balanced pest regulation[21], the external application of synthetic pesticides disturbs not just the soil life that keeps the pests in check but the humus building process, too[22]. In addition to that, beneficial insects are killed which destabilizes the ecosystem. As a result, more external pesticides are needed, their production and application, in turn, causes more greenhouse gas emissions and environmental damage.



With the decline of soil life, soil organisms cease to contribute to the maintenance of soil functions like nutrient exchange, water filtration and water storage.

Mycorrhizal fungi

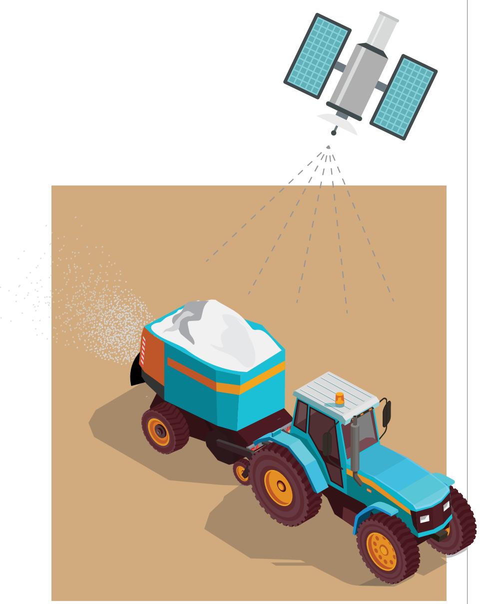


Mycorrhizal fungi are in close contact with the plant roots. They help the roots to better access nutrients, phosphate in particular. Mineral fertiliser damages them.

CLIMATE SMART AGRICULTURE AND PRECISION FARMING – PRECISELY MANAGED MALNUTRITION?

All in all, the currently most widespread farming systems suffer from a large oversupply of nitrate and an undersupply of carbon. This leads not just to humus depletion, but also enhances the generation of nitrous oxide (NO_2) and the leaching of nitrogen; apart from the climate effect, the result is a bad use of nutrients in general. The process of humus depletion leads to reduced soil life and soil compaction which in turn enhances nitrous oxide and methane emissions[23]. This is independent of the technique used to apply the nitrate fertiliser.

The so-called "Climate Smart Agriculture" (CAS[24]) mainly employs precision farming and no-till farming, (see below). In regard to climate protection the latter is actually counter-productive. Genetic engineering, too, is in some projects an unchallenged part of CSA. Agroforestry is mentioned, but overall the approach appears arbitrary. Apart from a lot of rhetoric on climate protection and sustainability, no proper definition can be found. The website features lots of images of small farmers from around the globe who, in all likelihood, are unable to afford direct seeding and precision agriculture practices.



If humus and phosphor content cannot be measured by default, what is the use of "precise", digitally controlled application techniques?

For example, precision agriculture works with colour recognition technology, leaf colour analysis is then used to optimise the application of nitrate fertilisers which can help limit the use of nitrate fertiliser and thereby the emission of greenhouse gasses, but this does not replace balanced plant nutrition. Leaf colour evaluation only gives indirect information and a rough estimate of whether the plant receives adequate nutrition; it's related – albeit indirectly – to nitrogen supply. To evaluate the resilience or health of a plant much more sophisticated measurements would be needed. What's more, on one hand such a "measurement" works only with a very homogenous plant community, whereas biodiversity within the system, like intercropping, flowers or hedges, are disruptive. On the other hand, even less or precisely applied nitrate fertiliser compromises the soils if they continue to lack organic carbon that feed soil organisms and build humus. If the mix of nutrients isn't right, plant and soil ecology suffer from malnutrition[25] even if the wrong mix is applied with more precision. It's "precise malnutrition". The negative effect within the system remains the same.

There is still no satisfactory way to calculate the humus content of soils, let alone measure its quality. The same is true for phosphorus, there are no measuring methods which could serve as the basis for the "precise" delivery: In Europe up to 16 different methods to measure the amount of phosphor in soils are being used. To this day, no chemical analysis exists that allows for the measurement of all plant accessible phosphor in the soil; therefore, organically managed soils are regularly considered to be phosphor deficient even though they are not. Organic bonded phosphor cannot be measured with the prevalent methods, yet it can amount to 25 to 65 % of available phosphor in the soil[26]. Thus, the question arises which data a "precise", satellite guided digital fertilisation system should use when establishing the humus or phosphor content...?

The same is true for many other soil factors. And time and again farmers face the problem of what to do with the rest of the slurry if application methods focusing on soil needs only use a "precise" fraction of it? If there is too much slurry it still has to go somewhere. Still, important open questions remain in regard to "smart farming" and "big data", not to mention network accessibility (for digitalization Germany ranks 11th among the 28 evaluated member states[27]) and ownership of farm data (who holds the rights and who eventually owns them?). It would serve us well to consequently apply and further develop known, climate friendly farming techniques (see chapter 4 and 5) before we continue with "precision techniques" on a whim. Unfortunately, in both research and practice this approach is rarely taken.

It would serve us well to consequently apply climate friendly farming techniques before we continue with "precision techniques".

GLOBAL ALLIANCE FOR CLIMATE-SMART AGRICULTURE

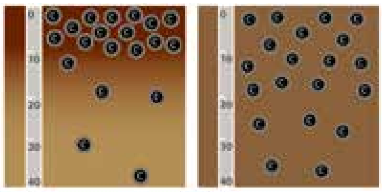
The "Global Alliance for Climate-Smart Agriculture", which counts more than 20 governments, 30 organisations, and companies like McDonald's and Kellogg as well as the world's largest fertiliser producers, Yara and Syngenta, among its members, mostly continues to bank on climate-damaging mineral fertiliser rather than on carbon storing methods like manure and compost applications, biodiversity, legume cultivation, agroforestry systems and building humus. It's not surprising, by promoting agroecological methods the members would harm their own business interest (fertiliser and pesticide sales at Yara and Syngenta). Agricultural systems with legumes are highly unattractive to fertiliser producers.

It was for a reason that Bread for the World and more than 300 other developmental and small farmers' organisations released a joint statement before the start of the 2015 Paris climate summit, warning explicitly of presenting "Climate Smart Agriculture" as a possible solution in the fight against climate change. The labels are geared towards industrial agricultural production and there are no proven criteria which farming practices, from an ecological standpoint, qualify as "climate smart" and which ones don't[28].

The policies implemented by many of the participating institutions and governments lead to land grabs through global investors and thereby undermine the development of more regional food sovereignty.
As Pat Mooney from ETC Group has put it: *"Climate smart agriculture has become the new slogan for the agricultural research establishment and the corporate sector to position themselves as the solution to the food and climate crisis. For the world's small farmers, there is nothing smart about this. It is just another way to push corporate controlled technologies into their fields and rob them of their land."*[29]

This goes nicely with the stance of the president of the „Agriculture and Turf-Division" at John Deere (one of the big players in the agricultural machinery and precision farming sector and at present starting to enter into data gathering and analysis) who describes agriculture as: "A farm is a factory in a remote area". [30]

Conclusion: The name „Global Alliance for Climate-Smart Agriculture" should be seen as false labelling.



Carbon distribution in profile for unploughed (left) and ploughed (right) soil.

CLIMATE SMART AGRICULTURE AND PRECISION FARMING

Contrary to frequent claims, no-till management (also called conservation agriculture) does not lead to a major humus increase. This was demonstrated through the meta-analysis of 69 global comparisons[31]. The German Thünen-Institute and a trial in the German federal state of Baden-Württemberg assessing the climate impact of farming practices come to the same conclusion:

"In regard to reduced tillage and under Central European conditions a shift of humus between soil horizons could be observed, but no additional carbon sequestration." [33]

Studies that found carbon sequestration measured only at a depth of 15cm or less, but no deeper. Nevertheless, many recommendations for climate protection measures by the FAO, at EU level and through agro-environmental programmes of member states (in Germany that includes some of the federal states) still are wrongly based on the assumption that carbon is being sequestered. That's simply wrong. The carbon remains in the top soil and is not shifted downward. No-till saves fuel but on the other hand increases the danger of higher nitrous oxide emissions because without tillage the soils show more compaction. This enhances nitrous oxide emissions[34]. Apart from that yields often drop by 10 % while weed and pest pressure rise[35].

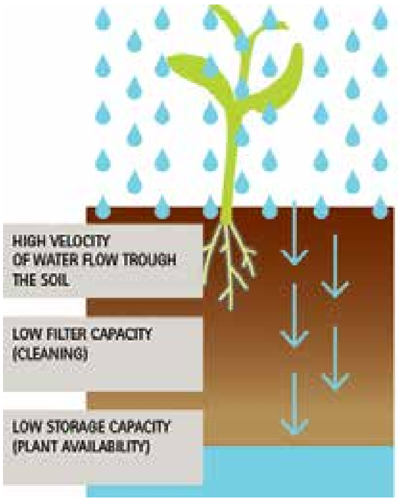
„In our opinion, switching to conservation agriculture or no-tillage at present cannot be recommended as a scientifically proven, efficient climate protection measure in agriculture", the Thünen-Institute concluded already in 2014

Because of the resulting high weed pressure, no till farming simultaneously sees an increase in the application of the broad-spectrum herbicide glyphosate. Without it, no till farming in conventional agriculture proves to be impossible. As glyphosate (Round-Up) and its metabolites have a negative impact on earth worms and other soil organisms[36], the claim that it is a means of "soil conservation" has to be seen as a dubious claim. Nevertheless, the statement that this technique promotes soil conservation, is frequently made, though at closer inspection it simply isn't true.

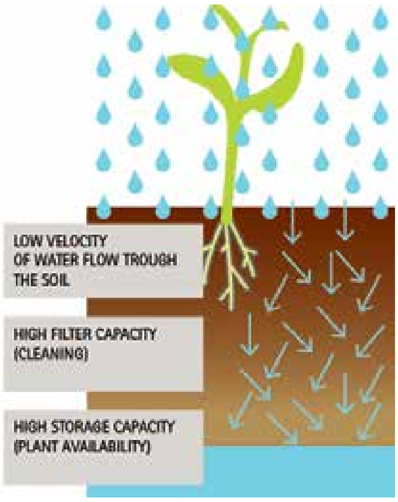
With no-till after the harvest a certain amount of plant residue remains at the surface. As such it does protect from rain erosion, but cover crops and undersowing do a much better job and avoid compaction.

After the harvest a certain amount of plant residue remains. If this plant residue is not incorporated into soil through tillage it stays on the surface. As such it does protect from rain erosion, but cover crops and undersowing do a much better job because soil organisms are being fed and humus is built at the same time. Stable soil aggregates that don't dissolve in water can form. Soil organisms and soil biology create a "sponge structure" and that is a much better protection from erosion than a bit of plant residue on the surface.

Soil structure without ploughing



Healthy soil structure



With short rotations no-till results in a compacted soil structure. Because of the large number of earthworms, the soil will be interspersed with worm tunnels, but the vertical tunnels hold the risk of unfiltered percolation water getting into the ground water fast. The compacted soil has few medium sized pores, percolation water runs through big earthworm pores and therefore will not be filtered. And because it cannot be held in the soil it's not available during a later drought period. Water retention is only possible in biogenic soil where microorganisms create the necessary 'spongy' structure with lots of medium sized pores. In regard to climate change such a compacted soil structure is a definite disadvantage for both, the resilience of the system and yield security. (also see chapter adaptation to climate change)[37].

Water retention is only possible in biogenic soil where microorganisms create the necessary 'spongy' structure. It needs biodiversity in the field and carbon rich fertiliser.

NO-TILL ONLY WORKS IN ORGANIC FARMING

If at all, no-till only makes sense in a biodiverse agroecological system – like organic agriculture – where a host of different roots from mixed crops build pores and thus protect against soil compaction. In such a system additional carbon is fixed in the soil, but it happens because of the diversity within the ecosystem and organic fertilisation, not because of no-till. The diverse root penetration prevents compaction and there is considerably less nitrous oxide emission.

No-till maize with clover underseeding

Photo: Beste

MYTH: WE NEED THE NEW GENETIC ENGINEERING TECHNIQUES TO CREATE DROUGHT RESISTANT VARIETIES

Currently there are renewed calls: We need the new genetic engineering techniques (CRISPR/CAS et al) so that we can finally breed drought or salt resistant plants. Generally, it's not about drought or salt resistance which one could *find* rather than *breed*. Generally, it's about creating new (plant) products, patents and profits.

The "Water Efficient Maize for Africa" (WEMA) project which is supported by the Gates Foundation and by Monsanto is the poster child of climate smart agriculture (see above). Drought resistant seed varieties are supposed to help small farmers to adapt to climate change. Predominantly hybrid maize and genetically engineered varieties are being promoted. Farmers cannot reseed but have to buy new seed every year which is expensive. What's more, high yielding seed varieties need a lot of agrochemicals, anything else wouldn't be a good business model for the industry. An analysis by the „African Centre for Biodiversity" concludes that the new varieties provide little additional benefit and instead warns about the existential threats to farmers' livelihoods: indebtedness, loss of traditional seed varieties and the rising influence of multinational agrobusinesses on the African seed market[37a].

Already in 2010, the German NGO "Welthungerhilfe" concluded: *„To this day there is no proof that genetic engineering in agriculture leads to a sustainable increase of income among small farmers, nor does it contribute to the fight against hunger."*[37b]

Some believe that things will be different with the "new genetic engineering techniques", but the false premise remains the same: Manipulating isolated genes in the plant DNA does not anchor the new traits as well as traditional breeding would. With traditional breeding the plant's genetic material reacts to the new combination and whether to firmly anchor the new traits in a polygenetic way. These changes will always be more stable at the end. Moreover that seed from heterogenous open pollinated varieties has a broader genetic base than the high yielding varieties that are currently being used, in the field such plants show a bigger variance. Therein lies a huge potential to better cope with changing environmental conditions and environmental stresses like plant diseases, pests and extreme weather conditions. Finding wild or heritage varieties can lead to success even without breeding: The MASIPAK network collected more than 2000 rice varieties and found 12 to withstand flooding for several days, 18 to be drought resistant, 20 salt tolerant and 24 resistant to certain local pests [37c].

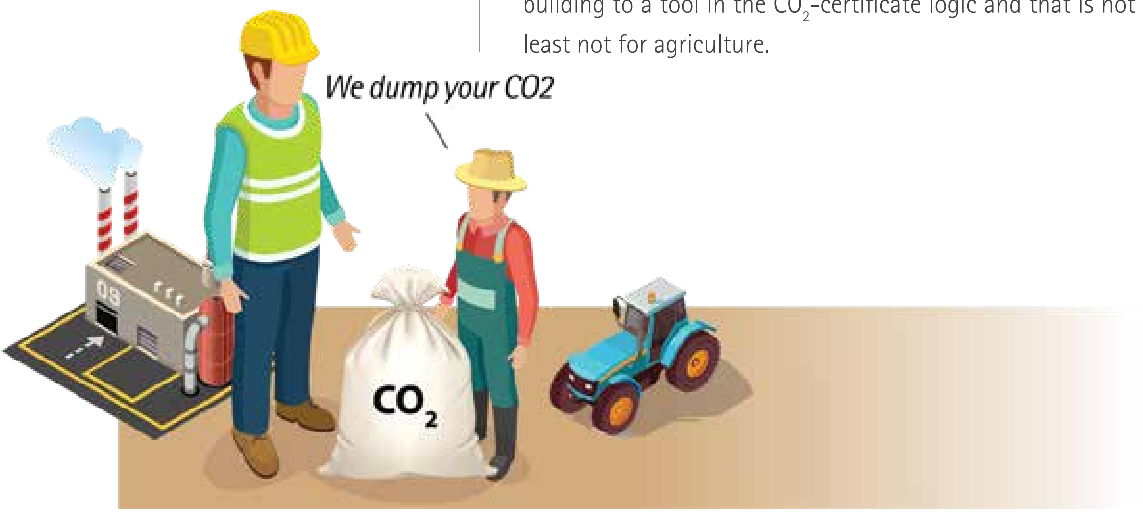
It would be far more efficient to look for existing drought or salt tolerant varieties than releasing new constructs into the environment which need costly risk monitoring procedures (rightly deemed necessary by the European Court of Justice (ECJ)) [37d].

"To this day there is no proof that genetic engineering in agriculture leads to a sustainable increase of income among small farmers, nor does it contribute to the fight against hunger"

German NGO "Welthungerhilfe", 2010

3. THE 4-PERMILLE INITIATIVE FOR HUMUS BUILDING

During the 2015 UN climate conference in Paris, France initiated a global programme for humus building. The "4-Permille Initiative" aims at an annual increase of carbon storage in soils by 4 permille. The assumption is that anthropogenic CO_2 emissions could be offset almost completely. No one will object to building humus in the world's soils. With very few exceptions, and if done correctly, it will have a positive effect on soil structure and substance exchange. However, it is highly questionable to justify the necessity for more humus in soils by arguing that other industrial sectors should be exempted from doing their homework and reduce CO_2 emissions. This line of argument reduces humus building to a tool in the CO_2-certificate logic and that is not an expedient argument, at least not for agriculture.



It does not do justice to the huge relevance building humus has for the maintenance of soil fertility and global food security. With such a narrow focus there is a danger that for soils, too, methods of carbon dumping that are harmful or of little benefit will be practiced just because they are financially rewarding.

With a narrow focus on carbon sequestration there is a danger that methods of carbon dumping with an adverse effect on soils will be practiced just because they are financially rewarding.

The positive effect of carbon in the soil is highly dependent on how and in what form carbon is added. Not every organic fertiliser is beneficial to soil organisms (slurry and large amounts of fresh, green organic matter do not enhance soil life). And not every carbon "fertiliser" was produced in an energy efficient way and without harmful substances. Techniques aimed at sequestering carbon in the soil long-term while safeguarding against decay – see biochar – negate the fact that, at least in temperate climate zones, it's the soil life which produces good soil, healthy plant food and bio pores for water retention and filtration. The fact that soil organisms decompose and change soil carbon is part of the system and has to be seen as a positive rather than a negative factor in the flux balance. So-called biochar does not contain nutrients for soil organisms and should not be introduced into the soil in large quantities. Chemical stabilisers that prevent or slow down the decomposition of carbon and with that the metabolism in the soil aren't recommendable either. They interfere with the soil ecology in multiple ways and should therefore be rejected. The same goes for artificial inhibitors in nitrate fertilisers if nitrate is present in a good, organically bonded C/N ratio they are not needed.

BIOCHAR – NEITHER SUITABLE FOR CLIMATE PROTECTION NOR FOR HUMUS BUILDING

Up to now soil enhancing qualities of biochar are not confirmed. One assertion is that coal particles have a very large surface and can therefore bond particularly well with humus, nutrients and water. This is certainly true and the reason why the yield enhancing effect can be observed particularly well in sandy soils where otherwise little water retention and nutrient exchange takes place[38].

However, it is still an open question whether the production and incorporation of biochar into the soil really yields extraordinary results in regard to humus building; in particular if the energy efficiency is taken into account and in comparison to agricultural practices that have been tried and tested over centuries and further optimised in organic agriculture – such as balanced crop rotation with diverse and deep root systems, permaculture, agroforestry, returning organic matter through solid manure, crop residue and compost[39]. According to the German Thünen-Institute the effect of biochar cannot yet be properly estimated. Because of the complex production procedure and the low volumes that can be incorporated, the climate benefit is regarded as questionable[40].

In the end, the purpose cannot be to turn soils into carbon storage facilities by getting in as much dead carbon as possible. Building humus must happen within an overall healthy ecosystem and primarily to build soil life and achieve long-term sustainable yields. Assuming that the biochar is produced contaminant free, it can help regeneration or kick-start the process in some cases – similar to other soil additives (like effective microorganisms or compost tea). Achieving climate protection by continuously incorporating considerable amounts of biochar into soils seems neither feasible – the raw materials are very limited – nor does it make sense for the soil life because biochar does not feed the soil life[41].

BIOENERGY DOES NOT AID CLIMATE PROTECTION

Over the past 20 years, the increase in acres of "flex crops", crops that can be used as food, as feed and for energy production (corn, palm oil, sugar cane), has led to a considerable change in land use patterns. Forests in Asia and parts of the Cerrado in South America were converted into agricultural land to plant oil palms, eucalyptus, soy or sugar cane[42] which cause enormous greenhouse gas emissions. In Europe and Germany in particular a lot of permanent grassland was ploughed up to grow corn for biogas or oilseed rape for biofuel[43]. In the EU27 four million ha of permanent grassland were ploughed up over the past 20 years.

Assuming that biochar is produced contaminant free, it can help regeneration or kick-start soil remediation. Not more.

„There are uncertainties inherent in estimating the magnitude of indirect land use emissions from biofuels, but a policy that implicitly or explicitly assigns a value of zero is clearly not supported by the science“,

write 168 international scientists.

Rain forests are cut down for agro-fuel.

In Germany permanent grassland areas shrunk by 875,000 ha between 1990 and 2009. Size wise that's about half the German state of Thuringia[44]. In 2000, fuel crops were planted on 2.5 % of agricultural land, by 2017 it was 20 %, equivalent to the land used for food production (feed: 60 %).

Sizable reductions in greenhouse gas emissions per unit of energy are only achieved through the use of farm manure and residual materials for agrogas and only in combination with the use of waste heat (!). To grow biomass for the production of agro-gas or agro-fuel is not climate friendly at all[45].

In its current climate strategy 2.0, the German farmers' association (Deutscher Bauernverband) still advocates the use of "bio energy" and "bio fuel" because of its presumed climate protection effect. But already in 2011, in a letter to the EU, 168 international scientists cautioned against "bio fuel".

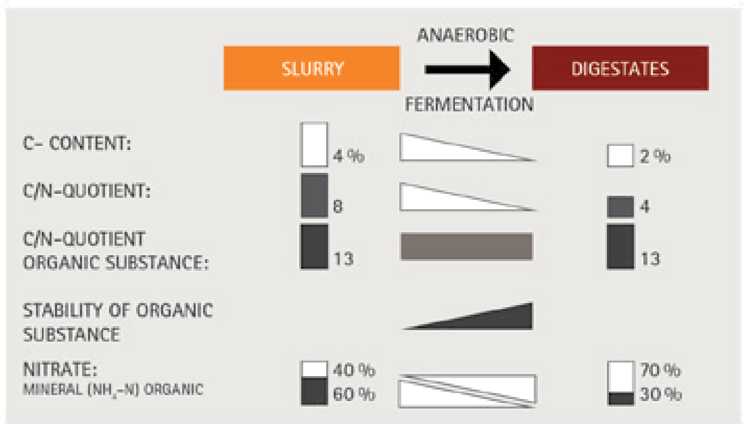
„There are uncertainties inherent in estimating the magnitude of indirect land use emissions from biofuels, but a policy that implicitly or explicitly assigns a value of zero is clearly not supported by the science“, so the scientists[46]. For agro-energy tropical rainforests would need to be cut down which would cause food prices to rise and thereby exacerbate hunger worldwide. In 2011 the United Nations (UN) added its voice in support. Since then ten international organisations recommend that the governments of the G-20 nations end "bio fuel" subsidies.

The governments of the G-20 nations should *„remove provisions of current national policies that subsidize (or mandate) biofuels production or consumption"*, write the authors. Among them are the World Food Program (WFP), the Food and Agriculture Organization of the United Nations, FAO, the World Bank, the Organisation for Economic Co-operation and Development (OECD) as well as six other international institutions[47].

In 2013, Leopoldina, the German national academy of sciences, too, advocated against the use of "bio energy", one of the reasons being its energy intensive production[48]. In addition, a 2014 study found that plant-based bio energy use, in particular that of maize, has the highest CO_2 prevention costs[49].

What is totally overseen: for many years now, shorter rotations and the substitution of cover crops that have a high humus building potential with humus consuming energy crops have led to humus depletion which is counterproductive to soils[50]. Decades long, expensive research projects for more diversity in energy crop production do not change that because the gas yield per hectare from maize is still unsurpassed. But during the production of agro-gas additional carbon is removed from the cycle ("bio gas" = CH_4), it is not returned via the C-reduced digestates and that causes additional humus depletion[51].

N and C content in slurry and digestates



Source: Gutser/Ebertseder, 2006

Today, in the overall tally, the use of agro-fuel or the fermentation of cultivated biomass tends to be seen as climate-damaging[52]. On the whole, in regard to efficiency the use of plants for energy production falls way short compared to solar cells: solar cells use sunlight up to ten times more efficiently than plants[53].

On the whole, in regard to efficiency the use of plants for energy production falls way short compared to solar cells: solar cells use sunlight up to ten times more efficiently than plants.

In comparison, growing small woodlands on fallow agricultural land or introducing trees and shrubs on permanent grassland can increase carbon sequestration. But as in arable farming, here too, the key is the duration. It may hold true for permanent woodlands. Short-rotation coppice and wood for energy sequester carbon short term but do not function as carbon stores. They are neither suited for CO_2 storage nor for long-term humus enrichment and they do not contribute to biodiversity. Almost all short-rotation coppices are vulnerable monocultures which need high pesticide inputs during the first few years. Diverse agroforestry systems (see chapter 5) are markedly different.

4. CLIMATE PROTECTION AND CLIMATE ADAPTATION GO TOGETHER

Year on year agriculture has to adapt to weather and climate. Farming has always been "risk management". The current challenges through climate change aren't totally new. But, compared to the past, the dimension and speed of the changes will increase, as will the unpredictability. The past few years, and in particular the summer of 2018, have already demonstrated that. To cope with these challenges, farming practices need to make our farming ecosystems more resilient[54]. From the bottom up. Technical or digital part fixes won't be much help.

RESILIENCE is the "the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks".

Source: Walker et al., 2004

Maize 2018

Photo: Beste

The introduction of insurance schemes negates that the existing agricultural systems have contributed in a major way to the adverse circumstances and the vulnerability of the system.

INSURANCE DOES NOT MAKE VULNERABLE SYSTEMS SAFER

In the course of climate change farmers increasingly face risks through extreme weather events which, in addition, often lead to plants being more vulnerable to disease. At present political policies focus on so-called risk management schemes as a solution. The emphasis is on financial safeguards through some type of insurance rather than adapting agricultural systems through agro-ecological measures which could minimise risks. The introduction of insurance schemes, compensation payments and relief funds negate that the existing agricultural systems have contributed in a major way to the adverse circumstances and the vulnerability of the system by causing climate effects and by disturbing soil functions. To create more security, these root causes should be addressed first.

Introducing farming practices known to minimise risk would be economically more efficient and likely to be more successful in the long run. To buy risk insurance only makes sense once there is nothing else one can do to minimise the risks inherent to the system. But starting out with insurance without having implemented risk managing practices is a waste of money. Yet, in the chapter on instruments for risk management in the EU Commission's current proposal on the EU agricultural policy there is nothing to be found on risk reducing farming practices. Though, in order to safeguard farms against the extreme effects of climate change, it obviously would make sense to create a fully funded, special "risk reduction and adaptation to climate change" programme and start by directly supporting education and training efforts for the use of known farming practices and by financing more research into how resilience can be enhanced. The proposal contains nothing of that sort and calls for such projects are rare.

Climate adaptation education and training

Photo: Beste

LEGUMES AND THE RIGHT WAY TO FERTILISE: SAVING GREENHOUSE GAS EMISSIONS AND HUMUS BUILDING

LEGUMES – PROTEIN CROPS – PULSES

The legume family is a very diverse plant family which includes peas, field beans, alfalfa, lentils, chickpeas, clover, lupine, vetch and soybeans.

Legumes are special because unlike other plant species they can actively absorb atmospheric nitrogen and convert it into nutritionally beneficial essential amino acids. That's why they play an important role in the diet of both, humans and animals. In a rotation, grain legumes are advantageous, too. They maintain soil productivity, enhance the supply of nitrogen and augment the quality of the rotation. In agriculture they are also used as cover crops to enhance soil quality. This is especially true for organic agriculture.

Both, as main and as cover crops, legumes have a very positive effect on the agricultural ecosystem. They contribute to a positive climate footprint in agriculture and, because they reduce the need for mineral fertiliser, energy and pesticides, they also help to lower production costs.[54a]


clover


lupine


field bean


alfalfa


lentils

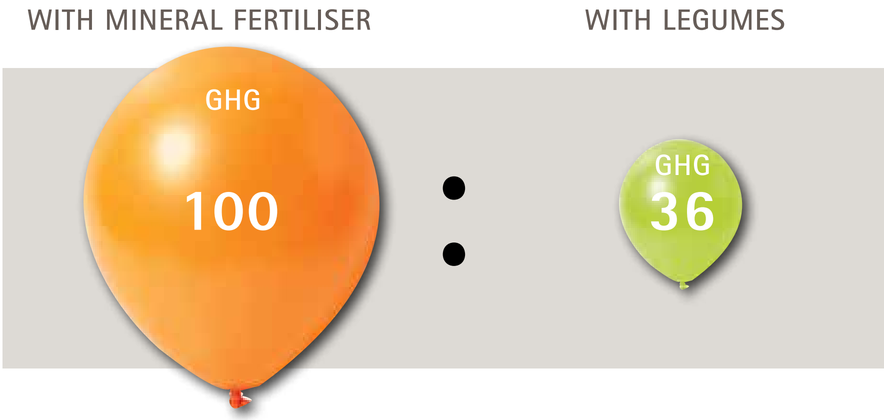

chickpeas


vetch


peas

The production of mineral fertiliser is very energy intensive. In industrial agricultural systems it accounts for 50 % of the energy use per hectare. If fertiliser input is avoided the gross energy use of the agricultural system decreases and the CO_2 balance improves. Through its ability to fix atmospheric nitrogen in the soil, a field bean yield of four tons per hectare supplies the equivalent of 180 kg mineral nitrogen. This equals an energy saving of 180 l of fuel or 480 kg CO_2 emissions, which would have been needed to produce this amount of mineral fertiliser[55]. What's more, the legume roots help to improve the soil structure (weed suppression and soil loosening decrease the need for ploughing) and save fuel through reduced tillage which translates into additional energy savings and fewer CO_2 emissions. Mineral fertiliser causes nitrous oxide emissions, (see above), they, too, can be greatly reduced.

Sample calculation: The total greenhouse gas potential (carbon dioxide, nitrous oxide and methane emissions) in a legume-based rotation versus a rotation based on mineral fertiliser shows a ratio of 36 to 100[56].



Organic, carbon rich fertilisation and diverse rotations result in humus building (nutritive and stable humus), it absorbs CO_2 from the atmosphere and reduces nitrous oxide emissions. Slurry and digestates are unsuitable (see above), because of their close carbon-nitrogen ratio (C/N) they provide the soil life with few nutrients. Systems with carbon rich fertilisers do not need nitrogen inhibitors (which slow down the N availability in the soil) because organically bound nitrogen is released at a slower rate anyway.

MARKET IDEOLOUGES PREVENT CHANCE FOR MORE CLIMATE ADAPTATION IN GERMANY

The increased use of legumes in a rotation reduces the need for nitrate fertiliser significantly. This not only decreases greenhouse gas emissions during fertiliser production and application, but it also lowers the farmers' overall production costs. A rotation that includes legumes saves fuel for tillage, the root penetration loosens the soil organically while humus content and soil moisture are better preserved. Less tillage is needed.

A 2009 study by the French General Commission for sustainable development estimated that the use of legumes could reduce fertiliser applications in France by as much as 215,628 tons, a saving of up to 100 million Euro annually[57]. France has subsidised legume cultivation for many years, in particular since the 2013 reform of the Common Agricultural Policy (CAP) explicitly permits it with a national agricultural budget of 2 %[58].

Since 2012 Germany has a protein plant cropping strategy (protein plants = legumes) which was expected to help reduce the protein deficiency in feed production within the European Union. But for reasons of market ideology (supposed market distortion through coupled payments) Germany unfortunately passed on the opportunity to use the coupled payments of up to 2 % of the national CAP budget which the EU explicitly allows[59]. Additionally, it would have been a big contribution to humus building and climate adaptation in agriculture and to flood protection. That's what the markets forces won't deliver.

TORRENTIAL RAIN AND FLOODS – DROUGHT AND WATER SHORTAGES

Sufficient soil moisture is a deciding parameter for plant growth. In critical developmental phases, both under- and oversupply can have a negative impact on agricultural crop yields. Over the last 40 years, soil moisture levels during the growing season have significantly declined, on both light and heavy soils[60].

A study of extreme weather conditions and their impact on agriculture shows the increasing danger of erosion and flooding in the coming years. The flooding of cropland causes an estimated damage of between 200 and 1000 Euro on average[61]. In the 27 EU nations the costs of flooding amount to 4.4 billion Euro annually. Every year around 250,000 people are impacted by flooding events[62]. Because of climate change, weather events like the 2018 torrential rains and drought are expected to become more frequent. Depleted, compacted soils are much less likely to mitigate such extremes than are healthy soils with good soil structure. That's why we need soils that are well supplied with carbon and rich in humus.

Organically farmed soils can on average absorb and retain twice as much water as conventionally manged soils. That's the conclusion drawn by the commission for soil protection at the German Federal Environmental Agency and the result of other studies[63].

Compared to conventional methods, ecological agricultural practices lead to significantly higher carbon storage. An international team of scientists measured on average 3.5 tons more carbon per hectare in organically farmed soils than in conventionally managed soils[64]. Living soil with good tilth can hold up to four times its weight in water. If we want to take active and preventive action against the consequences of climate change we need adapted soil management practices to increase water infiltration and storage potential[65].

In 2015, the implementation of the European Flood Risk Management Directive[66] necessitated the flood risk management plans to be newly defined (in Germany this has to be done individually by the federal states). Apart from other flood protection measures the guidelines did propose that farms in flood-prone areas should comply with management requirements. Instead of focussing on good soil structure on arable land, the idea of converting arable land into permanent grassland gained some traction which can make sense under certain circumstances (wetlands). (See chapters by Anita Idel). Common Agricultural Policy cross compliance rules stipulate however that the eligibility for direct payments is conditional on maintaining "the agricultural land in Good Agricultural and Environmental Conditions" (GAEC)[67]. Not only is the maintenance of such conditions rarely verified, in regard to soil protection the regulatory terms remain very vague. Not even humus balancing rotations are mandatory. Even for the so-called "greening" humus balancing measures are not obligatory. Up to now, none of the relevant flood prevention strategies discuss the manifold agricultural soil building practices as part of the solution. As early as 2014, Thomas Strassburger from the European Commission's Directorate-General for Agriculture and Rural Development wrote a pointed criticism. Soil protection is water protection, too, he stated[68].

Organically farmed soils can on average absorb and retain twice as much water as conventionally manged soils.

Depleted, compacted soils are much less likely to mitigate such extreme rainfalls than are heathy soils with good soil structure. That's why we need soils that are well supplied with carbon and rich in humus.

Good tilth with rich soil life, organic

Photo: Beste

So far, most relevant flood prevention strategies ignore soil compaction in agricultural land as a major source of flooding.

And hardly any publication dealing with climate change, neither on national nor on a European level, puts a serious focus on the connection between soil compaction and flooding.

Using equipment that is too heavy at a particularly sensitive time is a major problem, though not, as often claimed[69], the predominant one. Over the past few years, agricultural engineering and its potential for optimisation (limitation of wheel load, reduction of contact surface pressure with wide-base tyres, different tilling options) have dominated debates and research on soil protection in agriculture.

Yet, as soil research progresses, it becomes ever clearer that the supply of organic material and biodiversity in the agricultural ecosystem (including soil) through balanced rotations and the use of cover crops, have a much higher potential to promote a healthy soil structure. Time and again systemic solutions are superior to technical fixes[70]. The use of intensive mineral fertilisers and monocultures favour the creeping microstructural compaction of many soils (see above), this needs to be rectified[71]. This creeping compaction is examined only in the rarest of cases and therefore regularly overlooked. Over the past 18 years the author has examined the soil structure – macro and micro structure – at over 400 locations in Europe, mainly in Germany. The tests were undertaken at the behest of food companies, universities and chambers of agriculture or within the framework of advanced soil protection training courses for farmers[72]. On most conventionally managed agricultural land the degree of compaction is huge (see left picture below).

Because this type of analysis is very laborious there are no Europe or nationwide data available. But the negative effect of intensive farming practices on soil life is well known. As most agricultural land is managed in this way it is reasonable to assume a creeping compaction even without direct structural analysis (see above). To date, all relevant flood prevention strategies negate the necessity and the agro-ecological possibilities of actively building soil structure.

At an event in Brussels at the beginning of 2018, the EU-Commission's top most soil protector, Dr. Luca Montanarella, summarised the results of the European soil observation system LUCAS as follows: agricultural soils increasingly show symptoms of humus depletion, erosion and compaction[73,74].

Soil structure with impoverished soil life, conventional. Both loamy soil, Finnland

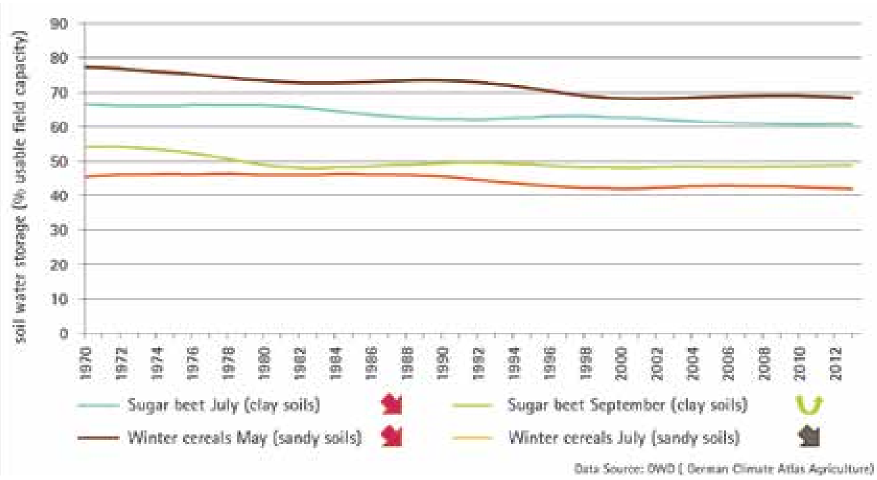
Photo: Beste

The soil in a land area no longer holds the water. The water retention capacity decreases. Four important soil functions are disrupted: water infiltration (erosion and flood prevention), storage capacity (climate adaptation, yield protection) water filtration and groundwater renewal. In particular in spring the following can be seen on level ground: standing water on more and more agricultural land which remains there for longer. Drought periods on the other hand, cause massive yield losses because there was standing water in the field that couldn't be stored in the soil.

Four important soil functions are disrupted: water infiltration, storage capacity, water filtration and groundwater renewal.

In August of 2003, the high-pressure system „Michaela" caused one of the worst natural disasters in Europe in the past 100 years. In 2013 yield losses amounted to 138 million Euro, in 2018 the German farmers' association demanded 1 billion Euro in aid because of persistent drought conditions[75]. In Germany, data taken between 1970 and 2013 show, that soil moisture levels under different crops decrease continuously.

Soil water storage in agricultural land



Sufficient soil moisture is a deciding parameter for plant growth. In critical developmental phases, both under- and oversupply can have a negative impact on agricultural crop yields. Over the last 40 years, soil moisture levels during the growing season have significantly declined, on both light and heavy soils.

Source: German Federal Environmental Agency

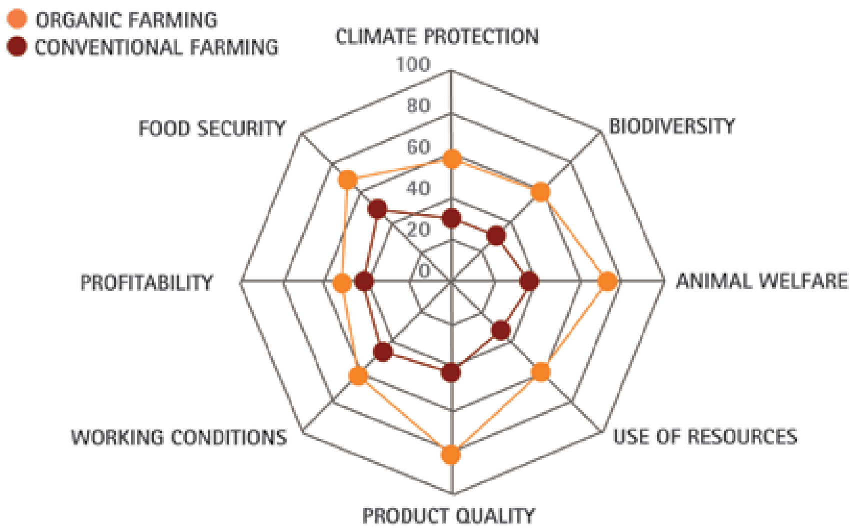
Soils with surface water run-off or coarsely porous soils with no biogen medium sized pores where water seeps into the groundwater fast offer no protection against weather extremes.

The German meteorological service's analysis of data from 1961 to 2013 as well as the trends from 21 climate models running until 2100 show an increase in extremely hot days which will likely occur more frequently, too. And, in the past 20 years the days without precipitation in March and April increased, as did the number of extremely dry days in summer. In future, the latter are expected to occur multiple times[76]. Figures from Bavaria show that the available field capacity, that is the moisture available to plants, was 71 % compared to the reference period (reference period for climate data); in some places only 63 % were recorded[77]. Soils with surface water run-off, or coarsely porous soils in which no medium sized biogen pores could develop and water seeps into the groundwater fast, (see above) offer no protection against such weather extremes. With such soils extreme weather events become an existential threat to some farmers. It is possible to insure against that. But soils can also be made fit and resilient which can even boost soil fertility and yield potential.

5. STABLE ECOSYSTEMS WITH HIGH PLANT DENSITY AND DIVERSITY: CLIMATE PROTECTORS AND FIT FOR CLIMATE CHANGE

In the long run, agriculture only shows a positive CO_2 and thereby climate foot print if additional permanent humus (so-called stable humus) is built. Based on what we know today, only organic farming is able to achieve this on a significant scale. Permaculture, agroforestry and silvopastoral systems where trees and/or permanent grassland are included, have an even greater impact[78]. What's more, they also increase the nutrient availability and the water storage potential. Even without techniques like permaculture and agroforestry which aren't widespread in Central Europe as yet, organic agriculture shows a very good ecological balance (see fig.). That's why it should be the basic principle for climate friendly farming[79].

To maintain the humus balance, the appropriate organic substances have to be supplied on a continuous basis. They serve as food for soil organisms and form stable humus colloids.



Source: Schader et al., 2012

PERMACULTURE

Permaculture cultivation practices are much older than the term: it was coined in the 1970s by the Australian Bill Mollison and means: permanent, sustainable agriculture: *„Permaculture" (permanent agriculture) is the conscious design and maintenance of economical, agriculturally productive ecosystems that have the diversity, stability, and resilience of natural ecosystems"*, Mollison 1990.

Bill Mollison developed the original permaculture concept in Australia together with David Holmgren. In 1981 he was honoured with the Right Livelihood Award. Today one would say in regard to climate change and other disrupting influences: it is a system that promotes high resilience under changeable external influences and extreme weather events in particular. It's farming with nature, based on natural cycles and ecosystems. Elements of this type of farming can be found in rice paddies in Asia or terraced systems developed by Berber tribes in Morocco or in traditional cropping systems in Brazil. Farmers there have worked with such methods for millenia[80]. The focus is not just on individual elements of the agricultural systems, but on their relationship to each other and how they can be optimally used to build highly productive cropping systems.

Example in grain cultivation: undersowing clover, radishes, salad and medicinal herbs once the cereal crop has flowered ensure a (feed) crop after the cereal harvest.

Example in mixed cropping: a mixture of corn, sunflowers and hemp are grown together with peas or beans. The tall plants provide support for the legumes and they, in turn, supply nitrogen.

The efficiency of a permaculture system cannot be measured by adding up the yield of each of its components. What can be measured are the overall production of proteins and carbohydrates, or even more accurately, the total biomass production per acre. When that's the benchmark, this cropping system, like the layers in the sustainable use of rainforests, is far superior to the cropping systems we currently employ in Central Europe[81]. Such cropping techniques not only provide opportunities for climate protection, but for climate adaptation, too – based on three components: humus building, regulation of the water cycle and promoting resilience in the whole agro-ecosystem[82].

In Germany and across Europe many institutions and universities offer education and training in permaculture techniques, including within the framework of the agricultural "European Innovation Partnership" (EIP-Agri)[83].

AGROFORESTRY SYSTEMS

In agroforestry systems perennial plants like trees or shrubs are specifically combined with cropping systems and/or livestock (agrosilvopastural). The result is a profitable ecological and economic interaction. It ranges from orchards with grazing to rows of trees in fields or forest gardens with interspersed trees and shrubs. Current research shows that agroforestry systems can be profitable and add to the sustainable production of food and raw materials, thus benefitting agriculture and environment.Until the 19th century

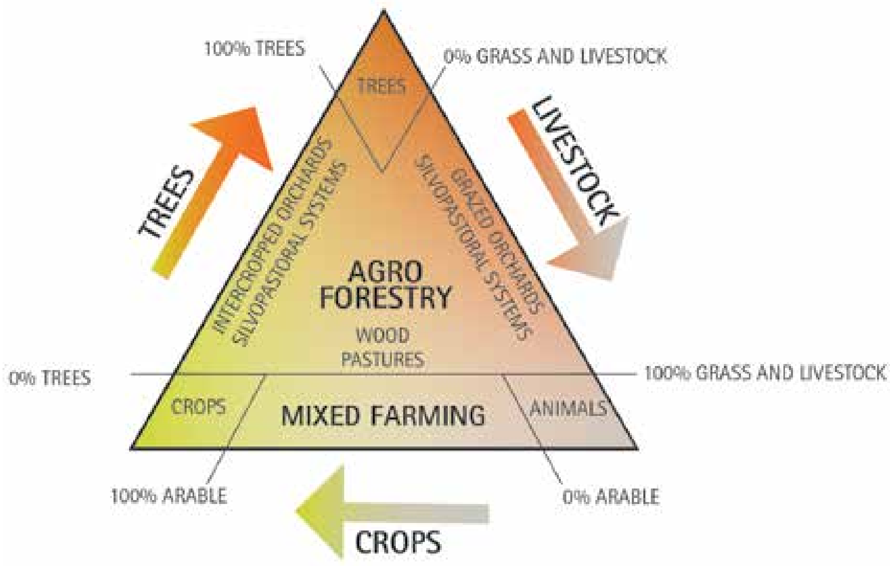
Permaculture in Brazil

Photo: Beste

In Germany and across Europe many institutions and universities offer education and training in permaculture techniques, including within the framework of the agricultural "European Innovation Partnership" (EIP-Agri).

Iberian pigs which are often kept semi-wild in cork and stone oak forests are still raised on a diet of acorns.

it was common in Germany to give pigs access to forests. Apart from general forest use, acorns, beechnut and chestnuts thus provided rich food sources. Iberian pigs which are often kept semi-wild in cork and stone oak forests are still raised on a diet of acorns. Only the meat of these animals can be used for Iberian acorn ham (Jamon Iberico de Bellota). Other examples for existing forms of forest pastures in Europe involving pigs are banded pigs in central Italy and pasturing woolly pigs in the Croatian Save wetlands[84].



Source: From Burgess' et al. lecture

THE DECLINE OF TRADITIONAL AGROFORESTRY SYSTEMS

With the introduction of chemical fertilisers in the 19th century, it was assumed that mineral fertilisers would bring more fertility. However, this increased yield was at the expense of natural soil fertility.

During the Middle Ages crop rotations were introduced and the dependency of maintaining soil fertility in arable land through nutrient transfers from forests and coppices ostensibly declined. With the introduction of chemical fertilisers in the 19th century, it was assumed that mineral fertilisers would bring more fertility. However, this increased yield was at the expense of natural soil fertility.

From the 19th century onwards agriculture and forest use were systematically separated and with varying policies for agricultural subsidies playing out during the second half of the 20th century, agroforestry systems became even less significant[85].

Moreover, in the course of agricultural intensification and mechanisation as well as farmland consolidation many woodlands had to go[86]. As a consequence, traditional agroforestry systems in Central and Northern Europe have all but disappeared. Climatic and economic conditions in Southern Europe made agroforestry systems more viable for longer, but they are in radical decline there now, too.

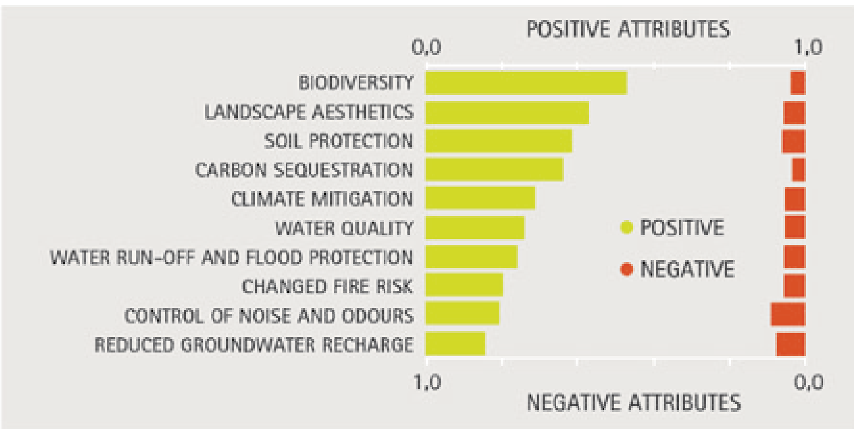
ADVANTAGES OF MODERN AGROFORESTRY SYSTEMS

Agroforestry systems (AFS) produce more photosynthesis and therefore potentially more biomass per unit of land. According to the agricultural research institute AGROSCOPE in Switzerland, under conditions typical for Central Europe, the figure for agroforestry systems is 10-30 % higher per unit of land than in conventional copping systems[88]. The production of food and protein rich feed are combined. Agrosilvopastoral systems also allow for grazing. This mitigates workload peaks and the diversified production ensures yield security. Humus building is enhanced. The agroforestry system in the AGROSCOPE trial showed significant humus building of 18 % after only 7 years, compared to the cultivated area. Humus building didn't just occur in the top soil but to a depth of 60cm[89]. This increased the water storage capacity significantly. Integrated trees and hedges improve evaporation and cooling. The higher water storage capacity increased the resilience of the systems which are better able to cope with extreme weather events. Biodiversity increases as does the number of beneficial insects. This raises the resistance to pests and diseases. Modern agroforestry systems are adapted to state-of-the art technology and can be managed with large size machinery.

AGFORWARD (AGroFORestry that Will Advance Rural Development[90]) is a research project funded through the European Union's seventh framework programme for research and technical development (FP7). With a running time of four years, the programme started in January 2014 and ended in December 2017. 100 scientists form 27 institutions in 14 European countries took part.

The results show the many benefits agroforestry delivers in a number of areas which are directly or indirectly linked to climate protection and climate adaptation. In addition, agroforestry has a huge stabilising influence on agricultural ecosystems.

344 respondents from 30 different faculties answered questions about the effects of agroforestry systems.



Source: www.agforward.eu

The integration of trees into the system is economically viable, too. Overall, in such a combination even short rotation plantations can contribute to biodiversity and system stability, but only, if they are part of a diversified system.

Agroforestry systems produce more photosynthesis and therefore potentially more biomass per unit of land. The production of food and protein rich feed are combined. Agrosilvopastoral systems also allow for grazing. Diversified production ensures higher yield security.

Agroforestry systems work in Europe, too.

Source: Mareike Jäger, AGRIDEA

System	Soil	Area	Yield	Price	Output/£
System monocultures	Short rotation plantation	100	8,33	60	500
	Organic wheat	100	5,00	270	1350
Agroforestry	Short rotation plantation	20	3,35	60	201
	Organic wheat	80	5,13	270	1385
					1586

Source: http://www.agforward.eu

The agroforestry system which combined organic wheat and flowers generated more income on the same acreage than the two crops did on their own (flowers or wheat only). Agroforestry systems have an as yet unrealised potential for intensive and sustainable, resilient production.

THE SOLMACC PROJECT

As part of a sustainability agenda that aims to deal with climate protection as well as climate adaptation by maximising "synergies with other environmental goals", climate friendly farming techniques should be evaluated according to whether they increase the resilience of agricultural ecosystems and farm enterprises long-term while simultaneously protecting or even improving resources (soil fertility).

A good example how to allocate research funds while keeping the above in mind is the SOLMACC-Project (Strategies for Organic- and Low-input farming to Mitigate and Adapt to Climate Change). The project is co-financed by LIFE and ran from 2013 to 2018. It funds the widespread introduction of innovative methods which contribute to meeting the EU climate protection targets in the food and agricultural sector while simultaneously relieving or improving other environmental media. Costs, too, were being considered. Twelve demonstration farms were chosen, four certified organic farms each in three different EU member states. The farmers contributed land, equipment and man hours and shared their experiences with implementing the newly acquired skills. Among the innovative methods were: on farm nutrient management, rotation, optimised tillage and agroforestry.

http://solmacc.eu/about-us/

SOL MACC
ORGANIC FARMERS COUNTERING CLIMATE CHANGE

6. CONCLUSION:
FOR A CLIMATE SMART AGRICULTURE WORTH THE NAME SYSTEMIC SOLUTIONS ARE FAR SUPERIOR TO TECHNICAL FIXES

- Soil fertility and diversification/biodiversity in agricultural systems are of key importance. Measures which stabilise agricultural systems and soils to withstand extreme weather events will in most cases also reduce greenhouse gas emissions (in particular humus building).

- To develop and maintain stable farming ecosystems needs a lot of expertise and knowledge, it depends on keen observation, independent decision making and flexibility. Such skills cannot easily be digitalised even though digital media can support the transfer of knowledge and know-how and facilitate observation (like an app for the qualitative structural investigations[91]).

- Organically farmed soils show higher levels of carbon content and storage as well as a significant sequestration of CO_2 from the atmosphere.

- Organically farmed soils emit less nitrous oxide (N_2O).

- Organically farmed soils can absorb and hold twice as much water as conventionally manage soils. That makes soils resilient to torrential rain AND drought and it prevents flooding.

- All of the above is already true for organic agriculture in Europe. With permaculture and agroforestry, the system could be optimised and much enhanced.

Agroforestry/permaculture with trees and vegetables

Photo: Beste

ABOUT THE AUTHOR

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THE MYTH OF CLIMATE SMART AGRICULTURE – OR WHY LESS BAD ISN'T GOOD

THE VALUE OF SUSTAINABLE GRAZING FOR SOIL FERTILITY, CLIMATE AND BIODIVERSITY

By Anita Idel

1. BACKGROUND

Next to forest[1], grassland is the largest biome on our planet, covering about 40 % of vegetated land surface[2]. Of all agricultural land worldwide, one third is cropland and two thirds are grassland[3]. The latter provides the livelihood for one tenth of the world's population[4]. The World Food Organisation, FAO, estimates that for 100 million people in dry regions and probably another 100 million people in other regions grazing animals are the only available income source[5].

Ploughing up grassland and cutting down rain forests are the two land use changes which substantially contribute to climate change.

Cutting down rain forests and ploughing up grassland are the two land use changes which substantially contribute to climate change[6]. In Europe (EU-27) less than 40 % of agricultural land is grassland, its share has dropped because grassland was converted to cropland and surfaces were sealed[7]. 875.000 hectares of grassland were lost in Germany between 1990 and 2009[8]. Between 1850 and 2000, land use changes on the North American prairies caused erosion which led to humus losses of 25 – 30 %. The losses are estimated at about 13 tons per hectare and year[9]. In 2014, World Bank and FAO published similarly dramatic results for the most fertile steppe soils in Europe, in Ukraine: soil losses of 15 tons per hectare per year[10].

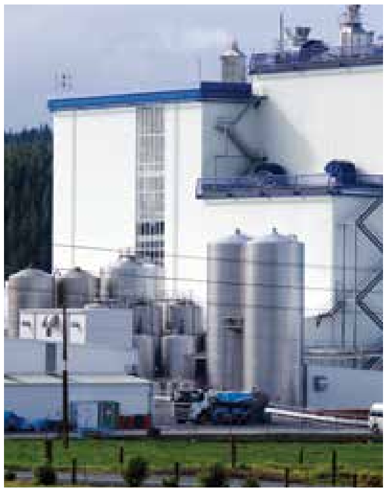
Photo: Idel

There is a lot less money to be made by actually farming than it is through agriculture. When grassland is converted to cropland, industrial agricultural conglomerates stand to profit most, those who supply farm enterprises and those who process agricultural produce. Among the suppliers are the chemical industry with seed, mineral and synthetic nitrogen fertiliser, pesticides as well as feed, antibiotics, anti-parasitic agents, hormones, etc. - add to this agricultural machinery manufacturers, producers of barn equipment, animal breeding companies. Apart from the transport industry, dairies, slaughter facilities and food companies dominate on the purchase side of animal agriculture. Accordingly, for animal products, too, the industry's focus is on crop production for concentrated feed. It's far more lucrative than grassland. With the expansion of dairy and meat producing enterprises worldwide, the ecological and climate footprint in animal production increases dramatically[11].

Science often underestimates the potential of grassland and grazing[11a], while in politics it's mostly ignored. However, in regard to land use and the sequestration of atmospheric carbon, research and public perception have focussed on forests for a long time[12]. Besides, because of reductionist mathematic modelling, cattle get increasingly bad press as "climate killer". During the digestion process cattle burp and release methane (CH_4), a greenhouse gas that heats up the atmosphere 25 times more than carbon dioxide (CO_2). In an unscientific manner, ruminants are often reduced to their methane emission and, as a result, frivolously compared to climate damaging cars. One kg of beef, so the claim, equals driving 250km with a compact car[13]. High-ranking staff at the World Food Organisation (FAO) too, are of the opinion that intensive chicken and pig production is "more efficient" and therefore "better" than beef[14].

Scientifically this view is not legitimate because it does not differentiate - between energy intensive and resource straining climate damaging agricultural systems on the one hand and sustainable, climate protecting ones on the other. Thus, it often leads to counterproductive conclusions in regard to the climate impact.

Cattle do not cause climate problems, energy intensive agriculture does, with monocultures for the production of concentrated feed, often fertilised with synthetic nitrate compounds. In particular the latter leads to nitrous oxide (N_2O) emissions which are responsible for the biggest share of agriculture's biggest "contribution" to climate change: the climate relevance of N_2O is 300 times that of CO_2 and 12 times that of methane[15]. Humans are the climate killers. Because we make cattle into competitors for food when we feed them more and more cereals, maize and soy and have them graze less and less. Instead, the potential of pasture farming for world nutrition has to come into focus of agricultural research and politics. Wetlands, mountain pastures, prairies and savannahs are not only among the best carbon stores, for the formation of proteins they are the biggest nutrient basis on earth[16]. The sustainable use of grassland is important for biodiversity[17]. It has a core function for the water balance in soils and the danger of flooding: increasing the fine root mass (hair roots) raises the water infiltration and holding capacity and exponentially reduces water erosion – a key function in regard to climate change[18].



Apart from the transport industry, dairies, slaughter facilities and food companies dominate on the purchase side of animal agriculture.

Cattle do not cause climate problems, energy intensive agriculture does, with monocultures for the production of concentrated feed, often fertilised with synthetic nitrate compounds.

Grass roots

Source: Prairie-Roots-Project USA[19].

THE LIFE CYCLE OF GRASSES

Permanent grasslands and "its" ruminants have co-evolved over millions of years. This co-evolution of plant and animal means that every bite a grazing animal takes is part of the life cycle of grasses: it triggers a growth impulse. **Compared to other plants and trees, their (fine) roots provide grasses with the special ability to produce more biomass below ground than above.** What is a root today will become humus tomorrow. That's why in regard to promoting soil fertility, on many soils nothing beats sustainable grazing - coupled with rest phases.

The root shoot ration in grasses varies between 2:1 and 20:1, favouring root mass. **In grassland soils therefore most of the stored carbon comes from the grass roots.**

Humus consists to more than half of carbon: one ton of humus contains about 0.55 tons of carbon (C). Together with the approximately 1.25 tons of oxygen (O_2), one ton of humus withdraws 1.8 tons of CO_2 from the atmosphere. But these days the use of grasslands through grazing or mowing is so intensive that little root mass can be produced. Subsequently, the potential for soil building, water storage, climate mitigation and biodiversity, is reduced. Because grasslands are often in bad shape, expectations are low, too: grasslands are perceived as being of less importance for soil fertility, climate and world nutrition. Politics and agricultural research continue to focus mostly on croplands.

That's detrimental. Still, in the long run grasslands are in better shape than one would normally expect because badly managed grassland does not necessarily loose its potential permanently. It is extremely flexible. Growth in grasses follows a totally different dynamic than growth in trees and field crops. Nevertheless, the potential of grassland is increasingly and dramatically underestimated, a trend that will lead to its potential remaining widely unused. This goes in particular for the importance of sustainable grazing for soil fertility, climate and biodiversity[20].

The core potential of grasslands – for soil fertility, biodiversity and climate – is being underestimated dramatically and often remains unused.

Underestimating the environmental potential is just part of the problem. Another roadblock is the economic disinterest shown by the above mentioned downstream agribusinesses which cannot make much money with fertile grassland sustaining healthy cattle. As a rule of thumb, with excellent fodder quality from grassland, dairy cows can produce roughly 10 times their body weight in milk per year[20a].

A look back in history gives crucial clues in regard to today's potential for grazing cattle[21] for world nutrition in the context of protecting resources and climate. Meat consumption plays an important role in (pre-)history, before humans settled down to cultivate gardens and cropland. This cannot and should not be a justification for today's excessive consumption of animal products, but it can serve as a historic clue to the direct and indirect importance of grasslands and grazing animals for humans: in particular the development of soils and their fertility.

Fertilisers play an important role for the use of soil. Chemical-synthetic nitrate fertilisers[22] have only been available for a century and only over the last 50 years or so they have been increasingly used. At the latest from the 1970s, the intensification in production of cereals, maize and soy was focused on the intensification of livestock rearing: by now about half of the world's grain harvest is produced for animal feed[23]. The feed needs of animals bred for high performance often greatly surpasses the amount of regionally available feed. Because more animals are being kept which, in addition, are being fed more concentrated feed, two thirds of the proteins fed to animals in the European Union (EU) have to be imported[24].

As a result, not only the use of chemical-synthetic nitrate fertilisers has increased dramatically, but the input of slurry, too. The disastrous consequences of over fertilisation are becoming more and more obvious: for wells, water bodies, biodiversity, soil life and climate (and in the end for human and animal health, too). (For the various consequences different quality fertilisers have on cropland see the contribution by Andrea Beste.)

Climate gasses per se are not a problem, on the contrary, they are vital and without CO_2 there would be no life on planet earth. Problematic is the amount of climate gasses in the atmosphere[25] and the speed in which they increase: the growing concentration in the atmosphere[26] is driven by industrialisation, the use of fossil fuels and changes in land use. Meanwhile, in relation to land use, science, politics and public regard cattle as the number one climate killer, only forests are seen as climate saviours. But it's people who decide the HOW – the current agricultural system. We decide whether energy intensive production of concentrated feed for high performing animals shall harm the climate or whether sustainably grazed cattle shall help to mitigate it.

Feedlot in Colorado

Photo: Kunz

Humans are the climate killers. They decide the HOW – the current agricultural system.

Photo: Idel

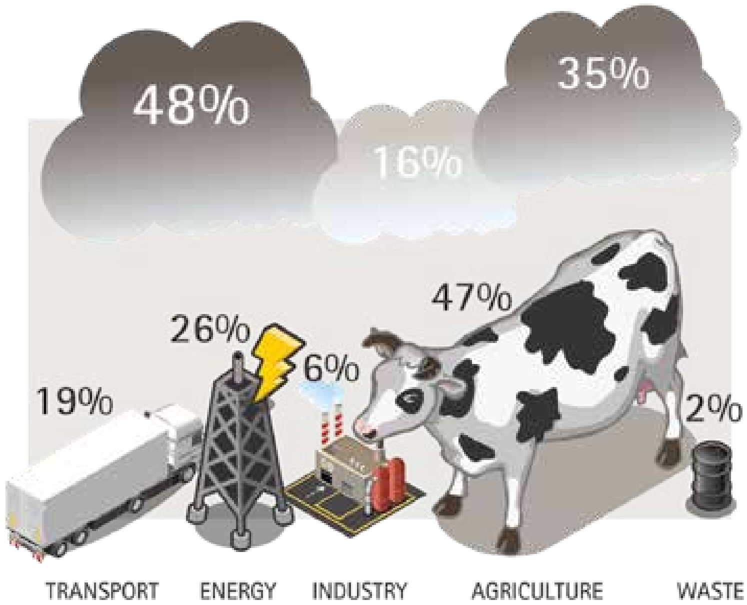
CO-EVOLUTION OF GRASSLAND AND GRAZING ANIMALS

Unlike trees and crops, over 60 million years grasses co-evolved with grazing animals in a unique way[27]. Grazing triggers a growth impulse – above ground for the green blades of grass and below ground for the grass roots. In short: "Today's roots are tomorrow's humus"[28]. In between lies the work of earthworms and other (micro)organisms which "digest" the rotting root mass and exsudates[29].

A change of perspective is needed: sustainable grazing by cattle and other ruminant "relatives" stimulates root growth and thereby humus building and carbon storage in the soil. In humus, more than half the content is carbon – the C from the CO_2 in the atmosphere. Each additional ton of humus in the soil absorbs about 1.8 tons of CO_2 from the atmosphere[29a]. Contrary to common assumption cattle can help to limit climate change. If we let them ...

2. COW MYTHS: THEY WASTE RESOURCES AND KILL THE CLIMATE

Wherever climate (and ecological) footprints are depicted beef and dairy usually make it to the top of the list of environmentally harmful (animal) products. By now cattle has such a bad image that it has become synonymous with all kinds of agricultural climate gas emissions – see fig. below.



Source: Illustration in the South African paper, The Green Times, 2017[30]

Whether it's Mercedes, Renault, Opel or Škoda – the car industry has used the image of cattle as a climate killer to sell their supposedly clean cars. But the agriculture lobby is strong: cattle bashing has disappeared from car advertisements. On the feature pages, however, "evil cows" still feature prominently. In science, too, comparisons with climate damaging cars make cattle look bad.

"More than 200 horses and fewer emissions than a cow." Source: Mercedes[33]

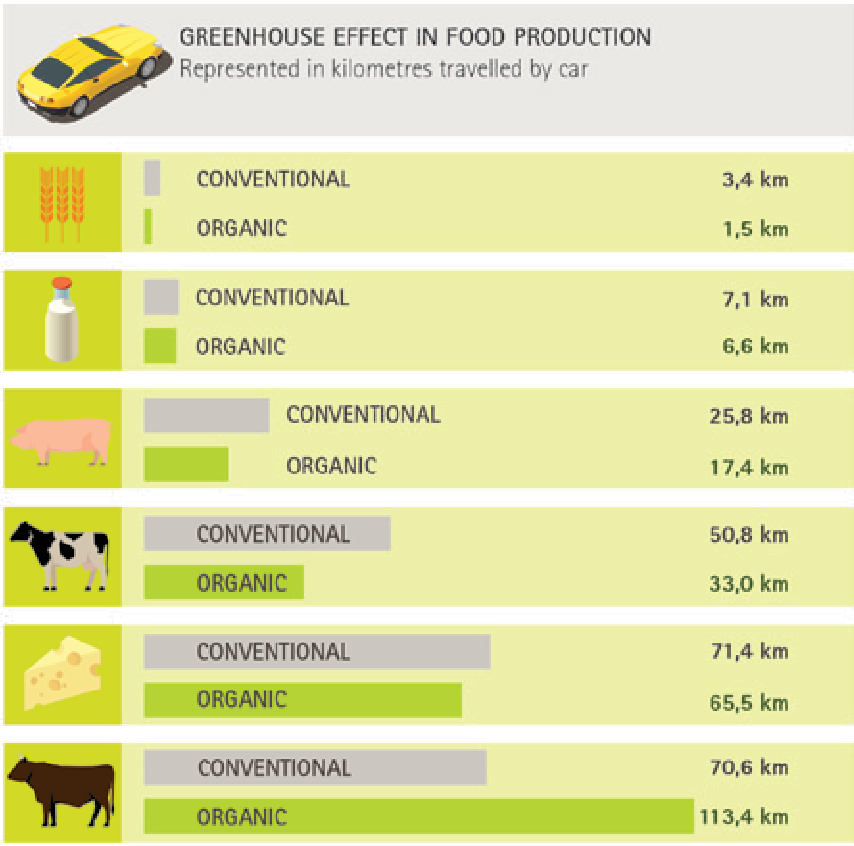
WHY DO CATTLE BURP METHANE?

Like humans, cattle wouldn't be able to digest grass if they didn't have a rumen: in this first of three oesophageal vestibules billions of microorganisms decompose the grass. A large part of the energy (fatty acids) is directly supplied to the animals via the mucosa in the rumen. The microbes use the remaining energy to proliferate. The huge amount of bacterial body protein (several kilograms per day) will later be digested by the cows in their abomasum. While humans and animals exhale CO_2, some of these microbes breathe out methane (CH_4) and ruminants like cows burp it up (so-called ructus).

Under the headline "Simply clever" Škoda advertised one of its compact cars: "More climate friendly than one cow, eight sheep, or three horses".

Source: Škoda[31]

The calculation of cattle methane emissions by Witzke and Noleppa (2007) follows a similarly biased pattern: "On average a dairy cow emits 111.7 kg of methane per year. Converted into the CO_2 equivalent, it equals an annual 18,000 km travelled in a car with an average CO_2 emission of 130 g/km, as promoted in EU policies"[36].



Source: Foodwatch, 2012[35]

Cheap only *appears* to be cheap: the externalised costs of industrial animal production have to be included into the calculations. It's a necessity for a serious assessment of the consequences for animals, environment, climate and health.

This ranking in which cattle and beef always fare worst, has two main flaws:

- firstly, there is no differentiation between energy intensive, resource draining agricultural systems and sustainable ones.
- secondly, the relevant consequences and costs of industrial animal production are externalised.

The biggest part of the global landmass is not suitable as cropland, grazing animals therefore are the only way to use this land **sustainably** for food production. Giving up animal products altogether would also threaten the potential for positive effects on climate protection and biodiversity which come with ecosystem based animal husbandry.

Such vexing research findings usually are not the result of wrong calculations or actual fabrications. The cause for most non-relevant and often even counterproductive conclusions about climate and resource protection can be found at the frontend of the studies: in most cases, the research question and design of the studies does not address the problem that actually should be investigated – agriculture and climate crisis as well as agriculture and protection of resources.

The myth of efficiency: "More concentrated feed, no grazing". That way methane emissions per kg milk or beef would be reduced - while simultaneously accelerating the climate crisis through other, hidden GHG emissions.

Feed imports and the production of chemical-synthetic nitrate fertilisers have to be included into the calculations because the industrial farming system impacts the climate.

It begins with the gathering and allocation of data and influences the outcomes of all studies that are based on them.

Transparency about data that were *not* gathered or not used is unusual, and that makes the evaluation of results more difficult. One study deviates in this respect, it was, conducted by the Heinrich von Thünen-Institute (TI) which is associated with the German Federal Ministry of Agriculture. The TI focussed on the agricultural greenhouse gas emissions in Germany in 2012 and published a "study for the preparation of efficient and well-coordinated climate protection policies for the agricultural sector"[37].

It explicitly lists the data which routinely are not gathered to determine the relevant "state-of-affairs for greenhouse gas and ammonia emission" or are not attributed to agriculture.

Listed specifically are emissions through:

- feed imports
- provisioning of mineral fertilisers
- energy use in agriculture
- use of domestic inputs
  (also see contribution by Andrea Beste)

Because of these omissions (externalisations) there is a danger that research findings suggest conclusions that are counterproductive for climate and resource protection. If feed imports and the provision of mineral fertilisers are not part of the calculation, essential climate influences are missing: emissions associate with the production of concentrated feed on cropland. As a result, the comparison between ruminant cattle and other species is even more skewed against the former.

This effect is augmented further through other data which routinely are not included in assessments of the current domestic status. Among them are the CO_2 absorption by plants – photosynthesis[38] and the resulting carbon sequestration. The increase in soil biomass in grassland is high, particularly because of the fine grass roots.
Who is conscious of just how important grassland is? (see page 51ff)
Last not least it's a misleading to routinely exclude emissions by the so-called Land Use, Land-Use Change and Forestry (LULUCF) (ploughing up grasslands and cutting down rainforests) from the agricultural related emissions.

MYTH NO. 1:
COWS ARE BAD FEED CONVERTERS

Why do so many studies conclude that cattle are bad "feed converters"? Since the 1970s breeders select farm animals for short term high performance. For cattle this means, depending on breed: a lot of milk **or** meat in as little time as possible. Cattle are perfect grass converters, but even then, universities taught that cattle were bad "feed converters". Then and now, this was based on studies which, by their design, made this conclusion inevitable. Because cattle are not evaluated in a ruminant appropriate system and thus they are not evaluated for what they do best: digest grass.

Instead they are put on a diet of concentrated feed made from energy intensive crop production. Thus, intensive feed became the basis for the absurd conclusion that cattle, compared to chickens and pigs, are "bad feed converters"[39]. In the end this is an unscientific conclusion. Even before any of these studies begin, it's well known that the digestive tract of omnivores like that of humans or of pigs and chickens can convert high caloric food or calorie dense feed much better than the digestive systems of ruminants and other grazing animals.

Today, there are 1.5 billion cattle and buffaloes[40] on planet earth, twice as many as in the early 1960s. It's a direct consequence of non-species appropriate feeding: the amount of regionally available grassland is no longer a limiting factor for the availability of feed, respectively, it is increasingly replaced by protein and high calorific concentrated feed.

MYTH NO. 2: COWS KILL THE CLIMATE!

Why do so many studies conclude that cattle are "climate killers"?
With this type of research, too, the study design preordains the conclusion[41].
The following applies to most of these studies:

- Firstly, they are limited to measuring emissions of the climate gas methane (CH_4) and
- secondly, they compare the ruminants like cattle with omnivores like pig or chicken (and sometimes even with fish and humans).

This also holds true for most of the studies published by the FAO. To this effect, the FAO published „key facts and findings": "Cattle (raised for both beef and milk, as well as for inedible outputs like manure and draft power) are the animal species responsible for the most emissions, representing about 65 % of the livestock sector's emissions."[42].

In reality cattle burp methane (CH_4) which is 25 times as relevant for the climate as is CO_2. It's also true that chickens and pigs only fart comparatively small amounts of methane. But, that is well known **before** the studies begin.

The otherwise correct calculation of these obvious facts leads to the inevitable conclusion that cattle are "climate killers" which is scientifically questionable. Again, it would be necessary to not limit comparisons to methane and to not compare different species, but draw comparisons within the relevant species and in regard to the total climate relevance of different farming systems[43].

Ruminants are often not evaluated for what they do best: digest grass.

Myth: Cattle are "bad feed converters"!

Photo: Idel

For decades cattle have been bred for high performance – milk or beef – and they are not fed in a species appropriate manner. In competition with humans over food they have to digest unsuitable feed. That is everything but efficient.

Myth: „Cows are climate killers": instead of researching only methane, the overall climate relevance in different farming systems has to be evaluated.

Individual studies in which the system boundaries were less narrowly defined have proven the connections time and again. But in the general climate of cattle and beef bashing such research has little traction. In reference to previous studies, Koneswaren and Nierenberg (2008) write: *"Raising cattle for beef organically on grass in contrast to fattening confined cattle on concentrated feed may emit 40-percent less GHGs and consume 85-percent less energy than conventionally produced beef."*[44].

There are other publications with a systemic approach. In 2013, a research team in the US did a "life cycle assessment" for the Great Plains region. As was to be expected, if only emissions were considered, the result seemed disastrous: the emissions for grass fed animals compared to all other cattle was "37 % higher – due to a longer finishing time and lower finishing weight.". But, as is scientifically correct, the authors then put the emission data into context and for grazing based systems they conclude: *"However, reductions to GHG emissions (15-24 %) were realised when soil organic carbon accrual was considered and may be a more realistic estimate for the NGP."*[45].

Global FAO estimates confirm: grassland soils store almost 50 % more carbon than forest soils.

Photo: Idel

While most studies and reports published by the FAO are limited to (methane) emissions and therefore advise against cattle rearing in favour of pigs and chickens[46], there are also some studies which take a systemic approach and promote the use of cattle. In a 2010 study for the FAO, Richard T Conant from Colorado State University emphasises the soil fertility of steppe grassland: according to global estimates by the FAO, grassland soil stores 50 % more carbon than forest soil[47]. Conant points out the necessity of sustainable use and the danger of degradation and even desertification otherwise: *"Good grassland management can potentially reverse historical soil carbon losses and sequester substantial amounts of carbon in soils"*[48].

However, grasses have to reduce their root mass if they are mowed or grazed too short. A part of the root mass is then not available for soil building. Given the heat wave in Central Europe during the summer of 2018, sustainable pasture management gains even more significance, not just for increasing carbon storage, but for the water balance, too: *"In cases where sustainable grazing management increases soil carbon stocks, soil water holding capacity increases. Both facets of enhancing water balance will increase drought resilience"*[49].

Grasses have to reduce their root mass if they are mowed or grazed too short. This root mass is then not available for soil building.

Image left:
furrowed fescue

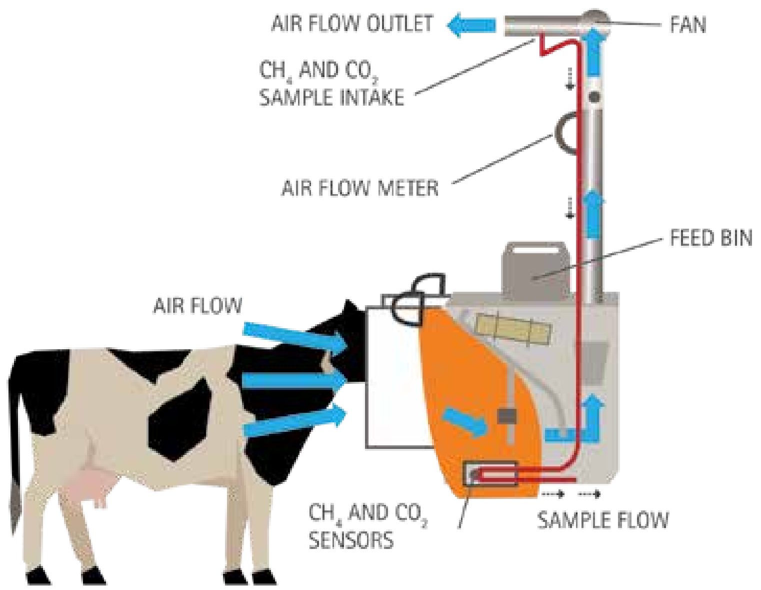
Image right:
sheep's fescuel

Photos: Lichtenegger

MYTH NO. 3: THE HIGHER THE (MILK) YIELD PER COW THE BETTER FOR THE CLIMATE

For more than two decades, research institutes globally have received millions in public funding to build so-called climate chambers to run respiration experiments. These chambers are completely insulated and the ventilation is controlled in order to assess as precisely as possible what amount of nutrients/energy a cow consumes and how it is metabolized.

climate chamber (schema)



Source: cattlebusinessweekly, 2013[51]

Many studies are limited in their design to a very narrow research question: the measure is the methane emission per kilogram of milk. Inevitably, a cow with a 10,000 litre annual milk yield will do better than two cows producing 5,000 litres each, and the 12,000 litre cow does better than the one producing 10,000 litres.

Methane emissions per kilogram milk with increasing annual milk yield per cow

Annual production (kg milk/cow and year)	Number of animals required (cows/ operation)	CH_4 emissions from dairy cows / operation (ton/year)
4000	200	18,7
6000	133,3	14,9
8000	100,0	12,3
10000	80,0	10,8
12000	66,7	9,8

Source: Flachowsky und Brade, 2007

"Those who really cause climate change will not be found in a barn, yet we search for the climate protection potential in a respiration chamber."

Christian Fasching 2015[52]

Maize and concentrated feed rather than grass reduce methane emissions. The assumption that it's good for the climate is another popular myth.

Greenhouse gasses in the atmosphere

GHG	Atmospheric lifetimes (in years)	CO_2 equivalence
Carbon dioxide (Co_2)	110 - 120	1
Methane (CH_4)	9 - 15	25
Nitrous oxide (N_2O)	110 - 120	300

Nitrous oxide, not methane[54], is responsible for agriculture's biggest impact on climate change.

Share of greenhouse gasses (GHG) from agriculture as part of overall emissions in the EU

GHG	Percentage
Nitrous oxide (N_2O)	70
Ammonia (NH_4)	95
Methane (CH_4)	50
Carbon dioxide (CO_2)	8

Source: carbo europe und icp.giss.nasa, 2009[55a]

The calculations by Flachowsky and Brade aren't wrong – but the basis of their design is. That's why they, too, draw the inevitable conclusion that cows should be selected for even higher yields, which really is not backed up by science[53]. It's about more than methane testing in climate chambers which the media ironically refer to as "exhaust emission test".

Scientists frequently fail to focus on the key question of basic needs. Containing climate change and feeding a global population need so much more than testing for methane emissions: It is necessary to systematically and scientifically assess the overal effects of milk production on the climate as well as on soil fertility and biodiversity.

Already in the 1960s it was known that a high share of concentrated feed will reduce the methane emissions in cattle. Yet, the conclusion that maize or other concentrated feed instead of grass benefit the climate, remains a widespread myth.

If the system is not inappropriately narrowly defined to include methane only, the opposite conclusion will be reached in regard to climate relevance. **Scientifically it is particularly important to assess the climate relevance of the feed needed to produce a particular milk yield:** higher performing cows depend on fodder crops and thereby become a competitor to humans over food. A 5,000 litre cow on the other hand is content with grass[54a]. Research projects which are limited to the reduction of methane emissions and the conclusion that high performance cows are "better" do not measure up to a proper climate impact assessment.

RESEARCH TO REDUCE METHANE BURPING

Often, attempts to reduce the immanent burping (ructus) of methane (CH_4) in ruminants, are based on lab trials or theoretical calculations, and generate expectations which will not be met in real life situations. Under such conditions methane reductions were achieved only for a short period of time, if at all. In 2007, Flachowsky and Brade summarised the results of studies for "The manipulation of processes in the rumen with the aim to sustainably reduce CH_4 production". This is difficult "because the complexity and interdependence of many processes [in the rumen] have not been fully understood"[55].

A permanent change in the composition of the microbiome – at the detriment of the main methane producers (archaea), requires a permanent supply of additives. There are often negative effects for animal health associated with it. By now there is a growing assumption that not the size but the composition of the archaea population in the rumen is responsible for the amount of methane emitted[56].

MYTH NO. 4
TO SAVE THE CLIMATE COW NUMBERS NEED TO BE HALVED

How should the - apparent - obvious demand to half the number of cows be assessed? The example of the German state of North Rhine-Westphalia (NRW)[57] illustrates why this demand, too, is part of the problem and not the solution. Between 1993 and 2013 the number of cows in NRW was more than halved. The remaining cows produced more milk then had been milked in NRW 20 years earlier. Farmers had gotten rid of the animals which had been bred to produce yield mainly from grasses and grazing. The high milk yield of the remaining cows – on average annually more than 8,500 litres with top performances of 12,000 litres – was based on their intensive feeding: non-ruminant appropriate (imported) concentrated feed from cropland which, in addition, makes ruminants and humans into food competitors.

A joint study by GRAIN, an organisation for fair and sustainable agriculture, and the Institute for Agriculture and Trade Policy (IATP) highlights how much the world's biggest dairy companies and meat processors contribute to climate change[58]. In the coming decades these companies could overtake energy groups like ExxonMobil, Shell and BP which currently are the world's biggest contributors to climate change. Jointly, the top five dairy companies and meat processors are already responsible for more greenhouse gas emissions annually than are ExxonMobil, Shell and BP. Whether this does or does not happen, what matters is that dairy companies (like Nestlé) and meat processors (like Smithfield) continue to grow unchecked. The same goes for seed and feed companies as well as fertiliser and pesticide producing agrochemical companies: their business model is still based on increasing animal production and processing.

Nestlé or Smithfield: Dairy companies and meat processors continue to fight for bigger shares in the global market and thereby speed up mass production and greenhouse gas emissions.

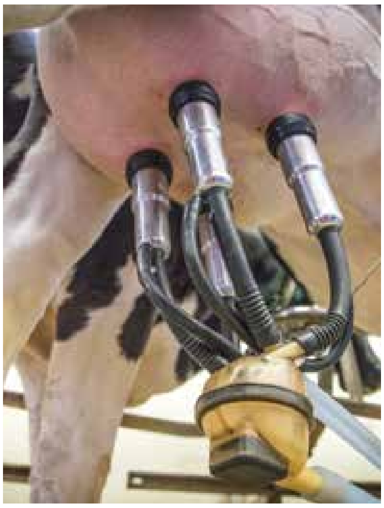
FACTS INSTEAD OF MYTHS: A FURTHER INCREASE OF MILK YIELD WILL NEGATIVELY IMPACT COWS, CLIMATE AND RESOURCES

More milk, more meat, more eggs per individual animal in ever shorter time – for decades that's been the guideline for breeding targets, feed and animal welfare standards. Ever since, the use of concentrated feed has caused a gargantuan nutrient transfer, which has worsened dramatically with the industrialisation of animal agriculture in the EU.

- not just because of increasing animal numbers in poultry and pig production
- but also because of the high-performance breeding in cattle, pigs and poultry.

Nutrients are being withdrawn from soils, (particularly) in South America while the excrements of the animals that consume these nutrients put a strain on soils, water bodies, climate and biodiversity in Europe.

A reduction of the number of dairy cows like the one in the German state of North Rhine-Westphalia does not result in a decrease of climate harming emissions. On the contrary: high performance can only be achieved with concentrated feed which, in turn, promotes further climate change: worldwide, ploughing up grasslands and cutting down rainforests are among the land use changes which considerably contribute to climate change[59]. Add to that the direct external climate effects connected with the production of feed crops and the processing of concentrated feed: firstly, the energy use for the production of seeds, pesticides and synthetic nitrate fertilisers, secondly the CO_2 emissions resulting from seeding, tilling and harvesting and thirdly, the formation of nitrous oxide (N_2O) when fertiliser is spread in the field[60]. **Nitrous oxide is agriculture's biggest contribution to climate change**[61]. (see contribution by Andrea Beste)



Myth: "High performance cows are better for climate and environment".

MYTH NO. 5
HIGH AND PEAK PERFORMANCE BENEFIT THE CLIMATE

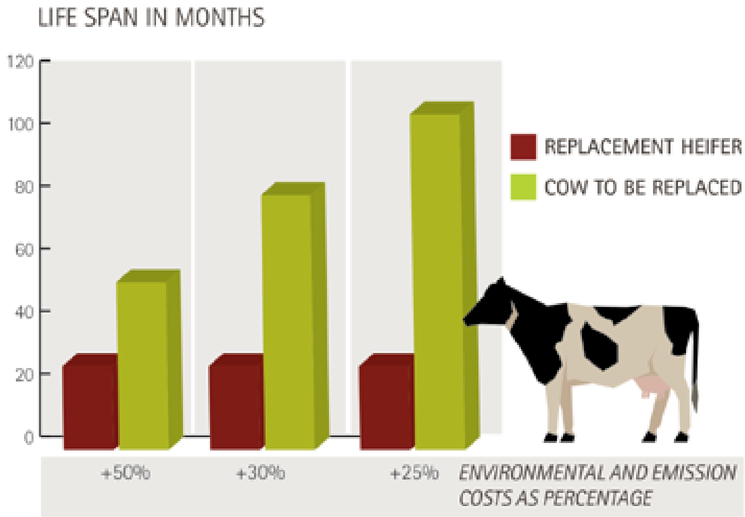
Why do so many studies conclude that one-sided performance increases are good for environment and climate? Industry and a relevant part of the scientific community propagate that each new generation should result in breeding advances in regard to an increase in performance over time[62]. Generally, such an approach is based on a questionable definition of productivity. And with these studies, too, a scientifically inadequate study design leads to the near inevitable conclusion that high performance dairy cows are better for environment and climate than cows with a lower milk yield. Again, the focus is far too narrow.

Most 5,000 litre cows (as in annual milk yield) on average live longer, while most 10,000 litre cows have shorter than average lives. The higher the productivity of an animal per day or year, the higher the risk of it becoming susceptible to disease and burn-out[63]. The younger the cows are that are removed from an operation, the more cows have to be raised to replace them. (See fig. page 47).

Neither scientists nor the public consider that the age and productive life span of dairy cows have decreased continuously since breeders started selecting for high and highest yields. For more than 10 years the average age of a cow going to slaughter in Germany has been about 5 years, this means she has calved only twice or thrice and, respectively, was milked only during two to three lactation periods[63a]. **At an early point in her lifetime a calf had to be raised in order to be ready to replace her.**

The higher the annual productivity of an animal, the higher is the risk of it becoming susceptible to disease and burn-out.

Longevity and low replacement rates protect climate and environment



Source: Idel, 2013[64]

The younger each individual departing cow is, the more her life cycle overlaps with her replacement. To assess high replacement rates correctly, one needs to consider the consequences for environment and climate that are connected to this shadow economy. Besides, there is an unavoidable gap between high milk yield and meat potential, male calves loose in value and are often neglected[65]. And there is another climate relevant consequence of intensive milk production: in dairy cattle selected for high and highest milk yields male and female animals don't gain much meat, therefore additional beef cattle need to be raised for meat production.

MYTH NO. 6
COWS NEED HUGE AMOUNTS OF LAND AND WATER

Why do so many studies conclude that cattle "use" huge amounts of land?
Worldwide animal agriculture is the biggest land user, by far. Whether that's good or bad – or neutral, depends on HOW the land is used. The increasing industrialisation of animal agriculture threatens the environment. In particular for cattle it holds true: whether rearing cattle is energy intensive and climate relevant or sustainable and species appropriate depends mainly on their feeding system.

Whether rearing cattle is energy intensive and climate relevant or sustainable and species appropriate depends mainly on their feeding system.

Photo: Idel

ECOLOGICAL FOOTPRINT

The ecological footprint is the share of land needed to permanently maintain the lifestyle and living standard of a human being (under current production conditions). It is called sustainability index[66].

ECOLOGICAL BACKPACK

The ecological backpack symbolises the amount of resources needed for the production, use and disposal of products or services. Within the framework of an ecological balance it is a measure of reference which illustrates the environmental consequences the provision of certain goods has[67].

Again, most studies on ruminants don't adhere to a science-based professional approach. As with the assumption that cattle are "bad feed converters", the calculation of the "water rucksack" (the amount of water they supposedly use) does not do them justice. Comparisons are not made between different agricultural systems, but between ruminants, i.e. cattle, and omnivores like pigs and chickens. Accordingly, it's disregarded that land used to grow concentrated feed for ruminants is not available for the production of food for humans (feed/food competition).

The ecological footprint or the ecological "backpack" are concepts developed to assess the industrial consumption of resources and allow the comparison of environmental and climate impact of different industries.
Therefore, the ecological footprint or ecological backpack is always the expression of solely negative effects:

- in regard to climate, perception and calculation is limited to emissions
- land *use* is equated with land *consumption*.

It is pretty disastrous that a concept developed for industry within the framework of environmental and climate policies was transferred to agriculture:

1. Climate:

Agriculture does not just produce emissions. With sustainable soil management, agriculture also has the potential to sequester and store C. This is particularly true for grassland.

2. Land use:

If land use is equated with land consumption and no differentiation is made between cropland and permanent grassland, calculations will result in:

- species which get more feed from cropland will fare better than ruminant cattle
- feeding systems for ruminant cattle fare the better, the more feed comes from cropland
- the more sustainable the management of grassland, the worse the system is considered to be

(see: Why so few people know how important grassland is. Page 51ff)

In sustainable grass management systems, cattle and other grazing animals have the potential to encourage root growth which, in turn, promotes humus building and contributes to carbon storage. This correlation is inextricably linked to climate mitigation.

The 2011[69] WWF report "Meat Eats Land", too, is based on studies comparing the size of the agricultural land used in regard to different species and management systems. If efficiency is limited to output/the above surface production of biomass, and the costs for the use of these resources is externalised, the consequences of erosion – including soils which can no longer be farmed – cannot be portrayed accurately. (See contribution by Andrea Beste).

When the question: "How much land is needed for meat?", is raised, cattle inevitably top the list which implies that they are less "efficient" in using land.

Calculation of area needed for the production of one unit of animal product in Germany/the EU and outside the EU (in m2/kg)

Animal product	Germany/EU	outside of EU
Beef/ Lamb	27,0	49,0
Pork	8,9	12,1
Poultry	8,1	9,9
Dairy	1,1	2,0
Eggs	4,5	6,2

Source: Witzke, Noleppa und Zhirkova, 2011

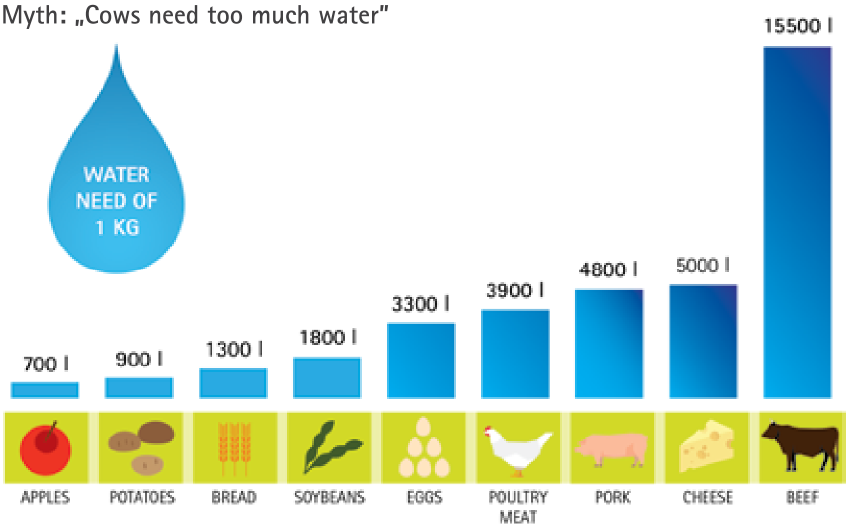
Myth „land efficiency"
"Beef production requires 28-times more land than the average of other livestock categories."
Eshela et al. 2014

This approach isn't just problematic for the comparison of the climate and environmental relevance of ruminants and omnivores. The comparison of ruminants inside and outside of the EU, too, leads to wrong conclusions. The ranking claims that the production of beef and lamb within the EU needs 40 % less land than outside of the EU and is therefore supposedly better. The reason: within the EU the bigger part of the feed comes from cropland while outside of the EU this part is smaller.

If no differentiation is made between grassland and cropland, livestock fares worse the more sustainably managed grassland is part of the system.

A 2014 study on US agriculture is another example for the counterproductive "land use efficiency" approach. Here, too, the authors inevitably summarise: "Beef production requires 28-times more land (...) than the average of the other livestock categories." (...) "The study thus elucidates the multiple environmental benefits of potential, easy-to-implement dietary changes, and highlights the uniquely high resource demands of beef." (...) "Preliminary analysis of three staple plant foods shows two- to sixfold lower land, GHG, and Nr [reactive nitrogen] requirements than those of the non-beef animal-derived calories"[70].

Myth: „Cows need too much water"



Source: www.waterfootprint.org[71]

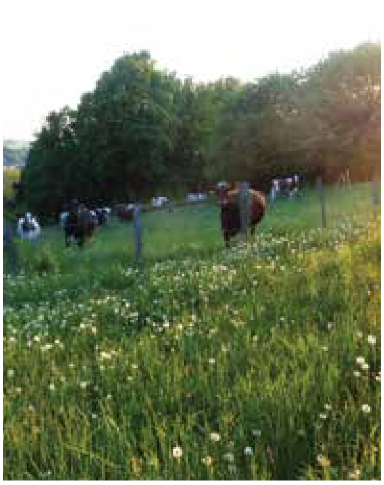


Photo: Idel

In regard to water use, sustainable cattle grazing on permanent grassland does not compete with human food production.

In accordance with the myth: "Cows use too much water", cattle are not just pilloried for their "land rucksack" but for the "water rucksack" too. The perception of cattle as the farm animal with the "highest water use" follows the same logic that proclaims them to be the "biggest land users". For the production of a single kilogram of beef, figures of up to 100,000 litres of water are bandied about[72]. Basis for such calculations is the amount of rain that falls on the permanent grassland acreage needed for grazing to produce one kg beef. Therefore, again, industrialised production inevitably comes off as being better because it presumably needs less land, while grass-based feeding systems appear to be worse.

The fact that in regard to water, too, sustainable cattle grazing on permanent grassland does not compete with other uses and therefore does not happen at the expense of human food production is usually ignored[73]. The same holds true for the essential importance of grasslands for groundwater regeneration: quantitatively because of its large share in vegetative cover of soils worldwide, and qualitatively because of its low exposure to mineral fertilisers, pesticides, antibiotics and medication to treat internal and external parasites.

Myths: "Cows have a large water rucksack"

1 kilogram wheat	715 - 750 liter
1 kilogram soy	540 - 630 liter
1 kilogram maize	1.650 - 2.200 liter
1 kilogram beef	50.000 - 100.000 liter
1 kilogram wool	ca. - 170.000 liter

Source: Meier, Wayne 2004[73a]

Photo: Idel

3. WHY SO FEW PEOPLE KNOW HOW IMPORTANT GRASSLAND IS

The simple and obvious answer is: "Because there is so much of it worldwide". Under the headline "Grassland" National Geographic writes: *"Savanna, steppe, prairie, or pampas: They're all grasslands, the globe's most agriculturally useful habitats"*[74]. And the FAO defines permanent grassland as "land used to grow grasses or other herbaceous forage naturally (self-seeded) or through cultivation (sown) and that has not been included in the crop rotation of the holding for five years or more"[75].

Why is grassland so important? For a start, because there is so much of it worldwide!

Grassland covers the largest part of the global landmass. There aren't just lots of different grasses, there are also very different types of grassland[76]. As the world's largest biome next to forests, communities of grasses make up close to 40 % of the vegetative cover of planet earth[77]. Of the world's designated agricultural land one third is cropland and two thirds are grassland[78].

In Europe (EU-27) the share of grassland in all agricultural land only amounts to just short of 40 %[79]. Despite its enormous spread and diversity there is a considerable lack of data[80]. This was recognised in a 2014 FAO report, too[81]. And despite their important contributions to soil fertility and humus building grasslands attracted little interest during events proclaiming 2015 as UN International Year of Soils (YS). The focus was on cropland. The same is true for the Global Soil Week[82] which is organised by the Global Soil Forum and has taken place five times since 2012.

In view of the limited agricultural land and the increased sealing of soils, the share of available agricultural land for each human being is decreasing while the world population continues to grow: in 2017 there were 7 billion people, 1.45 billion hectares cropland and 3.55 billion hectares grassland/pasture which left 2000m2 (0.20 ha) cropland and 5.700m^2 (0,57ha) grassland for each inhabitant of earth[83].

NON-ARABLE LAND…
…OFTEN MISCONCEIVED, IGNORED, NEGATED

Because most grazing land is unsuitable for crop production it is often called "marginal". But the health of such "marginal" areas is of crucial importance – for the survival of the locals. Worldwide about 800 million[84] to 1 billion[85] people – about one tenth of the world population – depend for their food and for their livelihood in general on grazing animals having access to pastures[86].

Another clue as to how the potential of grassland is either ignored or underestimated is the term often used in a scientific context as a synonym for grassland. It's the term non-arable land.

Photo: Idel

Very steep but good pasture
Photo: Idel

There are many regions too steep, too stony, too wet or too dry where arable agriculture is impossible. The special feature of this type of land is its particular suitability for grazing.

Globally, grassland is the largest terrestrial biome: there is no other vegetal cover on the global landmass which is as common as grassland communities.

A synonym that characterises grassland through what it can't do… In fact, there are many regions, which are too steep, too stony, too wet or too dry. There, arable agriculture is either impossible or would cause considerable damage. Such land is defined by its suitability for grazing, but it is unsuitable for tillage and often cannot be mowed or only at considerable financial cost.

In his 2008 scientific critique, the New Zealander Richard W. McDowell named lack of inter- and transdisciplinary as fundamental problems and linked it directly to grassland-based agriculture. Particularly because it is so common for scientists and politicians to have a special area of expertise, it needs to be placed in a wider context[87], he argues. Instead, science and politics with a narrow focus mainly concentrate on (methane) emissions. Accordingly, the authors of prominent publications by the FAO promote the continuing intensification of animal production with the non-ruminant omnivores, pig and poultry[88].

It is up to the FAO's "Grasslands Carbon Working Group" to publish the odd study with a wider approach. In 2009 the group produced a paper titled "*Grasslands – Enabling their potential to contribute to Greenhouse gas mitigation*"[89]. In 2010 the FAO published a report, summing up the current state of knowledge. *It emphasized that measures leading to carbon storage in grassland also tend to enhanced climate resilience*[90].

GRASSES AND GRASSLAND – THE MOST IMPORTANT TRAITS OF THESE MULTI TALENTS

FIRST, THREE SUPERLATIVES

Globally, grassland is the largest terrestrial biome: there is no other plant community on the global landmass which is as common as grassland. The regions in which communities of grasses can survive are much bigger than the habitats for tree communities, particularly because the latter need more moisture. As largest terrestrial biome grassland is also the largest permaculture: as perennial plant community permanent grassland covers more land than arable and horticultural perennial crops combined. And as plant community it is also always a system of diverse cultures – the largest globally.

The habitats of grasslands vary from extremely dry to extremely wet, from extremely hot to extremely cold[91]. In mountain regions we find even beyond the timberline grassland that can be used for grazing. That way humans can utilize mountain pastures or transhumance regions which otherwise could not contribute to feeding humans.

Communities of grasses can even cope with the rapid change between these extremes. The secret of their success is their flexibility: the diversity of the different grasses, regionally and locally adapted through natural selection, is present in the soil as seeds, too. Individual grasses in these diverse cultures can germinate and grow in a very short time span and thus react to particular environmental conditions. Today, such systems are known to be highly resilient.

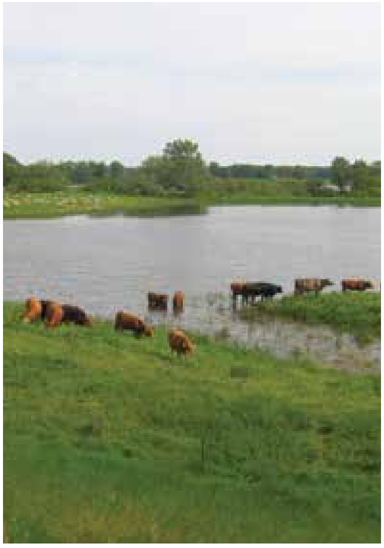
A vegetation period is the period of time in the course of a year in which plants can grow. To do so, they need chlorophyll – leaf green – and solar energy to absorb carbon dioxide (CO_2) from the atmosphere (photosynthesis). In Europe's moderate climate, the vegetation period of grass is among the longest, in particular compared to trees: once temperatures in the upper soil layer rise above five degrees Celsius, grasses can grow. In comparison, the vegetative period of deciduous trees[92] can only start with spring leaf growth. Only then is there leaf green for photosynthesis - and thus tree growth. But already from late summer the potential for activity decreases, from the colouring of leaves to the time they drop and no more biomass can be produced.

On the other hand, depending on temperature, sun exposition and precipitation, grassland can grow in any season. In the northern hemisphere cold is the limiting factor for grass growth, in the southern hemisphere it is drought. Some grass communities have adapted to either extreme.

In regard to climate change and the consequences of additional drought, the challenge and chance for our ecosystems rest in us giving grassland finally the attention that mirrors its potential - for the biodiversity of animals (including insects), plants and microbes[93]. And as the frequency of excessive rainfall events and flooding increases, it also becomes extremely important for the water storage capacity and the prevention of water erosion. Vegetation significantly mitigates the degree of soil erosion: when there is vegetation water erosion will be exponentially reduced.

Accordingly, the danger that soil on slopes starts to slide is highest when the fields are bare. The importance of grasses for the water economy in soils lies in the living roots: "*The increase of root mass also reduces water erosion exponentially*"[94]. Biodiversity contributes to resilience in another important way: there is a positive correlation between soil stability and root biomass[95]. In areas that are at risk permanent grassland is the safest usage form. A handbook of "Near to Nature Grazing Management in NATURA 2000"[96] provides comprehensive and updated information on preconditions and criteria for grazing in general and especially of wetlands.

Wetlands or steep slopes: permanent grassland with temporary grazing is the safest usage form to prevent water erosion.



Wetlands along the river Elbe between Dömitz and Lenzen

Photo: Luick

Photo: Idel

GRASSLAND NEEDS THE BITE

"Why do we mow our lawns?" "Because it grows", is the obvious answer – though only a partial one. The full answer should be: "Because it grows and so it grows". Most of us know that mowing lawns triggers a spurt of growth, in particular when it's sunny, warm and moist. Lawn reacts to being mown – by growing.

It's the result of the 60 million yearlong co-evolution of grassland and grazing animals: grasses receive a growth through the bite. Other plants are damaged by grazing animals and therefore try to protect themselves: if the plants were not bitten off as saplings and wilted, they produce bitter compounds or toxins as well as spikes and thorns. They invest energy into protecting themselves and minimise the risk of being nibbled at[99].

Holly (ilex): the more bite injuries there are, the more spikes the tree will produce.

Photos: Kämmer

AUROCHS, WISENT &CO.: GLOBAL LANDSCAPE GARDENERS

In particular aurochs and wisent but other grazing animals, too, roamed the post ice age landscapes of Europe. But in the western part of Central Europe they were already much decimated or pushed eastward during Roman times. Aurochs became extinct and therefore have been largely forgotten. They are not recognised as the global landscape gardeners whose legacy are some of the best agricultural soils. Until their near complete eradication in the 19th century, about 60 million bison grazed the prairies in North America. It's not that long ago and today's inhabitants still reconnect with the role grazing played in the history of origins of this fertile soils. When the Spanish conquerors arrived on the plains of the South American pampas in the 16th century they found more than 40 million guanacos (the wild ancestors of today's domesticated lamas) grazing there. During the next 100 years they were mostly slaughtered or pushed into the moutains[100]. Their importance for the extraordinary fertility of the pampas is only known to a few scientists who are becoming increasingly interested[101].
All these soils owe their tremendous fertility to the fact that they originated from steppes.

GRASSES ARE DIFFERENT

When assessing soils and their fertility potential today, the time since the end of the glacial period (about 12,000 years ago) is of great importance. During what's called the Weichselian or Devensian glaciation vegetation on earth had adapted to the changing climate: where the land surface was not covered by ice, mainly grasslands remained or developed, including steppes and tundra as well as (cold) deserts. Forest areas - including tropical rainforests – decreased because of the drought conditions caused by the cold; most of the water was trapped in the glaciers[102].

National Geographic writes: "Grasslands are found where there is not enough regular rainfall to support the growth of a forest, but not so little that a desert forms"[103].

To understand the triad of forest, grassland and desert one crucial piece of information is needed: grasses, then and now, naturally strive wherever animals graze and keep the land open. While promoting grass growth through grazing, animals hamper tree growth by biting off new shoots.

The reason for the opposite effect grazing can have lies in the fundamental difference between grasses and trees. A difference that was totally overlooked for a long time. Because both trees and grasses are perennial plants, grasses were considered to be some sort of miniature trees and neglected by science. It was often assumed that findings from forest research could be applied to grasslands[105].

Grasses and trees differ fundamentally in the way they grow:
Grasses grow from below: grazing triggers a growth signal for blades and roots.
Trees grow at the top, from the tip of the shoot or the seedling: the animal bite destroys the growth point(s).
It becomes very clear: grasses are not tiny trees but something very unique: grasses are different.

One of the main differences lies mostly hidden: grassland has a lot more root mass compared to the visible part of the plant above ground[105a]. The root-shoot-ratio in grasses varies between 2:1 and 20:1 in favour of root mass[106]. In grassland most of the stored carbon is root derived and to a lesser degree from the rotting down plant biomass above ground[107]. Most trees on the other hand grow more above ground than below – at a ratio of 1:2[108].

This important difference between grasses and other plants is also often ignored. It works against grasslands because their potential for soil fertility and the resulting benefit for the atmosphere is not perceived. Plants with a higher root mass can absorb nutrients from the soil more effectively and store considerably larger amounts of carbon in the soil[109].

While sustainable grazing promotes grass growth, any grazing of tree shoots hinders tree growth.

Photo: Idel

Grasses and trees differ fundamentally in the way they grow:

- Grasses grow from below
- Trees grow at the top, from the tip of the shoot or seedling

Alpine meadow-grass

Photo: Lichtenegger

Another important difference is the high water storage capacity and the potential to reduce water erosion[110]. And, compared to trees, grasses can build biomass more efficiently, using less energy. The assumption that plants with a higher number of buds can absorb more light energy for photosynthesis is not always correct. As leaves develop in spring they increasingly cast shadow on other leaves.

The fact that, compared to forests, the potential of grassland for soil building and climate mitigation is massively underestimated proves relevant in yet another way: the time factor usually is not considered. Trees accumulate the largest part of their biomass over decades and sometimes centuries as wood. A comparison has to be based on that **time period** rather than on the **current state** and as a snapshot in time: in addition to all carbon stored in the soil the total of the grass biomass has to be visualised, that is weighed. The same of course goes for the leaves which the trees have produced in that time period. However: grassland adds not just biomass but value too: grass is fodder for ruminants who produce meat or milk and meat.

PERMANENT GRASSLAND

- it is the largest biome – the largest-area ecosystem,
- it is the largest permaculture – the most expansive perennial plant community,
- it is the largest mixed cultivation – the most common plant community,
- it co-evolved with grazing animals,
- because of this co-evolution it depends on grazing/mowing: "Grassland needs grazing",
- because of its root mass with hair roots it has the highest potential for humus building,
- and, related, the largest water storage capacity and the largest potential to reduce water erosion.

GRASSES

- have very long vegetation periods, compared to other plants,
- in comparison to other plants they have a higher root to shoot ratio, favouring root development,
- have a large percentage of hair roots per unit of soil volume. They are therefore more efficient in absorbing nutrients and water than trees which have a so-called extensive root system[111],
- have a natural tendency to grow into a comprehensive soil cover (like a lawn) – which reduces erosion[112],
- grow from below and not from the top of the shoots[113],
- can live wherever trees can live – and beyond,
- are very flexible and can therefore adapt to change very quickly,
- in comparison to tree leaves, blades of grass don't significantly shade each other out and therefore photosynthesis is impaired less,
- receive a growth impulse through use (grazing/mowing).

WHY AND HOW CAN SOILS GROW?

For decades, the chapter on soil in geography text books stated: "Soil building is the result of rock weathering". Rock weathering is necessary so that mineral nutrients continue to be available to plants. But they amount to only a small fraction of the total soil mass, no matter whether the soil biomass has been recently built or has existed for some time.

So where does the main share of newly built soil biomass and bio soil mass in general come from? For a long time, **until well into the 19th, Aristoteles' theory that plants absorb carbon from the soil, prevailed. That would mean soils can't grow….**

The soil biomass consists mainly of carbon from the atmosphere – the C from CO_2, which plants can absorb through photosynthesis and sun energy. But in the second half of the 20th century scientists mostly lost sight of the circular model according to which soil is supplied with carbon from the atmosphere via plants and photosynthesis and humus building is the precondition for soil fertility and plant growth. The interest in soil fertility decreased when mineral fertiliser, and from the 1950s onwards chemical synthetic nitrogen fertilisers, became cheaper and increasingly more readily available. Buying fertiliser seemed a good replacement for soil fertility. (See contribution by Andrea Beste).

Carbon comes from the air and gets into the soil best via perennial plants. An additional ton of humus in the soil removes 1.8 tons of CO_2 from the atmosphere. Of that about 0.55 tons – about half - is carbon (C) and 1.25 tons are oxygen (O_2). Grasses are particularly efficient in promoting soil because of their roots. When leaves and compost are rotting above ground, part of the biomass is discharged into the atmosphere as CO_2.

(NON) PERCEPTION – OF SYMBIOSIS

Like humans and animals, many plants, too, live in close association with bacteria and other microbes. The plant microbiome is either directly associated with leaves, stems and roots – as is the biome in humans – or it exists in close proximity to the roots. The root- or rhizosphere is very much alive, plants, earthworms, insects and microorganisms contribute to each other's well-being and nutrition.

This insight and the definition of the term date back a century. "The rhizosphere revisited: root microbiomics" is the promising title Peter Bakker and his team chose for their 2012 study. They were thrilled with what they found and summarise: "*Recent studies show that the diversity of microorganisms associated with the rootsystem is enormous. This rhizosphere microbiome extends the functional repertoire of the plant beyond imagination*" [114]. This repertoire of abilities and functions mostly refers to the carbon transfer between plant (roots) and the surrounding microorganism. It is of central importance for soil building. Carbon sequestration is only limited in soils without root penetration, the authors ascertain.

The soil biomass consists mainly of carbon from the atmosphere – the C from CO_2, which plants can absorb through photosynthesis and sun energy. An additional ton of humus in the soil removes 1.8 tons of CO_2 from the atmosphere.

0,55 tons carbon (C)	
1,25 tons oxygen (O_2)	
1,80 tons CO_2	

Meadow fescue, partial view of the roots which are reaching to a depth of 273cm

Photo: Lichtenegger

The root sphere is very much alive. Here, in what's also called the rhizosphere, plants, earthworms, insects and microorganisms contribute to each other's health and food supply.

The rhizosphere may cover the largest part of the global land mass – yet, most people know at best only about another symbiosis: that of cows and microorganisms. Once cows have chewed their cud, breaking up the grasses, the microorganisms in the rumen, the biggest of a cow's four stomachs, take over. The rumen contains 100 billion micro-organisms per millilitre (!). They use the three gastro oesophageal vestibules as fermentation chambers. They find plenty of nutrients and a perfect habitat in which to multiply (cell division): while the cow grazes or ruminates there is a continues supply of food and an ideal temperature of 38 to 40 degrees Celsius.

A cow that consumes 50 kilograms per day will have about 100 billion bacteria develop in her rumen – that's a figure with 15 zeros[116]....

More and more research focusses on some of these symbionts invisible to the human eye, while other, visible ones remain mostly obscured: we see them but fail to recognise them or their importance. This is particularly true for the vast grass plains on our planet.

HOW DID SOIL FERTILITY DEVELOP BEFORE HUMANS SETTLED?

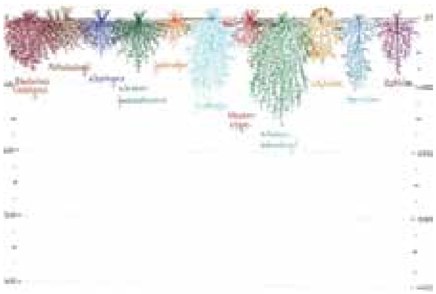
GLOBAL LANDSCAPE GARDENERS – OR: WHERE ARE THE WORLD'S MOST FERTILE PLAINS LOCATED TODAY?

Today, soil fertility is often considered to be man-made: on fields and in gardens as a result of humans settling. In fact, this type of soil management promotes the opposite: the loss of fertile soil through wind and water erosion.

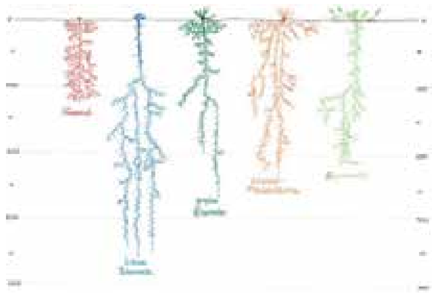
When the glaciers retreated at the end of the last ice age more than twelve thousand years ago, sun light once again reached and energised the soil where grass and tree seeds could now germinate. But tree saplings could only mature into trees once the earth's surface had warmed enough for more glaciers to melt and water to become available again as rain and dew.

Wisent Photo: Idel

Drawing of grass roots



Drawing of herb roots



Source: Kutschera and Lichtenegger - modified by Braun[119]

THE CO-EVOLUTION OF GRASSLAND AND GRAZING ANIMALS

Aurochs, bison, wisents, lamas as well as antelopes – at the time grazing animals and grassland co-evolved, there were mostly ruminants roaming the then fenceless world[117]. The daily uptake of plant food populated by microorganisms together with the daily discharge of microbe enriched residues in the shape of cow dung led to an interaction between the habitats of microbe above and below ground. Apart from dung beatles that's the main reason why in particular cow dung has such beneficial effects on soil fertility[118].

A cow pad – soil fertiliser as well as feed and temporary habitat for numerous insects

Photo: Idel

STEPPE SOILS OF THE HIGHEST FERTILITY – IN CENTRAL EUROPE, TOO

The world's largest and most fertile plains[120] developed through thousands of years of grazing. Today they are known as breadbasket, because for decades high yields were achieved for cereals, maize and soy, grown in monocultures and often intensively irrigated. That's why the carbon content in most of these soils decreases dramatically. The black soils (chernozem) of the North American prairies, the Ukraine, the Hungarian Puszta, the Baragan Steppe in Romania, the lowlands of North Germany[121] as well as those in Kazakhstan, Mongolia and China (Manchuria) or the subtropical Pampas in Argentina and Uruguay not only all have high fertility, but the same origin, too. They derived from steppes what means: grazed soils. A high share of mineral loess loam was a good precondition for the development of soil fertility, but it became animated only through its plant soil cover – that is from above. In Central Europe black soils developed 10 to 14 thousand years ago and in 2005, were the first to be nominated soils of the year - but not mentioning their development by grazing[122]. Their soil life developed in direct relationship with grazing animals – in particular through grazing the promotion of root growth and thereby the rhizosphere[123].

The extremely fertile grass plains on our planet – like prairies, pampas or the Eurasian black soils - are steppes which developed through the co-evolution of grasses and grazing animals.

But one can be blindsided by such soil fertility: monocultures threaten the breadbaskets. Soil fertility decreases dramatically: if the soil degradation is not slowed down, all topsoil worldwide could disappear within 60 years, said Maria Helena Sameda, an FAO expert for the protection of natural resources, on the occasion of the 2014 World Soil Day[124]. Still research and politics pay too little attention to the enormous eradication of humus through intensive agriculture, and, in particular, to the immense potential of sustainable grazing management, instead the focus is on burping cows.

DESERTIFICATION ...
... IS THE CONSEQUENCE OF THE MISTREATMENT OF STEPPE SOILS

Enormous soil losses have occurred on US cropland derived from prairies, grassland which had been grazed since the last ice age. Calculations show that soil loss through erosion amounts to roughly 30 % in 100 years; an estimated average of 13 tons of soil per hectare and year continue to be lost[126]. The same is the case in the Ukraine: According to a 2014 study by the World Bank and the FAO, soil losses[127] amount to 50 %, the

Monocultures threaten breadbaskets: if the soil degradation were not slowed down, all topsoil worldwide could disappear within 60 year. Maria Helena Sameda, FAO expert for the protection of natural resources on the occasion of the 2014 World Soil Day.

Maria Helena Sameda, FAO expert for the protection of natural resources on the occasion of the 2014 World Soil Day.

Extended periods of drought or an increase in heavy rain events: the potential of grasslands finally has to be promoted, through research and in practice.

current average loss can be up to 15 tons per hectare and year. This type of soil degradation through erosion is the unavoidable consequence of the non-sustainable use of the particularly fertile steppe soils.

The past, currently and prospective importance of grassland and its grazing animals is still being largely ignored and/or underestimated: for the naturally occurring building of soils through grazing as well as for sustainable grazing management. In view of the unused potential it is interesting to note, that the potential of grassland today is mostly reduced of that of non-arable land: grassland with little fertility. So, the steppe origin of the most fertile plains of the world – that of the so-called bread baskets – is almost always overlooked. With permanent grassland as an ideal, the "evergreen modell" (planting cover crops to always have living roots in the soil) avoids erosion in cropland, but as yet it's not widely implemented[128].

4. REALISING THE POTENTIAL – APPRECIATION AND IMPLEMENTATION

As yet, the immense potential of sustainable grassland use - for soil building and fertility and thus inextricably linked to climate mitigation – is not truly perceived and only marginally utilised. Grazing in particular is under-valued. As badly managed intensive use leads to overgrazing which of course makes things worse, the expectations for grazing are reduced while reservations regarding ruminants increase. While grazing too intensively damages the potential for soil fertility, zero grazing – as in an all or nothing approach – isn't the answer: sustainable grazing is.

Within the concept of climate change the challenge and the chance lies in turning the focus on grassland and its potential. This is particularly true for its potential to build soil and the climate mitigation linked to it. In addition, there are the effects on the protection of soils and water bodies during prolonged periods of drought as well as during increased heavy rain events.

The permaculture that is grassland has a different growth dynamic than the permaculture forest. For one, grasses produce less plant biomass per hectare than trees; worldwide, there is much more carbon stored in grassland ecosystems than in forest ecosystems. The challenge is to realise that this only seems contradictory because the whole of the organic biomass – including the organic carbon stored in top soils - has to be taken into account. Therefore, grassland and grazing management and their influence on biodiversity are absolutely key[129] for the building of fertile soils.

The solution does not lie in the one-sided reduction of emissions – neither through less methane per production unit nor through maximising long-term storage of carbon in the soil.

The solution lies in promoting biological cooperation rather than competition: through good management, shifting the balance from processes that degrade the organic soil carbon to biological processes that sustainably build fertile topsoil.

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POLITICAL DEMANDS

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The wet spring in 2017 and the drought in the summers of 2018 and 2019 have made it more than obvious: because of climate change and the resulting extreme weather events, farmers increasingly face risks. The political solutions offered? Compensation payments worth many millions. And the longer-term solution: precision agriculture and insurance. It won't be enough.

As Dr Andrea Beste and Dr Anita Idel have shown convincingly, we need to rethink the systemic approach instead.

My conclusion: this is what needs to happen

01 Organic agriculture has to be top of every agenda on climate protection and climate adaptation in agriculture.

Organic agriculture is effective in mitigating climate change and enhances the resilience of the agricultural system: in humus building, in water retention and storage as well as in biodiversity above and below ground. On the basis of the scientific knowledge available today organic agriculture is therefore the best available, controlled systemic climate adaptation and protection measure.

02 At least 20% of funds in the "Horizon Europe" research programme and in any follow up programme should be allocated to agricultural research for organic agriculture.

Research and development of organic agriculture are the best investment into future oriented crop and grassland systems.

03 Agricultural extension services have to be expanded and trained in known climate adaptation techniques like crop rotation and humus building.

04 Research, training and consultation in regard to permaculture and agroforestry systems have to be intensified and promoted on a large scale.

05 Subsidies for agro-energy have to be scaled down to zero.

Only bioenergy production from waste materials makes sense (cascaded utilization).

06 Programmes related to climate and environmental protection should not recommend no-till unless the practice is embedded in an organic agricultural system

On the contrary: No-till systems that depend on the use of herbicides hamper climate and soil protection.

07 Livestock farming has to be matched to the available forage area and growing conditions.

Industrial livestock farming that is not tied to the land is one of the most important factors in agriculture that drives climate change.

08 Support of on-farm cultivation of feed and protein crops in Europe has to continue. But intensively farmed monocultures like soy do not merit subsidies.

09 Research reflecting the special dynamics of grassland should be supported. The same goes for communicating the findings to practitioners working with grazing animals and grassland.

Better use has to be made of the particular potential of grasslands for the promotion of soil fertility, flood protection, balanced watersheds, climate mitigation and the enhancement of biodiversity

10 Pasture grazing must be supported – even with coupled payments.

Sustainable pasture grazing is active grassland and climate protection.

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THE BELIEF IN TECHNOLOGY AND BIG DATA

THE MYTH OF CLIMATE SMART AGRICULTURE – WHY LESS BAD ISN'T GOOD

At a time when rains fail and yields crash, not just climate compatible agriculture, but the climate adaptation of agricultural systems are more relevant than ever.

The study "The myth of climate smart agriculture – why less bad isn't good" discusses these topics. Has the impact of agriculture on climate change been accurately depicted so far? Methane burping cows are pilloried, but nitrous oxide emission from massive nitrogen inputs go almost unnoticed. Linking farm acreage to livestock numbers, soil fertility and pasture grazing – what role do such measures have to play in climate adapted agriculture? How big is the climate protection and adaptation potential of current digitalization and precision farming compared to that of ecological agricultural methods and organic agriculture?

By presenting facts and data, this study shows why the so-called modern intensive agricultural system is more climate damaging than climate smart. The authors show that corrections via Big Data, precision farming and increasing yields per hectare/animal unit cannot significantly change this.

In this study Dr Andrea Beste and Dr Anita Idel also show, how arable and livestock farming can be made truly sustainable, climate friendly and climate proof: cattle shouldn't be demonized instead their potential must be realised. Agricultural systems can become resilient and flexible and thereby able to even out extreme weather events for longer.

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