ECOLOGICAL RECYCLING AGRICULTURE

Guidelines for farmers and advisors Vol I - IV

Farming guidelines

Economic guidelines

Marketing guidelines

Farm examples

Vol I: FARMING GUIDELINES

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Partnership Instrument)

BERAS implementation
Baltic Ecological Recycling
Agriculture and Society

Baltic ECOLOGICAL RECYCLING AGRICULTURE and Society

What does BERAS mean?

In the BERAS Implementation (2010 - 2013) project a network of farms and social initiatives focusing on building the link within the whole food chain from farmer to consumer has been established to achieve a good environmental status of the Baltic Sea. The transnational project is part-funded by the European Union and Norway – The Baltic Sea Region Programme 2007 – 2013.

Ecological Recycling Agriculture is based on local and renewable resources and has the potential to

- reduce more than 50 % of the nitrogen surplus
- reduce the phosphorus surplus significantly
- avoid synthetic pesticides and enhance the natural control of pests through diverse crop rotations
- reduce greenhouse gas emissions through low input of external resources and increased carbon sequestration
- improve soil fertility and natural nitrogen reserves through legume cultivation
- protect biodiversity
- increase reliance on regional food supply
- enhance rural development in the region

An ERA farm is an ecological farm in line with the European Organic Regulations (EC No 834/2007) and additional criteria:

Crop rotation: at least 30 % legumes

Balanced livestock/land ratio: 0.5 - 1.0 animal livestock unit per ha

Self-sufficiency in resources: more than 80 % self-sufficient in fodder and manure

Effective nutrient recycling: within the farm and between farm cooperations

Ecological Recycling Agriculture
Guidelines for Farmers and Advisors

The Box of Guidelines contains

Vol. 1	Farming Guidelines
Vol. 2	Economic Guidelines
Vol. 3	Marketing Guidelines
Vol. 4	Farm Examples

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Vol. 1 Farming Guidelines

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Catchment area of the Baltic Sea

BERAS future

Following the conclusion of the EU project BERAS Implementation in 2013 a Network Agreement has been concluded to further develop BERAS and secure the continuation of the concepts both in the Baltic Sea Region and to share our competence and building alliances with initiatives in other parts of the world.

Preface

Resilience of our ecosystems is at stake

Despite various measures the eutrophication of the Baltic Sea is not decreasing and the resilience of multiple ecosystems is at stake. In this situation business as usual is not an option. New approaches are needed creating a safe operating space within the environmental boundaries. BERAS develops and implements practical examples where innovation and entrepreneurship from a multisectorial engagement flows into realistic, fully integrated ecological alternatives for the whole food chain - from farmer to consumer.

BERAS - background and main concepts

The BERAS concepts have been developed through two transnational projects part-financed by the European Union and Norway (the Baltic Sea Region Programme), BERAS (2003 – 2006) and BERAS Implementation (2010 – 2013). It is the common efforts from the partnership from nine countries around the Baltic Sea (Sweden, Denmark, Germany, Poland, Belarus, Lithuania, Latvia, Estonia and Finland), Russia and Norway and includes national and local authorities, universities and research institutes, advisory services, ecological and environmental NGOs, farmers' organizations, food chain actors and finance institutions.
The concept of Ecological Recycling Agriculture (ERA) is based on many years of research and studies on how organic farms can be organized to be truly sustainable and environment-friendly and has demonstrated its potential related to reduction of nutrient leakage from the farm, soil carbon sequestration/climate effect, biodiversity and increased soil fertility. BERAS has also successfully started the implementation of fully integrated, full scale examples of regional Sustainable Food Societies (SFS) in all countries in the Baltic Sea Region. The consumer engagement concept "Diet for a clean Baltic" offers a sustainable lifestyle with consumption of enough and good food without threatening the environment of the Baltic Sea or the planetary boundaries.

Guidelines for farmers and advisors

The Guidelines for Ecological Recycling Agriculture focus on the work by the farmer. It is the result of a transnational Baltic Sea Region cooperation by farmers, advisors and researchers. With the guidelines, we hope to encourage and help conventional farmers to convert to ERA farming as well as to support organic farmers to optimize their system towards recycling agriculture.
We want to thank each of the individual authors of these Guidelines for their dedication to the work and also for the coordinating function performed by Dr. Karin Stein-Bachinger at the Leibniz-Centre for Agricultural Landscape Research in Germany.

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HOW TO SAVE THE BALTIC SEA

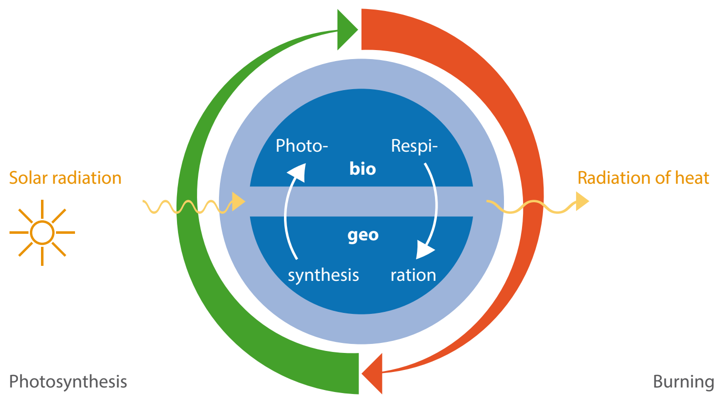
Artur Granstedt and Karin Stein-Bachinger

Key objectives

Global aspects

The flow of energy from the sun, the recycling of nutrients and organic matter and the diversity of living organisms in interaction give us the air we breathe, the water we drink and the food we eat. Birth and death feed on and into each other. In a balanced ecosystem the synthesis of complex organic substances through the photosynthetic capacity of green plants is in equilibrium with the decomposition and combustion of organic matter. Our future is now threatened because the decomposition of organic matter and the combustion of fossil carbon compounds are greater than the synthesis by green plants [24, 1].

Basic ecological conditions [24, compare 1]
energy flow, recycling and biological diversity



Ecosystem earth out of balance

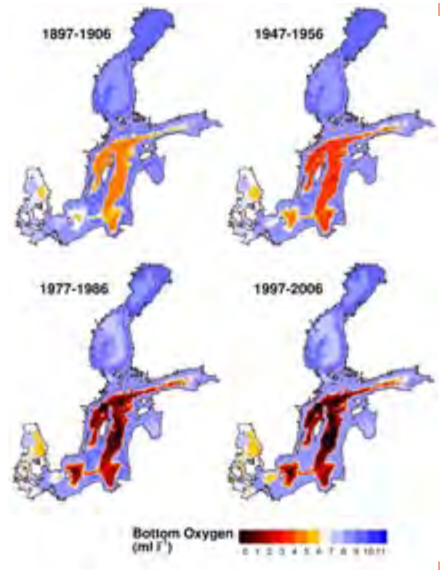
What can we do?

Without recycling in agriculture and other sectors non-renewable resources are exploited and released into the environment resulting in more and more pollution. The global growing surplus of carbon dioxide and other greenhouse gases in the atmosphere and the regional surplus of nitrogen and phosphorus compounds in the soil and water systems together with increasing amounts of poisonous chemicals is the challenge of our time.

Ecological farming and a changed lifestyle can help us meet these challenges - but we must act now! The objective of the BERAS Implementation project, of which these guidelines are a part, is to support activities within the agricultural sector that will help to restore the ecological balance through conversion to ERA farming including the whole food chain from farmer to consumer.

Ecological situation of the Baltic Sea

The Baltic Sea is a unique marine area. The losses of nitrogen and phosphorus via leaching and erosion are a prime contributor to the eutrophication of streams, lakes and, ultimately, the sea. There, they stimulate the growth of algae, leading to the so-called algae bloom. When the algae die in autumn their decomposition uses up the dissolved oxygen in the water. The depletion of the dissolved oxygen favors organisms that release hydrogen sulphide that kills many fish and aquatic organisms. This results in marine dead zones in the sea bed which increase every year. Hydrogen sulphide is now produced in large areas – close to 70,000 square kilometers [1].



Areas of the Baltic Sea that have oxygen-free (< 2ml O/ liter water) seabeds [47]

Drainage area

The Baltic Sea drainage area covers ca. 1.7 million km^2, an area about four times as large as itself. Sweden (25 %), Finland (19 %), Poland (18 %) and Russia (17 %) have the highest share, while Belarus (5 %), Latvia (4 %), Lithuania (4 %), Estonia (3 %), Denmark (2 %), Germany (2 %), Norway (1 %), and Ukraine (1 %) have a small share. A total of 85 million people live in this land area. It consists of 160 million ha of which 30 million is arable land. Agriculture is responsible for about 50 % of both nitrogen and phosphorus leaching to the Baltic Sea.

HELCOM

For three decades, the Helsinki Commission (HELCOM) has worked to protect the marine environment of the Baltic Sea from all sources of pollution through intergovernmental cooperation between the countries in this drainage area [42]. The HELCOM Baltic Sea Action Plan aims at restoring the good environmental status of the Baltic marine environment by 2021 (www.helcom.fi) (see [1] pp 49).

Present agricultural situation

In Sweden specialized crop farms dominate the fertile plains of the country. On these farms on average 150 kg nitrogen (N) per ha and year is applied. This is mainly in the form of artificial fertilizers produced with the help of fossil energy (about 1 kg oil per kg N and the additional emission of greenhouse gases from the Haber Bosch process). The return from this input is on average 100 kg N/ha in crop products resulting in a surplus lost to the environment of about 50 kg N/ha and year. The figure below is based on official statistics from the national extension programme for nutrient conservation "greppa näringen" in Sweden including more than 1,000 farms [1, 2].

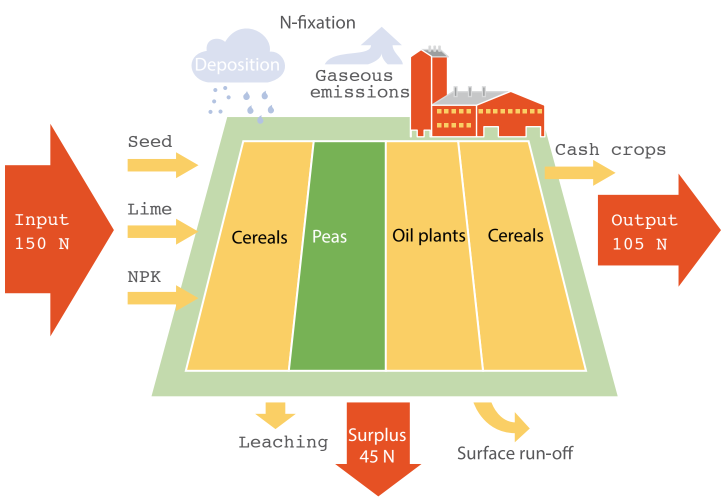
Although it is not these types of farms that have the highest losses of nitrogen and phosphorus running out into the Baltic Sea, it is here that the prerequisites are created for the high losses. Most of the crop production is sold via the fodder industry to specialized animal farms where high nutrient surpluses are accumulated and lost to the atmosphere and to water systems instead of being recycled (up to 130 kg N/ha) [1, 2].

The specialized crop farm is dependent on the annual input of artificial fertilizers, the macro-nutrients N, P and K, to compensate the output. As illustrated below mainly grain is produced. Approximately 80 % of all grain produced is sold via the fodder industry to specialized animal farms.

Specialized crop farm [1]

Input, output and surplus of Nitrogen (kg/ha and year)

Average: 563 farms 2001 - 2006, data from Swedish board of agriculture report 2008: 25



Animal production is mainly concentrated in southern Sweden, Denmark and Central-West Finland. Specialized animal farms have an animal density which is two to three times higher than that which can be based on the farm's own fodder production. As a result the manure production is much higher than what can be utilized in the farm's own crop production. Plant nutrients in the animal fodder produced on the specialized crop farms are exported to the increasingly fewer but more intensive animal farms where the surplus is accumulated and finally results in losses to the environment (a linear flow).

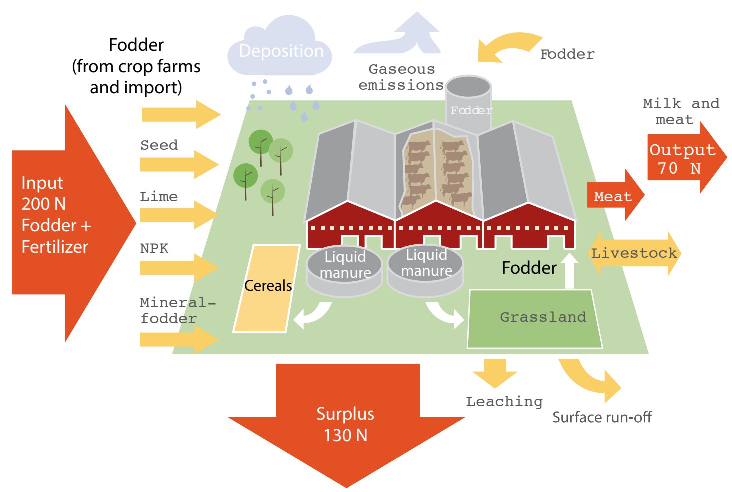
A part of the fodder input is additionally imported from other countries with serious environmental consequences such as deforestation to give room for soya and palm oil production. Animal farms with grassland also buy artificial fertilizers despite a surplus of animal manure.

Data from 701 farms [1, 2] presented in the example below show an average surplus on dairy farms of 130 kg N and 3 kg P per ha and year. The increasing animal density results in increasing surpluses of nitrogen and phosphorus. It is this type of farm that contributes most to agriculture being responsible for an essential part of the nitrogen and phosphorus pollution to the Baltic Sea.

Specialized animal farm [1]

Input, output and surplus of nitrogen (kg/ha and year)

Average 701 dairy farms 2000-2006, data from Swedish board of agriculture report 2008: 25



Future scenarios

If the new EU states Estonia, Latvia, Lithuania and Poland reach the same levels of nutrient surplus as Sweden, Finland and Denmark the surplus and the total load to the Baltic Sea would increase by more than 50 % [2, 3]. Long term field trials and the evaluation of nutrient fluxes on farms show how it is possible to increase soil fertility and natural production capacity through a highly productive, modern, organic farming practice based on local and renewable resources – Ecological Recycling Agriculture (ERA) by building a link within the whole food chain from farmer to consumer [1].

Effects of ERA

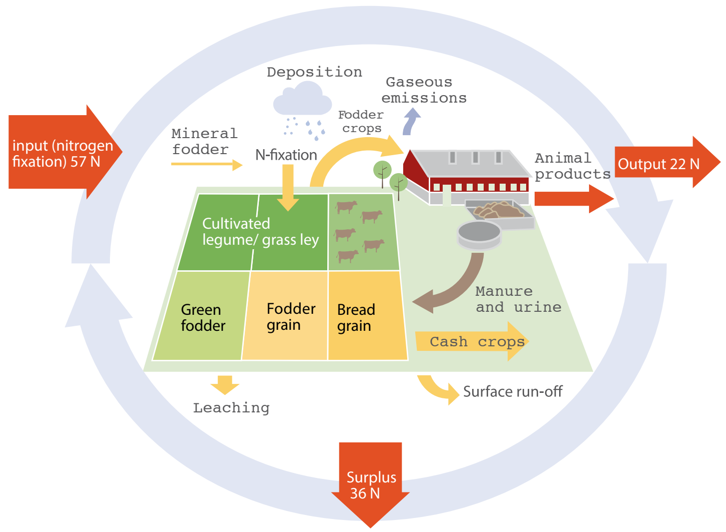
ERA results in a more than 50 % lower nitrogen surplus per ha and lower greenhouse gas emissions compared to conventional agriculture [2,3]. Nearly no losses of phosphorus will occur as well as a complete prevention of synthetic pesticide loads. Low input of external resources cause a reduction of greenhouse gas emissions. Additional improvement of soil fertility and quality of food as well as biodiversity are also well documented [1,3,12,50].

Ecological recycling agriculture does not imply that we return to the illusion of idyllic pictures from 100 years ago. However it does mean that we can – using all the technological and biological knowledge we have today – recreate agriculture that is based on the underlying conditions necessary for sustaining an ecosystem and make informed human participation possible in the future.

Principles of Ecological Recycling Agriculture

ERA is based on the recycling principle of ecological agriculture combined with diverse crop rotation with a high share of symbiotic nitrogen-fixing legumes like clover-grass leys, other fodder crops and food crops for sales. ERA farms have a good balance between crop and animal production with an animal density on each farm (or farms in close recycling cooperation) adapted to the farm's own fodder production. A maximum of 20 % of the fodder can be imported from other farms if the goal of 50 % lower losses of nitrogen per ha compared to the average conventional agriculture is to be realized [1].

Schematic illustration of the Ecological Recycling (ERA) farm [1]



The inner cycle shows the main flows of nutrients and organic matter between soil, stable and crops [1]. Key elements of the crop rotation are the legumes included e.g. in the leys. As humus building crops they ensure a sustainable soil fertility and nitrogen supply to the following crop and are beneficial for plant protection. A large share of the harvest from the farm feeds its animals. On ERA farms, ruminants (animal husbandry) play a main role as they can digest cellulose which means they can feed on crops that cannot be used for human nutrition. Their manure is returned to the soil and contributes to soil fertility.

Farm example – Nutrient recycling

This farm example describes the distribution of crops, crop rotation and animals on the biodynamic experimental farm Skilleby in Järna, Sweden, which is representative for the average of the Ecological Recycling Agriculture (ERA) farms studied [2, 3].

The number of animals is adapted to the farm's fodder production capacity (0.6 livestock units per ha). This is the same animal density that average agriculture has and is related to our consumption of animal products in Europe (2/3 of the protein consumption). On this farm this is based on ruminants. The rest of the arable land on the farm (16 %) is used for human food crop production, mainly bread grain but also horticulture production.

It is important to note that the stable manure on this ERA farm is also used for biogas production in a unique two stage biogas plant before being used as recycled fertilizer. The substrate for biogas production can also include ecological wastes from large scale kitchens, thus increasing the rate of recycled nutrients.

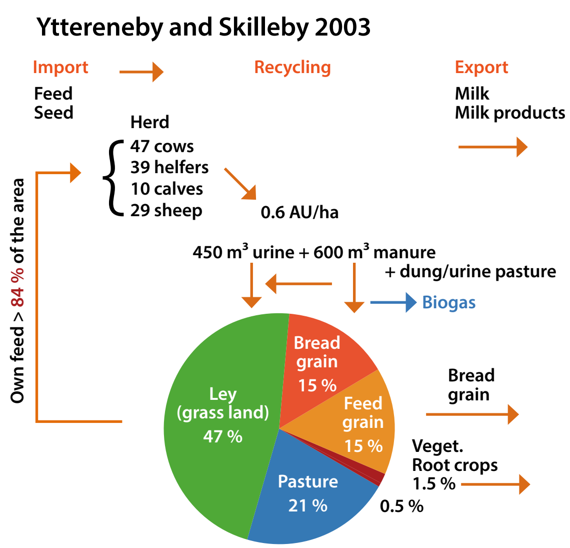
Example of Ecological Recycling Agriculture / ERA

Prototype farm

The prototype farm Ytterenéby – Skilleby in Järna, Sweden

The animal density is adjusted to the farm's feed production capacity. In this case fodder crops on 84 % and crops for sale on 16 % of the farm area and an animal density of 0.6 AU/ha (= average for Sweden and European food consumption) [1].

Arable land	ha		Crop rotation	
Crop rotation	106	Year	1	Spring cereals + insowing
Pasture	29		2	Ley I
Vegetable -			3	Ley II
Root crops	2		4	Ley III
Total	**137**		5	Winter cereals
Natural pasture	25			



BERAS implementation
Baltic Ecological Recycling Agriculture and Society

SOIL FERTILITY

Karin Stein-Bachinger

Why it matters

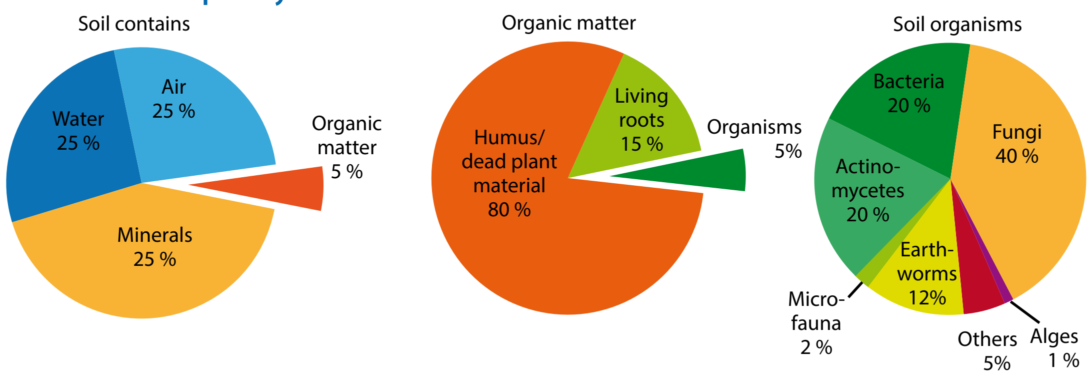
Global aspects

The soil provides a basis for life and is an unique and complex system, consisting of innumerable living organisms. Composed of organic matter, minerals, water and air, soil keeps the multiple metabolic processes going. Only about 11 % (1.5 billion ha) of the globe's land surface (13.4 billion ha) is arable land that can be used for crop production [34]. In addition, permanent grassland serves as the basis for fodder production for ruminants (animal husbandry). To ensure our future capacity to produce food for the earth´s increasing population, caring for a living soil that provides the basis for a sustainable food production is essential.
Agricultural systems with a high share of monocultures of annual crops, overgrazing and/or intensive use of harmful chemicals result in the degradation and deterioration of fertile soils. Replacing this lost arable land and grassland by opening up new forest areas results in deforestation which is one major source of increasing greenhouse gas emissions contributing to global warming.

Multifunctionality

In addition to the soil functioning as a natural habitat and a source of nutrients, soil fertility is essential for the protection of our water resources. Also, soils have the capacity to function as an important carbon sink and in this way reduce greenhouse gas emissions. ERA farming systems [1] contribute to the fulfillment of many important functions and ecosystem services through the maintenance of our most important resource: the soil.

The soil as a complex system [35]



A handful of soil contains more living organisms than human beings on earth! Looking deeper into the soil a huge variety of soil organisms like bacteria, fungi, earthworms etc. live on the soil organic matter or on other soil organisms and perform a number of vital processes in the soil. Special organisms are involved in transformation of inorganic substances [35].

Principles of soil fertility

Soil fertility cannot be bought. It results from continuous interactions between living and decomposition processes. Natural ecosystems have been built up through the continuous cycle of life and death of organisms that form soil organic matter (SOM). Within this cycle, the fixation of carbon and nitrogen are very important aspects. The recirculation and accumulation of all components of SOM via plant residues and the decomposition of residues together with a high share of soil forming organisms are the keys to life [35,36].

In an ecosystem strongly influenced by human activity it is very important to maintain a high capacity for the formation of soil humus to prevent soil degradation. In essence this means that arable soils need to have enough perennial crops to ensure nitrogen and carbon fixation. In ERA farming systems, it is necessary to have about one third of the crop rotation under perennial crops like clover-grass to compensate the decomposition of SOM and provide enough nitrogen mineralization on arable land (compare legumes).

Long term soil fertility is affected by all farm management decisions, mainly by the crop rotation and tillage, animal husbandry and the recycling of manure derived from fodder produced on the farm.

Organic matter includes all dead plant, animal and microbial materials in and on the soil and their organic conversion products, exudates etc. **Humus** is the final product of the decomposition process in the soil (humification) by its organisms [9]. It has a black or dark brown color, due to an accumulation of organic carbon. Up to 80 % of the organic matter consists of stable, inert humus, about 20 % can be metabolized. Increase in humus leads to C enrichment, a decrease leads to CO_2 release into the air. Dead and living organic matter are analyzed as carbon content (C_{org} in %).

The humus content is calculated by multiplying the C_{org} content with the factor 1.7.
Humus in mineral soils contains about 58 % C:
1 % C = 1.7 % humus
1 % C = 45 t C/ha = 80 t humus/ha in the top soil 0-20 cm
C : N ratio of 10 : 1 = 4,500 kg N/ha

Functions and benefits of soil organic matter

Distinctive for fertile soils is their sustained productivity, of great importance to farmers, as well as their high self-regulation capacity, e.g. against pathogens. Fertile soils provide us with clean groundwater, serve as filter, buffer and storage of harmful substances, store nutrients and carbon [36].

The guiding principle from the beginning of organic farming in the early 1920s is described by the functional chain: healthy soils – healthy plants – healthy animals – healthy human beings [36]. Humus provides the basis for continuous building and decomposition processes and influences the physical, chemical and biological soil characteristics. In ERA farming systems the equilibrium of these processes is a key element for sustainable production.

Soil organic matter and humus [9]

- improve soil life and its structure
- supply, inter alia, nutrients to the soil and soil microorganisms
- increase the water-holding capacity
- improve porosity for air and water as well as friability of heavy soils
- prevent nutrients from leaching
- stabilize soils against erosion
- improve plant growth in spring through a quicker soil heating
- lead to saving of energy through easier tillage
- have positive climatic effects as CO_2 sink.

CO_2 accumulation capacity

Calculations show [15] that a carbon accumulation in soils up to 500 kg C/ha and year is possible to achieve, depending on the initial content and the share of legume-grass and other humus building crops in the crop rotation. This equals about 1.5 up to 2.0 t CO_2/ha and year.

Humus content and quality

The humus content of the soil is characterized by organic carbon (C_{org}) and nitrogen (N_{org}). Their proportion gives some notion of the humus quality. The C : N ratio in soils varies between 10-12 : 1 (manure). Humus content can only be increased within a particular range (e.g. it takes 40 – 60 years to increase the carbon content in top soil by 1 % [25]). Arable soils contain 0.6 – 4.0 % carbon. In line with the Cross Compliance regulations there should be a minimum content of humus in different soil types when analyzed over a six year period (data for Germany) [18]:

Clay content < 13 %: 1 % humus (= 0.6 % C)

Clay content > 13 %: 1.5 % humus (= 0.9 % C)

Clay content > 25 %: > 2 % humus (= 1.2 % C)

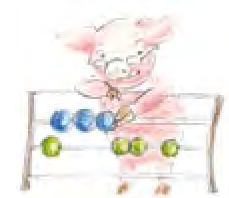
Fresh dead plant residues have a higher C : N ratio, while their decomposition leads to a lower C : N ratio. Organic material (from plants or manure) which is incorporated into the soil shallowly or deposited on the soil surface feeds the soil organisms, increases the aeration and the organic activity which leads to the mobilization of bound minerals making them available to the crops being cultivated.

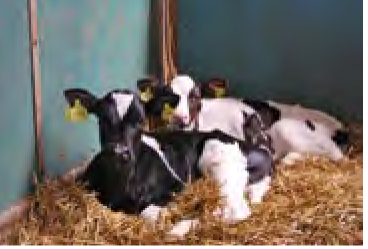
The activity of the soil organisms increases the weathering processes which in turn influences the mineralization processes. A short vegetation period, high precipitation and droughts all lead to a lower mineralization rate. Soil tillage and the liming of acid soils increase the activity of bacteria and can lead to a decrease of humus [9]. Crop rotations with legumes maintain the favorable microbial population balance thereby improving soil fertility.

On arable land the top soil contains about 60 - 90 t humus per ha. This is the equivalent of about 3000 - 6000 kg of N per hectare. Under good temperature and soil moisture conditions about 1 - 3 % of the organic nitrogen can, together with other nutrients such as phosphorus, sulfur and important trace elements, bound in the soil organic matter become available to plants through the mineralization [27].

Calculation example

Humus content of:		mineralization of:
1.5 %	➜	20 - 40 kg N/ha
3.0 %	➜	40 - 80 kg N/ha





How to maintain and increase soil fertility

Recommendations

All management decisions like crop rotation and tillage, animal husbandry and manure handling affect the soil fertility in the long run. Positive effects can be reached by [19, 9]:

- Carefully planning the crop rotation by including at least 30 % ley content, based on legume grass mixtures as the main humus-increasing crop. A balanced proportion of humus demanding crops and fertility building crops is necessary.

  One key factor for increasing soil fertility is the effective rooting depth of the cultivated plants. Annual crops like cereals can reach up to 1.5 m rooting depth, while alfalfa can reach 4.0 m if grown as a perennial. Root hairs have a substantial effect on the spatial access of the plant to potassium and other essential nutrients in the soil [37].
- Supplying organic matter via green manure (e.g. catch and cover crops) and animal manure (solid manure, slurry, compost). Harvest residues (stubble, straw) and roots have a positive effect as well.
- Equally distributing and incorporating plant residues and manure.
- Keeping the soil covered with plants as much as possible to avoid erosion and nutrient leaching.
- Minimizing tillage. Intensive inverting tillage can decrease humus content considerably.
- Preventing soil compaction. Microbial activity improves with aerated soil and water permeable pores. Well functioning soil drainage improves plant health, rooting depth and intensity and the uptake of nutrients.
- Ensuring a sufficient lime supply, which is the precondition for topsoil stability and nutrient availability. Acidity reduces bacterial activity which results in lower rates of decomposition and nutrient releases, phosphorus and molybdenum deficiencies can occur due to fixation. The optimum pH for most crops is between 6.0 and 7.0. Legumes are particularly sensitive to acidity, while potatoes thrive in moderately acidic soils. The availability of phosphorous decreases at pH > 7.

Source: adapted from Kutschera, Wurzelatlas (1960)

Earthworms [51]

Earthworms, along with other soil animals, play an unique role in building up soil fertility. With a life expectancy of up to 8 years they produce up to 100 t excrement per ha and year. This is the equivalent of up to 0.5 cm soil increase in arable soils, and 1.5 cm on grasslands. Their excrements contain 5 times more N, 7 times more P and 11 times more K than the surrounding soil. Their activities have a positive effect on the soil by building stable crumbly structures which increase the aeration as well as the water and nutrient holding capacity and the facilitation of soil tillage.

On arable fields earthworms incorporate up to 6 t of organic residues per ha and year and carry soil material from the subsoil to the top soil. Up to 90 % of the earthworm channels are occupied by plant roots allowing them to reach into deep soil layers without resistance. Intensive soil tillage decreases the amount of earthworm channels in the soil, leading to a reduced humus content. Especially rotation machines can cause earthworm losses of up to 70 % [35,51].

Keep in mind!

Crops and their effects on the humus content [25,38]

Negative humus effect			Positive humus effect		
---	--	-	+	++	+++
Sugar beet Potatoes Vegetables	Maize Vegetables	Cereals Oil plants	Grain legumes Stubble crops Legume-grass sown in autumn	Winter cover crops Legume-grass undersown in spring	Perennial legumes Legume-grass

Effects of agronomic measures on carbon (C) fixation in soils [15]

Measure	C fixation / reduction (t/ha and year)
Conversion from arable land to grassland, green legume-based fallow	> 1.0
Cultivation of perennial legumes/legume-grass mixtures	0.6 up to > 1.0
Organic fertilizers (manure, digestate, compost)	> 0.5
Reduced tillage	0 up to 0.25
Conversion from grassland/fallow to arable land	> -1.0
Cultivation of maize for silage	-0.4 up to -0.8

Control of soil fertility

From the farmers point of view, there are different ways to assess soil fertility. Because of the high complexity of the dynamic soil processes a combination of several methods is recommended: visual methods by going out on the fields, analytic methods and humus and nitrogen balancing methods [25, 36, 38, 39].

a) Visual check

- Healthy plants are an indicator of a good soil condition.
- Weeds like thistles and chamomile indicate soil compaction.
- Soil structure on the surface: round soil particles and small holes (e.g. from earthworm activities) indicate a fertile soil as opposed to erosion signs.
- Incorporation of plant residues: e.g. if straw remains on the surface for several months, the soil organisms are not active.
- A fertile soil smells and feels good (finger test).
- During wet periods and in early spring the crops indicate where mineralization and the content of plant nutrients are low. Soil compaction, bad drainage systems and water logging can result in a lack of nitrogen which would limit crop yields.

b) Visual check using inexpensive measurement equipment

- Spade diagnosis [36] to identify soil compaction, root density and diversity, structure of soil particles (round or sharp-edged, possibility to break them apart), earthworm channels, other soil organisms.
- With a soil penetrometer (a 1 m stainless steel cone designed like a plant root with a driving shaft with or without a pressure gauge, see picture) the extent and depth of compacted soil layers can be felt (because high pressure is necessary to push the penetrometer into the soil) or measured. It should be used at water holding capacity, preferably in spring, to get the best-case scenario for root development.
- The pH value can be measured by using indicator sticks.

c) Analysis of the nutrient content

- According to country specific legal requirements soil analysis should be carried out every 6 years/field, based on representative field samples (e.g. in autumn after harvest or early in spring) and analyzed with standard methods.
- The basic nutrients P, K, Mg, S as well as micro-nutrients should reach a site specific level. These values can be found in the country-specific fertilization recommendations. If clear deficiencies are analyzed, a fertilization of these elements is reasonable, using recommended fertilizers according to organic standards regulations.

  ➔ Be aware that both P and S are partly organically bound and are recycled with crop residues, organic biomass and the farms own manure. The potential mineralization of the organically bound nutrients is not included in the common analysis values.

- The pH value should reach a site specific optimum. Values below 5 or above 8 must be avoided. On sandy soils a lower pH (5.5 – 6.5) is common. Deficiencies cause soil and plant health problems. Approved lime fertilizers can be found in the organic standards.

- The analysis of the nitrogen and carbon content plays a special role as changes become apparent only over a long period. Regarding nitrogen more than 95 % of the N is fixed in the organic matter, only 1 - 3 % becomes available through mineralization each year. Measuring the organic carbon content (C_{org}) gives an idea of the soil specific values that should be reached, but does not provide information on soil fertility!
- Soil samples should not be taken after the spread of manure due to their uneven distribution!

Humus balances

As an alternative or supplement to the methods previously described, humus balancing methods can be performed under practical conditions using easily available management data [25]. During the last decades there have been a lot of efforts to develop different methods, mainly in Germany [38]. Humus balancing methods are based on the share of humus reducing crops (root crops, silage maize) and humus producing crops (like legumes) in the crop rotation adding the supply of carbon rich substances like manure and straw [25]. Keeping in mind that this method cannot be transfered 1:1 to other countries, the following examples can give an impression about the effects of different cropping systems.

Calculation examples

Crop rotation A) is based on 40 % legumes and 0.5 LU/ha which results in a positive humus saldo.

Crop rotation B) with 20 % legumes and potatoes plus catch crops and fewer animals has a negative effect on the humus saldo. To compensate for the high humus demanding potatoes, a higher share of legumes and a reduced share of cereals and/or potatoes would be necessary.

A)	Humus demand*	Humus supply*		Humus saldo*
0.5 LU/ha → 4 t manure/ha and year		Catch crops	Farmyard manure	
Legume-grass	600	0	0	600
Winter wheat 20 t/ha rotted manure	-280	0	800	520
Triticale	-280	0	0	-280
Peas	160	0	0	160
Winter rye + legume-grass undersown	-280	200	0	-80
Mean value of the crop rotation	-16	40	160	**184**

B)	Humus demand*	Humus supply*		Humus saldo*
0.25 LU/ha → 2 t manure/ha and year		Catch crops	Farmyard manure	
Legume-grass	600	0	0	600
Winter wheat	- 280	0	0	-280
Potatoes 10 t/ha rotted manure	- 760	200	400	-160
Triticale	- 280	0	0	- 280
Winter rye + legume-grass undersown	- 280	200	0	- 80
Mean value of the crop rotation	- 200	80	80	**- 40**

* in kg C/ha and year

Although, there is still more research needed for the improvement and adaption of that method to different site conditions, this method can provide a rough estimation of the effects of various management practices on field level, especially during the conversion phase. The basis for the calculations are humus reproduction coefficients, derived from long-term field experiments [38]. They are recommended in the German Cross Compliance Regulations as one method for evaluating soil fertility. These calculations are integrated in the software tool ROTOR as well.

Nutrient balances

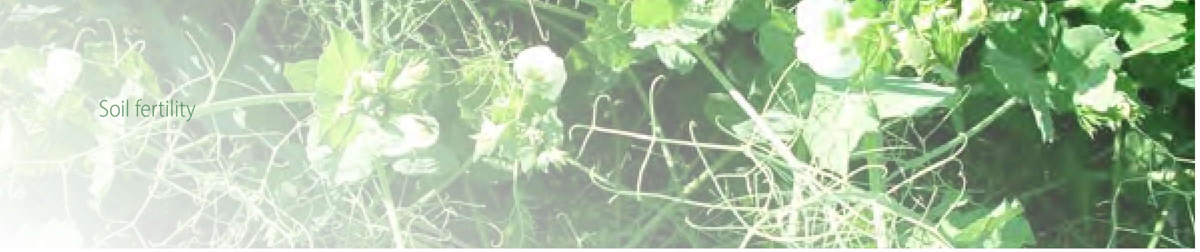
In addition to the previous methods, conclusions about nutrient fluxes and their efficiency on the farm level can be made with nutrient balancing methods (at the farm gate, field and stable level). Within the BERAS Implementation project as well as in the former BERAS project the farm gate balances for the involved countries have been calculated using the Swedish method STANK in MIND. Results can be found in several publications [1, 2, 3].
It is crucial to manage the binding and freeing of N and other nutrients in order to ensure that the level of available nutrients corresponds to the nutritional needs of the plant at any given time [1]. If this balance is achieved, nutrient losses to the environment are very low.

The nutrient balance at the **farm gate** provides information about the nutrient input from purchased goods (animals, seeds) including the N fixation of legumes. All sold products (crops, animals, milk etc.) are summarized as output [1, 5].
Taking nitrogen as an example, the difference between in- and output is an indicator for the farm and the environment:

Interpretation of the outcomes

1. Nitrogen surplus corresponds to potential N losses to the environment.
2. Balanced saldo (plus/minus 20 kg N/ha around zero) indicates a good status.
3. Negative saldo indicates a lack of nitrogen and an insufficient N supply within the farming system. The deficit needs to be compensated for by, e.g. increasing the portion of legumes within the crop rotation.

In case of phosphorus, a deficit of up to 2 kg P/ha seems to be well compensated through weathering processes and an uptake from the subsoil through deep rooting plants (e.g. clover and alfalfa) on mineral soils with a good status of non-soluble P stored in the mineral fractions.



Scientific results

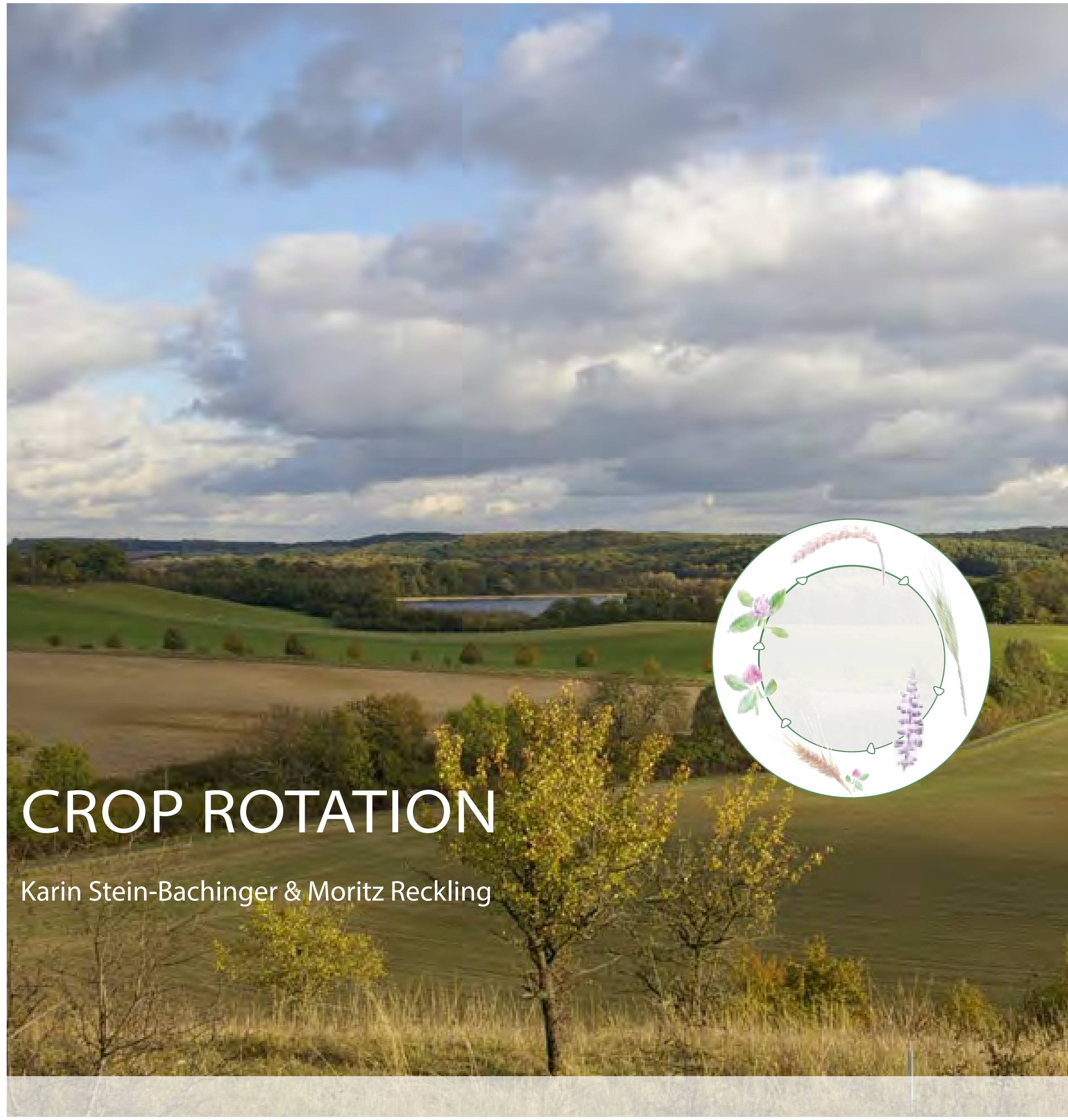
Farm gate balances on ERA farms around the Baltic Sea have shown that nutrient surpluses can be reduced effectively [1, 3]. Moreover, there is a whole range of agronomic measures (see crop rotation, legumes, manure, and phosphorus) to avoid potential losses from leaching with regard to specific site and weather conditions.

A new study based on a comprehensive assessment of 74 studies from pairwise comparisons of organic vs. non-organic farming systems [50] shows significant higher values of soil organic carbon for organically farmed soils, which means that organic/ERA farming has the potential to accumulate soil carbon.

However, investigations have also shown that nutrient deficiencies can occur [11, 40]. This can be the result of an insufficient share of legumes in the crop rotation or too little or ineffective manure handling. Investigations show that especially on specialized crop production farms the amount of legume-grass leys is reduced in order to maximize the share of cash crops. In such cases the necessary N-input could be provided by N-fixing cover or catch crops as well as undersown legumes in cereals. However, in the long run this can lead to a decline in soil fertility and to increasing weed infestation, which again would limit cash crop yields [40]. These are strong arguments for converting to ERA farming with integrated animal and crop production (on each farm or on cooperating farms in close proximity).

Legal restrictions

The permitted maximal N surplus since 2009 is set at 60 kg N/ha and year, the critical N-load in leaching water corresponds to a mean concentration of 50 mg nitrate/l [20]. In all countries official nutrient balancing methods are available in order to compare with the legal restrictions according to the Cross Compliance regulations. Ask your adviser for help with these calculations and their interpretations.



CROP ROTATION

Karin Stein-Bachinger & Moritz Reckling

Why it matters

Basics

Good planning and effective design of crop rotations are essential for ERA farms to ensure high yields and quality products as well as healthy and fertile soils. Legumes, which are deep rooting, nitrogen-fixing, humus and soil fertility building crops, are grown in combination with a balanced share of nitrogen- and humus-demanding crops like cereals and root crops.

History

The food demand of the growing population in the Nordic countries around the Baltic Sea 150 years ago could be met due to the integration of legumes in combination with the recycling of plant residues and manure. During this period every farm had only as many animals as it could feed from the farm [1]. In the middle of the 20th century, the increased use of mineral fertilizer and pesticides as well as the import of fodder from outside the farm led to an excessive simplification of crop sequences, with only a few crops that often did not include legumes. Since the 70s, when the interest in organic farming grew, the awareness of the importance of crop rotations increased as well. Nowadays effective crop rotations are acknowledged as being a foundation of successful organic cropping systems [21].

How to start?

During conversion to ERA farming, crop rotation needs to be adapted to the farm structure, site conditions, market options as well as labour and farm equipment. The main challenge is to ensure the farms profitability by building soil fertility for long-term productivity [8, 21].

The conversion process is started with the establishment of perennial legumes, mainly legume-grass mixtures, which are used as fodder or mulch. In many cases, farmers have more than one rotation sequence on their farm due to field variation and business decisions. However every crop rotation sequence on an ERA farm includes perennial legumes.

Definition

Crop rotation means the succession of humus-increasing and humus-demanding crops on a field throughout a cycle of several years, while at the same time taking the site and farm specific restrictions into consideration.

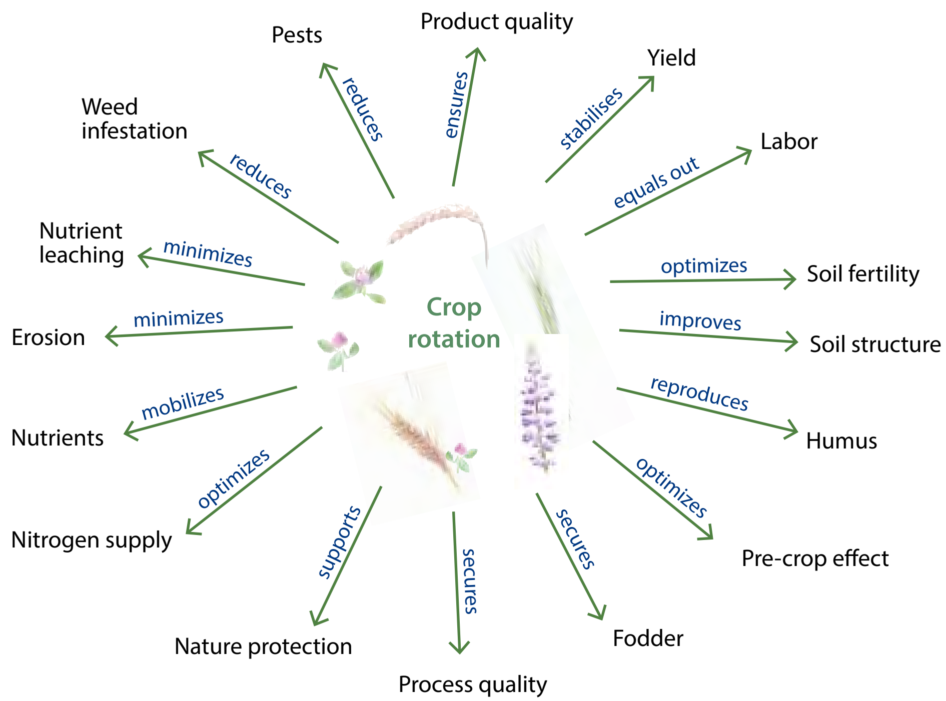
Aim and benefits of crop rotations

Main aims of designing crop rotations are to produce:

➜ economically profitable cash crops and
➜ high quality feed.

This is achieved by designing economic and agronomic sound rotations taking phytosanitary constraints and crop nutrition into account. In addition, well designed crop rotations provide many other benefits to the whole farm. They are the principle means for controlling weeds, pests and diseases, stabilize yields and ensure the quality of products, both food and feed. They also support environmental and nature conservation goals.

Multifunctional benefits of crop rotations [adapted from 58]



Most of these effects will be seen over several years and include both the direct effects between crops and the indirect preceding-crop effects through the soil which accumulate over several years.

Crop selection

To design sound crop rotations, the economic and agronomic characteristics of crops need to be considered carefully. The selection of crops that are well suited to the farming environment and farm structure is the most important aspect for designing a rotation.

The selection of crops is defined by

- the climate and soil type (rainfall distribution, temperature, pH and soil texture)
- the marketing potential and
- the feed requirements.

When converting to ERA farming the following steps can be implemented to ensure that the crops selected will fit the new system:

Six steps in the selection of crops when converting to ERA farming [22]

Step	Proposed change	Criteria for crop selection/exclusion	Crop examples
1	Exclude crops	Low marketing potential	Sugar beet, rape seed
2	Reduce share of crops	Phytosanitary constraints, diversification of cash crops	Wheat
		High weed infestation risk, low internal farm demand	Barley
		Nutrient supply difficult, replacement by legume-grass	Silage maize
3	Increase share of specific crops	Cover the demand for feed, N-fixation, weed and disease suppression	Legume-grass, grain legumes
4	Define share of cash crops	Marketing potential, economics, workload, crop rotation	Wheat, rye, potato
5	Include new crops	Marketing potential (occupy niches), crop diversification, crop rotation, N-fixation	Vegetables, spelt, legume-grass, legume/cereal mixture
6	Increase share of cover crops	Increasing soil fertility, fodder production, weed suppression, reduction of N-leaching,	Phacelia, rye/vetch, buckwheat, clover, mustard

The following characteristics need to be considered when selecting crops for inclusion in the crop rotation:

- the demand and supply of N
- effects on humus
- phytosanitary effects (maximum frequency and minimum breaks) and
- the risk of erosion.

The length of the crop rotation is defined by the minimum break and maximum frequency of the crops selected .

Crop characteristics relevant for ERA crop rotation (See also specifications for legumes) [expert assessment]

Crop	Maximum frequency (%)	Minimum break (years)	Demand of N	Supply of N*	Effects on humus	Risk of water erosion**
Forage legumes	strong regional differences		low	very high	strong increase	very low
Grain legumes	20	4	low	high	increase	low
Cereals (general)	75	see specifications in this table				
Leaf crops (general)	50	see specifications in this table				
Silage maize	66	0	high	low	strong decline	high
Potato	20	4	high	low	strong decline	high
Oat	25	3	low	low	decline	middle
Wheat, triticale	33	0	high	low	decline	middle
Barley	50	1	low	low	decline	middle
Rye	66	0	low	low	decline	middle
Rape seed	20	4	middle	rather high	decline	middle
Cover crops	-	-	low	high	increase	low

* the N supply describes the residual N effect; ** during the vegetation period

Proposed share of crop types (ha %) for different ERA farm types

[adapted from 22]

Farm type	Legumes	Cereals	Root crops	Catch crops
Dairy farm	30-50 [1)]	30-50	5-15	20-50
Mixed farm (mainly ruminants)	30-40 [2)]	40-60	10-20	20-50
Mixed farm (pigs)	30-35 [3)]	40-60	15-25	40-60

[1)] mainly forage legumes, [2)] forage and grain legumes, [3)] forage or grain legumes, for green manure, sale, clover seed production

Rotational characteristics

Crops and crop types need to be alternated in order to reduce infestation with problematic weeds, pests and diseases (plant protection). These include leaf and straw crops as well as winter and spring crops.

Bearing in mind the cropping limitations imposed by the farm structure, site conditions, market situation and the crop characteristics, the rotational characteristics describe the suitability of different crops in relation to each other. Note that specific details, such as new varieties and catch crops, have not been taken into consideration.

➜ For the suitability of crop combinations in the rotation, defined by one colour combining timing and phytosanitary constraints [23], choose the best combinations!

➜ Combinations of two crops with a very positive preceding-crop effect should be avoided ('luxury combinations').

➜ For the establishment of legume-grass different techniques are possible which require specific preceding crops e.g. cereals for undersowing.

➜ N-demanding crops with high economic value, e.g. potato or bread wheat, should be cultivated after legume-grass.

Suitability of different crop combinations in the rotation [adapted from 23]

Following crop \ Preceding crop	W. wheat	S. wheat	W. barley	S. barley	W. rye, triticale	Spelt	Oats	Maize	Legume-grass	Grain legumes	Potato	W. rape	Sunflower
W. wheat	Not advisable	Not advisable	Not advisable	Not advisable	Not advisable	Not advisable	Good	Good	Very good	Very good	Good	Very good	Unfavorable
S. wheat	Unfavorable	Unfavorable	Unfavorable	Unfavorable	Unfavorable	Unfavorable	Unfavorable	Very good	Very good	Good	Very good	Good	Good
W. barley	Good	Good	Not advisable	Not advisable	Unfavorable	Not advisable	Good	Not advisable	Good	Good	Unfavorable	Very good	Good
S. barley	Good	Good	Not advisable	Not advisable	Good	Not advisable	Not advisable	Very good	Unfavorable	Good	Very good	Good	Good
W. rye, triticale	Good	Good	Unfavorable	Unfavorable	Unfavorable	Unfavorable	Good	Good	Good	Very good	Good	Very good	Good
Spelt	Good	Good	Good	Not advisable	Good	Not advisable	Good	Good	Good	Good	Good	Very good	Good
Oats	Good	Good	Good	Not advisable	Good	Good	Not advisable	Very good	Good	Good	Very good	Good	Good
Maize	Very good	Very good	Very good	Good	Very good	Very good	Good	Unfavorable	Very good	Very good	Very good	Good	Good
Legume-grass	Not advisable	Not advisable	Very good	Very good	Very good	Very good	Very good	Good	Very good	Not advisable	Good	Unfavorable	Good
Grain legumes	Unfavorable	Unfavorable	Very good	Good	Good	Very good	Good	Very good	Not advisable	Not advisable	Very good	Good	Good
Potato	Very good	Very good	Good	Unfavorable	Good	Good	Unfavorable	Good	Very good	Very good	Not advisable	Very good	Unfavorable
Winter rape	Unfavorable	Unfavorable	Very good	Very good	Good	Good	Unfavorable	Not advisable	Good	Unfavorable	Not advisable	Not advisable	Not advisable
Sunflower	Good	Good	Very good	Good	Very good	Very good	Good	Very good	Not advisable	Unfavorable	Good	Unfavorable	Not advisable

W. = winter; S. = spring

Note: Plan to include catch crops before spring crops

Suitability of crop combination: Very good / Good / Unfavorable / Not advisable

Preceding-crop effects

Legumes, especially forage legumes are good preceding-crops because of their capacity to

- fix atmospheric nitrogen with the aid of nodule bacteria
- supply N to the following crop
- improve physical soil characteristics
- nurture soil organisms
- support accumulation of soil humus
- mobilize deep soil nutrient resources through deep roots
- supply phosphorus from soil store through mycorrhiza

Root and leaf crops are good preceding-crops because of their capacity to

- reduce weeds due to intensive mechanical cultivation measures
- improve physical soil characteristics often leaving crumbly, aerated soil behind
- supply high levels of N to subsequent crops due to low C/N ratio in crop residues

However they are less good due to their

- heavy decomposition of humus
- vulnerability to crop rotation diseases (especially potatoes and sugar beets)

Cereals are less good preceding-crops because they

- have a high C/N ratio in crop residues
- increase weed infestation risks and
- leave the soil in poor condition.

Note that cereals have a decreasing preceding-crop value from:
oat > rye > wheat > spring barley

Preceding-crop effect on yield

The preceding-crop effect on yield differs between crops and is influenced by the preceding-crop type and soil type. The yield of cereals, e.g. following legumes are 20-30 % higher in comparison to cereal pre-crops. Such effects on the yield of the subsequent crop need to be considered in the economic calculations and highlight the importance of well-designed crop rotations. The effect on yield is greater on infertile than on fertile soils.

Catch crops in ERA crop rotations

After selecting the main crops in the rotation, catch crops should be included where ever possible.

Catch crops like field mustard, rye/vetch, winter rape and legume mixtures, fulfil several functions in the rotation. These include:

- Reduction of nutrient losses through leaching and erosion
- Collection and storage of nitrogen (easily available for subsequent crops)
- Additional forage production
- Reduction of weed infestation
- Formation of additional root biomass
- Soil coverage and maintenance of good tilth.

Depending on the farm structure as well as the available vegetation period between the main crops, catch crops can be established as undersowings, or as summer or winter catch crops.

➜ The main factors to be considered when selecting catch crops are the length of the available vegetation period and water availability.

Recommendations

- Undersowings in dry regions and summer or winter catch crops in humid regions.
- Winter-hardy catch crops such as winter rape or rye grass should be used on sandy soils to reduce leaching.
- High infestation with perennial weeds should be controlled with stubble treatment which has priority over the establishment of catch crops.

To achieve the goal of 30 % legumes in the rotation, 33 % clover-grass in the 6 year crop rotation with more than 60 % clover would be necessary plus 1 year intercropping with legume mixtrure!
If less clover-grass is grown in the rotation, then the goal can only be met, if additional legumes (e.g. grain legumes) are included in the crop rotation!

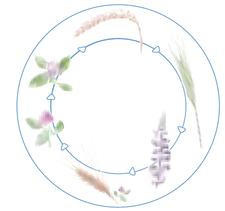
Share of legumes in rotations

In general the goal for ERA farms is to have at least 30 % legumes in the crop rotation, mainly of perennial clover-grass. Legumes grown in mixtures as main crops should be counted according to the following calculation example. Note that 30 % clover-grass is not the equivalent of 30 % clover in the rotation! Legume catch crops must be accounted less than main legume crops!

Calculation of the amount of legumes in a 6 year crop rotation

Crop mixture	% of the crop in the 6 years rotation	Legumes in the mixture (%)	Legumes in the rotation (%)
2 years clover-grass	33	30	10
2 years clover-grass	33	60	20
2 years clover-grass	33	80	25
1 year pea/oat intercropping	17	50	8
1 year grain legumes	17	100	17

Ten-point plan for crop rotation design [7, 8]



1. Select crops according to market potential and prices, feed requirements, soil type, climate and crop rotation characteristics.
2. A balanced rotation has from 30 % (pure legumes) to 40 % (legume-grass mixtures) legumes, a maximum of 20 % root crops and up to 60 % cereals. In cereal dominated rotations, integrate spring cereals and catch crops.
3. To achieve self-sufficiency in fodder, calculate the fodder requirements from field crops and arable forage taking the additional supply from permanent grassland into account.
4. To prevent serious soil borne pests and diseases (those with strong agronomic and economic consequences), apply cultivation breaks and maximum frequencies of host crops and crop families e.g. brassicas, cereals, grain legumes.
5. To prevent serious weed infestation, alternate between leaf and straw crops and between winter and spring crops and include at least one root crop.
6. Check the P, K, pH and humus status via soil analyses (soil fertility) and plan manure distribution carefully for each field during the crop rotation for best nutrient utilization and soil improvement to secure good yields and product quality, and to prevent nutrient leaching.
7. To determine the amount of cereals calculate the amount of straw needed for bedding.
8. To improve soil structure and the mobilization of nutrients and to assist drainage, grow deep rooting crops after shallow rooting crops and minimize soil compaction caused by heavy machinery especially during wet conditions.
9. To even out the work load and promote the germination of different weed species alternate between autumn sown and spring sown crops.
10. To prevent nutrient leaching and erosion minimize periods when soil is bare. Plant cover crops, plant catch crops after spring crops and vice versa, grow undercrops (legumes) and crop mixtures.

And finally: document failures and successes to help redesign the crop rotation for the future!

Do you want to make sure that the crop rotation is sustainable?

➜ Calculate humus balances (soil fertility)

Do you want support for crop rotation planning and evaluation?

➜ Use the software tool ROTOR

Examples of crop rotations

for mixed ERA farms
[21, 1, 5]

During the two year period of conversion it is recommended to increase the amount of legumes above 30 % to build up soil fertility. Pig and poultry farms have difficulties to reach such a high share of legumes, because these animals are not fed forage legumes. Instead these farmers should consider growing grain legumes, legume catch crops and legume-grass for mulching.

➜ Note that perennial legume-grass cultivation has a more favourable effect on soil fertility than annual cropping.

Agronomically sound crop rotations from around the Baltic Sea

<table>
<tr><th></th><th></th><th>Sweden</th><th>Finland</th><th>Germany</th><th>Latvia</th><th>Poland</th><th>Belarus</th></tr>
<tr><td rowspan="4">Year 1</td><td>Spring</td><td rowspan="10">Clover-grass</td><td rowspan="12">Clover-grass</td><td rowspan="6">Clover-grass</td><td rowspan="6">Clover-grass</td><td rowspan="6">Clover-grass</td><td rowspan="12">Clover-grass</td></tr>
<tr><td>Summer</td></tr>
<tr><td>Fall</td></tr>
<tr><td>Winter</td></tr>
<tr><td rowspan="4">Year 2</td><td>Spring</td></tr>
<tr><td>Summer</td></tr>
<tr><td>Fall</td><td rowspan="4">Winter wheat</td><td rowspan="4">Winter cereal</td><td rowspan="4">Winter cereal</td></tr>
<tr><td>Winter</td></tr>
<tr><td rowspan="4">Year 3</td><td>Spring</td></tr>
<tr><td>Summer</td></tr>
<tr><td>Fall</td><td rowspan="4">Winter cereal</td><td rowspan="4">Triticale</td><td rowspan="2">Catch crop</td><td rowspan="2">Catch crop</td></tr>
<tr><td>Winter</td></tr>
<tr><td rowspan="4">Year 4</td><td>Spring</td><td rowspan="2">Spring cereals</td><td rowspan="2">Silage maize</td><td rowspan="2">Silage maize</td><td rowspan="2">Spring oats</td></tr>
<tr><td>Summer</td></tr>
<tr><td>Fall</td><td rowspan="2">Fallow</td><td rowspan="2">Fallow</td><td rowspan="2">Catch crop</td><td rowspan="2">Fallow</td><td rowspan="2">Fallow</td><td rowspan="4">Winter triticale</td></tr>
<tr><td>Winter</td></tr>
<tr><td rowspan="4">Year 5</td><td>Spring</td><td rowspan="2">Spring wheat/ clover-grass (US)</td><td rowspan="2">Oats and peas</td><td rowspan="2">Grain legumes</td><td rowspan="2">Spring cereal/ grain legume</td><td rowspan="2">Spring cereal/ clover-grass (US)</td></tr>
<tr><td>Summer</td></tr>
<tr><td>Fall</td><td rowspan="2">Clover-grass</td><td rowspan="2">Fallow</td><td rowspan="4">Winter rye/ clover-grass (US)</td><td rowspan="4">Winter cereal</td><td rowspan="2">Clover-grass</td><td rowspan="2">Fallow</td></tr>
<tr><td>Winter</td></tr>
<tr><td rowspan="4">Year 6</td><td>Spring</td><td rowspan="2"></td><td rowspan="2">Oats/clover-grass (US)</td><td rowspan="2"></td><td rowspan="2">Whole crop silage/clover-grass (US)</td></tr>
<tr><td>Summer</td></tr>
<tr><td>Fall</td><td rowspan="2"></td><td rowspan="2">Clover-grass</td><td rowspan="2">Clover-grass</td><td rowspan="2">Catch crop</td><td rowspan="2"></td><td rowspan="2">Clover-grass</td></tr>
<tr><td>Winter</td></tr>
<tr><td rowspan="4">Year 7</td><td>Spring</td><td rowspan="4"></td><td rowspan="4"></td><td rowspan="4"></td><td rowspan="2">Spring cereal/ clover-grass (US)</td><td rowspan="4"></td><td rowspan="4"></td></tr>
<tr><td>Summer</td></tr>
<tr><td>Fall</td><td rowspan="2">Clover-grass</td></tr>
<tr><td>Winter</td></tr>
</table>

US = undersown; organic manure/compost is applied but not listed in the figure

Legumes | Legume-cereals | Cereals | Root crops | Fallow/catch crop

for ERA farm cooperations

Arable farms with no livestock are advised to arrange a farm cooperation with nearby livestock farms to exchange feed and manure to ensure nutrient recycling. Crop rotations differ greatly depending on the fodder requirements of livestock.

In arable farms, grain legumes and legume catch crops should always be part of the crop rotation. Forage legumes can be cultivated for mulching as fodder for a cooperating livestock farm, as biomass for a biogas plant or for seed production. A green fallow period can also be beneficial e.g. using a mixture of field beans, beerseem and persian clover and ryegrass.

Arable farms with no livestock have the following crop rotation options to include legumes:

Production of grain and forage legumes for cooperating dairy, pig or chicken farms

➜ Cultivation of catch crops and green manures (alternating winter and spring crops)
➜ 2-years of legume-grass to enhance soil fertility
➜ Legume seed production (grain and forage legumes)
➜ Green fallow period (mulching of legume mixtures)

If there is no animal farm nearby, cooperation with a biogas plant can be an option.

Review checklist [9]

For evaluating the planned crop rotation use the following checklist and discuss it with colleagues and your farm advisor.

Yes	No	
		Do you have at least 30 % legumes in the rotation?
		Have you checked the humus and nitrogen status?
		Have you checked the market opportunities and the gross margin?
		Does the crop rotation meet livestock feed requirements?
		Do nitrogen-fixers alternate with high nitrogen-feeders?
		Have adequate green manure and catch crops been included to minimize erosion and leaching?
		Do crops with small root systems alternate with crops with large root systems respectively low and high crop residues?
		Do deep-rooted crops follow shallow-rooted crops?
		Do weed-suppressing crops precede slow-growing crops?
		Have you put breaks between crops to minimise diseases and pests?
		Do the crops allow for effective use of the existing farm machinery and labour?

LEGUMES

Karin Stein-Bachinger & Moritz Reckling

Why they matter

Global aspects

Legumes are the key crops in ERA systems. In ERA farms, 30 % of the crop rotation should be grown with legumes to ensure a sustainable system. In conventional systems the importance of legumes in crop rotations has declined due to an intensive use of mineral N fertilizers and pesticides together with a high fodder import. Mainly soy beans are imported from overseas, as a result of the discontinuation of the EU subsidies for grain legumes. The concentration on a few very profitable crops and the neglect of important crop rotation principles (e.g. no legumes but high cereal proportion) has resulted in problems such as a decrease in humus content, soil erosion, nutrient and pesticide release into water bodies etc. Crop rotations that include legumes are able to minimize these risks considerably. Moreover, for ERA farms, legumes ensure high self-sufficiency in fodder and nitrogen.

Unique ability to fix nitrogen

Legumes fix nitrogen from the air with the aid of nodule bacteria living symbiotically at the legumes' roots. This is the most important N-source for ERA farms and the precondition for avoiding the use of mineral N fertilizers. The amount of N-fixation can be substantial – under favorable conditions it can result in a few hundred kg N/ha and year.

A successful management of nitrogen supply through legume cultivation in ERA systems includes:

- the optimization of N-input through symbiotic fixation and
- the N-transfer to subsequent crops with minimum losses.

How do you identify active root nodules? By the red colour inside!

Definition

Legumes are plants with pods belonging to the systematic family Fabaceae. They are one of the species-richest plant families with about 20,000 (cultivated and wild) species worldwide. They include annual, biennial and perennial herbaceous plants as well as trees and bushes.

Benefits of legumes

With effective management legumes have the potential to provide the following benefits:

For the farm (mainly legume-grass mixtures)

- maintain and increase long-term soil fertility
- be the most important N-source
- grain and forage legumes deliver high-protein fodder
- give very positive preceding crop effects
- develop deeper soil layers due to an extended root system
- mobilize phosphorus through symbiosis with mycorrhizal fungi
- reduce intensity of tillage procedures
- improve plant health and prevent weeds.

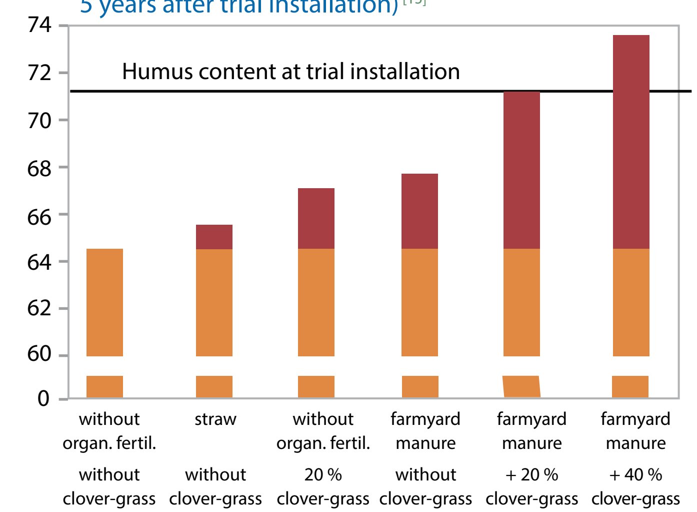
For human nutrition (grain legumes)

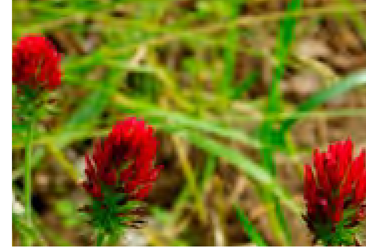
- provide high-protein food (2–3 times higher N-content than cereals)
- provide essential amino acids (very valuable complement to cereal nutrition)
- alternative to meat consumption
- provide raw material for innovative healthy food.

For the environment (legume-grass and grain legumes)

- reduce greenhouse gas emissions (N_2O – laughing gas) and energy consumption by replacing mineral N fertilizers
- enhance biodiversity in and above the soil through diversification of the crop rotation
- reduce pesticide use through improvement of plant health
- strengthen the local/regional production and reduce dependency on imported protein fodder.

Increase of humus content in different fertilization and crop rotation systems (long-term trial on sandy-loam, 5 years after trial installation) [15]





Basic data on grain and forage legumes

A balanced nutrient (P, K, S) and pH level in the soil is essential to maximize growth and N fixation. If a legume is cultivated for the first time or after a long break, seeds should be inoculated with the appropriate strain of Rhizobia (nitrogen-fixing bacteria). They can survive in the soil for several years.

Grain legumes

Grain legumes are an important protein source for food and feed. Compared to cereals, they leave very little stubble in the field, the crop residues have a low C:N ratio and decompose quickly. They have the ability to mobilize phosphorus from the soil through the secretion of organic acids in the rhizosphere.

Description of selected grain legumes (demands: + = high, - = low) [4,16]

Grain legumes	Water supply	Soil quality	Self-compatibility	Cultivation break (years)	Optimal pH-value	Yield (t/ha) (poor – rich soils)
Peas	+	+	no	5	6.0 - 7.0	1 – 4.5
Field beans	+	+	no	3-4	6.5 – 7.0	2 – 5
Lupines			no	3-4		
- yellow	-	-			5.0 – 6.0	1 – 3.5
- white	+	+			6.0 – 7.0	2 – 4
- blue	+	-			5.5 – 7.0	1 – 3.5
Soy beans*	+	+	yes		6.0 – 7.5	1 – 2.5

* Soy beans are short day plants. They require a temperature above 6°C, the vegetation period has to be 150 to 180 days. Rhizobium inoculation is necessary especially before first seeding. Note: Soy beans must be processed first before being fed to livestock.

Calculation example

Average nutrient removal/ha in harvested grain legumes:

1 t/ha of grain (86 % DM) ≈ 35 kg N, 4 kg P, 8 kg K

Note: A very efficient recycling of nutrients from grain legumes can be achieved if the grain is used for feeding stock and their manure is returned to the fields!

Mixtures

Grain legumes are often mixed with cereals, e.g. field beans with oats, peas with spring barley and rye with vetch. A uniform sowing without segregation within the seed drill and a simultaneously ripening is important.

Advantages: dense rooting; fewer problems with plant diseases; stubble and root residues will be decomposed and mineralised to nitrate more slowly because the C : N ratio of cereals is higher.

Disadvantages: a lower concentration of legumes results in a lower N-fixation and a lower net-N-input which reduces the positive preceding crop effect.

Forage legumes

Instead of harvesting forage legumes they can be ploughed in as green manure delivering, among other things, nitrogen to the soil. Clover and alfalfa are usually cultivated with different grass varieties in the crop rotation. Forage legumes are of tremendous importance for ERA systems as they fix and leave more N in the system than grain legumes and provide high protein feed for ruminants. As ruminants (animal husbandry) can digest cellulose, there is no competition for food. Furthermore weeds (e.g. thistles and couch grass) can be regulated and suppressed very effectively through perennial cultivation.
Between 25 and 80 t/ha fresh matter (FM) yield can be harvested (with two to four cuts/year), which means 5 – 16 t/ha dry matter (DM) (assuming 20 % DM in the fresh material) per year.

Description of selected forage legumes (demands: + = high, - = low) [4,16]

Mixture	Water supply	Soil quality	Cultivation duration (years)	Cultivation break (years)	Optimal pH-value
Alfalfa-grass	+	-	1 - 3	3	6 - 7
Red clover-grass	+	+	1 - 3	3	5.5 - 7
White clover-grass	-	-	1 - 3	0	5.2 - 7

Quick yield estimation

In practice it is often very difficult to accurately measure the forage legume yield without weighing the trailers or counting the hay/silage bales. On the field, a rough assessment of dense stands is possible using the following **rule of thumb** [5]:

Harvested height in cm x 0.1 = t DM/ha

Example: 45 cm growing height minus 5 cm cutting height = 40 cm harvesting height x 0.1 = 4 t DM/ha

This rule of thumb can be used for yield estimation in dense stands of grassland as well.

Calculation example

Average nutrient removal/ha in harvested forage legumes:

1 t/ha of clover-grass (100 % DM) ≈ 25-30 kg N, 3.5 kg P, 2.5 kg K

Note: In the first production year the nutrient removal is slightly higher than in the 2nd year.

Mixtures of catch crops

Other legumes or mixtures of clover/alfalfa with cereals can be used as catch crops (crop rotation):

- Winter catch crops: Crimson clover (*Trifolium incarnatum L.*), Landsberger mixture (winter vetch + crimson clover + annual rye grass)
- Summer catch crops: Crimson clover, Beerseem clover (*Trifolium alexandrinum L.*), Serradella (*Ornithopus sativus Brot.*), Persian clover (*Trifolium resupinatum L.*), Yellow trefoil (*Medicago lupulina L.*), Subclover (*Trifolium subterraneum L.*)

Methods to estimate the N fixation

This section gives you examples for a quick and simple estimation and an overview of the amount of N fixation depending on the legume species in use.

Grain legumes

Rule of thumb for estimating the N fixation by grain legumes:
The amount of symbiotic fixed N is comparable to the amount of N in the harvested grains [10,6].

The following table gives a survey of the symbiotic N fixation by grain legumes, based on recommended calculations in Germany [16].
Note: These are average data and the N-fixation capacity can vary greatly, e.g. with peas 50 – 300 kg N/ha.

Crop	Yield	N fixation	
	Fresh matter (t/ha)	kg N/t	kg N/ha
Field beans	3.5	40	140
Peas	3.0	35	105
Blue Lupine	2.5	40	100
Soy beans	2.5	50	125
Lentils	1.5	40	60
Vetch	2.0	40	80

Be aware that:

- Selling the seeds of grain legumes means that you are also losing the symbiotic fixed nitrogen! In most cases the net-N-input is zero if the grain is sold. It is also important to note that the N-balance can be negative.
- If the seeds are used as fodder for farm animals the greater part of the fixed N remains within the system if the manure is spread on the fields. Crop farms, especially in horticulture systems, need to use the whole crop for nutrient recycling within the farm.
- When converting to ERA systems, it is necessary to make a rough calculation (both at field and farm level) of how much biomass and manure should be recycled in order to guarantee a well-balanced N budget of the crop rotation (software tools)!

Forage legumes

The average N fixation of forage legumes is roughly 200 kg N/ha/year which is around twice the amount from grain legumes.
The estimation of the N fixation is difficult when mixtures with non-legumes like clover-grass are cultivated, because the amount of clover has to be estimated. Field observations before harvesting and the recording of the data are helpful to get an overview.

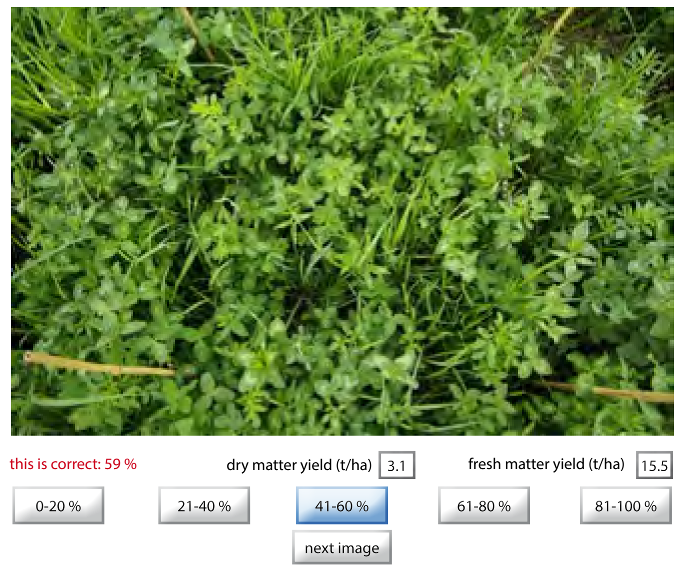
Rule of thumb for estimating the N fixation by forage legumes:
35 kg Nfix / 1 t legume yield (dry matter) [63,6]

How to estimate the legume proportion in legume-grass swards?

On a large scale you can use the following table:

	Legume yield proportion (%)	
Scale	Arable forage	Permanent grassland
very low	1 - 20	1 - 5
low	21 - 40	6 - 20
middle	41 - 60	21 - 40
high	61 - 80	> 40
very high	81 - 100	

Legume estimation trainer



As the estimation of the legume proportion is difficult and needs practice, you can train yourself with the help of this simple software tool.
It shows a variety of swards with different shares of legumes and non-legumes and allows you to test and train your estimation skills.

Examples

The following table shows huge differences in the total amount of N fixation depending on the yield and the legume proportion. A field that gives a total yield of 8 t DM/ha and year will give 168 kg N less with a low legume proportion of 20 % compared to 80 % legumes in the mixture!

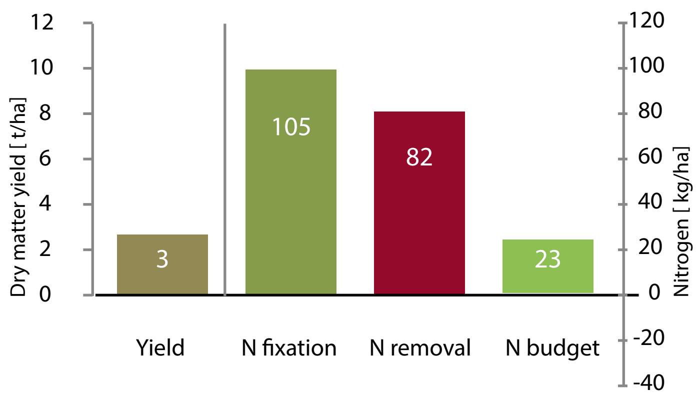
Amount of N fixation by clover-grass mixtures (using the rule of thumb) (in relation to the legume yield proportion for Central European conditions)

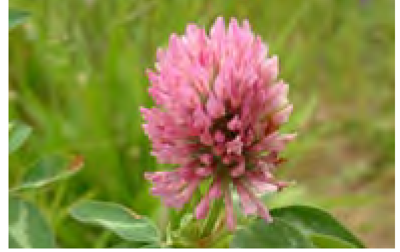
Gross yield (t DM/ha and year)	Nfix in kg/ha and year with a legume yield proportion of		
	20 %	50 %	80 %
4	28	70	112
8	56	140	224
10	70	175	280

Nitrogen-Budget Calculator

To facilitate the calculation of the N-input of forage legumes including a rough overview of the total N-balance of the field, you can use this user-friendly software tool. By changing a few input data according to your farm situation (e.g. yield or harvesting method) you can get an overview of the situation on your fields. An example calculation is shown in the following graph.
The example demonstrates that the N-balance by harvesting 3 t/ha of grass-clover as silage with 50 % clover in the mixture would be positive (23 kg N/ha). With only 30 % clover in the mixture, the N budget would be negative (- 15 kg N/ha).

DATA INPUT		
Average height	[cm]	45
Harvesting method	[select]	silage
Harvesting losses	[%]	20
Legume Proportion	[%]	50
RESULTS		
Yield (harvested)	[t/ha DM]	3,2
N fixation	[kg N/ha]	105
N removal	[kg N/ha]	82
N budget	[kg N/ha]	23





Level of N fixation by forage catch crops [16]
(Standard values in Germany)

Catch crops

Crop	Average yield fresh matter t/ha	N fixation kg/ha
Clover grass (50 : 50)	15	20
Clover	15	38
Serradella (*Ornithopus sativus*)	15	32
Peas (fodder)	15	38
Vetch (fodder)	15	38
Other annual fodder legumes	15	32

Grassland

White clover is the most common legume in grassland. Often a general value of 30 kg N/ha is indicated for the amount of N fixation. But just as for forage legumes on arable land, there is a more precise estimation for grassland:

1. For yield estimation use the rule of thumb shown on page 45.
2. The N fixation can also be estimated with the rule of thumb below [14].

Rule of thumb for estimating the N fixation in grassland:
30 kg Nfix / 1 t legume yield (dry matter)

There can be a wide range in the amount of fixed nitrogen depending on the amount of clover in the grassland.

Amount of N fixation on grassland (using the rule of thumb)

Gross yield (t DM/ha and year)	Nfix in kg/ha and year with a white clover proportion of			
	10 %	20 %	30 %	40 %
4	12	24	36	48
8	24	48	72	96
10	30	60	90	120

How to estimate the legume proportion in grassland?
The legume estimation trainer can be used to train and test your estimation skills on the proportion of legumes in permanent grassland.

How to increase the N fixation [5,17]

- A balanced P, K and pH level in the soil, a good soil structure and cultivation of crops adapted to the environment is advantageous.
- Legume-grass for forage production with a legume proportion between 70 - 80 % will give a positive N field balance.
- Cutting for fodder purposes results in a higher legume proportion as well as a significantly higher N fixation than mulching.
- Vigour growth is achieved if fodder legumes are allowed to blossom once.
- Maximum fixation rates are achieved during flowering and pod formation (grain legumes) so harvest and mulching should be carried out afterwards.
- Integrate legume catch crops in the rotation whenever possible.
- N fixation depends on both the soil temperature (> 6 °C) and the vegetation period. Legume catch crops normally start after 5 weeks with N self-supply. Therefore, they should be sown as early as possible.
- Cultivate grain legumes, especially peas, white lupines and soy beans as they can make phosphorus available which supports the N fixation.
- A mixture of field beans and oats is especially effective in reducing black bean aphids.
- Follow the recommended crop rotation cultivation breaks according to the different legumes carefully. Care in cultivating legumes is worth the effort.

Examples of nitrogen field balances [17]

The following example gives a rough understanding of the N field balance in different production systems. It is important to note that the sale of grain legumes may lead to a negative N balance. Moreover, forage legumes provide a nitrogen supply to two to three subsequent crops, compared to grain legumes supplying N for only one. Therefore fodder legumes should be cultivated before economically important crops (crop rotation).

	With animals		Without animals	
Legume	**Red clover**	**Pea**	**Red clover**	**Pea**
Kind of utilisation	fodder	grain fed	set-aside	grain sold
N-fix total plant	220	90	180	90
N in harvested products	-340	-140	0	-140
N-return with manure [1)]	170	70	0	0
Gaseous N-losses from mulching	0	0	-35	0
N-balance	+ 50	+ 20	+ 145	-50

1) estimated N-losses through animal refinement, storage and application: 50 %

Legume cultivation to reduce nutrient leaching [5, 7]

Legume-grass

- On sandy soils, tillage operations should be as late as possible (late winter, early spring) in order to reduce the risk of N leaching during winter. Reduction of the number and depth of tillage operations as well as harvesting the last stand before ploughing, decrease N mineralisation before winter.
- Legume mixtures should contain a yield proportion of non-legumes (grass, crucifers) of 20 to 25 % to reduce the leaching risks, because mineralized nitrogen can be caught immediately.
- It is important to note that mulching of legumes can cause ammonia losses (5-15 %).

Grain legumes

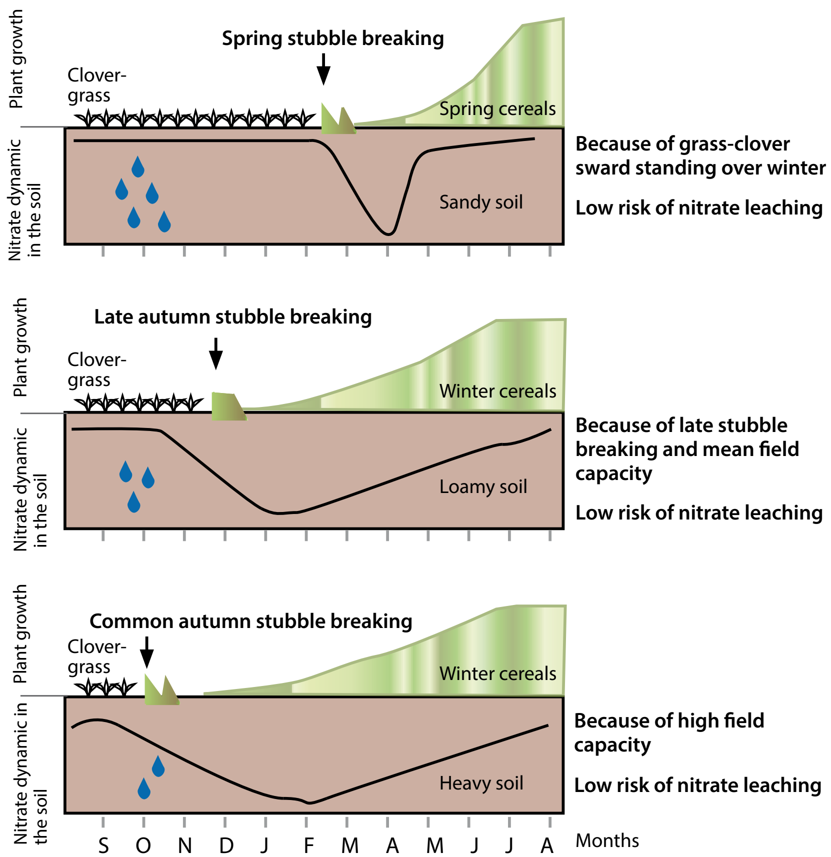
- Undersown grass takes up soil N and therefore reduces leaching on sandy soils.
- If spring crops (e.g. maize) are to be grown after grain legumes on sandy soils the cultivation of undersown grass or a winter catch crop is recommended to reduce leaching.
- If a winter crop (e.g. rye) follows the legumes it should be sown directly after the legume stubble is ploughed in.

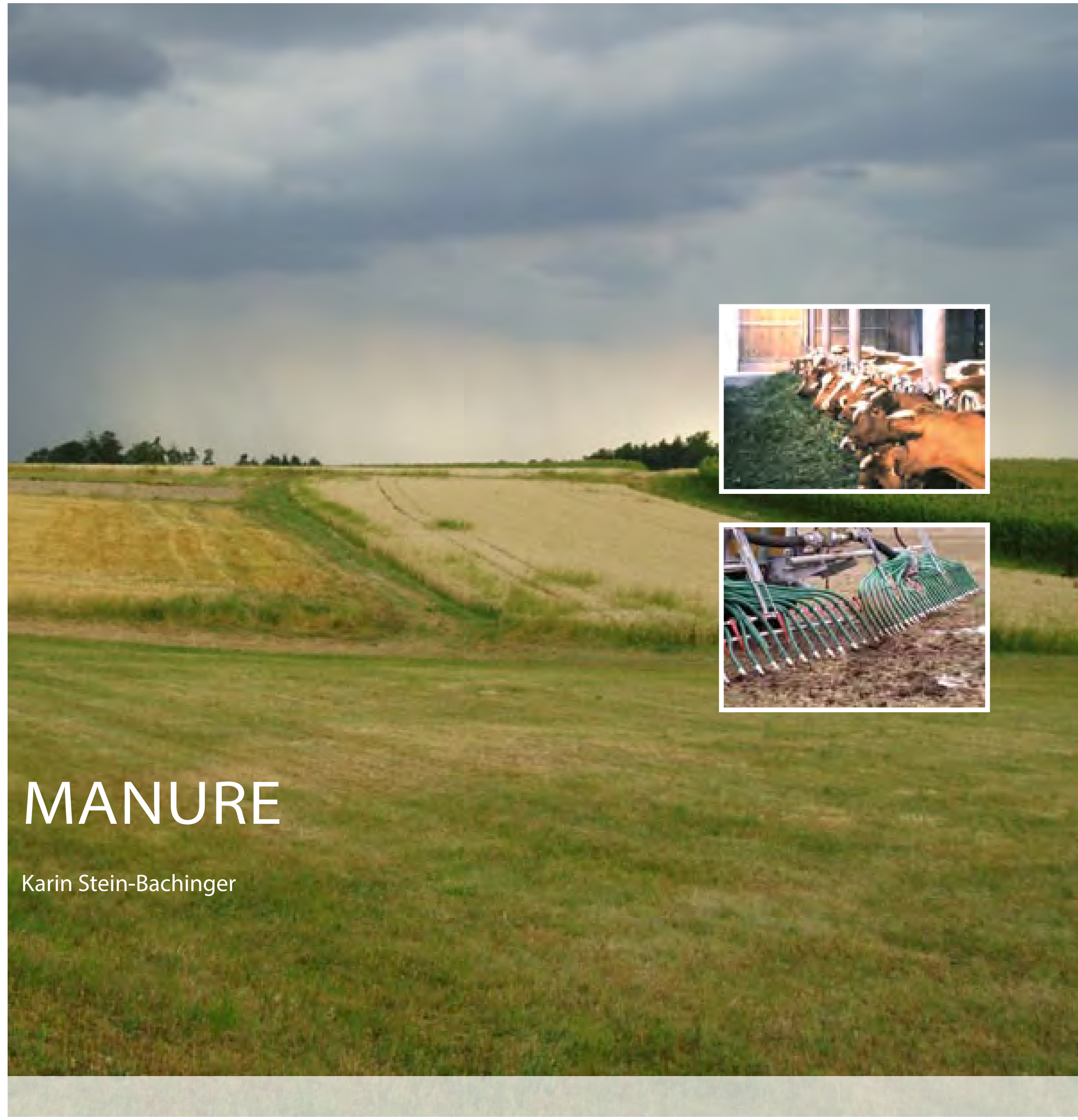
Legume catch crops

- On sandy soils, legume catch crops should be cultivated only in mixture with non-legumes.
- Ploughing in of legume catch crops in the spring is preferable.
- On soils with a high potential for nutrient losses, at least one winter-hardy non-legume should be part of the mixture.

Strategies of ploughing grass-clover to avoid nitrate leaching

Schematic description of the N content in the soil of different soil types after site-adapted ploughing of clover-grass [18]





MANURE

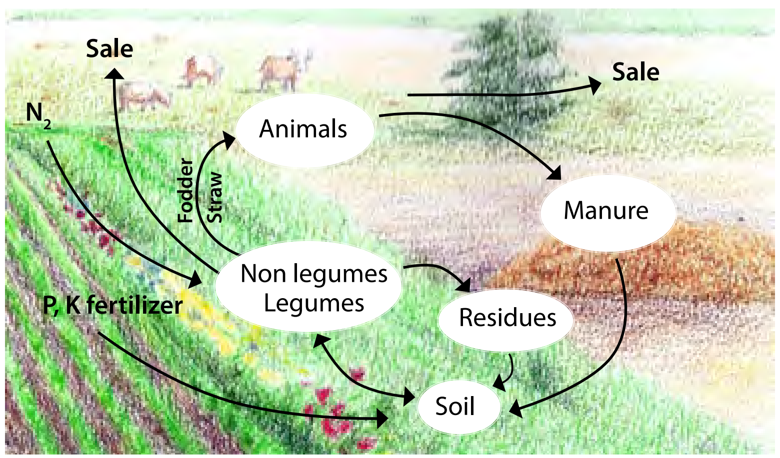
Karin Stein-Bachinger

Why manure matters

Value of manure for ERA farms

In livestock farming systems manure plays a key role in nutrient recycling on farm level. It not only contributes nutrients to the soil, it also maintains and increases the soil humus content and fertility (e.g. by improving water holding capacity, aeration, drainage and release of energy for increasing microbiological activity).
When converting to Ecological Recycling Agriculture (ERA) planning for effective manure storage and handling is essential, as nutrient losses are both a serious pollution problem as well as a waste of valuable nutrients. Manure is the primary source of fertilizer and it can be used very flexibly within the crop rotation. However the amount of manure is limited, because animal production must match the fodder produced within the farm/farm cooperative. In ERA farms, additional fodder from outside the farm should be less than 20 %.
About 75-90 % of the nutrients N, P and K that are fed to livestock pass directly through the animal into the manure (animal husbandry). The extent to which they can be returned to the soil and made available to subsequent crops as well as the soils humus building capacity depends on the way the manure is stored and handled.
These are crucial issues both for a successful nutrient management on ERA farms as well as for a healthy environment.

Nutrient recycling on farm level [65]



Definition of three types of manure

a) **farmyard manure** = mixture of animal excrement and straw (or other bedding material)

b) **slurry** = animal excrement (urine + faeces)

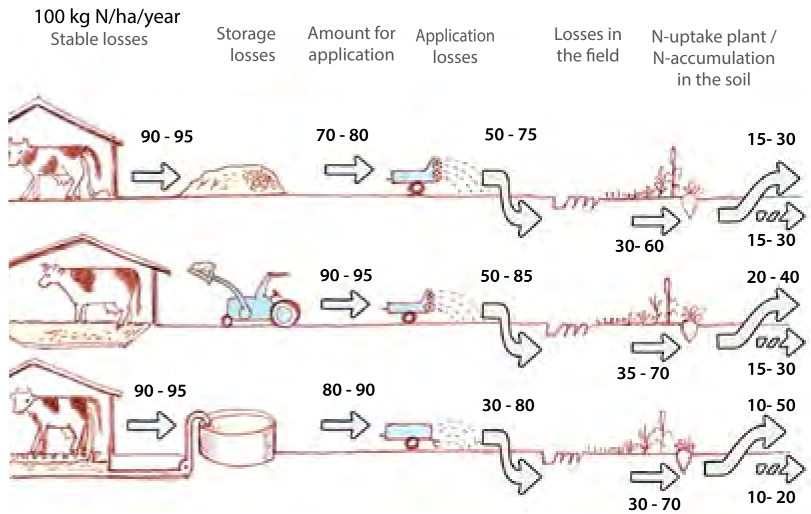
c) **liquid manure** = animal urine

Potential nutrient losses (N, P, K)

Nitrogen

Losses of nitrogen (N) can occur from the time the urine hits the bedding until it is absorbed by the plant[9]. The losses through volatilisation and/or leaching can vary greatly during the different stages from between 5 % to about 30 % (for each stage) depending on the storage, treatment and application practice.

Potential remaining N of manure depending on storage and application [62]

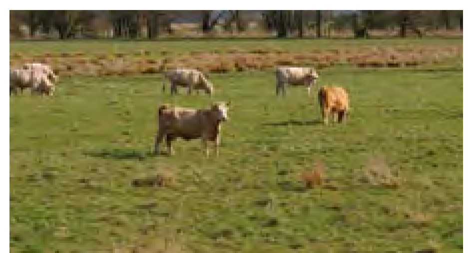


Potassium and phosphorus

Besides N, considerable losses of potassium (K), up to 50 %, can result from leaching and runoff during composting. As for phosphorus (P) the main losses normally occur as a result of soil erosion after the manure is spread on the fields.

Storage practices

The type of stable determines storage practices. Depending on the housing system, farmyard manure can be removed regularly and composted in a heap outside the stable or on the field before spreading. In deep litter systems the manure is stored in the stable up to several months, sometimes also in a heap outside before spreading. Slurry and liquid manure are stored in tanks. For advice on storage and application in order to reduce nutrient losses ➜ see following pages.



Basic data

The amount and the nutrient content of manure can vary widely depending on the source materials (kind of animal, type of bedding, diet) and the conditions and duration of storage. It is difficult, in practice, to accurately determine the amount of manure produced per year.
The following table provides a rough estimate of the average amounts of manure produced by cattle, pigs and hens per year. For more detailed calculations with regard to specific housing systems consult the general nationwide data bases [4].

Amount of manure production per animal and year (365 days) [4]

Animals	Farmyard manure[1)] t/year	Slurry m^3/year	Liquid manure m^3/year
1 cattle (> 2 years)	10 (22 % DM)	18 (8 % DM)	4 (8 % DM)
1 breeding sow with piglets	2 (22 % DM)	6 (5 % DM)	1.5 (5 % DM)
10 porkers	8 (22 % DM)	19 (6 % DM)	6 (6 % DM)
100 laying hens (fresh manure)	6 (22 % DM)	8 (14 % DM)	-

[1)] at low to average amount of litter: 2-4 kg/LU (livestock unit) and day;
DM = dry matter

Composting

Making good compost is an important issue for ERA farms. Usually, farmyard manure consists of manure mixed with livestock bedding, e.g. straw, which has a high carbon to nitrogen ratio (80:1) compared to dairy manure of 20:1. The composting process requires a carbon to nitrogen ratio of 25-35:1(see page 56).
The organic matter is decomposed by micro organisms in the presence of oxygen and the temperature of the pile can rise up to about 60-70°C within a week. To destroy pathogens, weed seeds and fly larvae, the temperature needs to be kept at 60°C for at least 15 days. Subsequently the temperature should be lowered to below 50°C. Above this temperature nitrogen is converted to ammonia and lost to the atmosphere [8,9].
Red worms are active in the final stages of decomposition, helping to transform the compost into humus. The volume of the fresh manure is reduced by 40 to 60 %, depending on the treatment as well as carbon and nitrogen losses .

Conversion factors

P	x	2.29	=	P_2O_5
K	x	1.21	=	K_2O
P_2O_5	x	0.44	=	P
K_2O	x	0.83	=	K

Nutrient content

As there are many different ways to treat farmyard and liquid manure, the nutrient content of the manure that is spread on the fields can vary greatly. Therefore it is advisable to make one's own manure analysis in order to get the necessary data. This will make planning easier, help avoid mistakes and save money.
If this is not possible then it is important to note that the official recommended data [4] tend to show higher nutrient content because they are based on conventional systems, where the nutrient input, e.g. through mineral fertilizer and protein fodder, is higher[6]. The following table provides average data from several organic farms [5,6] (with the exception of the chicken dung) and can serve as an orientation for one's own calculations.

Animals	Type of manure	DM (%)	N_{total}	P	K
Cattle	Farmyard manure fresh (kg/t FM[1)]) Farmyard manure compost[2)] (kg/t FM)	20 22	4 5	1.2 1.2	4.6 6.6
Pigs	Farmyard manure compost (kg/t FM)	20	6	2.5	5
Poultry	Dry chicken dung (kg/t FM)	60	30	10	13
Cattle	Slurry (kg/m^3 FM)	8	3	0.4	2.5
Pigs	Slurry (kg/m^3 FM)	6	4	1.5	3
Cattle	Liquid manure (kg/m^3 FM)	2	2	0.1	3

[1)] FM = fresh matter [2)] composted up to 6 months

Because of the volume losses during composting of farmyard manure, the C:N ratio will decrease over time. The storage of farmyard manure in a heap should normally not exceed 6 months.

Calculation examples

The amount of manure available for arable land from:

LU/ha (in barn)	Manure
1.0 LU/ha (220 days in barn) →	6 t/ha and year
1.0 LU/ha (290 days in barn) →	8 t/ha and year
0.6 LU/ha (290 days in barn) →	4.8 t/ha and year

Amount of nutrients from cattle manure per ha:

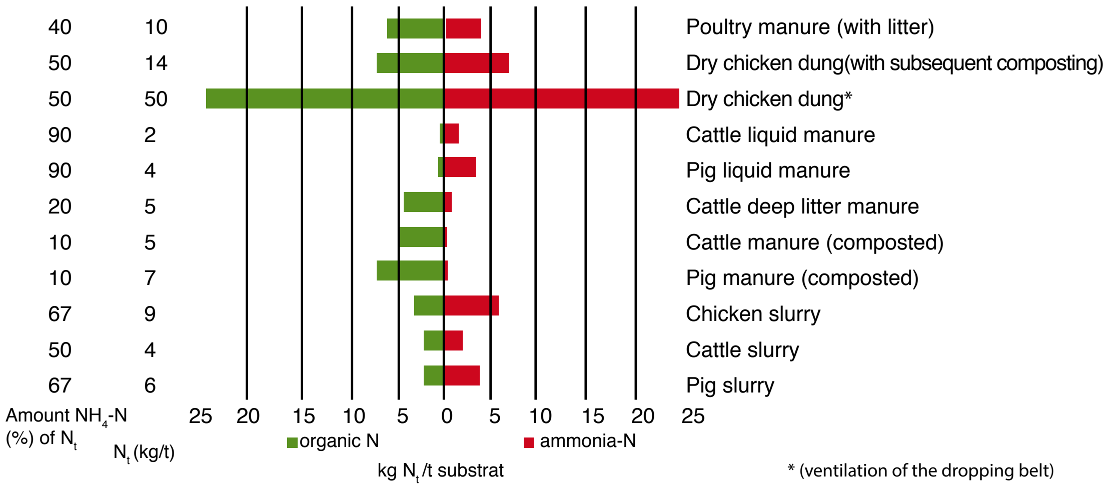
30 t farmyard manure compost	150 kg N	36 kg P	200 kg K
10 m^3 slurry	≈ 30 kg N	4 kg P	25 kg K
10 m^3 liquid manure	≈ 20 kg N	1 kg P	30 kg K

Nutrient availability

Nitrate, ammonium and total N

The mineral N (NO_3^- (nitrate) and NH_4^+ (ammonium) in the manure is directly available to plants, the organic N is only available after mineralisation during the course of several years. The higher the ammonium-proportion of the total nitrogen and the lower the C/N-ratio, the higher the direct annual effect.

Nitrogen characteristic of manure [4]



What is the C:N ratio and why is it so important?

All living organisms need relatively large amounts of carbon and smaller amounts of nitrogen. The balance of these elements is called the carbon-nitrogen ratio (C/N ratio). This ratio is an indicator of how easily bacteria are able to decompose organic material.
The more carbon in the material relative to nitrogen, the longer the decomposition process will take. In general, woody materials are high in carbon. The optimal proportion used by the bacteria averages about 25 parts carbon to 1 part nitrogen.

Carbon / Nitrogen ratio of different materials (orientation values) [9]

Humus	10 – 12 : 1
Peat soils	10 – 30 : 1
Dairy solid manure	20 : 1
Poultry manure	10 : 1
Vegetable waste	12 - 20 : 1
Leaves	45 : 1
Straw	80 : 1
Fresh sawdust	500 : 1
Wood chips	100 - 500 : 1
Newspaper	800 : 1

Key figures

Humus reproduction from organic material (in humus-equivalents) [4,25]

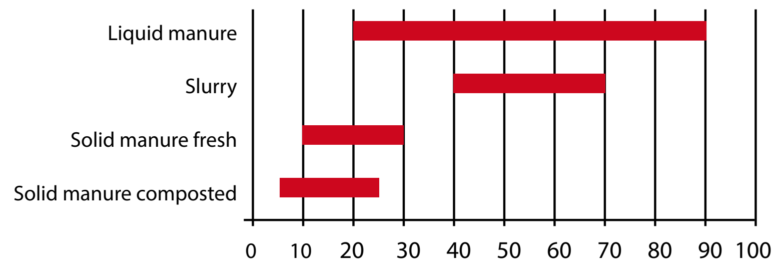
Fresh farmyard manure (20 % DM)	→ 28 kg Humus-C/t substrat
Rotted farmyard manure (25 % DM)	→ 40 kg Humus-C/t substrat
Composted manure (35 % DM)	→ 62 kg Humus-C/t substrat
Pig/cow slurry (8 % DM)	→ 8 kg Humus-C/t substrat
Poultry slurry (faeces 25 % DM)	→ 22 kg Humus-C/t substrat

Example: 20 t rotted farmyard manure provides 800 kg Humus-C/ha for humus reproduction (soil fertility, ROTOR).

N

The N-efficiency can vary greatly. Up to 90 % of the N in liquid manure can be available to plants, but there is a high risk of gaseous losses. The N-efficiency of farmyard manure is fairly low, but over the long term, up to 70 % of the nitrogen can become available [4,6].

Nitrogen efficiency in the first year (%)



P

K

In contrast, about 50 - 60 % of the total amount of phosphorus is available in the first year. Also most of the potassium is directly available to the plants as it mainly occurs as an inorganic compound. However, there can be considerable losses of K during composting (up to 50 % through percolate) as well as through leaching on sandy soils .

Potential availability of N and P from farmyard manure

Spreading of 30 t/ha/year =		Availability in the first year		Available amount / ha in the first year
150 kg N	→	20 %	→	30 kg
36 kg P	→	50 %	→	18 kg

Calculation examples

How to reduce nutrient losses during storage?

There are various possibilities to store farmyard manure and use it when it has reached a more mature stage. It can be stored outside the barn in heaps: either on a concrete slab where potential nutrient losses in the form of leachate can be easily gathered, or on field edges where special preconditions have to be fulfilled to avoid leaching to the soil. Slurry and liquid manure are usually stored in tanks (e.g. above ground). To both great attention has to be paid to prevent gaseous losses. There are country specific legal restrictions that have to be taken into consideration!

Farmyard manure

A random dumping of manure in a heap (and hoping for the best) should be avoided, because it can lead to high nutrient losses, especially through leaching. As described above composting on a concrete slab makes it easier for runoff to be collected. When a conversion plan is made the collection system should include both the silage and manure heaps so that all effluents can be collected [8].

Recommendations for storage on fields [5]

- Check the local zoning regulations
- Maximum storage: 6 months, change storage places
- Pick up 5-10 cm of the top soil to catch all 'rest'-nutrients
- Distance from water bodies: at least 20 m in flat areas
- Position on a slope: only across to the slope
- Removal preferably from spring until late summer, if there is no leachate generation

Cover of manure heaps and protection of the subsurface mainly to avoid N and K losses during composting [5]

Dry matter	Measure	Up to 500 mm precipitation	500 – 1000 mm precipitation	> 1000 mm precipitation
< 25 %	Cover	Straw (useful but not necessary)	Fleece	Fleece or foils after self-heating
	Controlled subsurface[2)]	Useful	Necessary	Necessary[1)]
> 25 %	Cover	Straw (useful but notnecessary)	Straw of fleece	Fleece
	Controlled subsurface[2)]	Not necessary	Useful	Necessary

[1)] plus: pre-composting on a concrete slab [2)] e.g. straw or clay minerals like bentonit

High risk of ammonia losses during composting [5]

Condition	Measures for improvement
Warm, dry, windy	Do not turn or move the manure heap
Flat heaps, large surfaces	Increase the height of the heap, cover with straw
Self-heating	Do not move or turn over

Slurry and liquid manure

With regard to the storage of pig slurry, the covering of the tanks is judged as the most efficient measure to reduce volatile emissions. The covering of tanks containing cattle slurry leads to a lower reduction of emissions, because a natural surface layer is built up [4], but it is still recommended.
As raw slurry can lead to pollution problems, a form of composting can be done by aerating the slurry in the tanks. Although there is a high risk of ammonia volatilization, odors from anaerobic conditions can be reduced as can risks for weeds and pathogens and the slurry is more plant-compatible. The tanks should have a storage capacity to handle at least 6 months of slurry production.

Recommendations for storage [5]

Criteria	Risk of ammonia emission	Measures for improvement
Open tanks	(Very) high	Maintain surface layer, apply chopped straw
Covered tanks	Low	
Aeration	Very high	Omit or reduce aeration, consider technical solution for treatment of used air
Fermentation (biogas production)	Low	Very quick incorporation after application

How to reduce nutrient losses during application?

By law, slurry, liquid manure and poultry dung have to be incorporated into the soil immediately after application on arable soils without vegetation. The application should be omitted during hot, dry and windy weather and when the soil is not drivable or frozen. Thick slurry should be diluted, it must run off the plants and penetrate into the soil.

As there is a huge range of different technical solutions the following tables gives general guidelines for manure application.

Hints for application of farmyard manure [6]

Techniques	Condition		Risk of ammonia emission	Measures for improvement
Spread on arable fields	Without soil cover	Warm, dry, windy	High	Immediate incorporation
		Cool, moist, calm	Low	Incorporation as soon as possible
	With soil cover	Warm, dry, windy	High	Avoid application
		Cool, moist, calm	Medium	Preferably in combination with harrowing
Spread on grassland	Warm, dry, windy		High	Avoid application
	Cool, moist, calm		Medium	

Potential to reduce of ammonia losses after the application of slurry or liquid manure [4]

Mitigation techniques/ measures	Location	Emission decrease % Cattle	Emission decrease % Pig	Limitations
Drag hose	Arable land -without vegetation -with vegetation (> 30 cm) Grassland -low vegetation (<10 cm) -higher vegetation (> 30 cm)	 8 30 10 30	 30 50 30 50	Steep slopes not too strong, size and shape of the field, viscous slurry, vegetation height
Drag shoe	Arable land Grassland	30 40	60 60	See above, not on too stony soils
Slurry grubber	Arable land	>80	>80	See above, not on too stony soils, very high traction force, only partly usable on arable land with vegetation
Direct incorporation (within 1 hour)	Arable land	90	90	With light machines (harrow) after primary tillage, with grubber/plough after harvest
Dilution	Grassland	-	30-50	Only on grassland

Agronomic recommendations for manure handling

Where?

- Prioritize the application to high nutrient demanding crops, like root crops, (silage) maize, fodder crops and fast growing catch/cover crops.
- Avoid manuring crops that follow crops with high nutrient residues (e.g. legume-grass leys with a high legume content).
- Avoid high amounts of slurry to legumes, as nitrogen fixation will be reduced.
- To improve nutrient mineralization/availability and avoid gaseous losses plough down farmyard manure
  - o on dry sandy soils up to 15-20 cm
  - o on heavy soils up to 10-15 cm.

When?

- The application of slurry and liquid manure is not allowed from 1st November to 31st January!
- Apply manure preferably before tillage to reduce gaseous losses.
- On sandy soils, avoid autumn application to winter cereals or grasslands, because it will increase nitrate losses during winter.
- Use liquid manure to cereals at tillering for increasing the yield, at flush for improving the protein content.
- Especially in spring, a late application of liquid manure to cereals needs special application techniques to avoid ammonia losses.
- Apply slurry to catch/cover crops or winter rape before September to ensure a high nutrient uptake.
- Avoid high manure application to potatoes directly following spring-ploughed legume-grass because of tuber health reasons.
- On meadows, use slurry in spring before the first cut, if the growing height is below 15 cm.
- On pasture, use slurry early in spring at least one month before grazing.

How (much)?

- Whenever possible, incorporate manure directly after the application.
- Use relatively low amounts to improve the nutrient efficiency.
- On grassland, ensure a uniform distribution to avoid sward damages followed by perennial weed infestation.

Manuring plan

How to determine the appropriate allocation in the crop rotation?
6 course crop rotation: 1 LU/ha, 290 days in barn:
8 t farmyard manure/ha = 48 t/ha over 6 years are available

Distribution in the crop rotation	24 t/ha for each of 2 crops or	16 t/ha for each of 3 crops
Amount of N	≈ 120 kg N/ha	≈ 80 kg N/ha
Minus 20 % losses	≈ 96 kg N/ha	≈ 64 kg N/ha
Availability in the first year	≈ 20 %	
Available N in the first year	≈ 20 kg N/ha	≈ 15 kg N/ha

Take long-term availability over the whole rotation into consideration!

Legal restrictions

Pay attention to country specific legal requirements!

In Germany several regulations for the application of manure must be taken into consideration, e.g. Düngeverordnung
http://www.gesetze-im-internet.de/bundesrecht/d_v/gesamt.pdf e.g. § 3, § 4,(extract)

- Amounts of N and P need to be known before application.
- Slurry or other liquid manure with a high concentration of available N must be incorporated immediately on arable land.
- A maximum of 170 kg N/ha per year from manure can be spread (on average for the total farmland area). **Be aware that the organic standards of the farmers associations allow only 112 kg N/ha and year.**
- Fertilisation has to be done with emission reducing practices.
- The application of manure with high contents of available N (farmyard manure is exempted but not poultry dung) is not allowed from:
  - o 1st November to 31st January on arable land
  - o 15th November to 31st January on grassland
- A minimum distance of 3m to water bodies must be maintained.
- Special regulations exist for water protection areas.

Research project within the Baltic Sea Region Programme Baltic MANURE (Baltic Forum for Innovative Technologies for Sustainable Manure Management)

BERAS implementation
Baltic Ecological Recycling Agriculture and Society

ANIMAL HUSBANDRY

Katarina Rehnström and Åsa Odelros

Ecological systems need livestock

Animal production is an important part of ecological farming that aims at achieving a balanced relationship between the soil, the plants and the animals in a farming system. Organic farming offers many solutions to the challenges posed by climate change and resource depletion, but we must strive continually to improve the local circulation of nutrients to ensure that we are producing food by methods that are both sustainable and resilient. This is why the farm acreage and possible feed production is important in deciding about the combination and type of farm animals and herd sizes. The environment and living conditions for ecological farm animals must be designed to suit the specific needs of different species. All animals should also have the possibility to express their natural behaviour.

The great thing about livestock is that they produce food from feed stuff that humans cannot consume. Ruminants turn fiber-rich plant parts into highly concentrated food. Pigs and poultry can utilize waste, spilled grains, worms and insects. Also, domestic animals are not only protein- and fat-producers as their special abilities can also be used in other contexts. Pigs can serve as cultivators in fields and forests, chickens have the ability to find nutrients and ruminants can select grass and weeds even in such places where it is not possible to harvest.

Ruminants have a central role in resource-conserving farming. The reason for that is the important role of pulses and ley in ecological agriculture. The monogastric animals, e.g. chickens and pigs, compete for the same food as humans and therefore should not have a front position.

In Sweden in 2010 the share of organic animal husbandry made up more than 19 per cent of the total lamb production, 15 per cent of beef cattle, 11 per cent of dairy, 3 per cent of pigs and 11 percent of layers. The share of certified organic milk cows, other cattle, layers and sheep is increasing every year while the percentage of certified pigs is largely unchanged.

Dairy

Katarina Rehnström, Åsa Odelros & Moa Larsson Sundgren

Breeding and feeding for high yields is neither environmentally nor animal friendly

The ability of ruminants to turn forage into milk and meat is very important in ERA farming. A high amount of concentrates in the cow's diet gives more milk, but it costs about 1.5 - 2 times more energy compared to ecological milk produced with roughage. High proportions of concentrates have a negative impact on both animal health and milk quality. Cattle cannot utilize all the nutrients in concentrates [59]. The nutrients that are not utilized can be lost to the environment.

The central idea in organic milk production is that cows should be given roughage based feed during the entire lactation period. Pasture is a natural feed for ruminants during the vegetative period, in Sweden from April to September. The possibility to grow, harvest and store winter feed of high quality is crucial for the farm economy. Effective feed conversion is important to improve productivity, but also to decrease the environmental impact. That can be achieved through animal health, genotypes, reproduction ability and long life[60]. It is also important that the breeding takes these additional aspects into account as well as the ability to produce as much milk as possible from roughage. Dairy cows can produce 6,000 kg milk/year on good quality roughage, some individuals up to 7,000 kg. Bulls with daughter-groups in conventional and organic systems gave a different ranking of top bulls for high milk yields. The difference shows the importance to select breeding bulls for organic systems [61].
Farmers have to continually make the following decision: maximize the milk yield with a high input of concentrate or increase the proportion of roughage with decreased milk yield for a lower feed price. In the end it is all about the production costs of milk that are important to create profitability.

Arable land requirement/cow/year, including heifers and calves, high degree of self-sufficiency (64)

Crop	Area
Forage (forage ley + whole crop)	0.75 to 0.95 ha
Grazing (dairy) *	0.15 to 0.25 ha
Cereal	0.25 to 0.40 ha
Pulses	0.15 to 0.25 ha
Rape	0.15 to 0.25 ha
Total	**1.45 to 2.10 ha**

* assuming that elderly young stock are on natural pasture

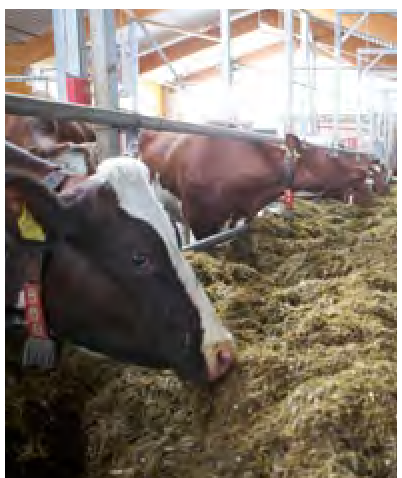
Roughage is the backbone in winter diets

The cows should have free access to roughage. This means that you have to accept some residues, 10 – 15 % so that the cows can sort and eat the best parts. Long eating times are important and also that feeding is evenly spread over the day. Select varieties of forage with high energy value and palatability. Timothy, meadow fescue and ryegrass are species that are tasty and have a high energy value.

Good quality clover silage according to the Nordic standards [64]

30 – 50 % clover
11 MJ /kg DM
150 – 200 g crude protein / kg DM
400 – 500 g NDF / kg DM

Whole crop silage including cereals or mixtures with peas or field beans can to some extent substitute clover silage. Examples of suitable combinations are peas with barley and oats whereas field beans mix well with spring wheat.
The proportion of peas or field beans in whole crop silage mixtures could constitute 30-70 per cent of the content. Maize silage also works well in combination with clover silage due to its high energy and low protein content.



Diet supplements

If necessary organic on farm grown cereals or protein feed can be added as supplement to the roughage based diet. The maximum daily intake according to recommendations are 5 kg cereals, 3 – 4 kg peas and 1.5 kg rapeseeds. The intake recommendations naturally depend on the cows individual milking capacity and the quality of the roughage. Potatoes are a great addition to cereals. Boiled potatoes contain more digestible energy than raw potatoes. Root vegetables such as fodder beets and turnips are counted as forage, which makes them particularly interesting for organic agriculture. They can provide high yields and they are tasty. The energy value corresponds to the grain. The daily ration is limited by the low crude fat and total solids content and should not exceed 25-30 kg root vegetables per day.

Alternative forage

In the old agrarian society leaves for feeding were important in the winter time. The nutritional value is good with a high protein content and a good amino acid composition. But leaves also contain several compounds that reduce digestibility such as tannins. Leaves from trees like elm, ash, linden, maple, willow, rowan and sell are quite well digested. A modern variant of feeding of leaves could be mixed silage with 10-20 % of the leading shoot of willow. A combined pasture with clover grass and energy forest could also be a possibility.

An example fodder ration for dairy cows [64]

- Go for hay, good quality roughage, whole crop silage is a good complement
- Supplement with cereals + peas/field beans in low- and mid-lactation
- and with rapeseed/lupin in early lactation

Lambs and beef cattle

A well suitable production on ERA farms - ecological lambs and beef cattle

There are a few differences between conventional and ecological recycling beef and lamb meat production. This type of production is well suited to ecological farming and only minor adjustments in the production strategy are needed. The conventional straw bedded sheep house conforms to organic standards and in cattle housing a straw bedded lying area is essential (the feeding area may be slatted).

Ecological meat production is largely based on fodder from natural pastureland and clover leys.
For sheep and beef production the problems to achieve profitable production levels with home grown feed are relatively easy to overcome. From both economic and physiological perspectives, the livestock will perform better on predominantly forage diets. However, there may be moments in the production cycle when supplementary feed is essential. Home grown pulse crops should be able to provide adequate protein at these times.

The proportion of forage, including grazing, varies between 80 and 100 % according to production model.

Take good care of clover in pastures [64]

➔ High nitrogen fixation secures long term soil fertility
➔ White clover is more suitable for grazing

The key issue for a profitable organic beef and lamb meat production is to achieve enough intensity and aim for slaughter maturity according to farm strategies and plans. It is important to learn how to judge the slaughter maturity, weigh the animals and deliver them to the slaughter house in the right moment. The best tool is a very good forage and grazing plan. For winter fodder the quality is very important and also the right volumes of course. Remember to analyse all feedstuff.

Pasture – convenient and cheap

In organic sheep, beef cattle and dairy production systems, it is important to maximise the quantity of fresh pasture in the diet. This helps us to achieve minimum feeding costs, with feed of maximum nutritive value.

A major part of the animal's growth is from pasturing and pastures which are the most natural feed for ruminants. About one third of the beef cow's diet is pasture and also the milk production depends on pasture. Grazing is totally ecological, in the meaning of complete recycling though nutrients. The nutrients pass from soil, through the cattle's or sheep and then back to the land. It is very essential to achieve a good balance in the summer between the supply of grass and the demand in nutrients for the animals.

The growth of the grass swards is very intensive in the beginning of the summer season and later on the growth slows down substantially. A good strategy is to rotate between several fields.

To be efficient in productive capacity, it is very important to plan acreage and the total grazing strategies. It is also a good habit to let the cattle and sheep out grazing as early as possible in the spring season. Also beneficial, especially for sheep are pastures containing a good diversity of herb species. If sheep have a free choice they will select herbs for two thirds of the diet and grass for the rest.

Grazing technique

The animals learn pasture behaviour from each other, to a certain extent even from other species.
A youngster grazing together with fully grown individuals, preferably their mother, becomes better in grazing technique. In that aspect, it is not a good idea to leave a young group on pasture without elders teaching them the best technique.

Optimal height of the sward is 5-8 cm for sheep and 8-13 cm for cattle.
Accept higher swards towards the end of season.

Production

A good pasture in early season holds an energy content of about 11 MJ per kilo dry matter. Results from research show that plenty of land and good grassland management combined with 1 – 2 kilos of supplemented hay is enough to produce up to 18 kg milk in early summer. Later around midsummer this pasture based diet will cover up to a production of 15 kg milk and in late season up to 12 kg. For young bulls it is possible to reach a growth rate of around 1,000 g/day. The growth or the milk production can increase somewhat if the lay contains a lot of clover.

Mixed grazing – minimize parasites and maximize the intake

Young calves 3-4 months old and young animals over all, are very sensitive to internal parasites. This is one of the reasons not to let young and old animals on the same pasture. When animals are let on a pasture for the first time it is important to always have „a clean field". A clean pasture means that there have not been grazing animals there of the same species the year before or that the field has been cultivated after grazing.

Another strategic approach is to mix or rotate grazing with other species for example cattle and lamb. This is an ecological way of controlling the internal parasites and also to use the pasture more effectively. In general it is a fact that on a farm with many different kinds of animals the problems with parasites are much smaller than on a farm with just one sort of farm animal. Following sheep with cattle or horses is considered the best option.

Prevention strategies are encouraged as an alternative to reliance on dewormers. In ecological recycling farming lower stocking rates, evasive grazing practices and genetic selection are encouraged and will reduce any worm burden.

Sheep

Example of a winter fodder ration (DM) for an 85 kilo ewe with 2-3 lambs [66]

Feedstuff	kg
Hey	1.8
Wheat	0.7
Oat	0.5
Peas	0.3

Pigs

Ecological pig production – an interesting niche

Pigs, like humans, are monogastric. They compete with human beings of the same kind of high quality proteins and cereals. This circumstance gives the pigs a secondary roll in ecologial farming, where the number of pigs has to match acreage and crop rotation. The function of pigs would be to efficiently refine leftovers from harvests and also to use nutrients in waste such as by-products from the local food chain, grocery stores and community kitchens. Pigs can at the same time be useful in cultivating the soil and fight unwanted insects. In addition they can also be used for an environmentally friendly way to manage forests and woodlands.

In future ecological recycling agriculture, pork meat production must be practiced in a much smaller scale than today.

Guidelines for organic pigs

- Pigs are natural foragers - they enjoy exploring and rooting.
- Pigs need free access to large fields – if possible all year round.
- Keep pigs and their shelters in rotation - intervals at least 3 - 4 years.
- Pigs need to be kept in family groups.
- The sow must be given the possibility to build a nest before the piglets are born.
- Pigs must be given enough space to be able to separate for feeding, drinking, resting and dunging.

Farm acreage is the key to herd size

Also our environmental law demands a certain acreage to spread manure and bedding mixtures. Manure should be applied to crop land based upon its nutrient content and crop nutrient needs. Pigs do fit well into an ecological rotation because they contribute with fertilizer at the end of the grass ley. The ecological pig farmer must plan carefully how to rotate foraging and rooting in fields in order to maintain animal welfare and minimize nutrient leakage.

Types of housing can vary much. Some farmers keep the pigs in shelters all year around while others prefer to house them in a farm building during the winter months and shelters in the field in the summer time. A third alternative is to house them in a permanent building.Indoor housing is permitted in severe weather conditions, provided that there is plenty of straw bedding for the pigs, and continued access to an outdoor run.

Feedstuff – ecological and on farm grown

Cereal is the main ingredient in ecological pig feed. It is necessary though to add high quality protein to the diet, especially to young pigs. Research work indicates that it is possible to feed older pigs a low protein diet and still maintain good results in growth and meat quality.

In feeding pigs organic, the most difficult stages are to feed lactating sows and newly weaned piglets.

The traditional way of keeping pigs on farms in the old days was based on feeding the animals with waste products. There are many options to supplement the diets with different kinds of alternative feedstuffs: wheat feed, wheat bran, dried sugar beet pulp, molasses, brewers grains, whole or skim milk and so on. Whole milk for example may be available as a by-product from the dairy. It is an excellent and highly digestible feed for pigs of all ages. There are no feeding limitations concerning the amounts used but careful attention is necessary when it comes to feed hygiene. Also different kinds of root crops offer a big variety of feed supplementation. Potatoes, carrots, fodder beets, swedes, turnips and sugar beet to mention some. For example, surplus potatoes or those graded unsuitable for the human consumption can be utilized as pig feed. Potatoes are an excellent source of energy, protein, essential vitamins and minerals. Approximately 6 kg of raw or 6.5 kg ensiled potato are needed to replace 1 kg barley. For finishing pigs, about 25 % of the diet dry matter can be provided from raw potato, but the performance is likely to be reduced relative to cereal diets. Cooking the potato improves its energy value by 40 % and also inactivates anti-nutritive factors.

Source-separated food waste constitutes a great potential for increasing the flow of urban plant nutrients back to agriculture. This flow can already be approved by certification bodies for use in organic production. Recycling systems should place high demands on traceability and low contamination in order to safeguard hygiene and environmental requirements.

Pasture and forage utilization depending on age

A pig's ability to utilize pasture and forage is related to its age and digestive capacity. Forages for pigs need to be leafy, with less stems and straw than a cow would enjoy. Older pigs can handle up to 70 % leafy forages, providing 50 % of their maintenance energy needs. Young piglets are unable to consume big amounts of roughage because of their undeveloped digestive tract. They need high quality grain and protein in their ration. However, when the animals grow older, their intake capacity increases. By restricting the amount of concentrate fed to growing pigs forage intake can reach 15 % of dry matter. In such a strategy the growth rate will decrease and result in a leaner carcass.

Pregnant sows have a high intake capacity and can eat and utilise large amounts of low energy forages. However, in lactation the sow need a concentrated diet otherwise she will be loosing weight and have a poor milk production. In this stage forages should be used as supplement.

Pigs are quick to decide about the quality of the pasture. If the pasture is poor the pigs root up the pasture and eat the roots. Some farmers include pigs in their crop rotation and use the pig's ability for turning in crops and aerating soil. The animals are moved after they eat the crops and weeds and tilt the soil. Pigs will also find worms and insects in the soil, which is a valuable protein complement to the diet. After the pigs are moved only light tillage is needed to prepare the ground for the next crop.

ERA farm recommendations

- Rotational grazing
- High quality pasture
- Supplemented with farm grown grains and legumes

Grazing woodlands

An interesting option is woodland grazing. Pigs are recognised for their valuable contribution to woodland management. Managed carefully they will help to maintain natural habitats by creating better conditions for the re-establishment of plants. Woodlands provide shelter and weather protection for the pigs. It is not recommended to put piglets younger than one month of age in woodlands. Pigs kept in forests must respond well to electric fences and they must be offered a dry resting area covered with straw.

An example fodder ration for lactating sows. This example assumes that sows farrow in early summer so that they will benefit from the good quality pasture [66].

Feedstuff	%
Barley	53.75
Skimmilk	11.75
Legume grass pasture	10.1
Whole crop silage with peas	10.35
Boiled potatoes	3.4
Concentrate	10.7

Poultry

The challenge of the laying hen in ERA farming

A hen has an excellent ability to search for and to compose a complete diet including all nutrients she needs in proper measure. Poultry have a built in mill and can eat almost everything e.g. seeds, insects and worms. They can be useful in fruit gardens, eating insects. They are also helpful in a mixed grazing system where they contribute to a better utilisation of the pasture by spreading cattle droppings and decreasing the amount of intestinal parasites of other species.

To keep organic layers is quite a challenge compared to conventional egg production. The modern genotypes are bred to produce a large number of eggs and for efficient feed conversion.

Most European organic poultry farms keep hybrids bred for conventional conditions. This is in fact one of the reasons why problems occur in feeding and managing the flock. To use a landrace, dual purpose breed or even an original breed is not yet a possibility in commercial production due to a very low production rate.

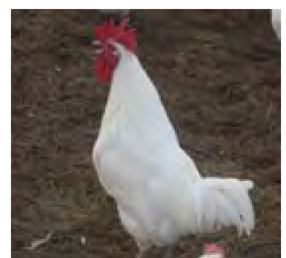
Farmed poultry and humans compete for the same feed ingredients. Also ecological hens are mainly fed cereals, corn, peas and soy beans and one might say that it is a limiting factor in creating a sustainable nutrient recycling system.

Examples of vegetarian farm grown crops for protein

Field beans
Peas
Sun flower seeds
Rape seeds

New ecological high value protein

Fly larvae meal
Algae
Mussel meal
Hemp cake
Sesame cake
Fermented amino acid products



Feeding

An ecological layer will eat about 130 grams per day. Cereals such as wheat, barley, oats or maize are the base in layer feed. A thumb rule for cereals is 1/3 of each component. A good protein quality in the diet means a higher proportion of on farm grown cereals in the daily rations. A normal content of cereals in the diet lies between 60-80 percents.

Soy is debated as it often is imported from distant countries and furthermore contributes to the destruction of rainforests and grasslands. Fishmeal, commonly used in ecological layer diets in Scandinavia is another debated protein source. New organic high value protein feedstuffs may also be interesting in the future.

Let the hen choose herself

A modern laying hen does not need to show foraging behaviour to obtain feed, but she is still highly motivated to do so. In the wild 65 % of the time is spent on ground pecking and scratching. It is indeed a challenge to satisfy the chickens need to express natural behaviour. The poultry farmer has to make sure to keep the flock occupied to avoid outbreaks of feather pecking and cannibalism.
If we let hens have a free choice what to eat we can save a great deal of work. Experiments have shown that at least in smaller flocks, about 30 hens, so called cafeteria feeding, is possible.
The animals were separately served whole wheat, whole oats, sea shells, fish meal, clover/luzern hay, and grass in the outdoor run in the summertime. In winter time they were also fed a mixture of mashed cereals, cod liver oil, cabbage and turnips, salt and trace elements.

Roughage

Experiences from recent years indicate, that poultry to a certain extent is capable of absorbing nutrients in roughage. The roughage also makes the hens calmer and less aggressive, feather pecking is reduced and mortality rate decreases.

In the summer time the intake of roughage should come from the pasture and in the winter time from for example silage or carrots. Hens prefer finely chopped, maximum 5 cm length roughage and whole crop silage. According to a Danish study a hen will eat as much as 50-60 g whole crop silage in one day. Cabbage as roughage is also a possibility. Hens like it and the protein quality is good.

Recycled waste food and by-products

Poultry in small scale holdings were once effective users of waste. Converting by-products from "local food chains" e. g. kitchen- and garden scraps and shop wastes into eggs. Laying hens were an important link in recycling. Why do we not use that power today?

There are several by-products that are useful in layer diets, for example dairy products, waste from breweries and bakeries. Recycled food will play an important roll in the future.

The importance of a good start in life

The rearing period is very important and it accounts for more than 60 % of the bird's production performance on a laying farm. It is important that the conditions in the rearing house, such as housing system, daylight, access to outdoor run etc. are similar to those on laying farms. It is very important to avoid behavioural disturbances during the rearing period. There has been observed less feather pecking in flocks that are reared with good litter. Presence of good litter remains important throughout the laying period. There is also more feather pecking in larger groups and in groups with higher bird densities.

Housing

The hen house must be carefully planned. There must be enough space, nest area and perches in the hen house, and plenty of opportunities to dust bathe in fresh litter. Make sure that the hen house is as rodent-proof as possible. Be sure that you can remove the manure on a regular basis, preferably once or twice a week. The hen house housing a large flock must have a good ventilation system while it is possible to achieve a good indoor climate using natural ventilation in a small hen house.

Mobile hen house – a perfect solution

A mobile hen house serves several purposes and is a perfect way to combine egg production with crop rotation. Hens fertilize the pasture area, find insects and green plants to eat. By moving the house regularly one will minimize the risks of parasites. It is possible to build a self made mobile house or buy a complete house with all equipments for 200 - 1,200 laying hens.

An example vegeterian fodder ration for 20-28 week old layers

Feedstuff	%
Wheat	16.85
Maize	6.0
Sunflower cake	10.8
Soybeans	30.57
Rape seeds	5.0
Hemp seeds	20.63
Alfalfa meal	2.0
Calcium carbonate	4.5
Cryster shells	4.3
MCP	0.15

PLANT PROTECTION

Stefan Kühne and Sara Preißel

Why it matters

Past and future issues

Pesticide-based plant protection in agriculture has led to vast ecological problems for the Baltic Sea as well as other ecosystems. Although the ban of some of the most harmful chemicals has alleviated the situation temporarily[26], pesticide use (especially of herbicides) [30] in the Baltic Sea catchment area has increased since the 1990s, and further increases are projected[28]. Accumulating in river estuaries, agricultural pesticides pose a threat for marine life and humans.

Rules for ERA farms

In organic agriculture, and on ERA farms, synthetic plant protection agents are not applied, so none of these pesticides are emitted to the Baltic Sea from such farms. Instead, weeds, pests, and diseases are controlled primarily through prevention. This requires thorough knowledge of the biology of pest organisms and their interactions as well as how agricultural operations influence their development.

Concept of Plant Protection for ERA farms

- **Ban on synthetic plant protection agents and especially herbicides**
- **Ban on genetically modified organisms**

Utilization of Natural Regulatory Mechanisms

Promotion and conservation of beneficial organisms through diverse habitat structures

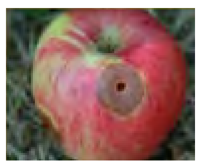
Flower strips promote aphid predators such as Green Lacewings

Biological and Biotechnical Plant Protection

Confusing pests with sexual pheromones

Application of beneficial insects, e.g. parasitic wasps

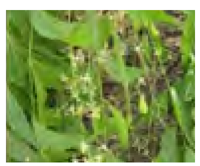
Use of microorganism (virus, bacteria, fungi)



Pheromone against Codling Moth

Plant Protection Agents based on Natural Substances

E.g. from plant extracts (Neem tree, Chrysanthemum) or insecticidal soap



Neem extracts against Colorado Potato Beetle

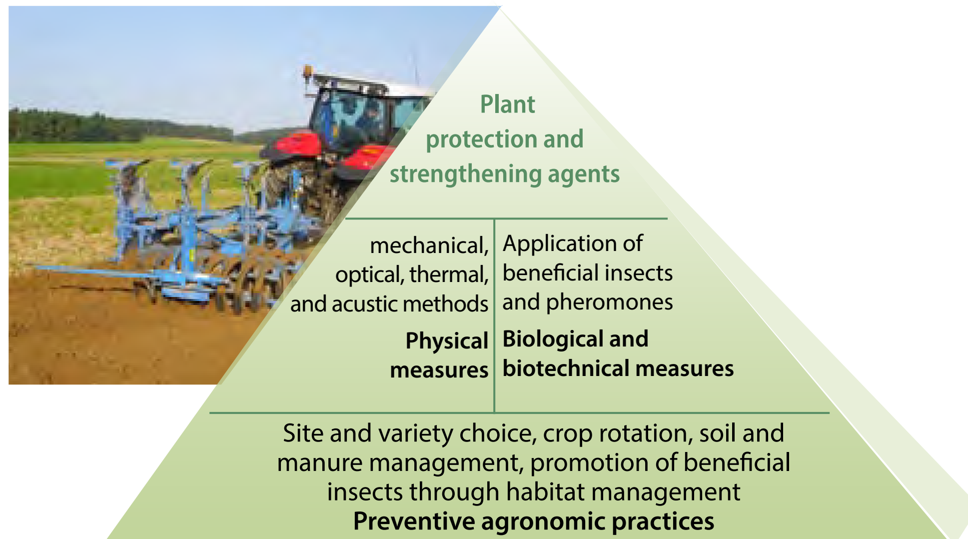
Principles of organic plant protection

What are the biggest challenges

It is important to establish which specific pests cause significant economic damage in one's fields – considering that the conversion to ERA farming changes the set of problems. Due to the wider crop rotations and lower fertilization, long-term organic farmers often experience more diverse but less severe infestations of pests and diseases. For example, organic farms have fewer problems with soil-borne diseases and aphids. Instead seed-borne diseases (cereals), potato late blight, pests and diseases of grain legumes (sitona weevils, aphids, fungi), mice and wireworms in fodder crops, storage pests, and weeds are often more problematic[29].

Even when all preventive measures are taken, regulatory measures may be necessary. It is important to carry out a close monitoring of pest development (e.g. with the help of sexual pheromone traps in fruit orchards and grain stores). Also an analysis of the economic and ecological costs and benefits of control measures needs to be made.
Preventive measures are the foundation of plant protection in ERA farming systems.

Framework for action



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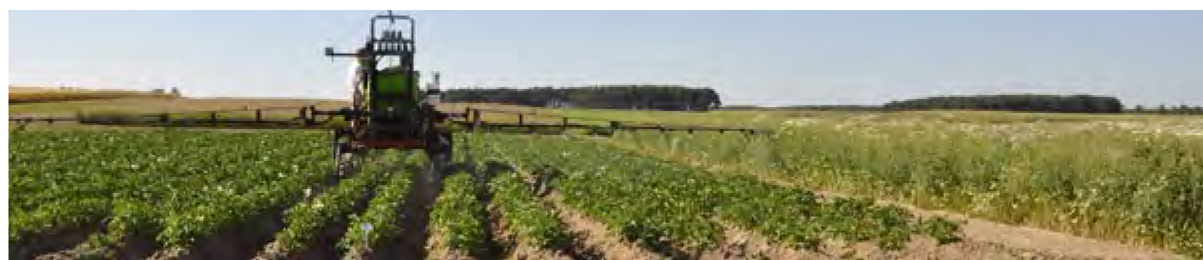
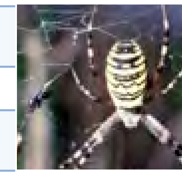


Preventive Plant Protection [30]

A preventive plant protection strategy must consider pests, diseases and weeds as an integrated whole, since there are many interactions between the three. For example, pests can transmit viruses and create an entry points for fungal diseases; weeds create a fungi-friendly microclimate and are hosts for diseases (e.g. mildew, rust fungus). On the other hand, flowering weeds are important for attracting beneficial insects. Select from the measures listed below to design a prevention strategy adapted specifically to address your key pest organisms. Contact your local agricultural advisors and agencies for information on suppliers, etc.

Measure	Examples/Specifications
Choice of suitable crop sites and adapted varieties	
Plant resistant varieties	E.g. Anthracnose resistant yellow lupine Alternate or mix varieties with different resistance genes Early potato varieties can be harvested before late blight
Choose varieties bred for organic agriculture	E.g. cereal varieties adapted to organic nutrient levels and disease spectrum
Use crop mixtures and variety mixtures that can improve plant health and stabilize yields through compensation	Crop mixtures are common for fodder crops Variety mixtures with different resistances, e.g. against mildew in barley
Plant certified seed to reduce seed-borne diseases	Organic seeds can be treated with hot water, hot air or natural fungicides
Diverse crop rotations	
Alternate cereals and broad-leafed crops	This breaks the chain of infection of soil-borne diseases, e.g. fusarium in cereals, nematodes in broad-leafed crops
Have crop rotations that follow the recommended time intervals for crops	Potato cyst nematodes and late blight, eyespot and take-all in cereals, many legume diseases
Have suitable cover and catch crops during winter	Mustard as catch crop reduces nematode populations Green manure and fodder crops reduce weed pressure Note: promotes slugs and mice

Measure	Examples/Specifications
Soil cultivation and manure management (soil fertility)	
Reduce turning tillage and increase soil cover (mulch, intercropping)	Increased soil life and soil cover reduce soil-borne diseases and weed seeds Note: promotes slugs and mice
Thorough tillage	Destroys crop and weed residues that carry pathogens and pest larvae, e.g. corn borer larvae and ear rot in maize, rye blotch
Balanced fertilization	Lower amounts of nitrogen fertilization reduce fungal infections
Thorough composting of manure and crop residues	Prevents the spreading of pathogens and weed seeds contained in farmyard manure
Promotion of beneficial insects and birds	
Habitat management	➔ See next page
Other measures	
Adapted crop spacing	Wider spacing reduces fungal diseases through better aeration (septoria, mildew in cereals, ascochyta in legumes) Wider row spacing facilitates mechanical weed management
Promote fast germination/ seedling development	Pre-sprouted potatoes mature faster and escape potato late blight to a degree Planting vegetable seedlings instead of seeds Optimal sowing conditions (large seed, shallow depth, optimal timing)
Mulch	Straw mulch between potato plants irritates aphid immigration due to its colour and surface structure
Apply plant strengtheners	Not regulated by the European Organic Regulations, consult your certifier to find out which substances are approved for your situation
Reduce the weed potential	➔ See next pages



Examples for plant strengtheners

- Plant extracts from Stinging Nettle, Field Horsetail, Tansy, Wormwood, Comfrey, Algae...
- Homeopathic preparations
- Minerals: Lava meal, alumina, silicate
- Microorganisms: *Bacillus subtilis*

Habitat management to promote beneficial insects and birds

On the fields

Beneficial insects can be promoted by creating and maintaining flower strips and hedges as biotopes. These provide:

- Winter habitats (e.g. for spiders and ladybird beetles) nectar and pollen (e.g. for parasitic wasps and hoverflies)
- Refuge during and after harvest

The biotopes should be well distributed over the agricultural areas, since the insects move in a ca. 50-300 m radius where they regulate aphids and other pests [31]. Hedges and flowers also provide food, refuge and nesting possibilities for birds supporting the regulation of pests.

Annual field ridges	Outer 3-8 m of the field Allow multiplication of arable field plants and insects
Perennial flower	Up to 10 m wide strips at the edge and strips within fields, e.g. sown with annual and perennial wild plants
Hedges	Establish a ca. 2 m wide strip along hedges, which may be mowed once every 2 years

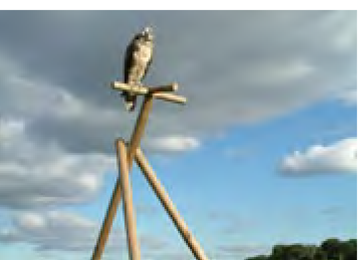
In fruit orchards

Nesting cavities are the limiting factor for bird density in fruit orchards. Nest boxes attract songbirds such as tits, tree sparrows and nuthatches. Birds regulate insect pests, e.g. one pair of tits consumes up to 3 kg of insects per year [31].

Nesting boxes for songbirds	Ca. 7 nesting boxes per ha Hole size 30 mm (excludes starlings)

On grassland

Infestations of mice are especially common on perennial grasslands and in fruit orchards, and to a lower degree on fields. Their numbers can be reduced by providing artificial raised stands from which their natural enemies, raptors (e.g. buzzard, kestrel) and owls, can hunt. Also martens, weasels, and hedgehogs hunt mice.



Raised stands for raptors and owls	1 stand per ha, 200 m distance from roads, height 2 m, installation September - April Mobile stands facilitate installation and removal

Weed management

Besides preventive methods like crop rotation etc., weed control in ERA farms relies on mechanical and thermal measures. These measures are most effective on small-sized weeds, the control of larger weeds is costly. Thus, timely weed control is crucial. Perennial weeds such as creeping thistle and couch grass on arable land and dock weed on grassland are difficult to manage and require a combination of measures.

Central points in weed prevention are[32]:

- Crop rotation with perennial legume-grass leys
- Turning tillage
- Stubble cultivation, repeated seedbed preparation (false seedbed), and pre-emergence weeding
- Prevention of seed production and rhizome formation
- Dense ground cover using appropriate varieties, variety or crop mixtures, cover crops, mulch, or under-sown crops
- Spacing that allows for efficient mechanical weed control

Weed control [32]

Measure/Tool	Application	Affected weeds
Harrow	False seedbed, before emergence, in young crops (careful in broad-leafed crops)	Small annual weeds
Hoe	Between rows (>15 cm spacing), with special equipment also on ridges	Up to large, well rooted weeds and grasses
Weed burner (High energy costs!)	Before emergence or between rows (> 30 cm spacing)	Small annual weeds
Ridger	Widely spaced crops, when planting, before emergence, in larger crops (cereals)	Medium-sized weeds
Rotary tiller, Tooth cultivator	During bare fallow	Rhizomes of perennial weeds are dug up and desiccate
Soil solarisation (High costs!)	Bare fallow in summer: sunlight heats up soil covered with plastic sheets	Weed seeds, plants and pathogens
Hand weeding (High costs!)	Within rows and after crop canopy closure	Large weed plants with imminent seed dispersal

Incompletely decomposed cereal residues are a dangerous source of fungal infections (Fusarium). The Guettler roll crushes maize stems and thereby destroys the winter habitat of corn borer pupae Solarisation with plastic sheets.

Direct Control of Pests and Diseases

Organic control of pests and diseases in the field makes use of:

1. **Beneficial insects** which are in exceptional cases applied in open fields, such as
   Trichogramma parasitic wasps against corn borers or harmful caterpillars in horticulture.
2. **Sexual pheromones** which disrupt the recognition of insect mating partners (confusion method).
   - **Traps** for monitoring.
   - **Dispensation** against Vine Moth and Codling Moth.
3. **Microbial pest management** with bacteria, fungi or viruses.
4. A limited choice of **natural substances** which may be applied when need is proven.
   In the long term, alternatives to some substances such as copper and sulphur are needed, because of their negative effect on the ecosystem.

The EU Organic Regulations (EC) No 834/2007 and No. 889/2008, Appendix II, approve pesticides (pheromones, microbes and chemicals) for organic agriculture. The specific formulations have to be approved by your country and certifier.

Control of Storage Pests[33]

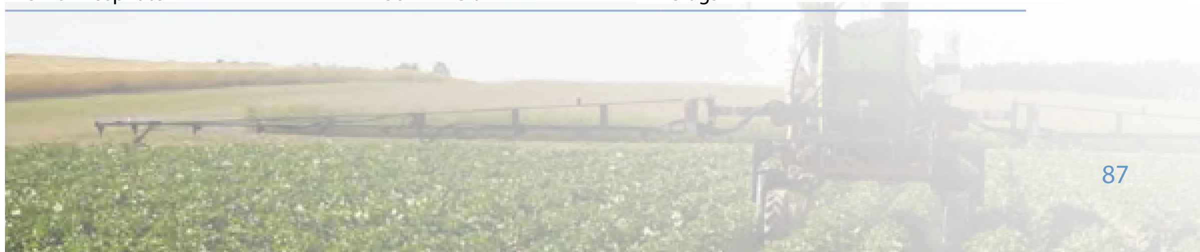
Once established, storage pests (e.g. Wheat Weevil, Flour Mite, Grain Moth) are difficult to control organically, therefore prevention is crucial: Always store clean and dry grain in clean stores.

Other measures are:

- Open and cool down grain stores during frost periods.
- Below 12° C, pest insects pause their development (flour mites < 5° C), many die below 6° C.
- Monitor pests with pheromone traps (Indianmeal Moth), ultra-sensitive microphones (Wheat Weevil), grain sampling.
- Mix diatomaceous earth with the grain to desiccate insect pests (cleaning from diatomaceous afterwards) or apply in empty stores. Cannot be combined with beneficial insects.
- Introduce parasitoid wasps against beetles, weevils and moths, and predatory mites against flour mites.
- Use heat treatments and fumigation with carbon dioxide or nitrogen.

Selection of organic pesticides

Active compound	Origin	Action & application examples
Insecticide		
Azadirachtin	Neem tree	Stomach poison E.g. potato beetle, caterpillars, aphids
Pyrethrum	Chrysanthemums	Contact poison E.g. potato beetle, spider mite, storage pests
Quassia	*Quassia amara*	Stomach- and contact poison, aphids, sawfly
Spinosad	Product of soil bacteria	Stomach and contact poison E.g. potato beetle, thrips, leek moth
	! Toxic for water organisms and bees, application restricted	
Rapeseed oil	Rape	Contact poison E.g. spider mites, white flies, aphids
Insecticidal soap	Potassium fatty acid soap	Contact poison E.g. aphids, white flies, sucking pests
Bacillus thuringiensis	Bacterium	E.g. larvae of corn borers, potato beetles, whites
Granulovirus Isolate	Virus	Larvae of codling moth and summer fruit tortrix moth
Fungicide		
Lecithin	E.g. soy bean	Powdery mildew
Sulphur	Chemical element	Powdery mildew, gall mites, fruit diseases **Also acaricide & repellent**
Copper (e.g. copperhydroxide, copper-oxychloride and coppersulfate)	Chemical element	Downy mildew, black leg and potato late blight, vegetable diseases
	Restricted to max. 6 kg per ha and year (exceptions possible for perennial crops)! German organic associations allow 3 kg/ha and year (4kg/ha and year in hop)!	
Pseudomonas chlororaphis	Bacterium	Bunt, blotch, fusarium, stripe in cereals
Coniothyrium minitans	Fungus	Sclerotinia disease in different crops
Molluscicide		
Ferric Phosphate	Soil mineral	Slugs



PHOSPHORUS

Karin Stein-Bachinger & Johann Bachinger

Why it matters

Current situation

Phosphorus (P), an essential macro nutrient for plants, is a non-renewable resource. Soil contains between 0.02 and 0.2 % P. Topsoil with 3 % organic matter contains about 1 ton of P/ha and of this only about 1 % is mineralized during the growing season becoming accessible to plants [44,52]. Phosphorus is always found in combination with other elements in the form of phosphates, it doesn't occur naturally as an element.

Agriculture is one of the biggest users of phosphorus. The main source is mined rock phosphate most of which comes from Morocco, China and USA. Europe is totally dependent on imports. According to various calculations it can be assumed that the global phosphate reserves will be depleted in 50 - 100 years [41].

Environmental issues

During the past decades, P from agricultural runoff and point sources has contributed to a high level of eutrophication and increased algae growth in the Baltic Sea. This in turn has resulted in growing areas of dead sea bottoms and the disappearance of aquatic animals [42]. Especially in farming regions with high animal densities and where production is based on purchased fodder, the potential for P losses is still increasing due to the application of high amounts of slurry [1, 44].

In areas with one-sided and intensive crop production the main pathway for phosphorus into water bodies is water erosion. More than 60 % of the diffuse P-inputs is caused by erosion and in the process arable soil is lost irreversibly. On arable land (e.g. with maize) up to 50 kg phosphate per ha and year can be washed away [55].

Satellite image of algae in bloom in the Baltic Sea, Summer 2006. Source: NASA (image processed and made available by SMHI).

http://www.smhi.se/kunskapsbanken/oceanografi/algblomningar-i-ostersjon-1.3008

Definition

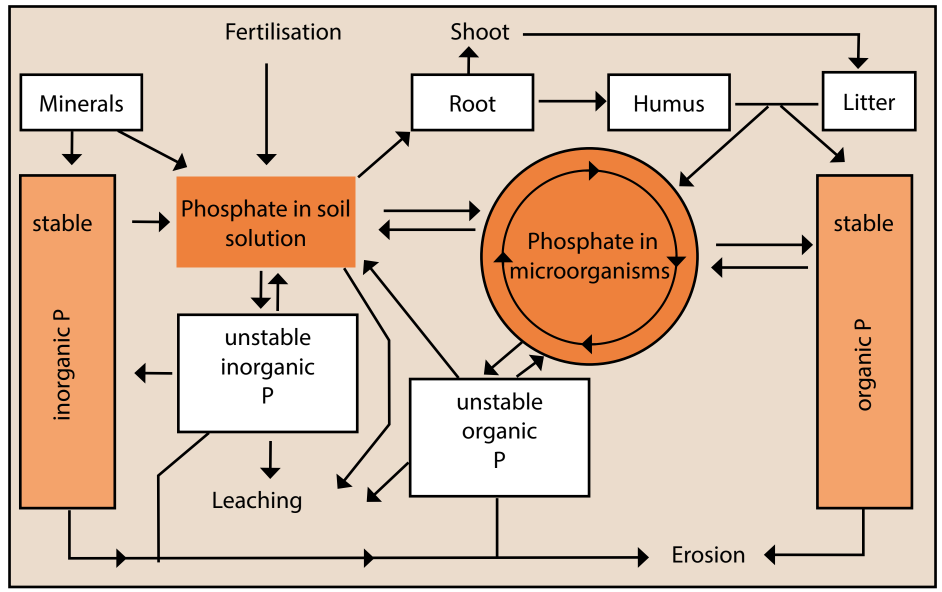
The word phosphorus is derived from the Greek ‚phos' meaning ‚light' and ‚phorus' meaning ‚bringing'.

Importance for plant growth

Multifunctional benefits of P

P is an essential component in every cell in all living organisms and cannot be replaced by any other element. P supports many plant processes [9,45] e.g. photosynthesis, microbial activity (especially nitrogen fixation), fruit formation, winter hardiness and competitiveness (especially of perennial legumes), disease resistance and building stalk strength.

The phosphorus concentration in the soil solution is very low. Therefore a quick and continuous mobilisation of P from the unstable fraction is necessary. As shown in the following figure, the soil microbial biomass is the main source and buffer for phosphorus which is available for the plants [55]



P cycle in the soil with the initial pools of the stable and unstable (labil) fractions (organic and inorganic) and the places of conversion: soil solution, microorganisms and plants [55]

The story of mycorrhiza

Necessary cooperation [46]

Beneficial soil microorganisms like symbiotic mycorrhizal fungi help to improve the uptake of nutrients like phosphorus that are difficult to access in the soil. The mycorrhizal fungi provide the plant with nutrients and moisture. This can happen because the fungi increase the surface absorbing area of the roots and thereby greatly improve the ability of the plant to access soil resources and release enzymes into the soil. These help to dissolve hard-to-capture nutrients, such as organic and mineral phosphorus and micronutrients. The plant utilizes these resources to grow and photosynthesize, capturing carbon dioxide from the air and transforming it into carbohydrates, which also provide nourishment to the mycorrhizae [46].

Undisturbed soils are full of these beneficial organisms. Intensive tillage and intensive use of readily soluble phosphorus fertilizers, erosion and soil compaction reduce or eliminate these mycorrhizae [46].

Additional advantages

Plants living in symbiosis with fungi are more resistant against diseases (e.g. nematodes) and bad weather conditions (e.g. droughts) [55,56]. On the whole, these mycorrhizae provide many direct and indirect services that contribute to increased agricultural productivity, improved water-infiltration and water-holding capacity, and soil carbon sequestration [46]. Therefore, it is essential for ERA farming systems to maximize the presence of mycorrhizal fungi. This can be achieved through, for example, a diverse crop rotation, minimal soil disturbance and the use of cover crops.

Definition

Mycorrhiza: comes from the ancient Greek words 'mycor' = 'fungus' and 'rhiza' = 'root'. Most plants like cereals, potatoes, legumes and even weeds can develop a symbiosis with mycorrhizal fungi. Only crucifers like rape, cabbage and mustard do not have the capacity to do so.

P on farm level

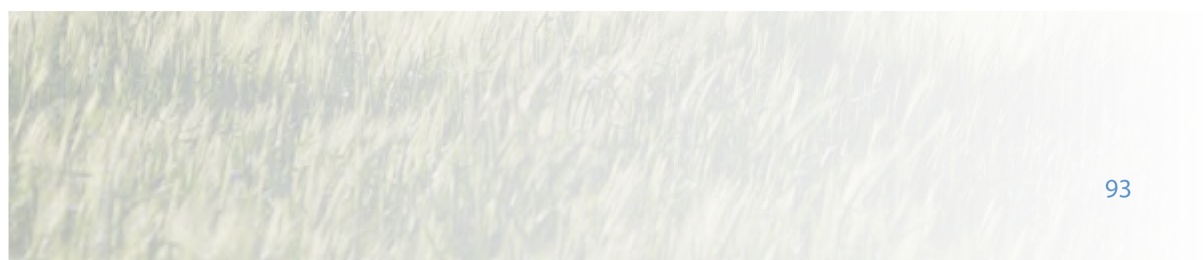
Usually on ERA farms, the P-balance is either zero or slightly negative (up to – 2 kg P/ha and year) [1, 3]. In general, most farms do not need to apply P because of the high P levels that remain in the soil. Within ERA farms, P is recycled via crop residues and farmyard manure. About 80 % of the harvested phosphorus is used as fodder, which passes through the animals and returns to the soil in the form of manure [2].

P content of different products [4, 5]	
1 t cereals or grain legumes	4 – 5 kg P
1 liter milk	1 g P
1 t cattle manure	1.2 kg P
1 t pig manure	2.5 kg P
1 t bone meal	85 kg P
1 t horn meal	10 kg P

Up to 40 % of the P can be taken up from the subsoil [44]. Active nutrient mobilization is accomplished for example by legumes which lower the pH in their root zones. This plays an important role for the P mobilization of calcium phosphates from e.g. raw phosphates [57].

Eventual P deficiencies can be detected through soil analysis or nutrient balance assessments, but it is important to take into account that the potential mineralization of the organic bound nutrients is not included in the common analysis values. A deficit of about 2 kg P/ha and year at farm level seems to be effectively compensated through weathering processes and the uptake from the subsoil through deep rooting plants like clover and alfalfa [1].
Deficiency symptoms which might occur include the dark-green older leaves turning red and violet and even stalks turning red in color. To meet P deficiencies, several agronomic options can be considered (see following pages) including fertilization by slowly dissolving fertilizers that meet organic standards.

In many cases it is the oxide form P_2O_5 that is used in agriculture:
1 kg P ≈ 2.29 kg P_2O_5
1 kg P_2O_5 ≈ 0.44 kg P



How to increase P efficiency

Measures to reduce P losses [43]

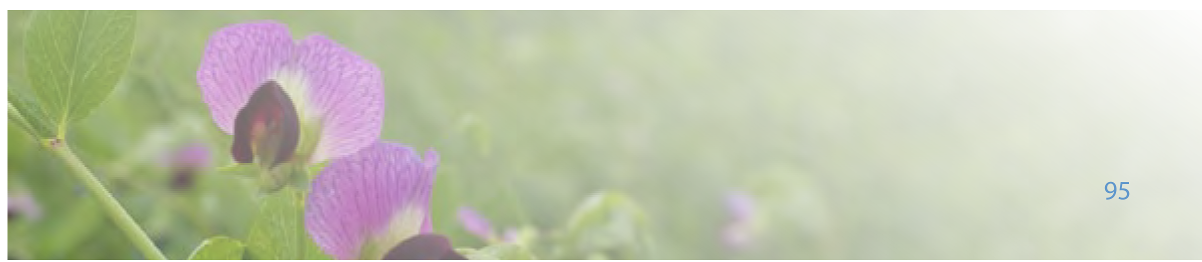
The greatest positive effects can be achieved by improving the soils' capacity to increase water infiltration and prevent soil erosion and surface runoff.

- Increase humus content (soil fertility) and rooting depth.
- Retain vegetation cover (crop rotation) throughout the year (e.g. grow catch crops followed by mulching).
- Reduce tillage operations in endangered sites, till across the slope.
- Reduce soil compaction (also on grassland): avoid cultivation on wet soils, reduce wheel pressure, combine farming operations.
- Apply targeted liming to increase P availability.
- Establish permanent grassland on hills and fields at risk from flooding and on buffer zones around water bodies.
- Replace maize in problematic sites (e.g. hills, fields adjacent to water bodies) with clover-grass.
- Use peat soils only for permanent grassland as there is a high risk for leaching of P.
- Promote incorporation of manure to avoid losses by surface runoff.
- Reduce losses in the food chain.

Measures to increase P recycling [52,53]

- Increase P mobilisation through mycorrhizal root fungi by improving soil fertility and rooting depth.
- Cultivate legumes (red clover, field beans, white lupins) and increase the legume proportion in fodder mixtures (70 - 80 %) to support the mobilisation of P. Legumes lower the pH value in the rhizosphere through proton sequestration (H^+) which leads to mobilisation of calcium phosphate, e.g. from rock phosphate.
- Cultivate buck wheat and serradella as catch crops to increase the mobilization of organic P reserves.
- Use manure and plant residues to improve the turnover of soil organisms and mobilisation of organic P resources.
- Ensure sufficient storage capacity for slurry to be able to choose the most effective application date at the beginning of the vegetation period in order to maximize nutrient exploitation.
- Use farm gate and field level assessment methods to get an overview of the overall P level within the farm.

With regard to the whole food chain, the main P-losses occur in sewage sludge, organic and green waste and slaughterhouse waste. However, the recycling of these materials is hampered by the contaminates and pollutants they probably contain (see next page).



Legal restrictions

Different regulations for the recycling of bone meal in different countries

The use of bone meal as organic P- and Ca-fertilizer is not allowed in every country in the EU. For instance, in Sweden, special products are allowed for use on organic and ERA farms, whereas in Germany several organic growers' associations ban these products completely (e.g. Demeter, Bioland), while the EU regulations for organic agriculture allow their use. In Denmark, bone meal (e.g. Biogrow) use is allowed by the national regulations; however, the Dairy Association has forbidden the use of bone meal on land used for organic fodder production.

The existing European regulations, such as the Nitrates Directive and the Water Framework Directive, focus on combating the leaching of nitrogen, not phosphorus [41, 44, 49]. P from agricultural sources as well as P-recycling are not yet subject to European regulations.

Future perspective

ERA farming can help to alleviate the problems of eutrophication (of the Baltic Sea) from P as well as increase recycling of P, a non-renewable resource.

For further information also see the phosphorus position paper:

http://www.balticcompass.org

FARM COOPERATIONS

Gustav Alvermann

Initial situation

On farm recycling

The ecological as well as the economic stability of organic and ERA farming mainly results from their conceptual versatility. Ruminants are fed forage from legume-grass and their organic manure fertilizes the cereals and other non-legumes in the crop rotation. Some of the produced cereals and other fodder crops are fed to pigs and poultry (animal husbandry) and their manure is returned to the fields to further stabilize the system.
A land use system, which includes legume-grass leys, annual cash crops and, ideally, a diversity of animal species, stabilizes the humus content of the soil and helps to reduce weeds and other pests.

Reasons for specialisation

However, most of the farms that have converted to organic agriculture since the 1990s are specialized in some way: cereals, row crops, forage crops or specific breeds of e.g. poultry, pigs or cattle. That a certain branch of production is dominant is often the result of one factor of production (e.g. the soil type, the regional market or the skills and interests of the farmer) being best suited to a specific kind of production. Through this specialisation a better return on labour and invested capital is achieved. When the farmer converts to ERA production, the specialised production is usually retained. To shift to a flexible mixed-farming system today is not an economic option for most of the farmers as the economic benefits of specialisation are often lost when the farm diversifies. Also many farmers may not have the necessary knowledge and experience to make such a transition.

Way out

To bridge these two important characteristics of successful farming - specialisation that gives economic stability and diversity of production that gives ecological stability - cooperation between two or more farms is possible. The specialised crop farmer supplies the specialised livestock farmer with fodder, such as legume-grass or whole crop silage, with grain from cereals or grain legumes and with straw for bedding. In exchange he receives an equivalent of nutrients in the form of organic manure.

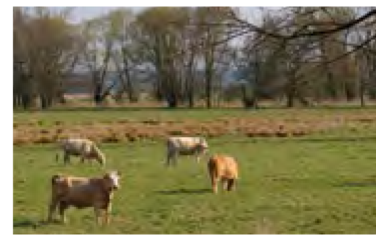
Basic models of fodder – manure – cooperation

There are basically three different models of fodder – manure – cooperation:

1. Forage (legume-grass or whole crop silage) for ruminants or for biogas plants in exchange for manure and slurry.
2. Fodder (cereals and grain legumes) for poultry and pigs in exchange for pig manure and fresh and dried poultry manure.
3. Straw in exchange for manure or e.g. mushroom compost.

The appropriateness of these different forms of cooperation depends on many factors including the distance between the cooperating farms and the nutrient density of the load. With silage, and even more so, slurry and fluid digestates, it is mainly water that is being transported. Cereals, straw and dried poultry manure have a much higher dry matter content.

Monetary value in € per ton of exchanged products			
Legume-grass silage	25	Liquid cattle manure	10
Straw	100	Pig manure	20
Cereals	350	Mushroom compost	25
Grain legumes	400	Dried poultry manure	65



The following forms of cooperation are discussed in more detail:

Cooperation type 1
Legume-grass exchanged for solid or liquid cattle manure

Cooperation type 2
Fodder grains exchanged for (dried) poultry manure

Cooperation type 3
Straw exchanged for manure or mushroom compost

Cooperation type 4
Combining different forms of cooperation

Examples of four cooperation types

Cooperation type 1: Legume-grass exchanged for solid or liquid cattle manure

How to start?

This form of cooperation is the most common in organic farming and therefore recommended for ERA farms since a high amount of legumes, mainly legume-grass in their crop rotation is necessary to maintain soil fertility and control weeds. An arable farmer and a nearby cattle farmer with limited access to land can benefit from that kind of cooperation. Ideally, a dairy farmer and a specialised crop farmer will start the conversion to ERA at the same time. Another possibility is when a dairy farmer wishes to expand but land rental costs are prohibitive. In such a situation the motivation for cooperation is positive and stable for both.

Economics

Usually, when forage and manure are exchanged no money is transferred. The crop farmer covers the cost for cultivation of the legume-grass. The cattle farmer covers the costs for harvesting and transporting the forage and spreading the manure onto the fields. In some cases the cattle farmer may make an additional payment for the legume-grass silage of between € 5 and € 10 per ton. Short distances between farms and a high legume-grass yield ensure that this valuable recycling method is economically feasible.

Biogas plants

The cooperation between a farmer and a modern biogas plant is similar. Most biogas plants operate with large quantities to ensure that payments for biomass and charges for slurry are correct. Alternatively the farmer supplies the legume-grass biomass and receives a remuneration of € 30 per ton. In this case the crop farmer covers all costs for harvesting, transporting and spreading the slurry on the farm. This remuneration of € 30 per ton biomass (33 % dry matter) delivered to the biogas plant is adequate. The harvest and transport of fresh biomass is estimated to cost € 15 per 10 kilometres and ton; the transport and spread of slurry on the field would cost about € 5. The expected return from 1 ton of silage is calculated with 0.75 m^3 fermented slurry. This gives a return of € 10 per ton of legume-grass silage or € 250 per ha with an estimated harvest of 25 tons of legume-grass per ha and, additionally the indirect fertilisation value of the returned slurry.

Cooperation type 2: Fodder grains exchanged for (dried) poultry manure

How to start?

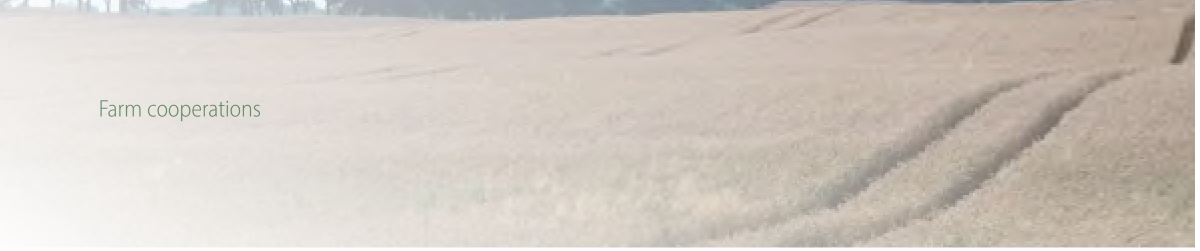
This form of cooperation is less dependent on local structures, due to the higher concentration of dry matter of the exchanged goods. For distances of more than 10 kilometres the transport of the manure by a transport company rather than by the farmer with his own tractor, may be more appropriate. Often this exchange is not direct as the grain passes through a fodder plant where appropriate feed mixtures are prepared. Many poultry farmers do not mix their own fodder on their farm.

Interconnection

Hence, the crop farmer supplies fodder cereals and grain legumes to the commercial fodder plant, which then supplies the organic mixed fodder to the poultry farm. In exchange, the crop farmer receives the nutrient equivalents in the form of poultry manure by lorry which will be spread in the spring before planting or in the fall on cereal stubble before sowing catch crops. A crucial point is the proper storage of the fresh or dried manure. This can be done at the poultry or the crop farm. Storage facilities on the poultry farm should be large enough to hold one lorry load of manure, have a flat and solid base and be able to be covered.

Economics

The value of manure received is usually equal to the fodder grains supplied by the crop farmer. The cost for transporting and spreading the manure is paid by the crop farmer. If the distance exceeds 50 km, the costs for transport are shared equally. This exchange is of course most effective when transport distances are short and in such cases it helps the crop farmer to maintain high cereal yields. The main application time of the poultry manure is in spring, when it is ploughed down before sowing spring cereals or other spring crops like corn.



Cooperation type 3:
Straw exchanged for manure or mushroom compost

Option 1

In some regions straw has become a scarce resource. This has created a possibility for an exchange of straw for bedding in return for straw enriched with animal dung and urine. Usually horse farms request this exchange. But because manure from horse farms usually has a high content of straw it is often not worth the effort and the crop farmer refuses. One option is to store this material for a time until it is appropriate to use as a supplement in legume production. Through this way nitrogen immobilisation can be avoided and the crop system can be strengthened. The costs for harvesting, transport from and back to the field as well as spreading are covered by the farm who receives the straw. Such cooperation requires a high level of organisation in order to ensure accurate timing for other production processes such as catch crop cultivation or stubble breaking.

Option 2

Another straw-manure-cooperation more appropriate over longer distances is the exchange of straw for mushroom compost. This is the decomposed organic residue from the production of white mushrooms. It is basically a mixture of straw, poultry manure and the mycelium from mushrooms. Because it contains a lot of macro and micro nutrients and has a good C/N balance it is valuable as a basic fertiliser and can also be used on legumes. In this cooperation model the mushroom producers cover all costs for harvesting and transporting the straw as well as for transporting and spreading the compost on the field. Because straw contains a lot of potassium, maintaining a balance among macro-nutrients is an important consideration. With other nutrients, usually a balanced intake can be achieved. If appropriate infrastructure is in place for easy transport and loading (onto the lorry) and the distance is not too great, the ‚straw' farmer can receive a benefit worth up to between € 50 and €100 per ha from this cooperation.

Cooperation type 4:
Combining different forms of cooperation

Innovative options

As outlined in the examples before, specialised crop farmers have many options to stabilise their farming system by cooperating with other enterprises depending on the specific situation in their area. One positive cooperative experience often leads to additional exchanges. This is exemplified in the following:

1. Local cooperation

25 % of the legume-grass in the crop rotation is delivered to a nearby dairy farm. In exchange separated thinned slurry is spread as a top dressing on winter cereals.

2. Regional cooperation

Fodder cereals are exchanged with a poultry farmer located 30 km away. The dried poultry dung is ploughed down prior to the spring cereal crop.

3. Supra-regional cooperation

All straw from the cereal production is pressed and delivered to a mushroom producer 100 km away. The returned mushroom compost is used as a basic fertilizer for field beans and legume-grass.

Present situation and trends with regard to distances between farms

It is obvious that these different forms of cooperation are more or less appropriate in different situations. For example, the exchange of fodder for manure and slurry is only possible within limited geographic areas, from 10 to 15 kilometres at most. On the other hand, cereals and grain legumes in exchange for dried poultry manure is possible over a larger geographic area. Regional models of cooperation that operate over distances of up to 50 kilometres and more already exist. The high demand for straw as the basic substrate in commercial mushroom production has led to cooperation and exchanges over distances of more than 100 km. Although there are many individual reasons for starting a cooperation, long distances (>50 km) between cooperating farms are not eligible according to the ERA principles.

Conclusions

There is a consensus that mixed ERA farming (combining diverse crop and animal production) is the most stable and sustainable farming system. However, such farming is not possible in every region or on every farm – certainly it is more difficult to practice today than it was thirty years ago.

For this reason cooperation between ERA farms in close proximity leads to an effective nutrient recycling and can provide an option for specialised crop and livestock farmers. But it has to be taken into account that the transport distances need to be limited.

In Germany the various organic farming associations have set up recommendations regarding the maximum distances allowed between cooperating farms (e.g. 50 km). For other countries within the Baltic Sea drainage area, the forms of cooperation that are feasible and eligible need to be assessed.

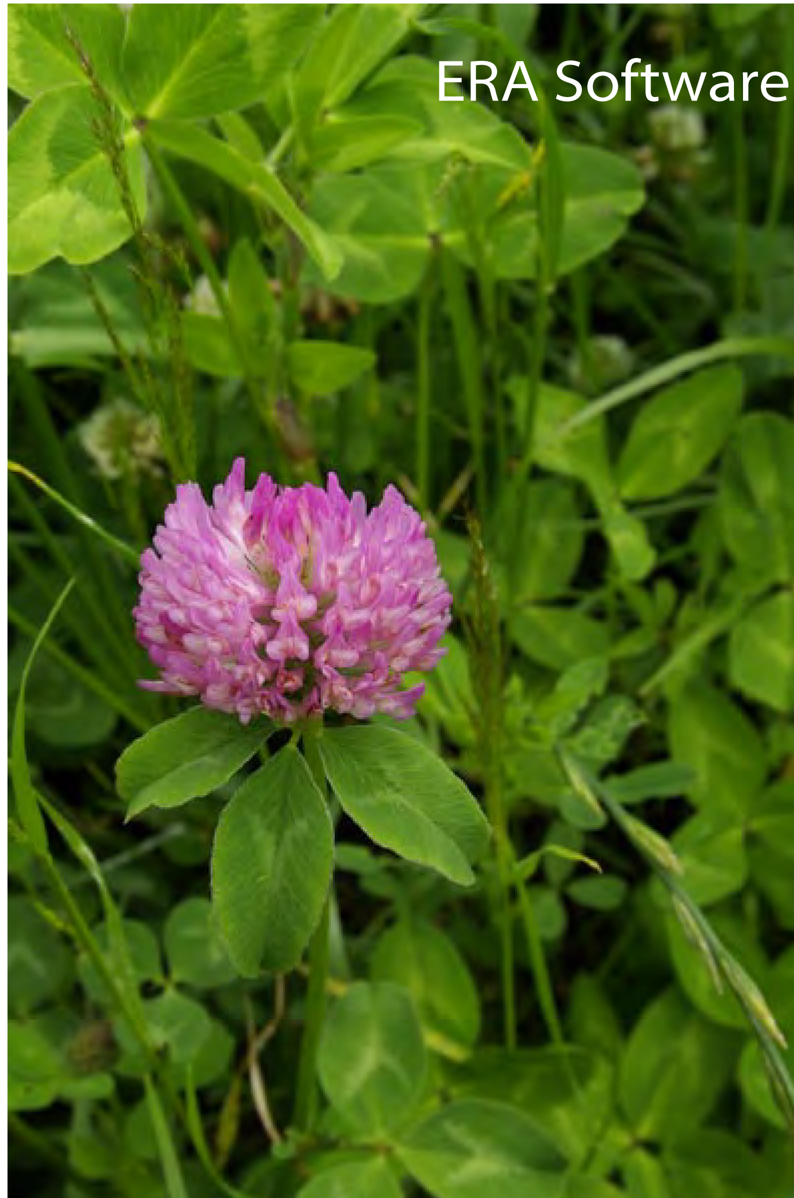
Ecological Recycling Agriculture
Guidelines for Farmers and Advisors

The Box of Guidelines contains

Vol. 1	Farming Guidelines	Software Tools
Vol. 2	Economic Guidelines	
Vol. 3	Marketing Guidelines	
Vol. 4	Farm Examples	

BERAS implementation
Baltic Ecological Recycling Agriculture and Society

ERA Software Tools



N-budget calculator

A tool to calculate N-budgets in organic forage systems

Legume estimation trainer

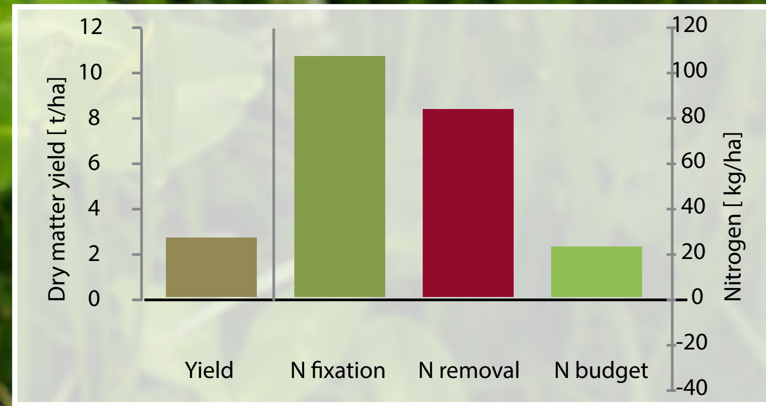
A learning tool for a better estimation of the legume proportion in forages

ROTOR– Organic crop rotation planner

A tool to plan crop rotations in organic farming systems

THE TOOLS ARE AVAILABLE AT: WWW. BERAS. EU

ERA Software Tools



NITROGEN BUDGET CALCULATOR

A tool to calculate N-budgets in organic forage systems

Moritz Reckling, Karin Stein-Bachinger and Johann Bachinger

THE TOOL IS AVAILABLE AT: WWW. BERAS. EU

Why it matters

Ecological recycling agriculture (ERA) aims at effective nutrient recycling through self-sufficiency in fodder and manure production and low levels of external inputs. Legumes play a key role in the crop rotation of ERA farms to balance the N-cycle through N-fixation. To ensure a stable production with low emissions to the environment, ERA aims for balanced N-budgets over the whole crop rotation.

Importance of N-budgets

In organic farming systems, the N-surplus is much lower than in conventional systems [2, 7, 11] and below the maximum amount of 60 kg N-surplus allowed by the European Nitrate Directive (91/676/EEC) [20]. However, studies also show negative N-budgets at field level in some organic farms which can result in lower yields [11]. Therefore, field level N-budgeting is recommended on a regular basis to ensure that legume-grass mixtures lead to a net gain of N that can be used by subsequent crops.
The N-budget calculator facilitates a quick assessment of N-fluxes in legume-grass mixtures and simulates effects of an adapted management. In combination with the Legume estimation trainer the effect of the legume proportion is visualized.

Who can use it?

The computer tool does not require any prior software skills, nor any installation. It can be used by farmers, advisors, lecturers and students. This manual provides background information, user instructions, assistance for interpretation of results and sample calculations.

How it works

The N budget calculator is designed for arable forage systems with legume-grass mixtures (different species and varieties of grasses, clover and alfalfa). The tool estimates the N input (as biological N fixation) and N output (through crop harvest) to calculate the N budget per ha for one or several cuts.

Data required

The yield is either calculated from the crop height or it is entered as a value. The harvested yield at 5 cm cutting height is calculated using standard values for dry matter and harvest losses. In the case of mulching, the crop yield remains on the field and gaseous losses are assumed to occur. The N-content of the harvested crop is calculated according to the legume to grass ratio with standard values. All standard values can be changed in the 'extended data' sheet.
Further N-losses (e.g. leaching and denitrification) are assumed to be balanced by the atmospheric deposition and non-symbiotic N-fixation and therefore neglected.

Optional harvesting methods and their characteristics* [4, 13, 14]

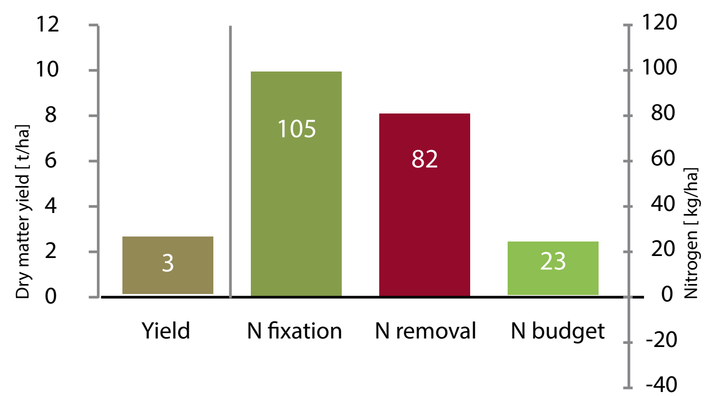
Harvesting method	Harvest timing	Dry matter content (%)	Harvesting losses (% DM)	Gaseous losses (% N)
Green forage	Early	20	5	-
Wilted silage	Medium	35	20	-
Dry hay	Late	85	35	-
Mulching	Early	20	-	10

*Standard values can be changed in the 'extended data' sheet

User interface

The user interface shows the data input and results. The results include the gross yield, total N-fixation, N-removal through crop harvest and the N budget.

DATA INPUT		
Average height	[cm]	45
Harvesting method	[select]	silage
Harvesting losses	[%]	20
Legume Proportion	[%]	50
RESULTS		
Yield (harvested)	[t/ha DM]	3.2
N fixation	[kg N/ha]	105
N removal	[kg N/ha]	82
N budget	[kg N/ha]	23



How to use the tool

The N-budget calculator is a software tool in Microsoft Excel and works with two data sheets.

- 'N budget calculator' presents calculations based on a small number of input data characterising the legume-grass mixture (e.g. yield, harvesting method and legume proportion).
- 'Extended data': input data and calculation functions can be altered (for use by experts).

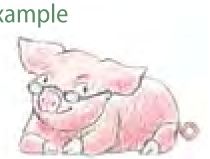
Minimum software requirements

Microsoft Excel, minimum version 2003 (XLS)

Learn about your N budget in 10 steps

1. Open the Excel document
2. View the sheet 'N budget calculator'
3. Go to the data entry field
4. Enter ***either*** the average height of the legume-grass mixture at the harvest time (cm) ***or*** the estimated yield (in tons fresh matter)
   → See the method for yield estimates in the chapter Legumes
5. Select the harvesting method (green forage, wilted silage, dry hay or mulching)
6. Enter harvesting losses manually (in %) ***or*** use the standard value by leaving the cell blank
7. Enter the estimated legume proportion in the mixture at harvesting time (in %)
   → Use the Legume estimation trainer to train your observation skills
8. Read the calculated results
9. Change the input data to visualize the effects of management changes
10. To estimate the N-budget for the whole year with several cuts, calculate the N-budget for each cut separately and add the values together:

Example



1st cut: - 15 kg N/ha
2nd cut: +10 kg N/ha
3rd cut: +13 kg N/ha

N budget: 8 kg N/ha

Interpretation of results

What does the N budget tell you?

The N-budget result is positive, balanced or negative. Different management options to increase the N inputs and decrease the outputs are given. Calculation examples provide an indication of which factors have the strongest effects on the N-budget.

Interpretation of N-budget results and possible management options

N-budget (kg N/ha)	Interpretation
-10 and lower	N-output exceeds the input. N is used from soil reserves and no N is contributed to the system. This management is not sustainable, leads to a depletion of soil N and can result in lower yields in the future.
-10 to +10	Additional N-output equals the input. N fixed by the legumes is removed through the harvest and hardly any N remains in the system.
+10 and higher	Additional N-input exceeds the output and leads to a net gain of N to the system which can be used by subsequent crops.

To achieve positive N budgets a change of management is required by

- increasing the legume proportion (legumes)
- increasing the yield
- changing the harvesting method

If your N budget is positive, maintain the condition and ensure that the N is kept in the system until taken up by the subsequent crop (legumes).

Hints for farmers

This calculator provides a quick and rough estimation of the N-budget of your legume-grass fields. Results should not be over interpreted. If negative results occur, check if the N budget calculator can help to improve the situation!

Enjoy experimenting with this ERA software tool!

Sample calculations

You can learn about the effects on the N-budget by changing the input variables e.g. by increasing or decreasing the yield, harvest losses and legume proportion.

Note: If the harvesting method cannot be changed, the legume proportion remains the key factor influencing the N-budget!

Two examples

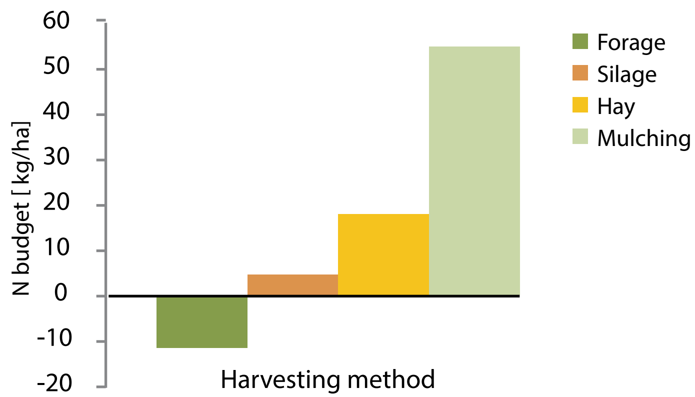
A farmer has four fields of legume-grass each with a gross yield of 3 t/ha (e.g. first cut at 5 cm cutting height). The calculated N-fixation is about 65 kg N/ha in each field.

Question: Under which conditions is the N-budget negative or positive?

Case A

- Fixed parameter: 40 % average legume proportion in each field
- Variable parameter: different harvesting methods

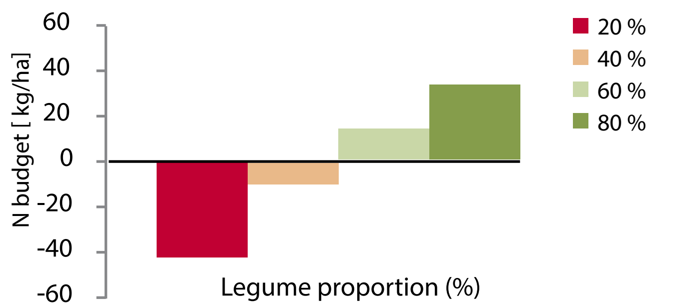
➜ Compare the effect on the N-budget



Case B

- Fixed parameter: harvesting method (forage)
- Variable parameter: 20 – 80 % legume proportion

➜ Compare the effect on the N-budget



Main factors influencing the N budget on legume-grass fields

- Legume proportion has a major effect and can be influenced by management (Legumes)
- Harvesting method has a major effect, but depends on the feed demand
- Yield has a medium effect and can be influenced by management
- Harvesting losses have a minor effect (higher losses mean less N-removal resulting in a more positive N-budget at field level)

BERAS implementation
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ERA Software Tools

LEGUME ESTIMATION TRAINER

A learning tool for a better estimation of the legume proportion in forages

Moritz Reckling, Karin Stein-Bachinger and Johann Bachinger

THE TOOL IS AVAILABLE AT: WWW. BERAS. EU

Why it matters

Forage legumes (e.g. clovers and alfalfa cultivated on arable fields and grasslands) build up soil fertility and therefore play a key role in crop rotations of ERA farms. Among other benefits legumes fix nitrogen (N) from the atmosphere which is available to current and subsequent crops. Moreover they provide a highly nutritious fodder for ruminants which, when their manure is recycled, also enriches the soil.

Why field estimations?

The amount of N fixed is dependent on the total yield and the percentage of legumes in the forage mixture [1, 5]. To assess the nutrient status of a rotation and to calculate N budgets a good estimation of the legume percentage is essential. This estimation needs to be conducted in the field at harvesting time. It cannot be estimated from the seed mixture [5]. Being able to accurately calculate the proportion of legumes in forages is important because this is one of the variables used in the N budget calculator. A more accurate estimation of the legume proportion will give a more accurate calculation of N fixation and N budgets.

Who can use it?

This learning tool is for farmers and advisors. It allows them to practice and improve their skills in estimating the legume percentage in legume-grass mixtures of arable and permanent grassland systems, an important variable in N budget calculations.

How it works

The Legume estimation trainer contains two sets of pictures to choose from – one of arable forage and one of permanent grassland. They show various legume-grass mixtures at different stages of maturity and the corresponding legume percentages. The data accompanying each photo are based on the results from scientific field experiments and nutrient analysis.

What kind of data is presented?

The computer based tool generates pictures randomly and allows the user to estimate the legume percentage of the dry matter yield by choosing one of the classes of percentages.

User interface

The user interface in the web-browser shows the legume-grass picture and options to estimate the legume percentage and additional information.

Estimate the legume proportion (%) in the mixture

How to use the tool

The Legume estimation trainer can be used with all standard web-browsers and can be started without any prior software skills or installations.

Minimum software requirements

Web-browser e.g. Mozilla Firefox, Windows Internet Explorer

Practice your legume estimation skills in 5 steps

- Open the file 'start' (it will appear in your web-browser)
- Choose between 'arable forage' and 'permanent grassland' and the training will start
- Study the first picture on your screen and read the information on yield below
- Estimate the legume percentage by pressing one of the buttons showing percentages
- If your estimation was correct, the exact percentage will be shown and you can press "next picture"; if not please estimate again.

Your estimation skills will improve with practice, so train regularly and monitor your rate of success. **Enjoy the training!**

Monitor your training!

- Estimate 100 pictures and note the no. of errors.
- Repeat this three times and compare the results to check your progress.
- Train until you have less than 20 errors – if you like!

Application of your estimation skills

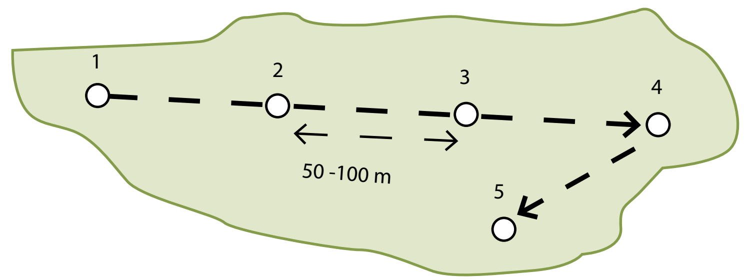
After the training, your estimation skills will be good enough to estimate the legume percentage in the field. To get a very rough estimation, you can estimate from the tractor or harvester at the time of harvesting. If time allows, a more precise estimation, at least on a few fields, is recommended. This can be done by a quick transect walk through the field.

How to estimate in the field (after the training)

How to carry out a transect walk?

- Use a record book for documenting all data during the field walk
- Walk diagonally through the field (transect)
- Take one sample every 50-100 m (avoid field margins)
- 5 samples for fields with little variation in legume percentage
- 10 samples for fields with high variation in legume percentage
- Estimate one square meter per sample (use a frame or sticks to mark the borders)
- Write the percentage for each sample in the record book and calculate the average
- Estimation should be repeated throughout each season since the percentage may vary between fields and cuts and from year to year

Estimation of the legume percentage in the field (more precise estimation)



Average legume percentage in the field

Sample	%
1	40
2	25
3	20
4	45
5	60
Average	38

Estimation of the legume percentage from the tractor (rough estimation)

Test your estimation skills by yourself

Equipment: 0.5 m² frame made of sticks and a kitchen scale

- Note your estimation on paper and cut the samples (0.5 m²)
- Sort the shoots into legumes and non-legumes
- Weigh the legume shoots and all shoots; and calculate:
  Legume percentage (%) = legume shoots (g) * 100 / all shoots (g)

This can be a group exercise with farmers facilitated by the advisor

Samples of arable forage

(Photos: ZALF)

Classification

1-20 %


11% Legumes / 4.2 t/ha DM / 51 cm


4% Legumes / 4.4 t/ha DM / 47 cm

21-40 %


37% Legumes / 2.6 t/ha DM / 37 cm


22% Legumes / 3.8 t/ha DM / 53 cm

41-60 %


59% Legumes / 3.1 t/ha DM / 51 cm


48% Legumes / 3.7 t/ha DM / 42 cm

61-80 %


78% Legumes / 2.7 t/ha DM / 42.6 cm


73% Legumes / 3 t/ha DM / 46.4 cm

> 81 %


94% Legumes / 2.1 t/ha DM / 24 cm


80% Legumes / 2 t/ha DM / 39 cm

Samples of permanent grassland

(Photos: ZALF and Engel, Aulendorf)

Classification

< 6 %


4 % Legumes / 4.2 t/ha DM / 30 cm


5 % Legumes / 2.8 t/ha DM / 45 cm

6-20 %


11 % Legumes / 2.2 t/ha DM / 37 cm

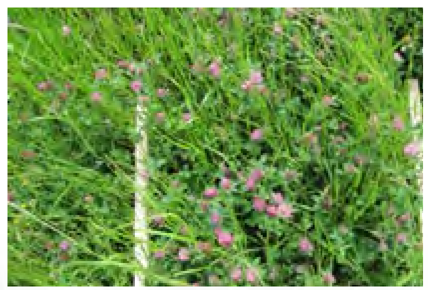

18 % Legumes / 3 t/ha DM / 27 cm

21-40 %


25 % Legumes / 1.7 t/ha DM / 33 cm


35 % Legumes / 2.9 t/ha DM / 29 cm

> 40%


45% Legumes / 3.6 t/ha DM / 60 cm


51 % Legumes / 2.1 t/ha DM / 25 cm

We thank Prof. Dr. Martin Elsäßer and Sylvia Engel from the Agricultural Centre Baden-Wuerttemberg, Department of Grassland Management and Forage Production (LAZBW Aulendorf) for most of the images and samples of permanent grassland. At the Leibniz Centre for Agricultural Landscape Research (ZALF) in Müncheberg, we thank Gerlinde Stange and the staff at the Institute of Land Use Systems and the ZALF Research Station in Müncheberg for their help and assistance with sample and data processing.
The first version of this trainer has been published in the book 'Nährstoffmanagement im Ökologischen Landbau: Ein Handbuch für Beratung und Praxis mit Anwendungs-CD" by Stein-Bachinger, K., Bachinger, J. and Schmitt, L. (2004).
ISBN 978-3-941583-14-6

ERA Software Tools

ROTOR – ORGANIC CROP ROTATION PLANNER

A tool to plan crop rotations in organic farming systems

Moritz Reckling, Johann Bachinger and Karin Stein-Bachinger

THE TOOL IS AVAILABLE AT: WWW. BERAS. EU

Why it matters

Ecological Recycling Agriculture (ERA) aims at effective nutrient recycling through self-sufficiency in fodder and manure production and low levels of external inputs. Well-planned crop rotations are therefore a key element to successful ERA farming.

Crop rotations should provide sufficient fodder, high yielding cash crops and ensure the long-term productivity as well as sustainability of the system. This includes phytosanitary restrictions, effective weed management, sufficient nitrogen supply through legumes, stable N- and humus-balance and reduced nitrogen losses.

Why to plan with ROTOR

Planning organic crop rotations requires to consider the management of nutrients, humus, weeds, diseases, cash and fodder crops, catch crops and manure applications.

ROTOR is a static rule-based tool for long-term planning at field level to regulate:

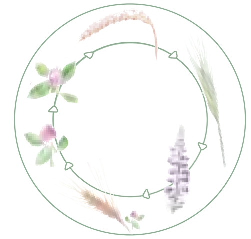
- Supplying sufficient fodder
- Regulation of weed infestation
- Taking phytosanitary restrictions into account
- Maximising N-fixation from legumes
- Minimising N-losses via leaching

ROTOR supports advisors to consider all these factors simultaneously. It provides complementary information to the local knowledge and experiences!

Who can use it?

ROTOR requires some previous software skills, and in some cases the installation of software (see software requirements). It has been designed for advisors, but can also be used by farmers, lecturers and students.

How it works



ROTOR calculates on the basis of predefined crop production activities (CPA). These describe all field operations per crop, beginning with stubble tillage and ending with the harvest. Each crop can be cultivated differently, therefore different CPA's exist with varying preceding crops and different field operations i.e. ploughing or non-inverting tillage, undersowing, use of catch crops, manuring, straw harvesting, and mechanical weed control.

Crop rotations describe a succession of CPA`s which are evaluated with agronomic criteria i.e. N_2-fixation, N-removal, N- and humus-balance, N-leaching, phytosanitary restrictions and the weed infestation risks.

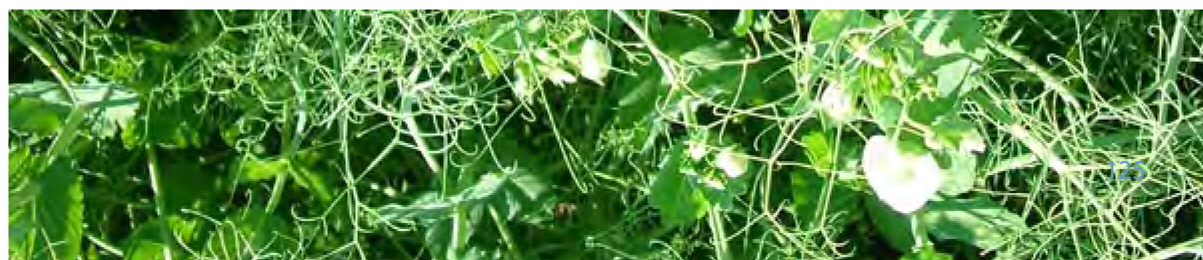
How to use the tool

ROTOR has been adapted to specific countries in the Baltic Sea Region. Within a country, different soil types are distinguished.

- ➜ Results can be used to compare between different crop rotation options.
- ➜ Absolute values should be taken with care.
- ➜ If you use ROTOR for other countries and sites it needs to be adapted if this is not done, please handle the results with great care!

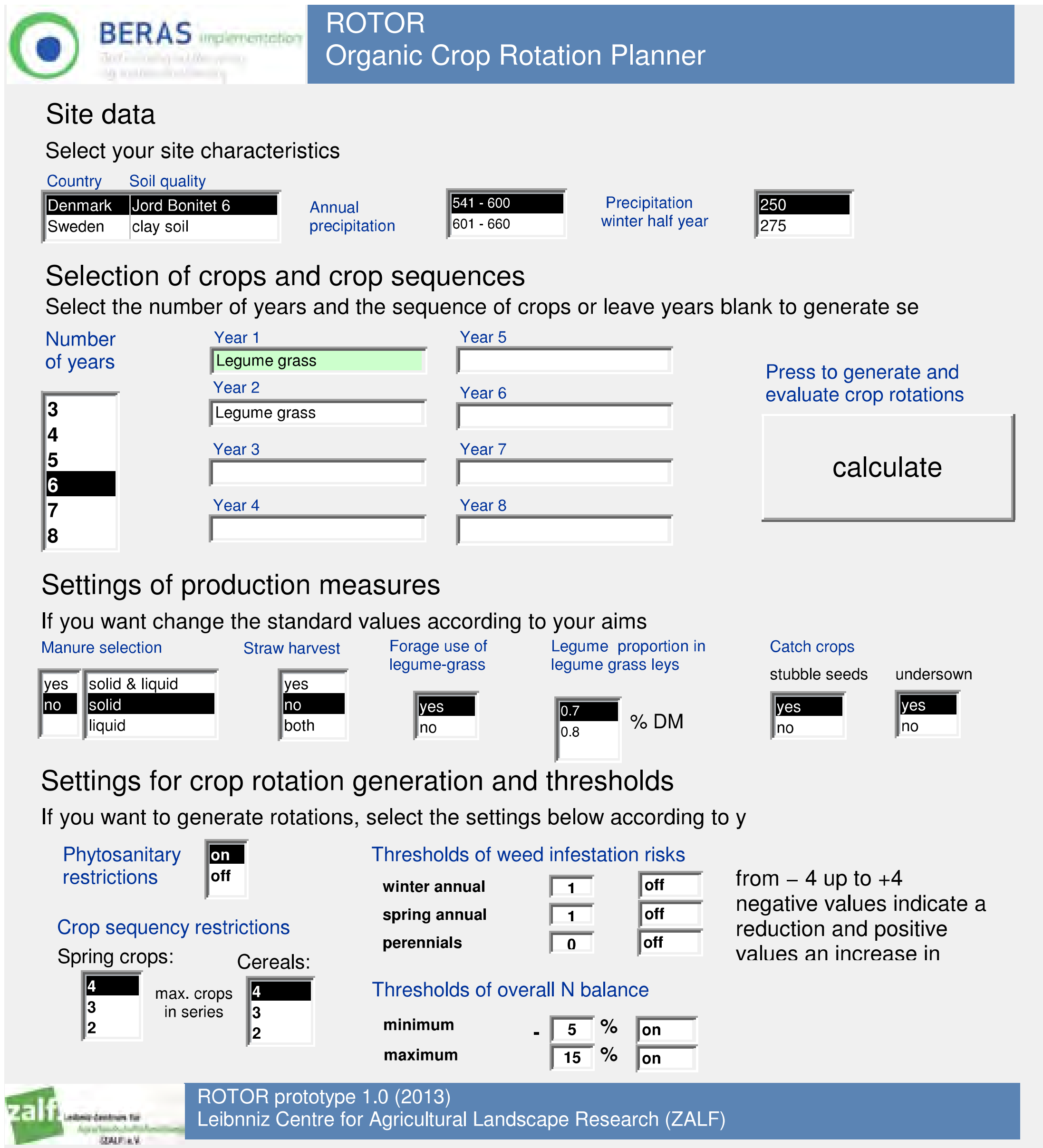
Software requirements

Microsoft Access, minimum version 2000



User interface

The user operates with two interfaces, the data entry form and the report of results. The data entry form is shown below.



Evaluate your crop rotation in a few steps

1. Open the Microsoft Access file.
2. The data entry form opens.
3. Select your site data (country and soil quality, mean annual and winter precipitation), if your site is not included you may use a comparable site or contact the developers.
4. Select the number of years and the crops of the rotation you want to evaluate, starting with a legume-grass mixture.
5. Specify the production measures or leave the standard values (manure, straw harvest, forage use of legume-grass, legume percentage in legume-grass, catch crops).
6. Press 'calculate' to evaluate the rotation.
7. The report of results will open (this can take a few seconds).
8. If you want to change the crop rotation or other settings please close the report of results and make the changes.

Generate crop rotations

1. Select the number of years of the rotation.
2. In the 'selection of crops and crop sequences' you can leave all or several years blank.
3. Change the settings for crop rotation generation and threshold.
4. Continue with step 6. from the list above.

To sort the report of results

The standard sorting of results is by 'N surplus' from lowest to highest; to change this:

1. Open the report of results and go to the 'draft view' (right click and select 'draft view').
2. Go to 'grouping and sorting' (right click and select 'grouping and sorting').
3. Find 'grouped by' (e.g. bottom of the report) and select a criteria from the list.
4. Define the ranking (from 'highest to lowest' or 'lowest to highest').

Interpretation of results

The report of results shows calculated values per crop and per rotation. Several options of crop rotations will be displayed, sorted by the N surplus (this can be changed).

Description of crop production activities
Details of crop production i.e. catch crops, undersowings, tillage and manure applications.

Yield [t/ha]
Dry matter yields calculated specific to soil, rainfall, pre-crop and manure (1 dt = 0.1 t)

N_2-fixation [kg N/ha]
Nitrogen fixed by legumes as a main crop, undersowings, intercrops and catch crops

N-leaching [kg N/ha]
Annual leaching of nitrogen ➜ should be as low as possible

N-removal [kg N/ha]
Annual nitrogen removal through the harvest of crops

N-balance [kg N/ha]
Mean annual N balance calculating N input – N output ➜ should be close to neutral (-10 kg to +10 kg) for long-term sustainability

N-balance % N-input [%]
N balance in % from the N input ➜ should be close to 0 to ensure long-term sustainability (set thresholds in the data entry form)

Humus reproduction [%]
Annual humus reproduction [25] ➜ should be more than 100% to ensure a stable humus-balance

Weed infestation risks [score]
Negative scores reduce and positive scores increase the infestation risk with perennial, spring and winter annual weeds (score from – 4 to +4) ➜ depending on your soil and farming, ensure to keep the infestation risk low and aim for negative values.

Example evaluation

An example crop rotation with two cropping options for a marginal sandy soil in Germany (Brandenburg), soil rating index 25 (sandy soil)

Precipitation: 500 mm annual and 225 mm in the winter half

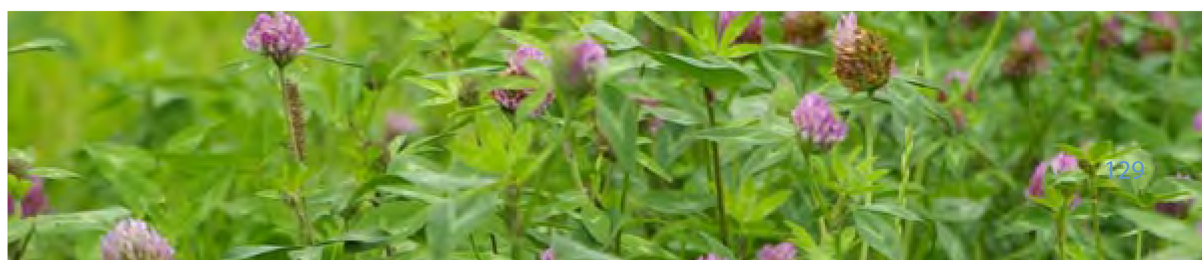
Crop rotation:
Legume-grass (mulching) – winter rye – winter rye –lupin – oat

Option A: Undersowing of legume-grass in oats
Mean legume percentage set to 50 % in the legume-grass sward

Crop	Yield	N_2-fixation	N-leaching	N-balance	Weed infestation risk (- reduces, + increases)			Humus reproduction
	[t/ha]	[kg N/ha]			peren.	spring	autumn	%
Legume-grass (50 % leg.)	24	124	3	105	0	-1	-1	
Winter rye	2.6	0	20	-57	-1	-1	3	
Winter rye	2.1	0	14	-44	-1	-1	3	
Lupin	1.5	76	26	-3	0	3	-1	
Oat + leg.-grass undersown	1.6	0	33	-54	0	1	-1	
Mean of crop rotation		**40**	**20**	**-11**	**-0.2**	**0.2**	**0.6**	**108**

Option B: Inclusion of a catch crop (turnip rape) before oat
Increased legume percentage set to 70 % in the legume-grass sward
➜ the changes in option B are marked in green

Crop	Yield	N_2-fixation	N-leaching	N-balance	Weed infestation risk (- reduces, + increases)			Humus reproduction
	[t/ha]	[kg N/ha]			peren.	spring	autumn	%
Legume-grass (70 % leg.)	24	167	12	139	0	-1	-1	
Winter rye	2.6	0	20	-57	-1	-1	3	
Winter rye	2.1	0	14	-44	-1	-1	3	
Lupin	1.5	76	26	-3	1	3	-1	
Oat + catch crop + leg.-grass undersown	2.0	0	13	-42	-1	1	-2	
Mean of crop rotation		49	17	-1	- 0.4	0.2	0.4	117



To find out more

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List of abbreviations

a	year
AU	animal unit
C	carbon
Ca	calcium
cm	centimetre
C/N	Carbon/Nitrogen ratio
CO_2	carbondioxid
C_{org}	organic carbon
DM	dry matter
ECM	energy corrected milk
ERA	Ecological Recycling Agriculture
e.g.	for example
FM	fresh matter
g	gram
H^+	hydrogen
ha	hectare
K	potassium
kg	kilogram
km	kilometre
l	litre
LU	livestock unit
m	meter
m^3	square metre
MCP	monocalcium phosphate
MJ	mega joule
mm	millimeter
N	nitrogen
N_t	total nitrogen
NDF	non digestible fiber
Nfix	nitrogen fixation
NH_4	ammonia
NO_3	nitrate
P	phosphorus
ROTOR	ROTation ORganic
S	sulfur
SOM	soil organic matter
t	ton
US	undersown
°C	degree centigrade

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Finnish Environment Institute
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Estonian University of Life Sciences
www.emu.ee

Estonian Organic Farming Foundation (EOFF)
www.maheklubi.ee

LATVIA

Latvian Rural Advisory and Training Centre
www.llkc.lv

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Aleksandras Stulginskis University
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Baltic Foundation HPI
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Institute of Soil Science and Plant Cultivation – National Research Institute
www.iung.pulawy.pl

Kujawsko-Pomorski Agricultural Advisory Centre in Minikowo, www.kpodr.pl

Polish Ecological Club in Krakow, City of Gliwice Chapter
www.pkegliwice.pl

Independent Autonomous Association of Individual Farmers ‘Solidarity’
www.solidarnoscri.pl

Pomeranian Agricultural Advisory Center in Gdańsk
www.podr.pl

GERMANY

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DENMARK

The Danish Ecological Council
www.ecocouncil.dk

BELARUS

International Public Association of Animal Breeders “East-West”

PURPOSE

The environment of the Baltic Sea is endangered. Input of plant nutrients from highly intensive and specialized agriculture are a main source. BERAS Implementation can solve this problem through a systemic shift to Ecological Recycling Agriculture in association with the whole food chain from farmer to consumer.

WHO CAN USE THE GUIDELINES?

The guidelines will help farmers and advisers to practice and develop Ecological Recycling Agriculture. This type of agriculture will improve the environmental conditions of the Baltic Sea. They can be equally used for educational purposes, by decision makers and by politicians.

CONTENTS

The guidelines consist of four books that cover the following topics:

The Farming Guidelines give basic practical recommendations for implementing ERA and present proven agronomic measures and optimization strategies for effective nutrient recycling within the farm and between different farm types during and after conversion. Included are Software Tools that help to assess and improve sustainable crop rotation planning and nitrogen fluxes on a farm level.

The Economic Guidelines give advice and support to farmers how to plan the conversion process and highlight how the changes to ERA farming will affect farm economy.

In the Marketing Guidelines farmers can find support and ideas on how to more effectively promote and sell organic and ERA products.

The Farm Examples provide a personal presentation of different farms around the Baltic Sea, mainly farms in conversion to ERA, their challenges and future plans.

The books are available at www.beras.eu in digital form.

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