Intelligent crop production

AMAZONE

4th Edition

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Part I
3C – the crop establishment concept

Part II
Soil tillage from a scientific viewpoint

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Intelligent crop production

We would like to show you, our customers, how the use of our equipment can be combined into economically and ecologically efficient establishment systems. The aim of this book is to give you a overview of our in-depth knowledge with regard to "Intelligent Crop Production".

Part 1 deals with "3C – the crop establishment concept". Within the "Cost Cutting Concept" framework various operational solutions are available by which you can achieve higher yields with less costs and, additionally, savings in time. We aim to inform you, for example, about the cost-saving by combining the various operational passes from "harvest to harvest". These findings are the result of numerous long-term field trials based at different locations around the world.

In this book, not only do we present to you the latest trials results from Germany, but also from AMAZONE trials in France, Great Britain, the Netherlands and Eastern Europe. For AMAZONE, it is a special challenge to be able to offer and always use the right machinery and the right systems, worldwide, for any climate and for any farm structure.

This book is intended to give practical answers to the question of how tillage, drilling and crop care can be carried out at the most reasonable cost according to the farm's specific circumstances. There are, for example, farms which cultivate their land completely without the plough whereas others practice this partially or not at all, depending on the given situations on each farm. The intention of this book is to not only point out the possibilities, however, but also the potential pitfalls of the different systems.

The second part of this book focusses on the soil tillage systems. We would like to particularly thank Dr. Joachim Brunotte and Dr. Claus Sommer from the Institute of Agricultural Technology and Biosystems Engineering at the Johann Heinrich von Thünen Institute for their work. By means of numerous studies performed by them and other scientists, these two agronomists describe the effects of mulch and direct sowing methods not only on costs, but also on environmental compatibility. They also show ways to implement these methods successfully in practice.

In both parts of this book we want to illustrate that the comprehensive and competent system advice that we offer to our customers is a very important part of the AMAZONE philosophy. It is important that we continue to co-operate with farmers and contractors from all over the world to optimise the systems in practice. We also attach great importance to the cooperation with scientists and consultants with whom trials have been carried out for many years on various sites. We thank all who contributed to these findings.

Enjoy reading the book and hopefully it will help keep you up to date with the latest trials results and the application of the systems in practical operation and the AMAZONE team wish you every success in putting that knowledge into practical operation.

Hasbergen, June 2014

Dr. Justus Dreyer
Managing director

Christian Dreyer
Managing director

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Intelligent crop production

Part I

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Soil tillage from a scientific viewpoint

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Definitions concerning soil tillage

In accordance with KTBL 2013

Inversion soil tillage "conventional sowing"
Main feature is the annual loosening of the top soil with the plough. Weeds and organic residual matter are inverted into the soil resulting in a loose field surface, free from residual material, enabling the trouble-free operation of common sowing techniques.

Non-inversion soil tillage – "mulch sowing"
Renouncing the plough and leaving the residual matter from a previous and/or catch crop on the field's surface, conservation cultivation features two basic ideas:

- The reduction of the usual intensity of the primary soil tillage according to method, depth and frequency of the mechanical operation. The aim of a non-inversion loosening is a stable, firm soil structure as a preventive measure against compaction by following vehicles.
- Leaving crop residues in the vicinity to or on the soil surface. The target is possibly soil coverage over the whole year via an intact soil structure as preventive protection from capping and erosion. The sowing operation is defined as mulch sowing as one sows into the prevailing mulch layer.

Strip Till
The ground is not completely moved but is just worked in strips at a spacing of 45 to 80 cm; the soil is worked down to the depth of the top soil. Additionally, either mineral fertiliser or organic manures can be placed below the surface (at up to 10 cm deep) or under-root (at more than 10 cm deep) This could be carried out as a separate pass or in a combined operation.

Direct sowing
Sowing without any prior soil tillage since the previous harvest. Disc, tine, or chisel openers are utilised.

3C crop establishment concept
Cost Cutting Concept: the optimum combination of the system steps: stubble work, soil tillage, sowing and husbandry of the standing crop.

1. Soil cultivation as the focus of arable farming

For many years, AMAZONE has integrated the principle of sustainable and efficient arable farming into the development of its machinery and, on this basis, has developed the 3C concept (Cost Cutting Concept). The focus of this concept is the optimised combination of the system steps of shallow stubble work, soil tillage, sowing and the following crop management. In this context, the 3C concept provides a clear overview of the different combination possibilities, assesses the advantages and disadvantages and simultaneously shows the potential for cost optimisation.

The starting point for all other system steps is always the soil tillage system. So, no matter whether using the plough, cultivator, a Strip Till system or direct sowing, all the other system steps have to be matched accordingly (classification of the systems according to KTBL, 2013, please also see Part II – Soil tillage from a scientific view.

Table 1: **Aims of soil tillage**

In accordance with Lütke-Entrup and Oehmichen, Textbook plant production, Volume 2. 2000 edition

Arable farming objectives	Plant production objectives	System technical objectives
Creation of optimum growth preconditions	Preservation/increase of productivity	High efficiency and timeliness of operation
Targeted and demand orientated cultivation	Creation of optimum field emergence	Reduction of variable costs
Preservation of a stable soil structure	Preventive and direct weed control	Versatile utilisation of the technology applied
Incorporation of organic matter	Fulfilling specific demands of plants	Creation of favourable conditions for the following operational passes
Compliance to relevant environmental demands		

Table 2: **Most important advantages and disadvantages of the systems in an overview**

Conventional soil tillage	Conservation soil tillage	Direct sowing
Advantages • good market orientation possible (close cash-crop crop rotation) • highest yields easy to achieve • little demand on system knowhow • seedbed free from organic matter for a safe germination • low disease carry-over risk • reduced use of crop protection agents	**Advantages** • highest yields possible • high efficiency • low operating costs • good erosion and soil protection • active soil life • good traffic carrying capacity	**Advantages** • low system costs (machinery and establishment time) • highest efficiency • perfect soil saving and erosion protection • ideal for dry regions • good traffic carrying capacity
Disadvantages • higher system costs • little erosion protection • lower carrying capacity of the soils • danger of plough pan compaction • heavy soil decomposition • disturbance of soil life	**Disadvantages** • site specific individual system configuration necessary • demanding management of tight crop rotations • increased slug and mice risk • increased expenditure for crop protection agents especially in market orientated crop rotations • higher demand on system knowhow • intensive capital investment in various mechanisation chains	**Disadvantages** • uncertain yield situation, especially in maritime regions • balanced crop rotations required • problems with persistent weeds • increased risk of resistance due to unbalanced use of crop protection agents

For a better classification of the advantages and disadvantages of these still very differing systems, please initially bear in mind the general objectives that need to be achieved from all of them. On top are economy and ecology plus, on the one hand, sustainable soil fertility has to be ensured and, on the other hand, the production of high yields and decent quality at reduced costs. Going into detail further and looking at the objectives in Table 1, a distinction can be made as to arable farming, crop production and system technology criteria.

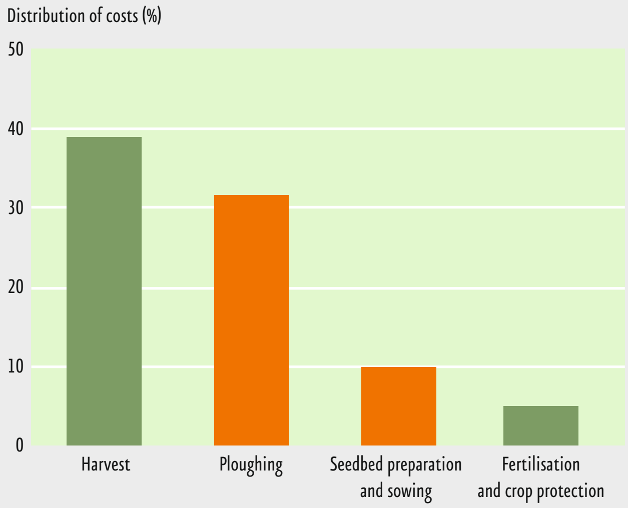
Against the background of these objectives, a comparison between conventional soil tillage with the plough, conservation soil tillage or direct sowing can be established. In Table 2, the advantages and disadvantages of the systems are listed.

The total evaluation and suitability of the system regarding the objectives of soil tillage varies considerably depending on the climatic region. It one looks, for example, to maritime or slightly continental orientated climatic regions of Western Europe (see map on page 56), which, due to their high yield potentials and intensive cultivation, involve specific challenges; it becomes obvious that conservation soil tillage best fulfils the different demands. This especially applies with regard to the conservation of resources and sustainability. However, depending on the individual farm situation – above all in times of high commodity prices – various advantages speak in favour of conventional soil tillage using the plough, whereas direct sowing is of little importance in this region.

Influencing factor of soil type

A contributing factor as to which soil tillage system is utilised in maritime climate regions is, in the first instance, the prevailing soil type. So medium soils, with a score of 50 – 70, offer the best preconditions for using conservation soil tillage techniques as during cultivation they mostly have the right structure, they break up well and can be cultivated without any prob-

Fig. 1: Cost structure of arable farms greater 100 ha



The distribution of cost allocation shows that a big savings potential can result from the reduction of the tillage intensity (the value "other costs" is not taken into account in the graph).

lems. Sandy clays and loams, which are especially prone to erosion on slopes, require mulch sowing even more strictly.

Heavy soils, also called minute soils, are, however, even more critical. These are especially difficult to handle, not just when working without the plough, but also when ploughing. These soils are mostly characterised by a short time window for cultivation. AMAZONE trials, in the Hellevoetsluis region near Rotterdam, Holland, underline the fact that conservation soil tillage also functions under these conditions. On these soils it even has to be said that conservation systems have to be considered of decisive advantage as they can be carried out more efficiently and at the optimum time.

The most demanding on soil tillage are light, sandy soils because compaction is a potential issue. So continuous shallow operation is applicable, but this needs to combined with a deeper pass which should be carried out every two to three years. Otherwise the level of oxygen in the compacted soils will become the limiting factor, the plant root, however, needs at least 10 % oxygen by volume. That conservation soil tillage works also on sandy soils is proven by many farms, for example in the Uckermark region (Brandenburg), which has used this system for many years.

Influencing factor of crop rotation

In addition to soil type, crop rotation is an important factor for success. The wider the crop rotation, the simpler is the handling of a mulch sowing system, especially in a cereal-dominated crop rotation, where the continuous cultivation of winter wheat following winter wheat hinders the success of mulch sowing systems because of the short period of fallow between harvest and sowing. Crop rotations with a high proportion of root crops or spring cereals, however, allow a clearly longer period of fallow. This also significantly reduces the disease pressure, because more time remains for the rotting down of the previous crop residues.

In narrower crop rotations, the plough offers some advantages because a good seedbed can be prepared within a short period. Long term AMAZONE trials, both in Huntlosen and Leipzig show, however, that also under these conditions a successful cultivation without the plough is possible. Of importance here in any case are the high work rates alongside a well-matched straw management regime.

Thus even very wide crop rotations can actually offer the ideal preconditions for conservation soil tillage in an organic farming situation. On the other hand, however, here the possibilities of applying crop protection agents are missing so that the conservation soil tillage is a particular challenge on farms who are just organic.

Influencing factor of disease pressure

Problems due to disease pressure, weed seeds and volunteer grains may be more susceptible when mulch sowing than when utilising the plough and these can then only be compensated for by the relevant crop protection measures and by taking a greater care in the choice of variety. Even if, because of this, the costs rise, any additional measures in many cases pay off due to the additional expenditure of time and fuel arising when operating with the plough. The social conflict of objective between the use of little crop protection agent on the one hand and low fossil energy input on the other hand cannot be solved by individual farms.

Influencing factor of straw management

Irrespective of the soil tillage system, utilising the correct straw management technique is an important factor in the bid for success. So, the intensity of all following soil tillage operational passes depends entirely on the quality of the straw chopping and distribution process. Even the best machinery solutions used later for soil tillage and sowing will not compensate for any mistakes made in this process.

Any system has its justification

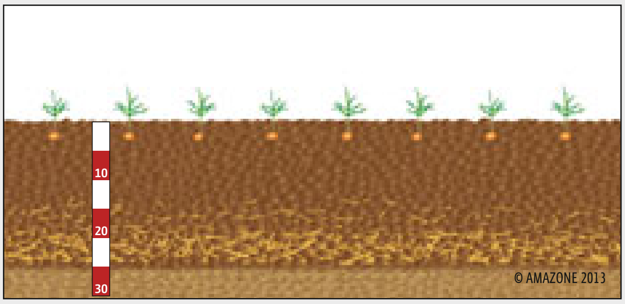
Whether utilising conventional or conservation soil tillage or direct sowing – it becomes obvious that all systems can be justified. The most important benefits of conventional soil tillage are that they are simple and universally practised. This practise is utilised more where the cost pressure is lower, where the more difficult the soils are to manage and the rainfall is better distributed. On the other hand, the costs and the demands on operational time are often significantly higher than during conservation soil tillage or direct sowing.

In comparison, the handling of conservation soil tillage and mulch sowing is more demanding because it includes different system versions. Which version is the right one depends on the individual site, the yield expectations and the relevant current economic situation. Meanwhile, the AMAZONE trials, which are carried out at seven different sites show, that the mulch sowing system, in principle, can be utilised everywhere.

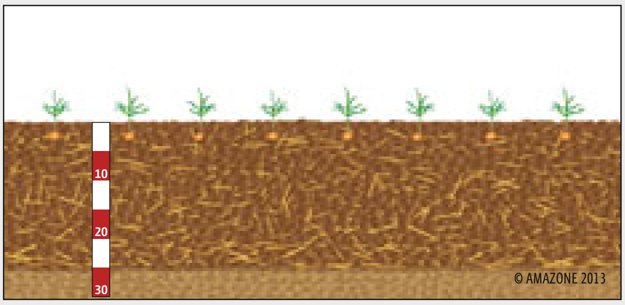
On the other hand, for example, under the dry continental climatic conditions of Eastern Europe, the advantages of direct sowing become most noticeable as because here, it is paramount to move the soil as little as possible, and at low cost, thus saving the soil/water balance. For direct sowing, above all, a balanced wide crop rotation is an important precondition to keep disease pressure as low as possible and also ensures less weed competition.

As oppose to a few years ago, the adoption of differing soil tillage systems today is significantly higher and more flexible on many farms. So, farms which formerly only ploughed now rely on conservation soil tillage within individual crop rotation links to save costs. However, other farms which for decades cultivated all fields using conservation cultivation techniques, have reached their limits of practicability in narrow crop

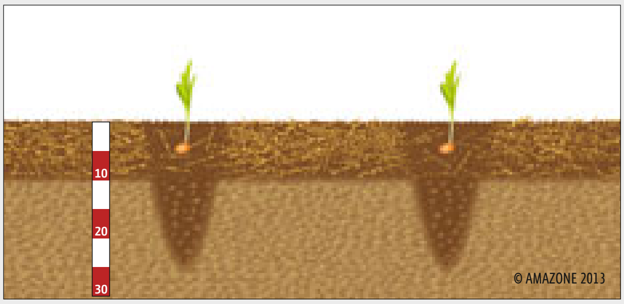
Fig. 2: Arable farming systems in an overview



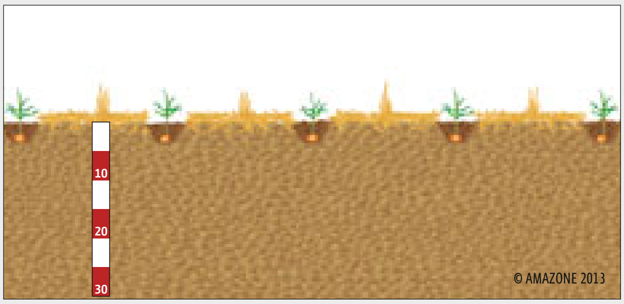
Conventional soil tillage using the plough



Conservation soil tillage using the compact disc harrow and cultivator with deep loosening



Conservation soil tillage using the compact disc harrow and strip-wise loosening – intensive Strip Till



Direct sowing

rotations or for extremely dry or extremely wet years. This has resulted – so to say as a trend in modern arable farming – that more and more farms utilise two or even three soil tillage systems in parallel.

Three examples to explain this:

- The medium-sized farm, with a maize/cereal crop rotation, relies on the plough to ensure, above all, the re-establishment of winter wheat after the maize harvest. On the other hand, sowing of winter catch crops after cereals is carried out with the mulch cultivator and pack top GreenDrill seeder box. When there is winter rape in the crop rotation, also wheat following rape is established without the plough.
- For years, larger arable farms have relied on mulch sowing. Here it also became apparent that, in addition to the continuous shallow incorporation, deep loosening is necessary to achieve the highest yields. Under wet and cold conditions the farmer now again relies on the plough and accepts the somewhat higher system costs. Even when the fields have been ploughed once, the advantages of conservation soil tillage return relatively quickly.
- For the large estates in Russia, direct sowing with chisel openers has developed into being the standard system. The very short periods between harvest and the onset of winter require high work rates whereby the furrow is cleared by the seed drill to ensure very good field emergence. However, in order to accelerate the growth of sunflowers, which develop very slowly early on, here also a shallow primary cultivation with the compact disc harrow is carried out. In future, an even higher potential might be offered here by the Strip Till system which offers a plough-like approach to warmer seedbeds and a deeply loosened root area that is protected from evaporation.

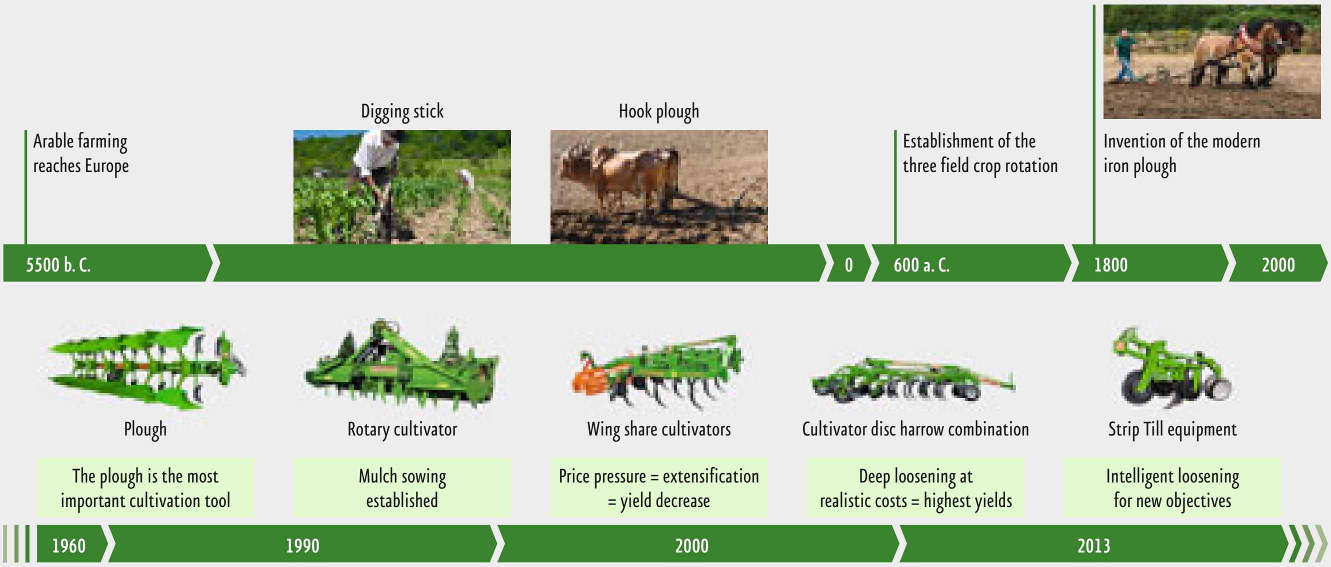
Trials area and test tracks behind the AMAZONE BBG factory site in Leipzig.

Table 3: **Problems and solutions with conservation soil tillage**

Problem	Solution
Soil compaction	Deep loosening if necessary
Increased infection pressure due to straw	Chopping straw into shorter pieces, good distribution and good mixing
Poor seed/soil contact	Better re-consolidation
Weed problems	Good and shallow stubble working, Glyphosate containing agents
Mice and slugs	Good incorporation of straw, reduction of green matter growth, avoiding an open structure by improving reconsolidation

Historical development of arable farming systems in Middle Europe

From manual work via the plough to Strip Till



After many centuries of simple manual farming, modern arable farming began at the beginning of the 19th century with the invention of the iron plough. The plough following the horse or later following the steam engine allowed comparatively high acreage outputs and made an especially "clean sweep" in the field prior to cultivating the next crop.

Then, in the course of the industrial revolution – due to increasing world population and increasing urbanisation – new areas were exploited for arable farming (Great Plains in the USA, Kazakhstan steppes). Hereby the plough was the dominant operational in agriculture for many years.

The first limits in cultivation showed during the 1930's with appearance of the "Dust Bowls" in the USA. The wind erosion had the effect that the soils on the prairie which had just been cultivated with the plough were blown away within a short time. From these origins, the first approaches were made towards mulch and direct sowing (foundation of the Soil Conservation Service, today the Natural Resources Conservation Service). In those days, it was initially knife profile coulters which were widely used for mulch sowing to eliminate weeds without crop protection agents and also without using the plough.

In those dry climatic regions, additionally one had to look at the possibility to reduce costs to allow, never the less, successful arable farming at low yields and fluctuating market prices. An additional big step in the establishment of reduced soil tillage systems was the invention of synthesised crop protection agents in the 60's and 70's of last century. In 1974, Monsanto introduced the first complete herbicide with the agent glyphosate onto the market. With the aid of direct sowing methods, this crop protection agent made competitive arable farming possible even in continental climate regions despite the low yields (10 – 30 dt/ha wheat).

In Europe, at the beginning of the 90's, the fall of the Iron Curtain had a dramatic effect on the development and establishment of cultivation systems. From then on, the larger farm and field structures in Eastern Germany and Eastern Europe had to be operated with more cost effective methods than utilised so far. So, due to the competition among the agricultural machinery manufacturers, many different developments emerged which, until today, resulted in a large range of soil tillage implements and systems being available.

During the recent years the increasing prevalence of automatic GPS steering systems with highly accurate RTK correction signals additionally resulted in a further flexibility for cultivation techniques. This technology paved the way for the introduction of the strip-wise soil loosening via the Strip Till system, initially started in the USA and today also in Europe.

But the plough still remains to be an important soil tillage implement. However, today, thanks to the alternatives, it is utilised far more carefully and more targeted than in the 1930's.

2.
What counts: the basic rules of the 3C crop establishment concept

"3C" – hidden behind this banner headline is AMAZONE's "Cost Cutting Concept". In the 3C-Concept, AMAZONE combines all its experience of machinery and systems for soil tillage, sowing and crop management. It includes different system variants, which, in spite of different technical solutions, always have the same target: efficient and cost effective cultivation resulting in higher yields.

New findings from science, consultation and agricultural practice continuously merge into the 3C concept allowing the further optimisation of the AMAZONE machinery programme to derive practical recommendations for the optimum operation.

2.1 Rules for conservation soil tillage:

- As deep as necessary
- As flexible as possible
- Preservation of soil moisture
- Optimised incorporation of straw into the soil
- Quick and early completion

Rules for conservation soil tillage

Especially applying to mulch sowing, the demands of the individual farm depend on many factors, such as, for example the prevailing field size, the climatic conditions or the crop rotation. Therefore, depending on the individual farm, different machinery and system combinations are utilised and in addition different steps of intensity for when carrying out the operational passes.

In spite of all these differences in the individual operations, basic rules can be derived to offer practitioners a good guide. In the following we have initially listed these rules for conservation soil tillage. They show what matters most when it comes to achieving high yields as cost effectively as possible.

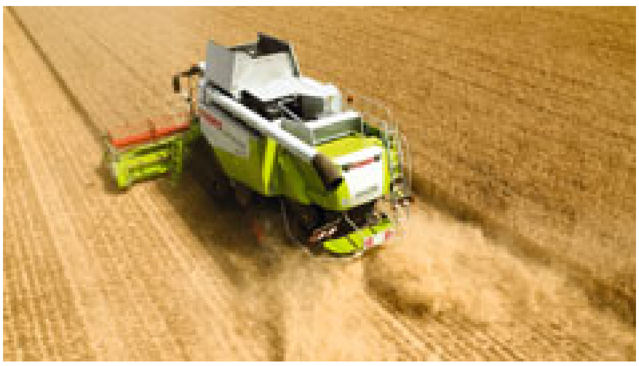
Rule 1:
As deep as necessary

The preservation of the soil structure is an important target in soil tillage. On the other hand, greater or lesser amounts of crop residues that remain from the previous crop have to be incorporated into the soil prior to the new sowing operation.

That means: the better the straw distribution provided by the combine harvester and the shorter the chop length then the less the intensity of the straw incorporation can be. At the same time the working depth/intensity after root crops, such as beet, potatoes or rape can be lower than after crops with large amounts of straw (maize, cereals). After leaf crops often just one relatively shallow operational pass is necessary.

When the pre-condition of good straw and chaff distribution quality is fulfilled and, in addition, the subsoil is well structured and sufficiently provided with oxygen the general rule applies: 1 t straw/ha requires a minimum of 1 cm working depth for incorporation. On soils with a weaker structure, however, for example, on sandy soils which tend to compact, or in areas with temporary stagnant water, the soil requires the top soil loosening down to 20 cm to 30 cm. Only in this way can sufficient oxygen supply down to the roots be ensured.

The better the straw and chaff distribution provided by the combine harvester and the shorter the chop length, the intensity of straw incorporation into the soil can be lessened.



Rule 2:
As flexible as possible

Theory requires: shallow stubble working (primary pass, e.g. using the Catros) followed by a deeper operation (secondary pass, e.g. using the Centaur). For different reasons (crop rotation, soil type and weather), however, this procedure can not always be implemented completely or in this sequence.

In fact the following rules apply (see Table 4):
- When the first pass was shallow, the second pass needs to be deeper in order to incorporate volunteer grains.
- When the first pass was deep, the second pass has to be shallow (not a cultivator) in order not to lift the straw again, possibly it can be left out completely.
- Sometimes both passes are reduced to just one pass which then normally takes place immediately before sowing the following crop. In some cases if the previous crop was rape it can even remain unworked until the actual sowing operation.

Table 4: **Alternative combinations of 1st and 2nd operational pass**

	Primary pass	Secondary pass	Notes
Alternative 1	Shallow	Deep	Incorporation of volunteer grain and weed seeds
Alternative 2	Deep	Left out or very shallow	Do not lift the straw again in the second pass
Alternative 3	Combined into one pass immediately prior to sowing		
Alternative 4	Both passes are left out		e.g. after rape

In most cases the primary pass is shallow stubble cultivation.

Rule 3: Soil moisture preservation

Above all, in areas where the soil moisture content acts as the limiting factor, evaporation should be prevented as far as possible. Therefore stubble breaking should immediately follow the combine harvester and so the output capacities of the compact disc harrow and combine harvester must be nearly the same. Working widths and operational times of these machines should be accurately matched.

The same applies to the operation of cultivator and seed drill, because any second pass and sowing operation also should take place within a few hours, the best being that both systems operate simultaneously in the same field. Thus the required acreage output of the cultivator depends on the acreage output of the sowing technique used. The target is also here to preserve the remaining soil moisture allowing the freshly sown grain to germinate. In cases of insufficient capacity of the cultivator this can be increased either via larger working widths following bigger tractors or by prolonged operational times or shift work within the time available for working in the field.

Rule 4: Optimised straw incorporation

This rule is also valid in adverse conditions. Therefore, the Catros compact disc harrow is the preferred machine for stubble breakage. It is easily pulled and provides high area efficiency simultaneously with a low specific fuel consumption.

In case of problems, such as, for example, insufficient straw distribution by the combine harvester or long/lying chaff after lodged grain, the first pass is carried out with a heavy disc harrow or a straw harrow, if available on the farm. When equipped with the appropriate shares, one can also use a cultivator such as the Centaur or the Cenius to mix the straw into the soil.

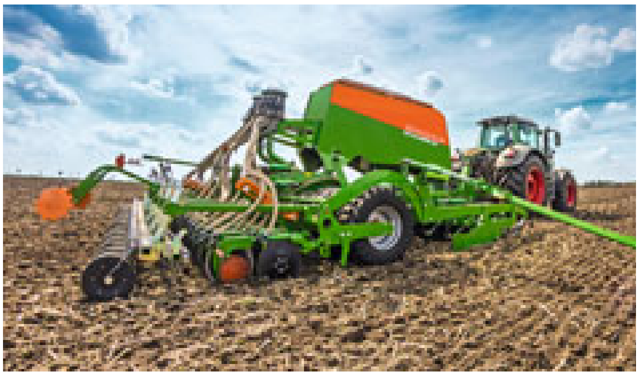
Where dry conditions prevail and there are signs that straw rotting after the first pass is less than expected the rule then is: the less rot, the deeper the crop residues should be incorporated with the second pass.

With the AMAZONE Cenius or Centaur, deep loosening is achieved best if they are equipped with the relevant narrow shares: They loosen the soil down to the desired depth and mix in the straw without, however, the simultaneous inversion of the soil.

In this situation some farms use the plough in order to loosen and mix the soil as deeply as possible. One preferably ploughs between maize and wheat and also following wheat or maize where the rotation is a following spring sowing (beet, potatoes, malting barley, peas, etc.). Depending on the soil type, the deep loosening is carried out in the autumn (heavy soils) or in the spring (light to medium soils).

The Cenius and Centaur loosen the soil without inverting it, mixing the straw in very well.

PTO-driven combinations of rotary cultivator/harrow and seed drill achieve, depending on the working width (3 m to 6 m) daily outputs of 15 ha to 50 ha.



Cirrus is equipped with pre-cultivating disc elements and achieves daily outputs of 25 ha to 60 ha (depending on working widths of 3 m, 4 m or 6 m).

In a split operation, the second cultivation and the sowing pass are carried out separately – and, depending on the local conditions, with more or less a timely operation.

Rule 5: Quick and early preparation

In order to maintain time schedules, especially in bad weather conditions, farms have to have available, machinery capable of high work rates. This not only applies just to stubble working, but also above all however, to the sowing operation.

Sowing combinations with actively PTO driven cultivators are used in preference on small to medium size farms. Combinations of rotary cultivator/harrow and seed drill: depending on working width (3 m to 6 m) combinations with rotary cultivator/harrow and seed drill provide a daily output of 15 ha to 50 ha where the advantage of the active combinations is an optimum combination of soil tillage and sowing operation.

If the total field area cannot be cultivated with an active combination at the optimum time, the AMAZONE programme includes the Cirrus sowing combination. These combination machines, equipped with pre-cultivation disc elements, manage daily outputs of 25 to 60 hectares (in working widths of 3 m, 4 m or 6 m).

For even higher acreages, AMAZONE recommends the Citan solo large area seed drills in working widths of 6 m, 8 m, 9 m, 12 m and 15 m providing daily outputs of 75 ha to 120 ha. However, they are not equipped with any method of pre-cultivation. So, the bigger the necessary acreage output of the seed drill is, the more this is at the expense of the intensity in the seedbed preparation, so much so, that in the end, a separate pass is necessary prior to sowing.

Even though conventional soil tillage with the plough is easier to handle than a conservation soil system, it applies here also to observe the rules to optimally exploit the possibilities of this system.

2.2 Rules for conventional soil tillage:

- Good straw and stubble management
- Choice of timing
- As deep as necessary
- Good reconsolidation prior to seedbed preparation
- Avoid damaging compaction

Rule 1: Good straw and stubble management

The precondition, even for conventional soil tillage with the plough is careful straw management. Also here the distinction is an even as possible straw and chaff distribution by the combine harvester. Then the capillarity of the soil is interrupted by a shallow stubble cultivation so that straw rotting can start and the volunteer grains are stimulated into emergence.

Then the remaining straw and chaff layer should be ploughed in as a straw-soil mixture as homogeneous as possible to promote the rotting process of the harvest residues. It is important that the organic matter is not deposited as a straw mat at the bottom but that it is distributed across the lower two thirds of the ploughing depth. Therefore the careful adjustment of the skimmer is of great importance. In no case should organic residues remain on the surface in order to ensure a “clean start”.

Rule 2: Choice of timing

Depending on the soil type, conventional soil tillage is carried out closer to or further away from the sowing date. Now applies: the lighter the soil is, the closer the ploughing date can be moved to sowing. On heavy and medium soils, then usually at least one additional pass is required to produce a sufficiently fine crumbled seedbed.

In addition, soil moisture should be observed. If it is too dry, the penetration of the plough gets difficult, wear and tractive power increase plus any remaining ground water evaporates increasing the chance of wind erosion. On the other hand, with too moist a soil condition, wheel slip on the tractor is increased and thus fuel consumption. In addition, the plough sole smears the furrow bottom affecting the gas and water balance of the soil.

In order to make optimum use of the system, various rules have to be also observed in conventional soil tillage.

Rule 3: As deep as necessary

In general “as deep as necessary” also applies to when utilising the plough as, in just one hectare, 150 tons of soil per cm depth are moved. As a matter of principle, the reduction of the ploughing depth offers the possibility to reduce the fuel consumption and the operational time. On the other hand, the optimised ploughing depth depends on the soil type, the crop rotation and the climatic conditions at the relevant site. Here it should be noted: the more loosening the soil requires, the deeper the ploughing is required. So, for example, a shallow ploughing furrow does not make sense from an arable farming point of view on structurally weak sandy soils which are prone to compaction.

In addition, the depth of the top soil plays a decisive role. So, by no means, should one plough up humus poor soils. Also the amount of organic residual matter left by the previous crop affects the ploughing depth as it is important to ensure a good mixing within the soil and thus a quick degradation of crop residues. Therefore the ploughing depth on cereals can tend to be shallower than that for a leaf crop.

Rule 4: Good reconsolidation prior to seedbed preparation

To restore the capillarity and to improve the traffic carrying capacity for the following passes, the loosened soil should be reconsolidated after ploughing. A good reconsolidation at the same time is the basis for an even seed placement and high germination.

For simultaneous reconsolidation, the combined use of a packer following the plough makes sense. The packer accelerates the settling of the over-loosened soils so that the narrow periods between harvesting the previous crop and sowing of the following crop are easier to handle. In regions which are dominated by spring or summer drought, the combined use of the plough and the packer should be carried out in the shortest possible time prior to sowing in order to keep the evaporation of ground water to a minimum.

Especially on heavy soils the packer can also achieve an initial cultivation of the soil surface. This is equivalent to a first pass of any subsequent seedbed preparation.

Rule 5: Avoid damaging compaction

In order to avoid the formation of compacted wheel marks or plough pans, it makes sense to plough from year to year at different depths. Today, however, the problem of a plough pan formation is less serious because, due to the larger plough working width, an increasing weight transfer onto the land wheel and the relevant reduction of that on the furrow wheel are achieved (please also see the relevant research results in the second part “Soil tillage from a scientific viewpoint” Page 139). Nevertheless, the danger of forming a plough pan should be prevented by the use of all wheel tractors which are properly ballasted and equipped with high quality tyres at an air pressure as low as possible.

3.

AMAZONE machinery within the 3C crop establishment concept

For the different variations in soil tillage and the following crop establishment systems, AMAZONE offers an optimally matched product programme: the Catros compact disc harrow, the Cenius mulch cultivator, the Centaur tine & disc combination cultivator, the Cayron plough and, on the drill front, various seed drills or till and drill combinations as well as fertiliser spreaders and crop protection sprayers.

Catros mounted compact disc harrow, 3 m to 6 m.

Primary pass: Stubble cultivation

For the first pass – the stubble cultivation – the Catros compact disc harrow (3 m to 7.5 m working width) provides uniform shallow soil tillage over all the surface – even in undulating terrain.

For farms, where the purchase an additional machine for stubble cultivating is not economical, AMAZONE offers the Cenius mulch cultivator (3 m, 3.5 m, 4 m, 6 m and 7 m). It can be used both for the intensive mixing, medium deep to deep soil tillage (second pass) and also on the first pass for shallow stubble incorporation. For all these applications, special share types are available.

Catros trailed compact disc harrow, 3 m to 7.5 m.

The Centaur is ideally suited for the second pass on larger size farms.

The Cayron for conventional soil tillage.

XTill strip loosener

Secondary pass: Deeper soil tillage

In the same way as the Cenius, the Centaur tine and disc combination cultivator, in 3 m to 5 m working widths, is the ideal machine for the secondary pass in non-inversion soil tillage. The Centaur provides not only reliable, intensive mixing of crop residues and soil at a medium working depth but also for deep loosening the topsoil. As a multi-functional soil tillage tool, the Centaur can also be used for shallow stubble work.

For the second pass in conventional soil tillage, AMAZONE also offers highly efficient technology in the form of the Cayron 200 mounted reversible plough. Initially the Cayron is offered as a 5 or 6 furrow plough and is designed for operation following tractors of up to 240 HP.

The use of the new XTill strip loosener is AMAZONE's solution when it comes to a Strip Till system. The XTill, from the company Vogelsang, is utilised as an intermediate operation and offers the possibility to carry out deep mineral root fertilisation alongside the strip wise loosening operation.

As a trailed sowing combination, the Cirrus makes higher operational speeds possible.

Third pass: Sowing (solo or in combination)

For the sowing operation, AMAZONE offers machinery both with either PTO-driven or passive cultivation or solo seed drills. The advantages of the active solutions, such as the rotary cultivator-Pack Top sowing combination, the Avant front tank combination in up to 6 m working width, are demonstrated in high soil moistures (due to reduced slippage) and on sloping terrain, in unfavourable field sizes, on heavy or clayey soils, poor straw management and where there is little proportion of fine soil. In addition, the PTO driven combinations often prove to be the "problem solution" for late sown crops.

In cases of good straw management, larger areas and with medium soils, however, the trailed passive combinations are streets ahead due to their faster forward speeds and higher work rates. Here, AMAZONE recommends the use of the Cirrus sowing combination or, for higher outputs, the Citan large area solo seed drill.

AD-P Pack Top pneumatic seed drill for operation on medium size farms.

Or the AD-P Super above all for contractors and arable farms from 200 ha to 500 ha.

The AMAZONE programme includes mounted, trailed and self-propelled crop protection sprayers in working widths from 12 m to 40 m and tank sizes from 900 l to 11,200 l.

Fertilisation and crop protection

For the successful development of the crop through its various vegetation stages, the professional planning and carrying out of fertilising and crop protection measures are of decisive importance. The technology utilised does not only require reliability but, above all, the highest precision in application.

With their complete machinery programme, AMAZONE also here meets the differing demands of each farm size. For fertilisation, the mounted centrifugal fertiliser spreaders or trailed large area bulk material spreaders with working widths of 10 m to 54 m are available. For crop protection AMAZONE offers mounted, trailed and self-propelled crop protection sprayers in 12 m to 40 m working widths with tank sizes from 900 l to 11,200 l.

For fertilisation AMAZONE offers centrifugal mounted spreaders and trailed bulk material large area spreaders in working widths from 10 m to 54 m.

4.
Cooperation: theory and practice together for optimum functionality

The success of any soil tillage implement system mostly depends on to what extent the technology utilised meets the required demands. If the machines produce results of average quality or if the systems do not function correctly the advantages are quite reasonably questioned by the user.

Therefore, quality, safety, reliability and comfort are all criteria that play an important role at AMAZONE with the focus of the design work not only on robustness and longevity but also operational quality, operational safety and operational comfort. Today of special importance is also reducing, as far as possible, the fuel consumption during the machine operation.

Initially the engineers develop the basic design, incorporating robustness into the working elements of such a soil tillage implement on the computer. One tool for the solving such complex design tasks is, for example, finite-element computer programmes that enable the engineer to simulate the play of forces on the machine in operation and to carry out necessary the improvements on screen.

Centaur on the test track in Leipzig.

See the sparks fly – KG rotary cultivator in operation on the Hude stone torture track.

After the design work on the computer, the individual parts and tines are initially tested in the laboratory followed by the first pre-series machines and in-field tests. In order to check, for example, the strength in stony soil conditions, AMAZONE owns various test tracks, such as the stone torture tracks, where the machines are tested under the most arduous of conditions for their suitability and endurance.

Finally, for reliable operation, the machines are tested and optimised extensively in practice. For this AMAZONE cooperates with agricultural partner farms all over the world so that the operational reliability of the machines can be tested over thousands of hectares. At this important stage, AMAZONE engineers change role and suitably dressed in overalls and boots they are present on site in order to further accompany "their" machines in field operation.

In this way at AMAZONE a comprehensive but reliable programme of soil tillage and sowing technology has been and is still being developed and we would like to introduce the details of the actual technology and systems which are not easily recognisable, just like that, from the outside.

Stubble germination with the Catros compact disc harrow

For stubble work, the surface soil layer requires loosening, crumbling, levelling and re-consolidating. So, immediately after harvest the most favourable preconditions for the germination of volunteers and weed seeds are present.

Therefore, the Catros compact disc harrow operates with two rows of aggressively angled concave discs and a following roller. It is extremely short, compact and easy to manoeuvre. The discs are mounted to the frame with elastic rubber spring elements offering stone protection (see Fig. 3). As opposed to other machines using a rigid implement frame, the concave discs follow the ground contours during the first shallow pass so that the undulations are not simply filled up but are also worked. Therefore, with the Catros system, operational quality means that, even in undulating terrain, an even shallow first pass is possible.

With the following wedge ring roller the Catros leaves re-consolidated strips behind providing an optimised soil contact – ensuring a reliable germination of volunteer grain and weed seeds and as the reconsolidation is carried out in strips open gaps remain, preventing capping – even on non-pressure sensitive soils. Since the Catros offers high acreage outputs and, in addition, also operates blockage-free and with little wear, it is more and more used instead of the formerly more popular two row wing share and disc cultivators.

The Catros programme includes three-point mounted machines from 3 m to 6 m and trailed machines from 3 m to 7.5 m in working width. The latest innovation

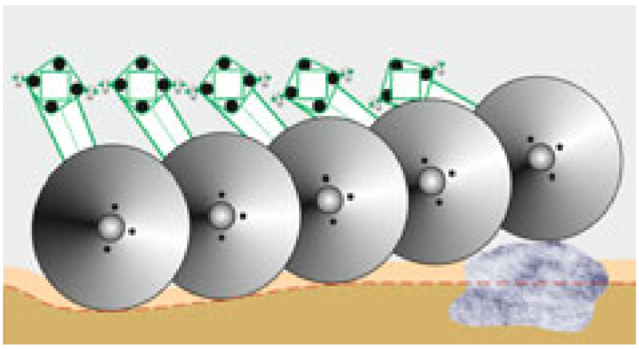
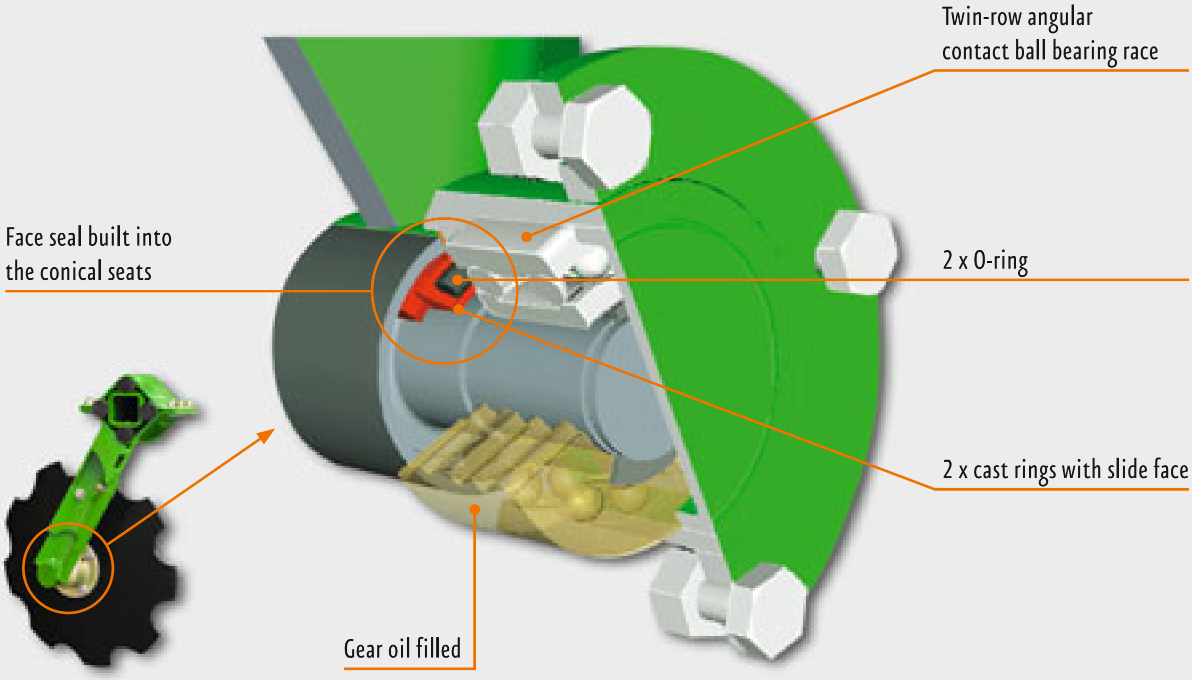


Fig. 3: Rubber sprung elements for stone safety on the Catros

Fig. 4: Maintenance-free bearings on the Catros discs thanks to combined sealing of felt ring and face seal for the twin-row angular roller bearings



High work rates, low fuel consumption and little wear are the strengths of the Catros compact disc harrow.

The standard equipment on the Catros-2 TS trailed machines in 4 m, 5 m and 6 m working widths includes a bogey chassis and drawbar.

is the trailed Catros-2 TS trailed compact disc harrow in 4 m, 5 m and 6 m working widths. These machines are equipped with a swivel bogey chassis and are characterised by a perfectly smooth travel because, during operation, the running gear folds completely over the centre frame bringing the centre of gravity forwards. In addition, the weight of the running gear uniformly increases the soil penetration across the entire machine.

All models in the Catros programme are, from choice, available with either the smooth Catros discs for shallow tillage or the Catros$^+$ discs. The bearing assemblies of both disc versions are completely maintenance-free (see Fig. 4). The Catros$^+$ discs with their serrated edges and a larger diameter show their strengths when incorporating large amounts of straw or plant organic matter. They are, for instance, used for the incorporation of maize stalks and stubble, the working up of grassland or for the replanting of land left fallow. For stubble work, in cereal fields, the Catros$^+$ discs work slightly deeper at 5 cm to 7 cm.

As an alternative to the wedge ring roller, all three-point linkage mounted Catros, and the models with a bogey chassis, can also be equipped with a choice of cage, tandem, tooth packer or knife ring roller.

The simple cage roller is mainly used where smaller tractors with limited lift capacity are available as the carrying vehicle. This roller is comparatively cheap, achieves less reconsolidation and is less suited to operation in wetter soil conditions.

Tandem rollers are often used for seedbed preparation. As the rear, smaller roller, rotates faster than the one in the front, it slightly loosens up the top soil enabling

The Catros$^+$ models with their serrated discs are superbly suited for the incorporation of large amounts of straw.

The range of application for the knife ring roller is in medium to heavy, clay soils and on sites where only few stones prevail.

wet soil to dry better. Where wet conditions and/or too many stones prevail, tandem rollers are not recommended.

With tooth packer rollers, an even, however less intense, soil reconsolidation is created over the entire working width. They are favoured for use in vegetable production systems.

The range of application for the knife ring roller is, on the one hand, heavy and clayey soils where the cutting rings and knives provide an intensive crumbling and a smooth travel. On the other hand, the knife ring rollers are superbly suited for the use on light sandy soils where the soil would bulldoze in front of a closed roller and block it up.

In combination with the GreenDrill seeder box, the Catros compact disc harrow can also be used for sowing fine seeds. Alternatively, the GreenDrill seeder box can also be operated with the Cenius mulch cultivator, the KG rotary cultivator or the KE rotary harrow.

Whether as a three point linkage machine mounted onto a self-propelled slurry tanker, or as a tool used for a separate operational pass: In combination with the special "pro" equipment package, the Catros compact disc harrows are also able to be used for liquid manure incorporation. The unique disc technology with its maintenance-free bearings, and the perfectly matched rear rollers, ensure utmost functional reliability even under these extremely harsh conditions.

Cenius mulch cultivator intensively mixing and incorporating.

Soil tillage with the Cenius, Centaur or Cayron

Cenius mulch cultivator
The main operational range of the Cenius mulch cultivator is for intensive mixing, medium-deep to deep soil tillage. In addition they can be used for shallow stubble working and seedbed preparation in spring.

AMAZONE offers the Cenius both in three-point linkage and trailed models. The Cenius is offered in working widths of 3 m, 3.5 m and 4 m and the Cenius T machines are equipped as standard with a wedge ring roller for both seedbed reconsolidation and as running gear for road transport. The three-point linkage machines are available with a choice of cage, tandem, tooth packer or knife ring rollers. On the Cenius mounted cultivators the hydraulic depth setting is optional whereas on the Cenius T trailed machines it comes as standard.

Tines with either shear bolt or 3-D spring overload safety device
The tines (from choice with either shear bolt safety device or with 3-D tines with their integrated spring overload protection) are arranged in three rows (see Fig. 5b). So, the Cenius right from the start incorporates straw residues evenly and intensively. The special arrangement of the tines and a larger frame clearance ensure high functional safety even where large amounts of straw prevail. For soil tillage to differing depths from 5 to 30 cm then various share types are available.

Cenius 6003-2TX Super

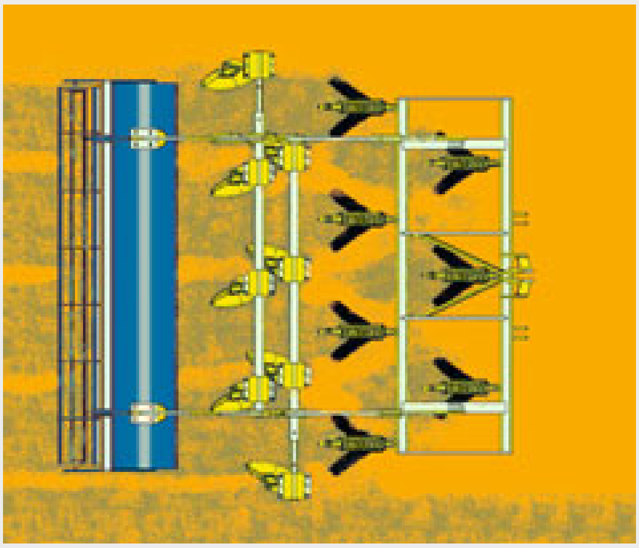


Fig. 5a: Poor straw incorporation and the simultaneous formation of swaths with a two row wing tine cultivator

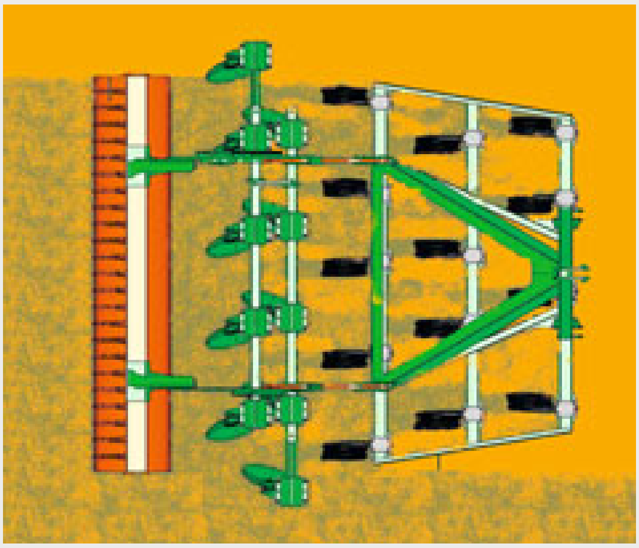


Fig. 5b: Even incorporation of straw via a cultivator with three or four rows

For the following mixing in and levelling operation for the soil then, from choice, either the levelling spring tine elements or the maintenance-free concave discs can be used. Both can be adjusted centrally without tools.

AMAZONE has further expanded the Cenius range with its 4-row Cenius TX models in working widths of 4 m, 5 m, 6 m and 7 m. The specific features of these cultivators include, amongst others, the newly developed C-Mix pressure spring overload tine safety device (see Fig. 6) and the mid-mounted transport axle.

Centaur tine & disc combination cultivator

As a multi-functional tool for conservation soil tillage, AMAZONE additionally offers the Centaur in working widths of 3 m to 5 m. Besides shallow stubble working, the operational range of the Centaur includes the reliable, intensive mixing of crop residues and soil at a medium working depth or deep loosening of the topsoil. Depending on the desired working depth, special shares are available for each operational pass. To meet the demand “as shallow as possible, as deep as necessary” the working depth of the Centaur can be hydraulically adjusted whilst driving and thus simply and quickly be matched to the prevailing conditions (volume of straw). Clear advantage: fuel consumption is reduced.

Fig. 6: C-Mix Super tines with sprung pressure protection on the 4-row cultivators – Cenius TX

Centaur tine & disc combination cultivator

Centaur tine & disc combination cultivator

The four-row Centaur Super is characterised by the staggered tine arrangement and the large frame height which is of great importance for a trouble-free passage of straw and reduced fuel consumption. Also, here especially, are the unique 3-D tines offering the highest stone safety thanks to their integrated overload safety device. Two horizontal springs keep the tine at the preset depth – only with a load of more than 500 kg do the tines deflect and subsequently return automatically to their operational position. The special suspension allows both horizontal and vertical movement, which means three-dimensional deflection behaviour of the tines, when encountering obstacles in the soil.

At the rear of the tines, the Centaur crumbles and levels the soil via its twin-row disc harrow element and then reconsolidates the seedbed in strips with the following wedge ring tyre roller so that only slight soil moisture losses occur. For deep loosening of the topsoil narrow shares are used so that the pulling power requirement is reduced. Simultaneously the wedge ring tyre roller serves as the running gear for road transport.

The Cayron plough

Since autumn 2013 AMAZONE has been producing the 5 and 6 furrow Cayron reversible plough which is the ideal tool for conventional soil tillage. With a variable working width of 30 to 55 cm and a large dimensioned 130 mm hollow shaft for the turnover mechanism, the Cayron is designed for operation with tractors of up to 240 HP.

Especially important for a clean performance is the accurate design and production of a plough so that it can be precisely adjusted even after many years. With this in mind, the AMAZONE Cayron offers some unique design features. So, the strong rectangular main beam (200 x 120 mm) ensures a high torsion resistance. Thanks to the deep beam in the vertical plane there is little elasticity so that the working depth from the first to the last plough body is always maintained.

The top and bottom faces of the Cayron beam are free from any holes improving the robustness and the longevity. At the same time, with its 83 cm beam height and its smooth surface, the Cayron ensures an especially good passage of soil and trash. With the aid of exclusively formed elements, consisting of pins and discs, the plough body is attached to the beam ensuring a movement-free connection.

Cayron mounted reversible plough.

With regard to the conversion from road to field position, the combined support and transport wheel has been designed to be ingeniously simple. The attachment of the wheel to the side is within the working widths to enable fields to be ploughed out right up to the border.

The headstock of the Cayron is equipped with a sprung cross shaft which provides a very good damping function and so clearly reduces the strain on the lift linkage of the tractor. This is enabled by two pivoting bearings located at either side of the cross shaft which safely absorb any shocks. In addition, the cross shaft is height adjustable to allow the always optimum fitting position of the tractor lower links. The linkage to the tractor lower links comes as standard in Cat. III.

With its 83 cm frame height and smooth beam surface, the Cayron ensures especially good trash passage.

Rotary cultivator with pack top seed drill.

Sowing with rotary cultivator-seed drill combinations, Cirrus, Citan or tine coulter seed drills

Seed drills or sowing combinations have to ensure an accurate seed placement in the straw-soil mix at the desired depth. In the following section, two different system versions are introduced: either rotary cultivator sowing combinations or secondly, solo seed drills.

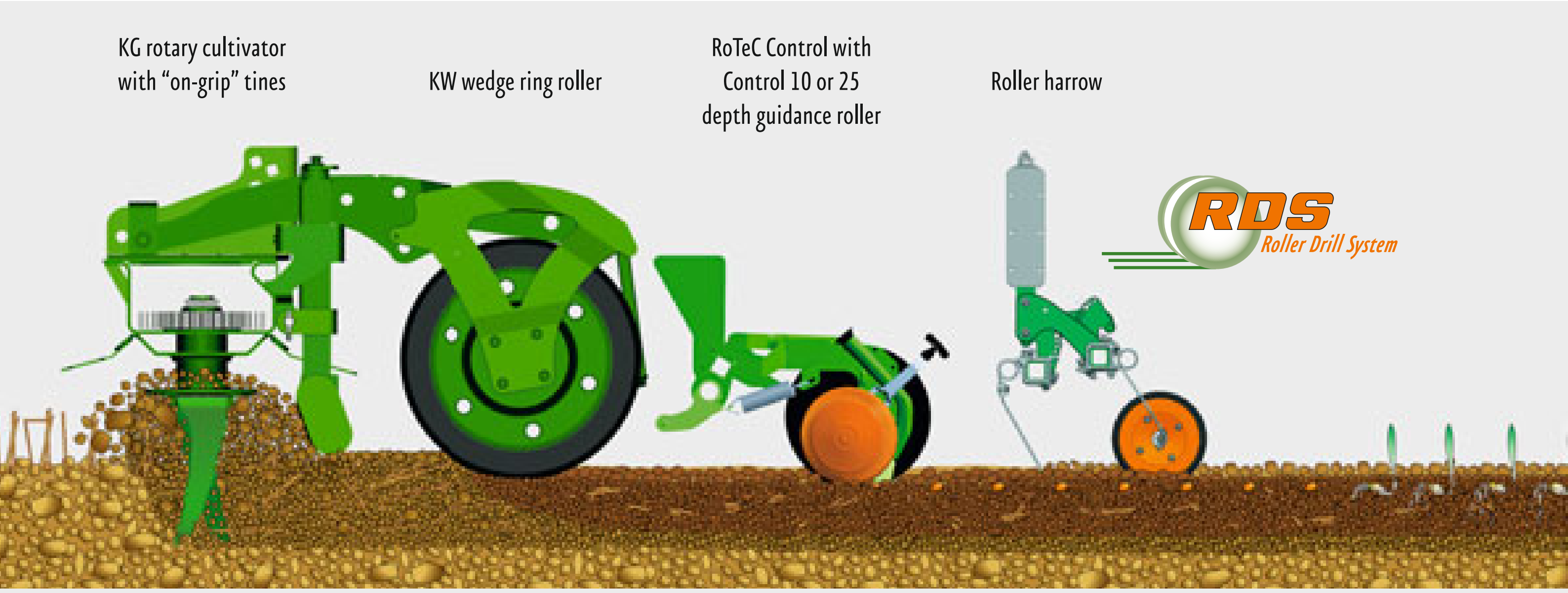
By combining the rotary cultivator, roller and seed drill, the operational passes of straw incorporation and seedbed preparation are coupled (see Fig. 7). The advantages:
1. the initial primary soil tillage can be carried out with less effort.
2. The quality of straw incorporation can be further improved. Where large amounts of straw prevail and in cases where the cereals are sown following cereals the latter always has a positive effect on the yield. AMAZONE offers the option of rotary cultivator-Pack Top sowing combinations or the Avant front tank sowing combinations in working widths up to 6 m.

From an economical point of view, however, the combined use of PTO-driven machine, packer roller and seed drill is appropriate and useful when the sowing operation can take place at the optimum time. Since these combinations have a lower output than solo seed drills one would have to increase the acreage output due to increasing farm size via larger working widths and bigger tractors but this, however, is only possible to a certain extent.

Thus, the system change to a higher output solo seed drill is made in almost every case when the sowing operation with one employee is not possible on the total area at the optimum time. Depending on specific farm conditions, this limit is between 500 ha and 700 ha.

If above this limit a solo seed drill is used, the seedbeds have to be thoroughly prepared prior to the actual sowing operation. But then the sowing operation can be carried out with maximum acreage output. Special coulter systems are required to be able to increase, with a sufficient seed embedment quality, the acreage output via higher forward speeds.

Fig. 7: Function overview of a rotary cultivator combination: precise rolling with the wedge ring roller, precise sowing with the RoTeC Control coulters and flexible embedment with either the Exact following or Roller harrows.



AMAZONE till and drill combinations are utilised both after the plough and in conservation soil tillage.

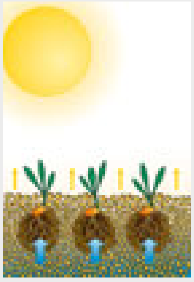
The all-rounder combination

AMAZONE till and drill combinations have proven themselves a thousand-fold over, both for cost-effective mulch sowing, with or without previous loosening and conventional sowing following the plough. The KG rotary cultivator with its "on-grip" tines loosens even hard, firm soils maintaining the preset working depth and simultaneously mixing in the straw. Thanks to the large clearance between the tines, the straw-soil mixture can also pass through the machine even above the tine carriers without any problems. The following levelling board levels ridges and furrows.

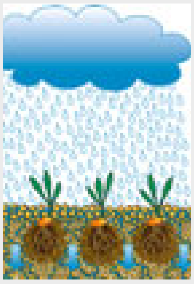
The RDS 'roller drill system' describes the teamwork ensured by the accurate matching of the wedge ring roller, the RoTeC control disc coulters and the Exact following or Roller harrow. The wedge ring roller reconsolidates the soil in strips along the seed furrow and it is into these furrows that the RoTeC Control disc coulters place the seed. The coulters run especially smoothly and are able to track the furrow very accurately as they embed the seed into the re-consolidated furrow bottom. The coulters are followed by either the Roller harrow or the Exact following harrow which cover the seed with loose soil, or give additional consolidation where the Roller harrow is used. The pressure of the Roller harrow can be adjusted independently from the coulter pressure and, if required, the Roller harrow can be raised out of work completely.

Of special benefit with the RoTeC Control coulters, which operate at a coulter pressure of 35 kg, is the Control 10 depth guidance disc with a contact surface area of 10 mm, or the Control 25 depth guidance roller with a contact surface area of 25 mm that are fitted to the side of each coulter. As these discs run directly on the side of the sowing coulters, they maintain a very precise depth control.

Fig. 8: System of function for an active sowing combination: Straw incorporation, seedbed preparation and sowing in one pass



In very dry conditions capillary water is brought to the seedling.



Heavy rainfall seeps away into the non-rolled, loose areas.

Gaseous exchange via the loose soil – allowing the roots to breathe.

The Cirrus cultivates and levels the soil using its twin-row disc harrow element.

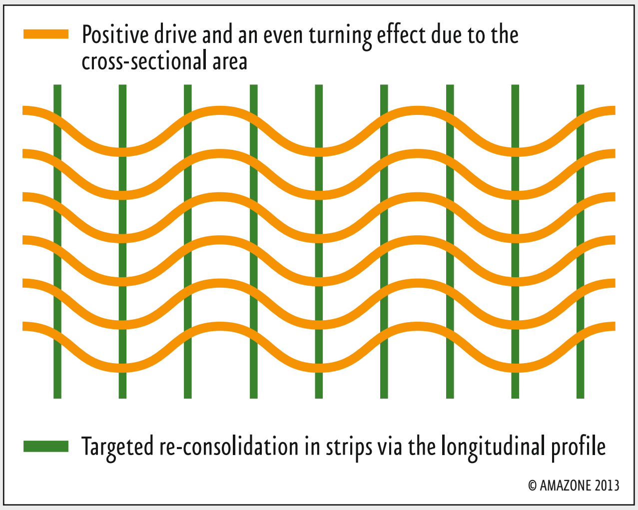
The trailed Cirrus sowing combination
The range of the new Cirrus 03 series includes one model with 3 m working width (Cirrus 3003 Compact) and a folding version in 6 m working width (Cirrus 6003-2) with a hopper capacity of 3,600 l. The Cirrus 6003-2C model version is equipped with a twin-tip 4,000 litre pressurised tank for Single Shoot fertiliser metering. With the Cirrus 3003 Compact, with its 3,000 litre seed hopper, AMAZONE offers an especially manoeuvrable model for smaller field sizes.

The decisive innovations on the Cirrus 03 series include, amongst others, the tyres on the packer roller which simultaneously serve as the running gear. It consists of the newly developed 400 mm wide and 880 mm diameter Matrix tyres. With these tyres the machine is licensed in Germany for 40 km/h road transport with the tank full of seed. This means a clear increase in output for farms which do not have the capacity for in-field filling.

At the same time, the new Matrix tyres feature a special radial cross-sectional profile. The combination of the new profile and large tyre diameter reduces the rolling resistance when operating in the field and thus also the tractive power requirement. At the same time, the radial profile of the tyres results in the strip-wise reconsolidation of the soil, whereas the narrow cleats on the

The Matrix tyres of the packer roller are one of the decisive innovations of the Cirrus 03.

Matrix principle



Matrix tyres

Thanks to the good wall flexing, the radial designed profile of the Matrix tyre virtually rests evenly on the soil across all the rows creating even germination conditions.

With the Cirrus 3003 Compact, AMAZONE offers an especially manoeuvrable model for smaller field sizes.

Both the Cirrus and also the Citan seed drills can be folded in to a transport width of 3 m in the shortest of time.

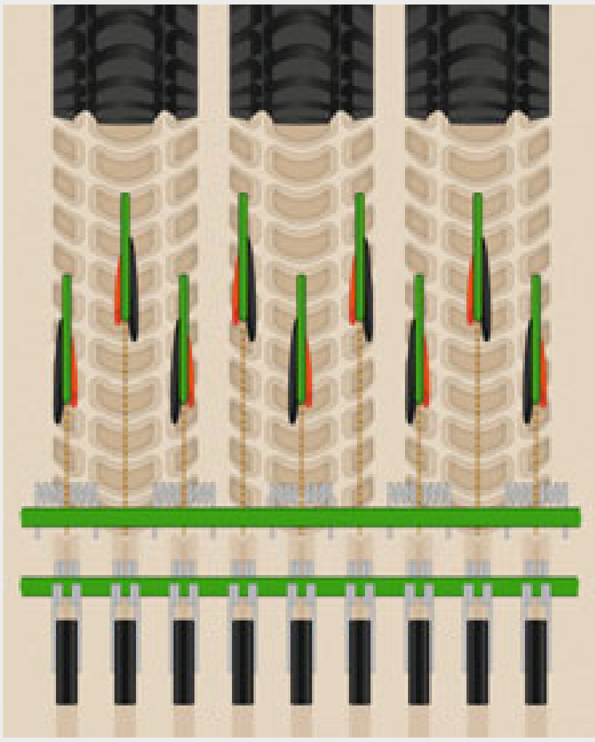
profile ensure that more fine soil is available for the following seed coverage. In this way a heterogeneous soil surface is created which provides the optimum growing conditions for the emerging plants. Thanks to their design, the radial tyres – with a standard 3.5 bar tyre pressure – offer good self-cleaning and thus scrapers are not necessary.

As an alternative for regions which are less sensitive to germination conditions, AMAZONE offers a 15.0/55-17 AS cross-ply tyre. Thanks to its short cleats, this tyre also features a very low rolling resistance.

The front disc element of the Cirrus 03 models features more aggressively angled, serrated discs providing a good mixing of the soil. The driver can adjust the working depth of this unit from the tractor cab. As an option, AMAZONE also offers a hydraulically adjustable Crushboard which levels the soil in front of the discs.

On all Cirrus models, the transfer and distribution of the seed is carried out via the hydraulically-driven blower fan. Depending on the tramline rhythm, the metering heads allow a half-side shut off. Simultaneously, the RDS Roller Drill System with its RoTeC pro coulters, Control depth guidance rollers and 55 kg of pressure acting directly on the coulters provide a smooth coulter run and an even sowing depth; even at high operational speeds.

Strip-wise reconsolidation via the Matrix tyres



Row spacing 16.6 cm

Plants at a row spacing of 16.6 cm

The Citan 6000, in a working width of 6 m, for operation with tractors from 120 HP.

The Citan solo seed drill

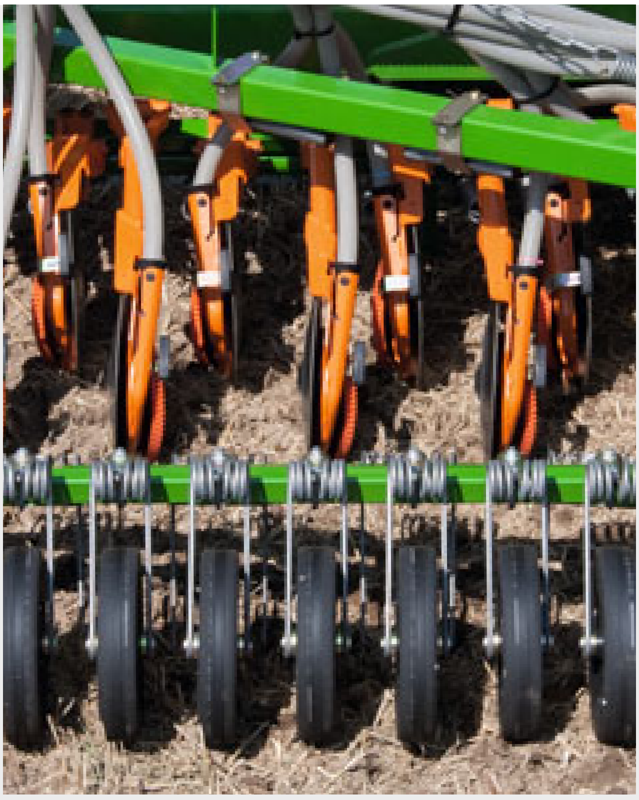
The Citan large area seed drill (6 m, 8 m, 9 m, 12 m or 15 m working widths) is used wherever high outputs are required in the course of conservation or conventional crop production methods. Since this solo seed drill has no pre-working cultivation element, more or less intensive soil tillage over several operational passes is necessary (with Cenius, Centaur or Cayron) before the machine can be used. The targeted single process, the large working widths and the high operating speeds result in a further, enormous increase in the actual drilling capacity – an important argument for large farms. So, the Citan manages operational speeds of between 10 and 20 km/h, depending on the prevailing conditions. Rough rule: approximately one hectare per hour per metre of working width. At the same time, the fuel consumption is only 2.8 l/ha (measured at the DLG test centre) and a pulling power requirement of around 25 HP per metre of working width.

Produces extremely high acreage outputs – the Citan with both grain and fertiliser and in up to 15 m working width.

The Citan 12001-C and 15001-C offer the possibility to place, in addition to the seed, also fertiliser down in the seed furrow. For this reason, the hopper is divided and can be filled 2/3 with seed and 1/3 with fertiliser or a second kind of seed. If division of the tank is not necessary, it can be completely filled with one kind of seed. The metering is carried out via Vario gearboxes which can each meter seed rates of 2 to 400 kg per hectare.

In spite of the high operational speed, the quality of seed placement is excellent. Also with the Citan, the RoTeC$^+$ coulters and Control 25 depth guidance rollers ensure a very smooth travel and an absolutely accurate depth limiting. For the optimum embedment of the seed, the Exact following harrow or the Roller harrow are offered, the latter with adjustable pressure intensity.

Divided hopper on the Citan 12001-C and 15001-C.



For operation in dry areas, the Citan seed drills can be equipped with a roller harrow.

Seed drills with either tine or chisel coulters

For systems utilising virtually no tillage, and also for direct sowing in the continental regions, AMAZONE recommends the use of seed drills equipped with special tine coulters. This recommendation also applies to sowing under particularly difficult soil conditions, e.g. extremely hard soils or soils with many stones. With the Primera DMC, the Condor and the Cayena, AMAZONE offers three different machines which have been designed for specific purposes. The common feature of all the machines is that the tine or chisel coulters which place the seed below the crop residues to ensure good seed/soil contact resulting in optimum germination conditions. These shares are characterised by their narrow shape. This not only reduces the soil movement and thus keeps soil moisture losses to a minimum but also means the tractive power requirement is low. All machines feature good contour following properties of the coulters, and the ability to sow a wide range of crops.

The Primera DMC is, from choice, available in 3 m, 4.5 m, 6 m, 9 m or 12 m working widths and can be used universally, not only for direct and mulch sowing, but also for conventional sowing following the plough. It features the parallelogram guided AMAZONE chisel openers at a row spacing of 18.75 cm. The chisel openers are depth guided via hoop rollers, diagonally angled to the left and right behind each coulter. These rollers provide the safe depth guidance of the openers even at high sowing speeds. At the same time, they divert the soil flow thrown out by the chisel openers from either side back onto the furrow and so ensuring that the seed is covered with loose soil even in very wet soil conditions.

The four stagger coulter units are arranged on longitudinal cross beams resulting in a diagonal "opener to opener" spacing of 75 cm. This allows, on the one hand, a relatively narrow coulter spacing of 18.75 cm and, on the other hand, prevents blockage due to harvest residues.

Sowing on stony soils is no problem, thanks to the Revomat stone safety release system. Optionally, the Primera DMC can simultaneously apply seed and fertiliser. The machine operates at speeds of up to 18 km/h and is characterised by its easy pulling, the wide range of operational applications and its high efficiency.

Primera DMC for direct and mulch sowing systems.

TineTeC coulter

The Cayena, equipped with its TineTeC coulters, is suitable above all for sowing on hard and stony soils.

The Condor for direct sowing in dry soil conditions and large field sizes.

The 6 m Cayena tine seeder is particularly suitable for sowing in hard and stony soils in arid regions, no matter whether tillage has been performed or the direct sowing method is used. The Cayena is the perfect machine, for example, on sites in Central and Southern Europe which are characterised by weathered limestone soil. It is equipped with special TineTeC coulters (16 cm row spacing) which place the seed precisely in the seed slot. Reconsolidation is performed by a wedge ring tyre roller consolidating the seedbed in strips, precisely and exactly above where the seed is placed in the soil.

The coulters arranged on the main frame adjust to the ground contours via rubber spring elements which simultaneously serve as overload protection. The Cayena, which is able to operate at speeds of up to 15 km/h requires only minimal pulling power.

With the Cayena 6001-C, AMAZONE also offers a fertiliser version. The 4,000 litre hopper is divided proportionally 60:40 into two sections each with its own electric metering drive. Both parts can be filled from choice with either seed or fertiliser. The seed and fertiliser hopper is pressurised to enable the application of high rates of seed and fertiliser at high forward speeds.

The Condor in 12 or 15 m working width is specifically designed for direct sowing where arid soil conditions and large acreage structures prevail. Parallel to seed placement this machine also feeds fertiliser into the slit (2/3 seed + 1/3 fertiliser).

The ConTeC coulters of the Condor are only 12 mm wide and each connected with a following packer wheel; this permits optimum adaptation of the coulters to undulating ground and correct depth control. At the same time reconsolidation is effected by the packer wheel which ensures soil contact of the seed. The coulters are arranged in a three-stagger layout at a spacing of 25 cm or, from choice, at 30 cm. This arrangement, and the frame height of 80 cm, permit trouble-free operation without blockage even in cases where very large amounts of crop residues or unfavourable straw distribution prevail. Daily outputs (13 h days) of around 150 ha can be achieved with the 15 m wide Condor at operating speeds of just 9 to 10 km/h.

AMAZONE offers the ED precision air seeders in working widths of 3 to 12 m.

EDX 6000-2C with integrated fertiliser hopper, 8 rows and 6 m working width.

Precision seeding with ED and EDX

With the ED Precision air seeders in working widths of 3 m to 6 m AMAZONE offers professional, highly efficient machines which enjoy an excellent reputation primarily among contractors. On the one hand they are characterised by their sturdy design and simple and convenient operation, on the other hand they excel in accuracy of placement, reliability and their lasting value.

Depending on the application various seeder units are available for the ED, among them the Contour seeder unit which is suitable for conventional and mulch sowing as well as – depending on the conditions – direct sowing. This unit creates a sowing environment which is virtually free from organic matter. The furrow former undercuts the disc which results in a well reconsolidated, wedge shaped groove. These are the optimum pre-conditions for good seed embedment and a high germination percentage.

The EDX precision seeders provide an especially efficient solution for sowing maize, rape and sunflowers. With operational speeds of up to 15 km/h, these machines achieve work rates of about 50% higher than

EDX 9000-T precision air seeder with 12 rows and 9 m working width.

conventional precision air seeders. The EDX complete programme includes 3 three-point mounted machines in a 6 m working width and two trailed machines in 6 m and 9 m working widths. With its comprehensive range, the perfect machine for all relevant farming applications is available.

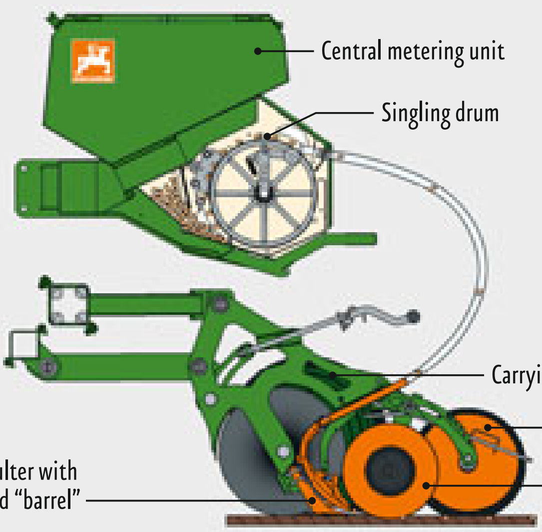
The heart of the machine is the Xpress singling and placement system (see Fig. 9). This system was awarded a gold medal at Agritechnica 2007 and, instead of the usual vacuum singling, with the Xpress system, a pressurised system is used and grain singling and grain placement are separated. Whilst the exact pneumatic singling of the grains is carried out in up to eight rows via a centralised singling drum, the pressurised system delivers the seed at pace for precise placement down to the seed furrow. There the individual grains are safely caught by the catcher roller and pressed into the furrow.

With the aid of the centralised, large seed and fertiliser hoppers, a centralised stripper finger adjustment and a centralised hydraulic pressure adjustment for the fertiliser and sowing coulters, AMAZONE has also decisively reduced the set-up and non-productive times on the EDX. Also the effort required to individually adjust manually the strippers is clearly reduced because the adjustment is carried out simultaneously for several rows. As an option, even in-cab stripper adjustment is available via plus/minus keys on the AMATRON 3 so that the driver need not stop or leave the tractor.

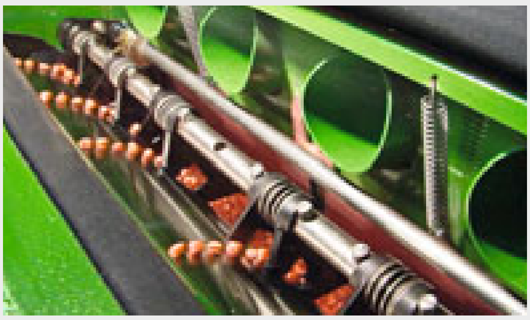
EDX 6000-T precision air seeder with 8 rows and 6 m working width.

All EDX precision air seeders are suited for plough, mulch and direct sowing. Narrow sowing specifications are possible, so that, for example, the special demands of the Erosion Prevention Decree can be fulfilled. On request the machines are also available with a tramline and part-width section control.

Fig. 9: System overview of the new Xpress grain singling and placement system



View of the central metering drum of the Xpress singling system.



Fertiliser spreader and N-sensor for site-specific fertilisation.

Trends in fertilising technology

Balanced crop nutrition is also an important part of modern crop production. Prior to any specific fertilisation measures it is necessary to optimise the local conditions in view of a complete nutrient utilisation by the crop, i.e. to provide the basis for optimum nutrient uptake already during tillage and sowing.

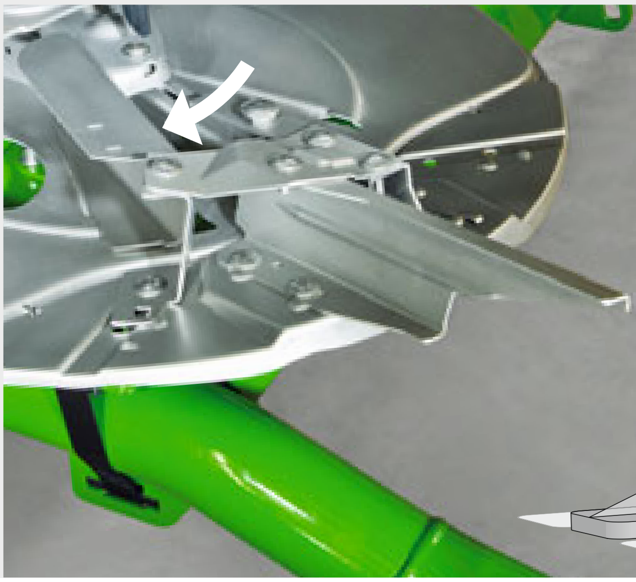
AMAZONE offers their customers **mounted and trailed spreaders** of various capacities with working widths from 10 m to 54 m and hopper volumes from 500 l to 8,200 l. With the SBS Soft Ballistic System, all AMAZONE spreaders are equipped with a system that ensures an especially gentle treatment of the mineral fertiliser. On the new ZA-TS, for instance, the fertiliser drops from the slowly rotating star agitator via the aperture on to the working width dependent delivery point in the centre of the spreading disc. Low disc speeds and long spreading vanes then permit gentle and even acceleration of the fertiliser to the optimum ejection speed. This results in precisely defined trajectories and thus in optimum spread patterns.

The **forward speed related spread rate adjustment** on the fertiliser spreader is of particular importance during operation with tractors with power shift gearboxes to exploit the full speed potential. The electric shutter regulation enables the individual settable plus/minus rate control. The operation of this system is carried out in the “Tronic” and “Hydro” equipment packs via AMATRON 3, the CCI-100 terminal or AMAPAD.

Longitudinal distribution can be further optimised by means of **weighing systems.** On the ZA-TS spreaders, AMAZONE has integrated weigh cells into the parallelogram frame. The weighing system recognises changes to the fertiliser flow behaviour within a very short time and automatically adjusts the shutter slide so that the spread rate always remains the same. The optionally available tilt sensor corrects the weight measured and in this way ensures the maintenance of the high metering accuracy even on slopes. Calibration is no longer necessary and this saves time and fertiliser and everything is always under control.

Where border spreading is concerned, border spreading discs which are exchanged by hand and can be adjusted to the functions side spreading, boundary spreading or water course spreading are the simplest equipment variant. The Limiter border spreading system which is lowered into the spread fan by a hydraulic spool valve is much more convenient as the tractor driver only has to leave the tractor cabin when changing the various spreading materials. With the ZA-TS, the desired boundary spreading function can be adjusted directly on the terminal with the aid of the Auto-TS function, saving time and simplifying the control of the boundary spreading operation.

Hydro fertiliser spreaders with hydraulic spreading disc drive meter the fertiliser quantity independent of the engine speed and can be changed into fully automatic spreaders e.g. in combination with GPS-Switch. One advantage consists in the fact that the



AutoTS boundary and side spreading device.

Fig. 10: Fertiliser spreader with hydraulic spreading disc drive for the 8-section automatic part-width shut-off.

tractor can be operated at fuel-saving, low speeds and with up to an 8 section part-width shut-off system, fertiliser application can be adjusted to the conditions even more precisely (see Fig. 10). Spread rates (shutter size) and spreading widths (spreading disc speed) can be individually adjusted on both sides.

Systems for site-specific nitrogen fertilisation have been known for years. Today some service providers offer soil sampling with GPS support. By means of the results, an application map can be created to serve as the basis of site-specific fertilisation in combination with AMATRON 3, AMAPAD or other ISOBUS terminals. Via this method, the nutrient supply is balanced and thus, from the crop nutrition point of view, optimised part-area site specific conditions for plant growth are created.

Further potential can be tapped **by means of sensor systems.** Biomass, plant height or chlorophyll levels or the green colouring serve as indicators for the already taken up nitrogen or the nitrogen demand. By means of an active sensor this data is determined and converted into optimum application rates by modern on-board computers such as AMATRON 3, CCI-100 terminal or AMAPAD and the spread rate is then controlled accordingly. Further technical development of mineral fertilisation is also determined by sensor systems that record the various data on-line and control complex distribution systems.

Trailed fertiliser spreaders with hopper capacity of 5,000 l or 8,200 l.

The Pantera self-propelled sprayer is the flagship of AMAZONE's crop protection programme.

Trends in crop protection technology

Both in conservation and conventional systems the following crop protection measures serve the purpose to achieve further yield increases in crop production. Because many farms have virtually reached the optimum in crop protection thanks to increased tank volumes, larger working widths and reduced transportation times and now electronic systems have become more and more the heart of technical innovations.

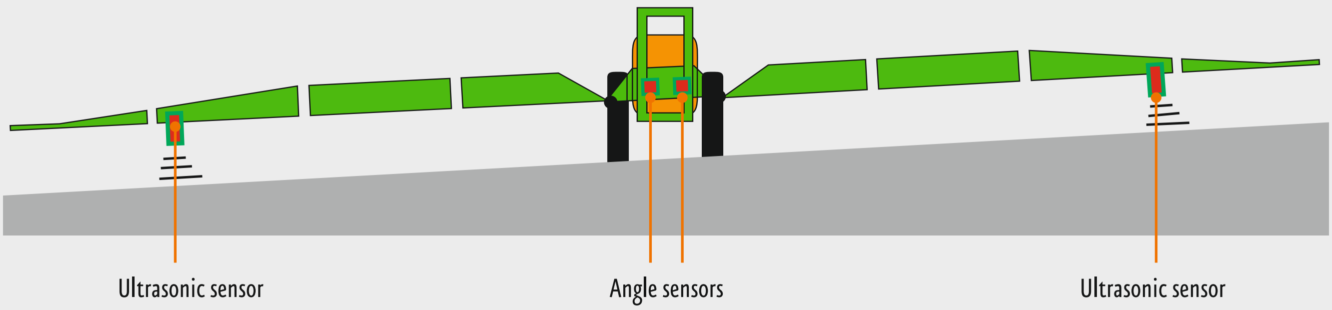
DistanceControl; the automatic height and tilt adjustment system, provides excellent comfort for the driver. Automation is effected via ultrasonic sensors and the operating terminal. Once set, the booms adjust to an optimum height of 50 cm and automatically follow the terrain contours. In addition, for increased driver comfort, spraying faults can be avoided which may be caused by accidental crop contact or excessive spraying heights. The Auto-Lift function, with which all the field sprayers with Profi-fold are equipped, ensures that when the last part-width section is switched off, the boom automatically raises to a predefined height on the headland. When switching on again, the boom is automatically lowered.

The "Comfort-Pack" from AMAZONE enables **automation of filling, agitation and cleaning.** When the sprayer is being filled the suction valve switches automatically off as soon as the preset level is reached. Meanwhile the driver can concentrate on adding the crop protection agents. During application the agitation intensity is automatically adjusted to the current tank level.

The driver starts cleaning the agitation system and the tank also via the on-board computer. The diluted residual quantity can immediately be sprayed out. Because the driver does not have to leave the tractor cab, it is easy to repeat this operation several times. Only this ensures that the residual quantity is highly diluted when sprayed out and that only very small, and at the same time highly diluted, residual quantities remain in the system. In addition to complete cleaning it is possible to clean only the booms out if for any reason the spraying is interrupted and this prevents any deposits in the spray lines and potential nozzle blockages.

"Speed Spraying" is the term AMAZONE uses for **crop protection equipment that increases output performance.** In practice e.g. higher spraying speeds are

Fig. 11: DistanceControl – the automatic boom height and tilt control system



increasingly used to increase work rates. The multiple-cushioned AMAZONE booms – supported by DistanceControl – allow these higher operating speeds, and as far as the equipment technology is concerned, to ranges even beyond 20 km/h.

Likewise **reduced amounts of water** are becoming more and more popular to increase the output. Please note, however, that water rates below 200 l/h risks endanger the success of crop protection measures. Also the warranty of the agent manufacturers may become void. Application by this method requires an optimally adjusted nozzle system. The crop protection technology from AMAZONE permits precise control of even very small amounts.

When liquid fertiliser needs to be applied at higher forward speeds the pump capacity becomes the limiting factor. The optional high-performance fertilisation equipment "HighFlow" enables both pumps to be connected in parallel on the sprayer to apply larger amounts of fertiliser via a second spray line. In this way for instance, up to 700 l/ha of liquid fertiliser can be applied with a trailed sprayer and a 36 m boom at 8 km/h; even in instances where rates up to 350 l/ha at 16 km/h are required do not constitute a problem.

For UF mounted sprayers AMAZONE developed the FT front tank which can significantly increase efficiency. Thanks to the flow control system, which makes the FT 1001 front tank an integral part of the mounted sprayer, the operator does not then have to carry out any manual transferring from front to back because this is done by the electronic control system. An intensive circulation has already started during the automatic filling of the FT. An injector capacity of up to 200 l/min in both directions facilitates quick homogenisation of even crop protection agents that are difficult to mix. Simultaneously the system ensures that the weight is always evenly distributed on the tractor independent of the fill levels. Only when the fill level in the mounted UF sprayer has dropped below 30 % of the nominal volume, the spray agent is pumped from the front tank to the rear. Automatic residual quantity emptying guarantees minimum residues. In combination with the Comfort-Pack the complete system can be cleaned from the tractor cab. An additional 100 l clear water tank permits extensive cleaning of the system on the field.

The electric AmaSelect individual nozzle switching for the Super-L boom provides many new possibilities for part-area site specific application to fulfil the

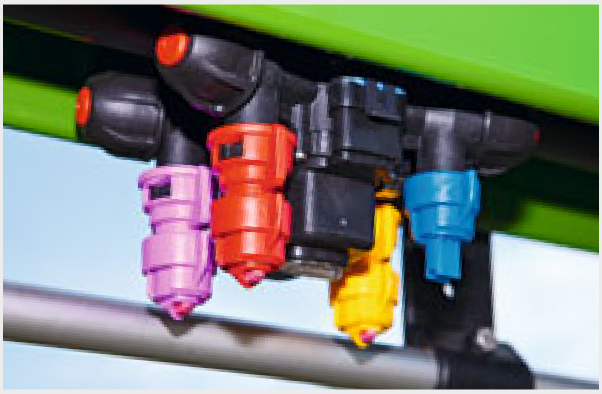
The UX with a tank volume of up to 11,200 l is the flagship model of the AMAZONE trailed sprayers.

The FT front tank increases the capacity of the UF mounted sprayers by 1,000 l to 2,800 l max.

The work lights on the booms or LED individual nozzle illumination eases work after dark.

demands of Intelligent Crop Production. The special feature of AmaSelect are the four fold nozzle bodies with flexible access of each individual nozzle. With changing spray rates and/or forward speed changes, AmaSelect automatically switches over between predetermined individual nozzles. Even two nozzles can be accessed simultaneously so that, in conjunction with the HighFlow equipment up to 1,000 l/ha at 6 km/h (up to 400 l/min flow rate towards the boom) can be sprayed. This is necessary, for instance, when spraying stabilised liquid fertilisers within arable farming or when growing vegetables.

Thanks to the flexible access to the individual nozzles of the four-fold nozzle bodies, the AmaSelect individual nozzle switching offers many new possibilities for part area site-specific application.



If AmaSelect and GPS-Switch are combined, part-width sections at a spacing of 50 cm can be controlled individually and this keeps the overlap zones down to a minimum. This is optimum, both from an economic and also an ecological point of view.

The extension set for the nozzle bodies enables the driver to switch over between 50 cm and 25 cm nozzle spacing and – during application – for instance, from a coarse droplet, low drift nozzle of the size 05 (operation at the field's edge) to two fine droplet 025 double flat fan nozzles (operation inside the field) and vice versa. In addition, via AmaSelect, different nozzle types with different nozzle characters can be accessed across the boom at the same pressure. So, for example, with larger working widths (> 30 m) coarse droplet work is possible just on the outside of field where necessary but, towards the inside of the field, a fine droplet and an agronomical optimum application is maintained.

In addition, AMAZONE provides integrated LED individual nozzle lighting within the AmaSelect nozzle bodies. So the spray fan is very well visible even at dawn or dusk. Thanks to its intelligent electronics, the AmaSelect System is exclusively supplied via the conventional 12 Volt electrics of the tractor and therefore does not require any air assistance when switching between nozzles.

Electronics in Intelligent Crop Production

Electronics provide a large number of useful, new technologies. Thus, on the one hand, recording of yield-relevant parameters (soil and yield values) and operational data and their documentation and evaluation can be automated. On the other hand, sensor, control and feedback systems enable noticeable savings, contribute to a better utilisation of the yield potentials and simultaneously protect the environment. AMAZONE has combined all its activities around electronic control, feedback, recording, monitoring and documentation under the term IT-Farming.

AMAZONE offers its customers machine-specific terminals as basic equipment for the operation of the machines. They meet minor requirements and their function and display are matched to the respective machine. Electronic remote control of certain functions and display of relevant parameters, e.g. area worked, quantities sown or applied and pressure are among the core areas of electronic applications. If they are equipped with a feedback function, they offer, in addition, an interface for communicating with third party devices.

AMAZONE offers their customers the machine-specific terminals AMALOG+ and the AMADRILL+ for seed drills, AMADOS+ for fertiliser spreaders and AMASPRAY+ for sprayers. The last two are equipped with an interface which permits simple communication for documentation (e.g. field mapping). The connection of sensors or via application maps site-specific makes the adjustment of the application rate is possible.

For recording the work carried out, AMAZONE introduced the ASD (automated field-related documentation) interface together with various partners. Numerous electronic field maps support this type of automated data transmission. So the operator is not bound to a

Fig. 12: Data exchange between the AMATRON 3 operating terminal and other IT-Farming technology is simplified via defined and open interfaces

certain system, but can flexibly decide, or use an existing solution for documentation.

A machine overlapping operator terminal supporting graphics offer a wider scope of functions than the machine-specific terminals. The intelligence of this technology is held in the job computers of the respective machines, so that in case of a machine change, one and the same operating terminal always remains in the cab. The identical operating logic is one advantage of these terminals. Operation – even of complex machines – can be optimally adjusted to the known user interface and provides a high degree of recognition and a maximum of comfort for the operator. Equipped with separate job managers, numerous jobs and clients can be created, managed and saved.

Fig. 13:
GPS-Switch enables the fully automated headland and part-width section control of crop protection sprayers and fertiliser spreaders.

The advantages of GPS-Switch are, amongst others, the additional comfort for the driver, the improved application quality and safety and less overlapping that results in savings in both costs and fertiliser. Unworked areas are minimised and with GPS-Track, AMAZONE offers an additional parallel driving aid which can be integrated into the AMATRON 3 terminal in no time at all.

With the AMATRON 3 ISOBUS terminal, AMAZONE offers such a universal operator option for seed drills, sprayers and fertiliser spreaders. The characteristics of this terminal is that not only can it be operated with ISOBUS machinery of most various manufacturers but in addition it is downwardly compatible to all those AMAZONE machines which have so far been operated with the AMATRON+ terminal. In this way, AMATRON 3 forms a bridge between the non-ISOBUS and the ISOBUS world without having to change the terminal. Also, the following functions GPS-Switch, GPS-Track and GPS Maps can also be installed in AMATRON 3 so that again there is no additional terminal is required.

In addition to AMATRON 3, two other ISOBUS terminals are available: the CCI-100 terminal and AMAPAD. The CCI-100 terminal originates from the co-operation of several agricultural machinery manufacturers within the CCI (Competence Center ISOBUS e.V.). With the CCI, AMAZONE and its partners have laid down the foundations for introducing ISOBUS into practice. Whereas the AMAPAD terminal features much more computing power and thus is designed for newer future-orientated intelligent applications. So, for example, with AMAPAD several machines can be operated and monitored simultaneously.

All three terminals offer the possibility for data transfer within other IT Farming technologies (see Fig. 12 for an example with AMATRON 3). So, for instance, connection to N-sensor systems for site-specific fertilisation or application of crop protection agents and for documentation and evaluation systems on the farm PC is easily possible. The decision as to which system meets the specific requirements and wishes should be flexible and not bound to a certain manufacturer.

There is a strong demand in the area of IT Farming on GPS-Switch, a GPS based, fully automatic headland and part-width section control for field sprayers and fertiliser spreaders as well as a variety of seed drills and precision seeders (see Fig. 13). Once the field borders are known, the use of the machine in automatic mode allows the driver to fully concentrate on driving. At the headland, and in cases of overlap, such as for example, when in wedges, the system automatically switches on and off the relevant part-width sections.

Besides the increased comfort for the driver, GPS-Switch offers obviously better application quality and safety. So overlaps can be avoided, saving operating costs. Unworked areas are reduced or made visible. Whereas any savings in operating costs can be quantified, there are other important advantages of such a system, such as, for example a more even crop with less tendency to lodging, that can only be put into figures with difficulty. Because the system operates independently of day and night to the same precision, the length of operation can be prolonged into the evening or the night.

With GPS-Track, AMAZONE also offers an in-house parallel steering aid which proves to be of enormous advantage for maintaining orientation in the field. Operation and function of GPS-Track are, as in to GPS-Switch, simply and clearly laid out. A third function which can be operated with AMATRON 3 is GPS-Maps, the new software tool for the handling of application maps directly in the field. The modular format of the GPS functions allows the use to be made of an existing GPS receiver for position fixing.

SmartRefill and WindControl are two useful AgApps (Agricultural Applications), which can be utilised in combination with the AMAPAD. SmartRefill checks the actual fill level of a field sprayer and compares it with the area still to be worked. If the volume is not sufficient to last over the next tramline the software recommends the early refilling of the sprayer. When spreading fertiliser, WindControl detects both the direction of wind and the wind speed and readjusts the settings on the machine accordingly. With too strong a wind, WindControl recommends that the driver finishes the operation.

The CCI-100 terminal originates from the co-operation of several agricultural machinery manufacturers within the CCI (Competence Center ISOBUS e.V.).

The AMAPAD terminal features especially a high level of calculating power and thus is already designed for new future-orientated intelligent applications.

5. AMAZONE methodology – the systems

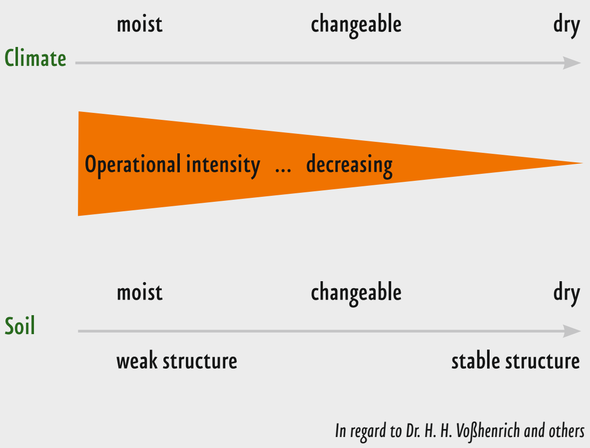
Soil tillage, sowing, fertilisation and crop protection – with AMAZONE technology the different individual operational steps result in optimally matched total systems that are valid for both conventional or conservation soil tillage is the message: "Saving from the system!"

The decisive criteria when matching system chains are the economic prime factors such as field shape and size as well as farm size and structure. AMAZONE meets the different demands with a wide range of working widths and capacities. In addition, a large number of machines allow the multi-functional use over several operational passes so that even smaller size farms are able to make optimum use of the technology.

The even bigger influences on mechanisation are, however, the prevailing soil and climatic conditions. So, moist soils have to be worked more intensively than changeable or dry soils. The same applies to the system procedures which, in maritime Middle Europe look entirely different from those in continental Eastern Europe. Because of the reduced water availability, shorter growing periods and decreasing yield levels, demands on the intensity of the soil tillage are reduced.

Thus, for example, a system chain consisting of a Cenius cultivator, Cayron plough and an active PTO-driven KG-AD rotary cultivator-sowing combination is typical for the smaller farm sizes and higher cultivation intensity in maritime climatic regions. Catros, Cenius or Centaur and Cirrus, on the other hand, represent a combination which is ideally suited for the medium tillage intensity on larger farm structures under rather more continental conditions. Tine and chisel coulter seed drills, such as the Primera DMC, Cayena or Condor, are the ideal solution where there are low demands on intensity, there is a lack of water or where special site conditions (e.g. limestone disintegration soils) dominate the farm situation.

Fig. 14: Operational intensity depending on climate and soil type



Intelligent crop production

Soil tillage | Sowing | Fertilisation | Crop protection

Application-optimised concepts

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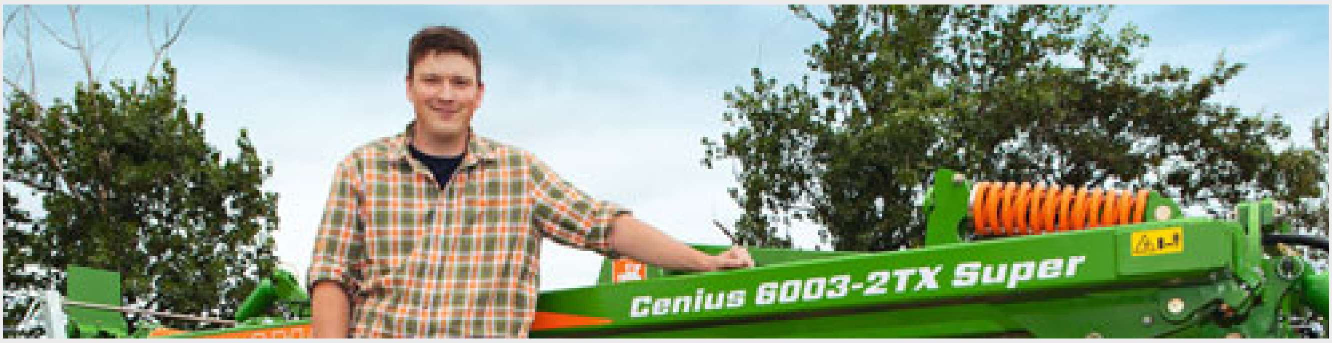

Expert knowledge of the farm manager

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Individual system solutions for the farm

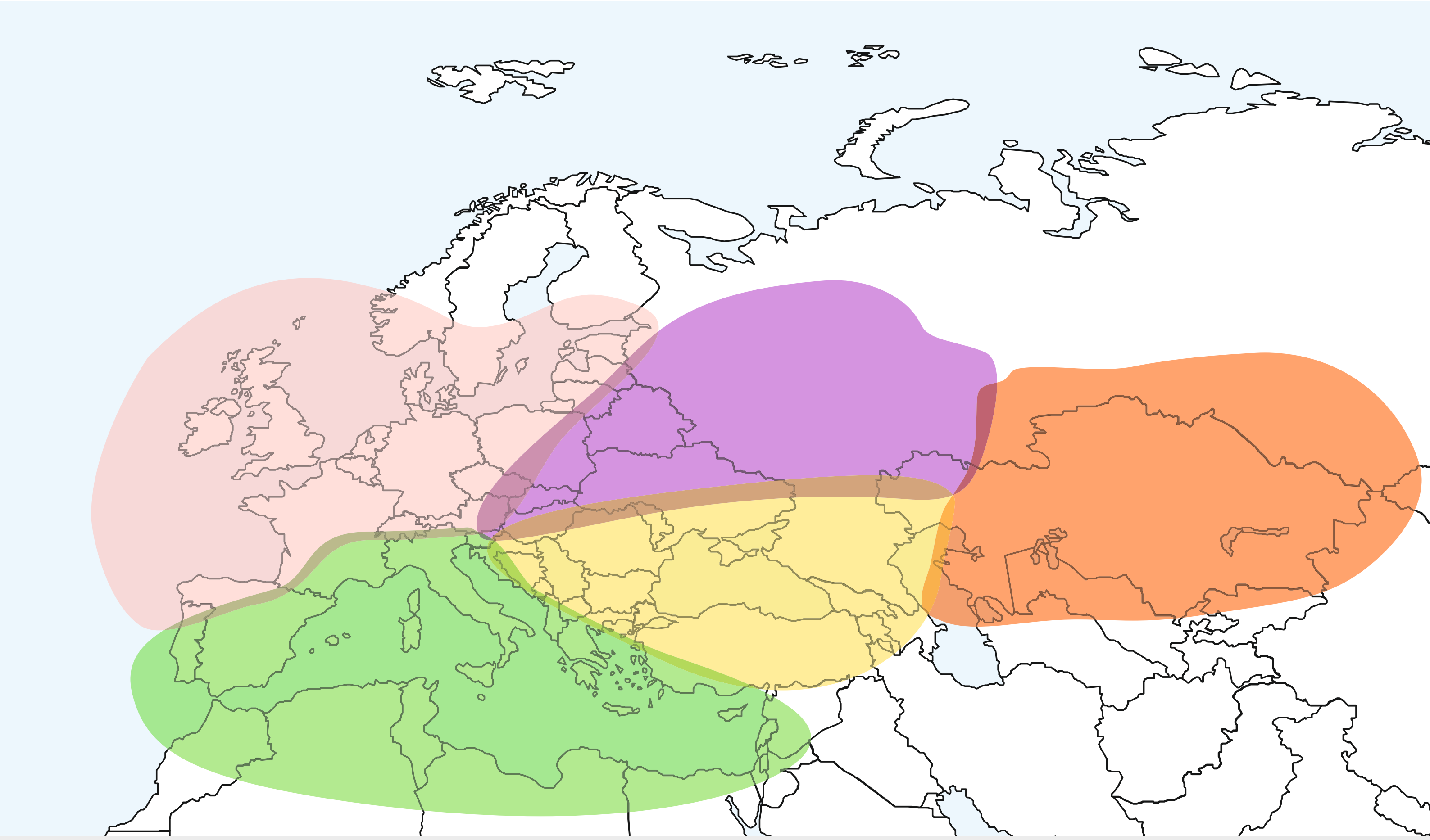
In co-operation with agricultural practitioners and contractors, AMAZONE has developed application-optimised concepts for the various farm structures on the basis of trial results and from a transfer of knowledge with science and consultants. The individual farm manager – with his expert knowledge of his own land – from this derives the individually best system solution for his farm.

Arable farming and crop production systems in the climatic regions of Europe

Looking at arable farming from Western Europe across to Siberia/Kazakhstan along the agriculturally-important 50th northern latitude, five agro-climatic zones can be identified. In each zone, specific cultivation methods are required which again leads to differing systems and levels of mechanisation.

Illustration 15 shows the location of these zones. At the boundary between the individual zones, smooth transition can be seen. In addition, there are regional deviations in any zone which are often based on the topographical location such as rain shadows or conventional rainfall. If, in other parts of the world, similar climatic conditions prevail, often also these system chains are compatible (e.g. New Zealand with its maritime climate, Canada with dry-cold steppe climate).

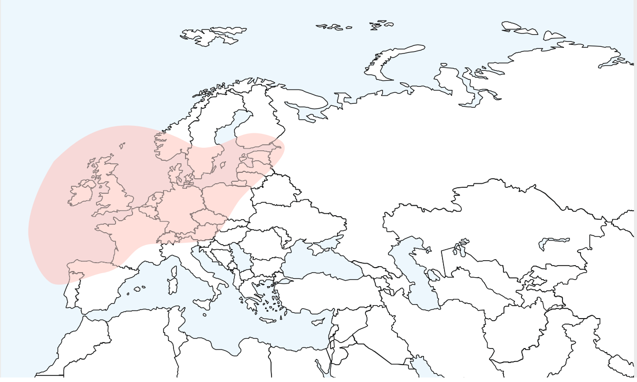
Fig. 15: Agro-climatic zones from Western Europe to Siberia and Kazakhstan



Maritime zone | Mediterranean zone | Moderate continental zone | Warm continental zone | Dry, cold Steppe climate

Map based on the new European regional approval of crop protection agents (Source: EPPO, European and Mediterranean Plant Protection Organisation and Bouma 2009). European zones due to own knowledge of cropping easily changed and expanded to include Siberia/Kazakhstan.

Arable farming and crop production in the maritime zone



The maritime zone extends along the entire North-West European coast line up to South-West France. The zone runs along north of the Alps up to the Hungarian border. To the North it runs further east from the Czech Republic and Poland until the coastal region of the Baltic States. Also Southern Scandinavia can be included in this zone. Characteristics of this zone are (according to Bouma):

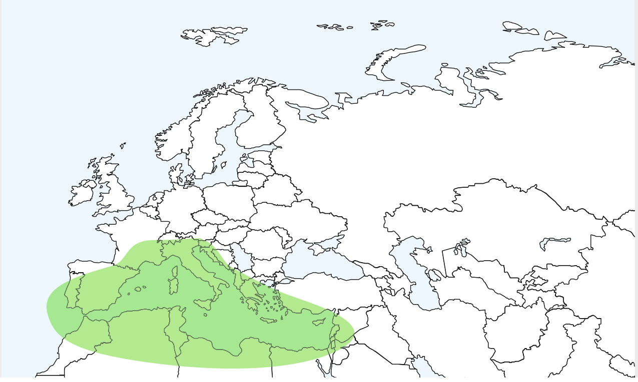
- Cool or cold winters
- Relatively mild summer temperatures
- Relatively moist winters and moist to partly dry summers
- Annual rainfall amounts to between 500 to 1,000 mm

In this maritime zone, apart from cereals, maize and rape, also root crops, such as beet and potatoes, feature high to very high yields (winter wheat 70 to 110 dt/ha). In mild winters, the long growing period for winter wheat especially contributes to the high yields. Due to the very good yield situation and the high population density, family farming plays a large role in this zone. In some places, the high competitive pressure causes a narrow and very market-oriented crop rotation. In order to achieve the highest yields usually a relevant high soil tillage intensity and intensive crop management pays. Therefore, especially on the small to medium farms, the plough is utilised. If rainfall is limited (e.g. Northern Spain, Southern France) or if the cost pressure is very high, however, conservation soil tillage is very common. In many regions, a farm-overlapping machine operation by means of machinery rings, co-operatives or agricultural contractors is established.

In the maritime zone, mainly on small and medium sized farms, the plough is often used.

If rainfall, however, is limited or the cost pressure is high then conservation soil tillage is particularly prevalent.

Arable farming and crop production in the Mediterranean zone



The Mediterranean zone includes the adjacent states of the Mediterranean Sea. In the north it is limited by the French Massif Central and the Alps, in the east by the coastal areas of the Balkan States until the coasts of Turkey and in the south of the North African countries. The characteristics for this Mediterranean zone are:

- Mild winters and warm summers
- Relatively moist winters and dry summers
- Annual rainfall from 300 to 700 mm

In this zone, the degree of yield is mainly limited by the missing rainfall and, due to climatic location; here tropical fruits, olives and wine and fruit growing play a very important role. From an arable farming point of view, the soils of shallow depth with little to medium yield level (winter wheat 30 to 60 dt/ha) are a special challenge. In good topographical locations with relevant high winter rainfall, heat tolerant durum wheat is cultivated. As a tradition the plough and PTO-driven soil tillage technology are very common in the Mediterranean zone. Increasingly, however, also mulch sowing systems utilising tine seeders to establish crops with guaranteed yields at relatively low operational and cost expenditure.

In the Mediterranean zone, mulch sowing systems using tine seeders that ensure reliable yields at comparatively low operational and investment expenditure are becoming established.

Arable farming and crop production in the warmer continental zone

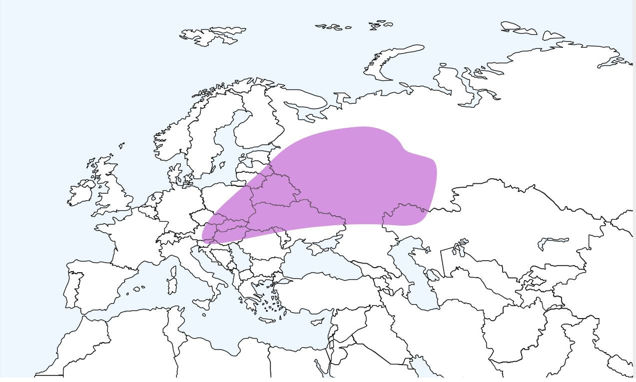
The warm continental zone extends from the arable farming regions of the Balkan States via the large plains of Rumania, Bulgaria and the Ukraine to the South of Russia. It includes, in addition, Northern Turkey around the Mediterranean Sea. This warm continental climate is characterised by:

- Relatively cold and dry winters
- Warm and at times moist summers
- Annual rainfall between 400 and 700 mm

In these regions, ideal conditions for the cultivation of grain maize and sunflowers prevail. However, the climate is also suited for cropping soya beans; however, the scope of cultivation – compared with the world market volume – is still relatively small. In this region it is mostly too hot for sugar beet and, due to the excellent performance of grain maize and sunflowers, cereals mostly play a secondary role. Due to the wide cropping variations, the mechanisation in this zone is highly diversified. The precision sowing technology is of great importance and is utilised after soil tillage with cultivators or disc harrows. Especially in the eastern regions, mulch sowing systems are very common, whereas in the western regions, with their smaller farm sizes, conventional soil tillage with the plough is still of importance.

In the warm continental zone, precision sowing technology is of great importance and is utilised following soil tillage with a cultivator or disc harrow.

Arable farming and crop production in the moderate continental zone



The moderate continental zone includes mainly the central black earth regions of the Ukraine, Russia and Belarus. It extends along the Volga River until the southern edge of the Urals. In the northern regions the winters are especially hard and the growing season is short. This zone is characterised by:

- Relatively cold and wet (lots of snow) winters
- Mild to warm and dry summers
- Annual rainfall amounts to 400 to 600 mm

On the black earth of this region the cultivation of winter cereals and sugar beet is possible. With the high rainfall, the wheat yields up to 70 dt/ha. Rape, however, is often only represented as spring sown. Maize, sunflowers and partly soya only prevail in the southern regions. In the north of this zone, poorer, often lighter soils prevail. Due to the short growing period here, crops are only rotated between an arable and a forage crop.

In these historically established, very large field sizes, extremely high demands on work rates, cost reduction and soil protection result. Even though for decades the plough was mainly used, in the meantime now mulch sowing systems are utilised (split system with solo seed drills). Increasingly important is also direct sowing. When direct sowing, the tine seeders perform best with these machines also often being used for mulch sowing. Many farms are, due to their history, very large and have a large core staff and a multitude of smaller tractors. In this case, several seed drills with a 6 m working width fit into a mulch sowing system for the optimum farm specific utilisation. Newer farms, with fewer employees, implement their efficiency with the aid of fewer but larger tractors. For this, extensive mulch sowing, and increasingly also direct sowing, with seed drills in working widths of 12 to 18 m are best suited.

In the moderate continental zone, different system chains are available to most farms due to their size which they can vary the use of depending on the weather and sowing conditions.

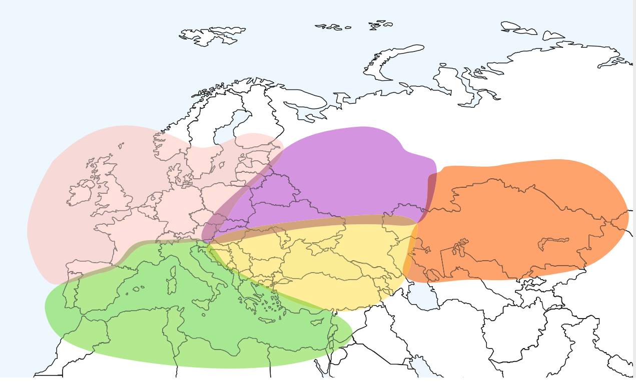
Arable farming and crop production in a dry cold Steppe climate

The dry cold climatic "Steppe" zone extends from the northern Kazakh Steppes to South-West Siberia. This zone is characterised by:

- Very cold and changeable winters with periods of lots of snow or little snowfall
- Short and hot summers
- Annual rainfalls of 500 mm in the north to 220 mm at the southern border of the climatic zone

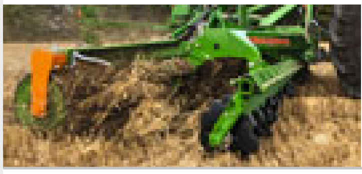
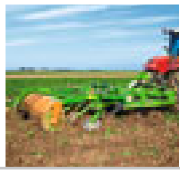
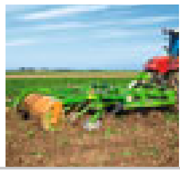
In north Kazakhstan and in the Siberian regions nearly only spring sowing is carried out. Whereas formerly, after two years of cereal cultivation, one bare fallow was usual, today, in addition, spring barley, spring rape, sunflowers and linseed are also sown. In good years, yields of 20 to 30 dt/ha can be achieved with spring wheat, in dry years just 5 to 10 dt/ha. Additionally in the north, sunflowers are an interesting alternative crop due to their heat tolerance. Due to their historical origin (formerly Kolchoses and Sowchoses) farm structures are very big (farm sizes of 20,000 to 100,000 ha). As in these regions the majority of the tractors utilised have an engine capacity of between 220 and 320 HP, direct seeders with working widths of between 12 m and 18 m are currently most represented. With higher rainfalls, these are often operated in combination with a compact disc harrow providing the initial pass. In the southern, central Kazakh regions with a total annual rainfall of less than 220 mm, arable farming is only very limited or not at all possible. Therefore, the area here is mostly used as pasture.

In the dry, cold Steppe climate often direct seed drills are used and mulch and direct sowing-capable precision seeders.



AMAZONE system chains in the climatic regions
As to what kind of system chains are used in the differing climatic regions on the one hand depends on the yield capability of the soils and, on the other hand, on the historical development of the farm structure. Depending on the amount of rainfall, temperature patterns and availability of water, the demands on soil tillage and sowing technology are very different. Here, the AMAZONE product programme offers a suitable solution for all conditions. Table 5 shows you which AMAZONE machines and system chains are utilised in the different climatic regions.

Table 5:
From stubble cultivating to soil tillage: system chains, climatic regions and farm structures in an overview

Stubble cultivating	Soil tillage
	
	 
	 
	 
	
	
	
	 
	

Precision seeders have not been considered in this overview

Sowing	System	Maritime	Mediterranean	Warm continental	Moderate continental	Dry cold Steppe climate
		Climatic zones and farm sizes				
	Plough	Cultivator ▶ Plough ▶ Rotary harrow with seed drill (3 m)				
		10 to 150 ha	10 to 150 ha	10 to 150 ha		
	Plough/ Mulch	Cultivator ▶ Cultivator/Plough ▶ Sowing combination with rotary cultivator (3 to 4 m)				
		50 to 300 ha	50 to 300 ha	50 to 300 ha		
	Plough/ Mulch	Compact disc harrow ▶ Cultivator/Plough ▶ Sowing combination with rotary cultivator (3 to 4 m, also up to 6 m with front tank)				
		100 to 800 ha	100 to 300 ha	100 to 300 ha		
	Plough/ Mulch	Compact disc harrow ▶ Cultivator/Plough ▶ Trailed sowing combination (3 to 6 m)				
		200 to 1,200 ha	100 to 500 ha	100 to 500 ha	200 to 2,000 ha	
	Mulch	Compact disc harrow ▶ Cultivator ▶ Tine seeder (3 to 6 m)				
		200 to 600 ha	100 to 500 ha	100 to 500 ha	200 to 2,000 ha	
	Mulch	Compact disc harrow ▶ Cultivator disc harrow combination ▶ Trailed sowing combination (6 to 9 m)				
		400 to 5,000 ha	100 to 500 ha	400 to 5,000 ha	1,000 to 40,000 ha	
	Mulch	Compact disc harrow ▶ Cultivator disc harrow combination ▶ Solo seed drill (6 to 12 m)				
		400 to 5,000 ha		400 to 5,000 ha	1,000 to 40,000 ha	2,000 to 40,000 ha
	Mulch/ Plough	Compact disc harrow ▶ Plough ▶ Solo seed drill (6 to 12 m)				
				400 to 5,000 ha	1,000 to 40,000 ha	
	Direct seeding	Direct seed drill (up to 12 m)				
		400 to 5,000 ha	100 to 500 ha	400 to 5,000 ha	2,000 to 40,000 ha	2,000 to 40,000 ha

High importance   Low importance   Insignificant

Fertilising and crop protection technology from Western to Eastern Europe

Whereas in the choice of implements for soil tillage and sowing, mainly climatic and arable farming aspects play a role, the answer to which techniques are utilised for fertilisation and crop protection mainly depends on the field size, farm structures and logistics.

Fertilising and crop protection technology in Western Europe

Against the background of a generally high yield level, for crop protection and fertilisation in the maritime and Mediterranean zones, an intensive crop management programme with adequate work rates is of particular importance. The developed farm structures in these regions are mostly characterised by small to medium-sized family-owned farms where the on-farm mechanisation with mounted fertiliser spreaders and sprayers is usual. Also, on these smaller sized fields, the mounted equipment proves to be manoeuvrable, safe on sloping terrain and compact during road transport. This, of course, also applies to the combination of a mounted sprayer and front tank.

However, the tank capacities of mounted sprayers in combination with a front tank are limited to a maximum of 2,800 litres. Therefore, with the increasing size of farms, trailed sprayers with tank capacities of more than 3,000 l are utilised. The storage of the sensitive crop protection agents, and thus the filling of the sprayer, is mostly carried out at the farm yard so that these larger tank capacities reduce the transport and set-up times and thus efficiency is increased. The bigger the farm-field distance is, for example, across widely dispersed rented areas or for farm cooperatives, the more sprayers such as the UX 11200, with tank capacities of more than 11,000 l, are advantageous.

On further increasing farm sizes, the Pantera self-propelled sprayer makes sense as an alternative, provided a high utilisation rate can be ensured. For farms which grow also beet and/or maize in addition to cereals, the high ground clearance and the variably adjustable track width of the self-propelled sprayer are of additional benefit.

These benefits come into effect also in a farm overlapping situation with agricultural contractors and machinery rings so that here also the self-propelled sprayer is gaining more and more importance. So, it is ideally suited to carry out particular applications, such as, for example blossom spraying in rape. The increased flexibility of the self-propelled sprayer is especially demanded in cropping regions where the farmers invest their knowhow and their operational time into livestock farming and pass on arable farming more and more to agricultural contractors.

The application of mineral fertiliser is carried out at several rates and is less time critical than the use of the crop protection sprayer. With a wide range of mounted fertiliser spreaders available in different sizes and technical specification, AMAZONE offers for any farm size the suitable machine. For farm sizes exceeding 1,000 ha, for example, larger mounted fertiliser spreaders with hopper capacities of 3,000 to 4,200 l make economic sense. However, here a well organised field side logistics matters to ensure maximum work rates.

To further increase the efficiency on the larger sized farms, also trailed fertiliser spreaders with hopper capacities of up to 8,000 l are used. Otherwise in Western Europe, trailed fertiliser spreaders are of particular importance for the farm-overlapping application of base fertiliser and lime.

Fertilising and crop protection technology in Middle and Eastern Europe

Also on the larger farm structures which prevail in the continentally-biased regions of Middle and Eastern Europe especially high daily work rates are important. Their mechanisation is initially orientated towards existing tractors which are of a simple design (e.g. Belarus with 80 to 120 HP). A small trailed sprayer (3,000 l) and a simply equipped trailed fertiliser spreader (5,200 l) can achieve high efficiency in a 24 m tramline system. The important pre-condition, however, is also here well organised field side logistics.

If farms do convert to more modern systems they tend to also invest in larger trailed sprayers (5,000 to 6,000 l) and trailed fertiliser spreaders (8,200 l). In the 36 m tramline system these machines – assisted, for example, by automatic boom height guidance on the sprayer – achieve higher forward speeds and thus enormous efficiency increases. They are mostly operated

How many metres of working width are required to cope with all the work on your own farm on time? How many hectares can a machine perform per hour and per day? To this and similar questions the AMAZONE output calculator provides the answers on the internet at www.amazone.de/leistungsrechner

with tractors of 250 – 350 HP engine size which are also used in the course of the year for the light soil tillage (Catros 7.5 m) or for sowing (Citan 12 m).

The cost of field side logistics in crop protection is enormously reduced, if, for example, the UX 11200 with a 12,000 l actual volume is utilised. Even then if operated with low water application rates of 50 to 100 l/ha, it only has to be refilled once within one 12 hour shift and more than 500 ha can be treated.

Here, also the self-propelled sprayer is an alternative, to enable, above all operation with increased forward speeds in difficult terrain. However, tank capacities are limited to 3,000 to 5,000 l and so relevant water logistics are also required. Here, the self-propelled sprayer demonstrates its strengths – like in Western Europe – when better ground clearance is necessary, for example, for application in maize, rape or sunflowers.

For an overview of which fertiliser and crop protection techniques are utilised on the different farm sizes in Western and Eastern Europe, please see Table 6.

Table 6:
Fertilising and crop protection technology from Western to Eastern Europe

Farms in Western Europe					Farms in Middle and Eastern Europe		
Mounted sprayers up to 1,200 l, mounted fertiliser spreaders up to 1,500 l							
20 up to 150 ha	100 up to 400 ha						
Mounted sprayers up to 1,800 l, mounted fertiliser spreaders up to 3,000 l							
20 up to 150 ha	100 up to 400 ha				300 up to 1,500 ha		
Mounted sprayers with front tank up to 2,800 l, mounted fertiliser spreaders up to 3,000 l							
20 up to 150 ha	100 up to 400 ha				300 up to 1,500 ha		
Trailed sprayers up to 3,200 l, mounted fertiliser spreaders up to 3,000 l							
20 up to 150 ha	100 up to 400 ha	300 up to 1,500 ha			300 up to 1,500 ha	1,000 up to 5,000 ha	
Trailed sprayers up to 5,200 l, mounted fertiliser spreaders up to 4,200 l							
20 up to 150 ha	100 up to 400 ha	300 up to 1,500 ha	1,000 up to 5,000 ha			1,000 up to 5,000 ha	3,000 up to 10,000 ha
Trailed sprayers up to 5,200 l, trailed fertiliser spreaders up to 8,200 l							
		300 up to 1,500 ha	1,000 up to 5,000 ha			1,000 up to 5,000 ha	3,000 up to 10,000 ha
Trailed sprayers up to 11,200 l, mounted fertiliser spreaders up to 4,200 l							
	100 up to 400 ha	300 up to 1,500 ha				1,000 up to 5,000 ha	3,000 up to 10,000 ha
Trailed sprayers up 11,200 l, trailed fertiliser spreaders up to 8,200 l							
		300 up to 1,500 ha	1,000 up to 5,000 ha			1,000 up to 5,000 ha	3,000 up to 10,000 ha
Self-propelled sprayer, mounted fertiliser spreader up to 4,200 l							
	100 up to 400 ha	300 up to 1,500 ha	1,000 up to 5,000 ha	Agricultural contractor		1,000 up to 5,000 ha	3,000 up to 10,000 ha
Self-propelled sprayer, trailed fertiliser spreaders up to 8,200 l							
	100 up to 400 ha	300 up to 1,500 ha	1,000 up to 5,000 ha	Agricultural contractor		1,000 up to 5,000 ha	3,000 up to 10,000 ha

High importance   Low importance   Insignificant

6.
Trials results regarding tillage and sowing

For optimum success in crop production AMAZONE offers comprehensive advice concerning the use of the different systems based on many years of trials with tillage and sowing which AMAZONE has carried out on different sites in co-operation with scientific establishments.

The choice of the trials site represents the different farming possibilities and structures, considering at the same time the different climatic conditions and crop rotations and on the following pages we hope to inform you of the most important results.

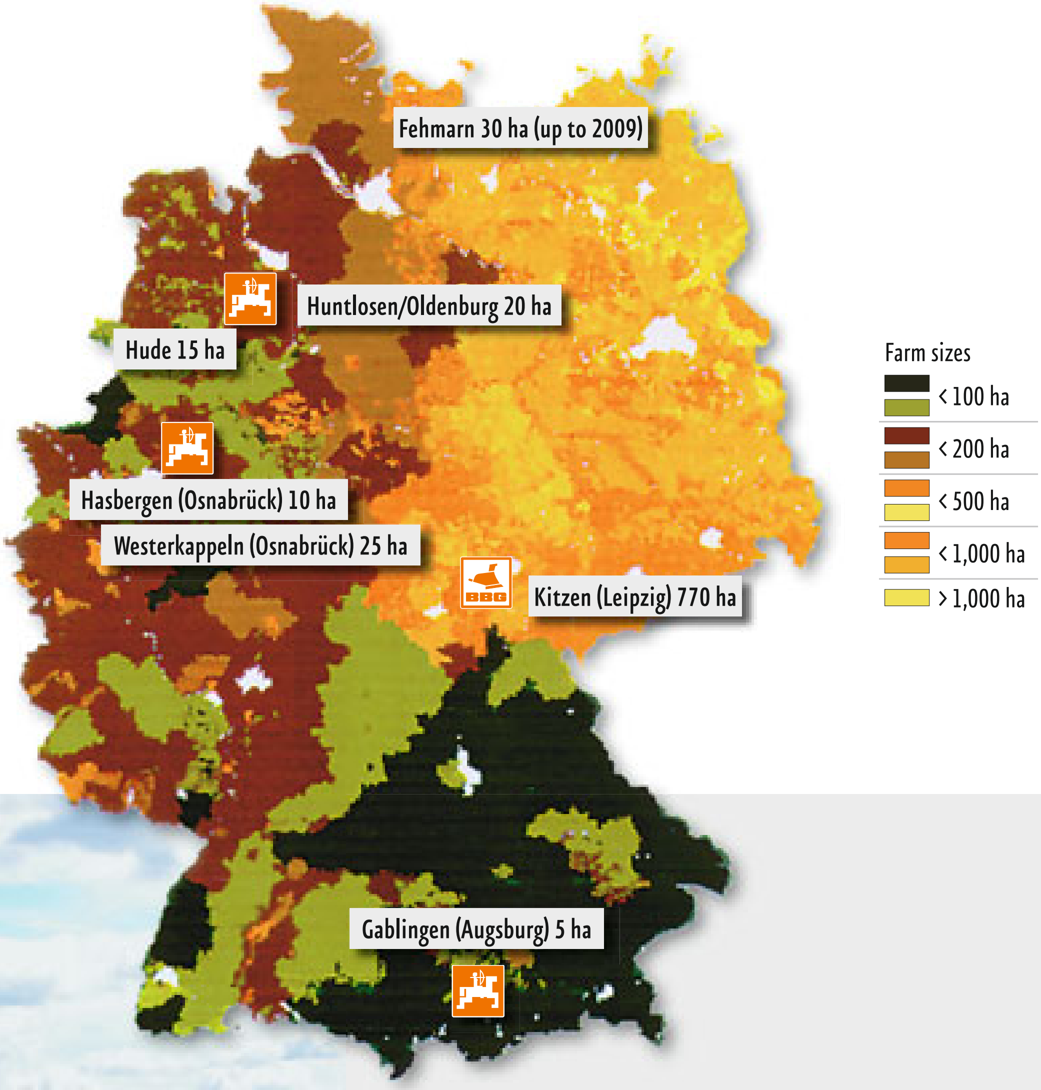
In co-operation with the German Agricultural Society (DLG) AMAZONE has also investigated the different tillage and sowing operational chains for the first time in respect of fuel consumption and working time requirement. These results clearly show that the use of AMAZONE machinery for conservation tillage systems combines, not only the same yields, but also clear cost advantages.

AMAZONE, acting as an international supplier of agricultural technology, continuously looks to establish new trial sites in all important export countries. There are already trial sites in Great Britain, France, Russia, the Netherlands and Denmark.

Fig. 16:
AMAZONE trials sites in Germany

AMAZONE co-operates with numerous farms not only in Germany but also all over Europe.

Additional sites are located, for example, in France, Great Britain, Russia and Denmark.



Trials sites and projects in an overview

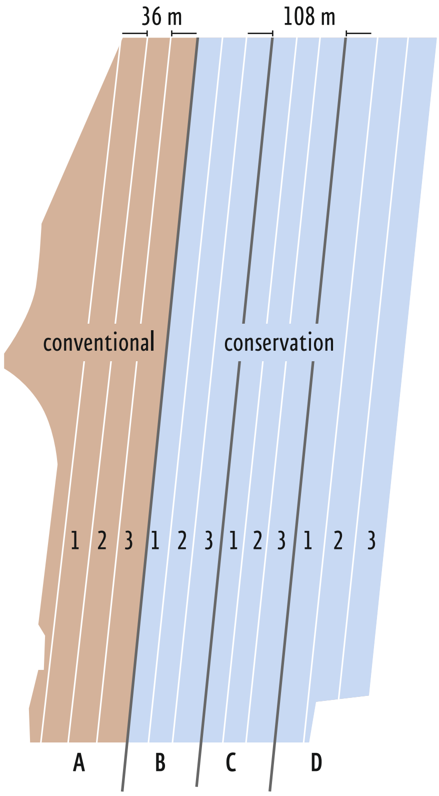
AMAZONE trials at Leipzig, Saxony (yield results)

The Leipzig site, in Saxony, is representative of arable farming on large acreages. A continental climate prevails – little rainfall and early summer drought are representative and here, water and climate are the yield limiting factors.

The trials site is situated on the farm of Agrarprodukte Kitzen e.G. near Leipzig. Out of a farm size of just over 3,000 hectares approximately 770 ha of trials are cultivated in co-operation with AMAZONE. On a total of 75 ha (fields Molkerei and Hager) exact trials have been carried out now over the last 12 seasons since 2000 and evaluated by the Johann Heinrich von Thünen-Institut (vTI) Braunschweig (under Dr. Voßhenrich). With regard to crop protection and fertilisation all the plots are treated identically.

Site data: fields Molkerei and Hager	
Soil type	Clay sand, part-brown soils, humus share 3.1 %
Climate	Annual rainfall: 530 mm, average temperature: 8.6° C
Crop rotation	Winter wheat, winter barley, maize, winter wheat, winter barley, winter rape
Tramline width	36 m

Fig. 17: Layout of 40 ha trial field (Molkerei) on the farm Agrarprodukte Kitzen e.G. near Leipzig



Plot A is cultivated conventionally with the plough, plots B, C and D are cultivated with conservation mulch sowing; each with 3 different sowing systems (see Table 7).

Trials results in an overview:

On the site characterised by a continental climate equal yields are achieved on the mulch sowing plots and on the conventional plots.

Working depth is round about 15 cm, which has been matched to the soil conditions and preserves the ground water supply in the crumb and results in the highest yields.

At the same time, the reduction in the working intensity results in a clear reduction in the operational costs.

Comment to the trials results in Leipzig (field Molkerei)

by Michael Mersmann, M. Sc., AMAZONEN-WERKE

The crop rotation related long-term trial at the site in Leipzig with the field Molkerei (40 ha) is in its 12th year in 2013. So the farm's normal crop rotation has been now trialled almost twice in that time.

The comparison between conventional and conservation tillage shows that at comparable tillage depths (plot A and B) plough tillage seemingly produces higher yields. But leaving the peculiarities of the extreme year 2003 on plot B1 (22 cm mulch sowing) out of the equation the yields are at a comparable level (see Table 8).

Table 7: **Trials plots on soil tillage, seedbed preparation, Leipzig site (Molkerei and Hager)**

	Plot A Plough 25 cm			Plot B Mulch sowing 22 cm			Plot C Mulch sowing 15 cm			Plot D Mulch sowing 8 cm		
	Plot A1	Plot A2	Plot A3	Plot B1	Plot B2	Plot B3	Plot C1	Plot C2	Plot C3	Plot D1	Plot D2	Plot D3
Mulching after maize	Flail mulching machine											
Stubble working	Catros, working depth 6 cm											
Tillage	Plough 25 cm – Catros			Centaur 22 cm			Centaur 15 cm			Catros 8 cm		
Seedbed and seeding: cereals, rape	KG – AD-P Super	Cirrus	Citan	KG – AD-P Super	Cirrus	Citan	KG – AD-P Super	Cirrus	Citan	KG – AD-P Super	Cirrus	Citan
Seeding: maize	EDX precision air seeder											

decreasing tillage intensity

Table 8: **Yield results (dt/ha) in comparison, Leipzig site (Molkerei)**

	Plot A Plough 25 cm			Plot B Mulch sowing 22 cm			Plot C Mulch sowing 15 cm			Plot D Mulch sowing 8 cm		
	Plot A1	Plot A2	Plot A3	Plot B1	Plot B2	Plot B3	Plot C1	Plot C2	Plot C3	Plot D1	Plot D2	Plot D3
Winter barley 2002	79	77	82	84	85	82	86	89	86	81	87	–
Grain maize 2003	66	62	37	33	64	56	60	67	56	52	60	42
Winter wheat 2004	105	104	99	98	103	104	101	95	97	100	99	92
Winter barley 2005	95	94	98	90	97	96	91	97	93	97	95	84
Biofuel rape 2006	53	49	52	52	53	57	59	58	59	57	59	55
Winter wheat 2007	86	91	93	91	98	96	93	98	96	91	95	86
Winter barley 2008	88	87	85	78	79	84	79	87	90	85	89	81
Silage maize 2009 (DM)	175	165	155	156	153	180	167	177	177	182	181	179
Winter wheat 2010	85	85	82	81	84	85	86	90	88	86	85	73
Winter barley 2011	57	57	60	55	56	60	59	60	60	61	57	49
Winter rape 2012	43	41	37	41	37	34	37	39	39	39	39	37

The yield results were authenticated in co-operation with PD Dr. Voßhenrich from the vTI Braunschweig

Table 9: **Yield results (dt/ha) in comparison, Leipzig site (Hager)**

	Plot A Plough 25 cm			Plot B Mulch sowing 22 cm			Plot C Mulch sowing 15 cm			Plot D Mulch sowing 8 cm		
	Plot A1	Plot A2	Plot A3	Plot B1	Plot B2	Plot B3	Plot C1	Plot C2	Plot C3	Plot D1	Plot D2	Plot D3
Silage maize 2008 (DM)	167			180			172			164		
Winter wheat 2009	97	98	97	101	99	101	99	99	97	99	99	99
Winter rape 2010	53	54	54	51	54	50	54	51	52	50	53	51
Winter wheat 2011	87	86	81	86	82	83	90	94	92	89	91	90
Winter barley 2012	107	115	112	107	101	108	93	99	100	96	99	103

Reduction of the tillage depth in Plot C (15 cm working depth) results in an increase of the annual average yield. Depending on the crop rotation element additional yields of up to 10 % are achieved. This is due to the increased water availability which influences growth mainly in years with severe pre-summer droughts.

Reduction of the tillage depth to 8 cm (Plot D) produces yields at the level of conventional tillage. Despite tillage depth being reduced by 60 % the yield level can keep up with that of plough tillage at significantly reduced labour costs. Compared with Plot C, however, the yield level is slightly lower because the water availability is impaired by the negative effect of an increased straw concentration in the surface layer.

The second trial site in field Hager (35 ha) is located directly in the vicinity of Molkerei. Site data and trial establishment are the same on both sites. The Hager field was established in 2007 as additional trial field because the Molkerei will no longer be available in the medium term. Thus, by the smooth transition, a large data pool with significant results regarding severel crops and years can be established.

In summary: the yields are influenced mainly by the primary tillage system used, not by the sowing technology. Hence tillage method and depth are the decisive factors.

In addition conservation tillage results in large saving potentials which are the result of targeted measurements concerning labour requirements and fuel consumption, the results of which are presented on the following pages.

Results regarding fuel consumption and working time (Leipzig/Saxony)

In view of continuously increasing fuel prices, the potential savings offered by crop establishment systems are of particular interest. Therefore, in co-operation with the German Agricultural Association (DLG) comprehensive measurements have been carried out on the trial sites at BBG Leipzig in the years 2005 and 2006. The trials and the layout of the plots have already been described in connection with the yield results.

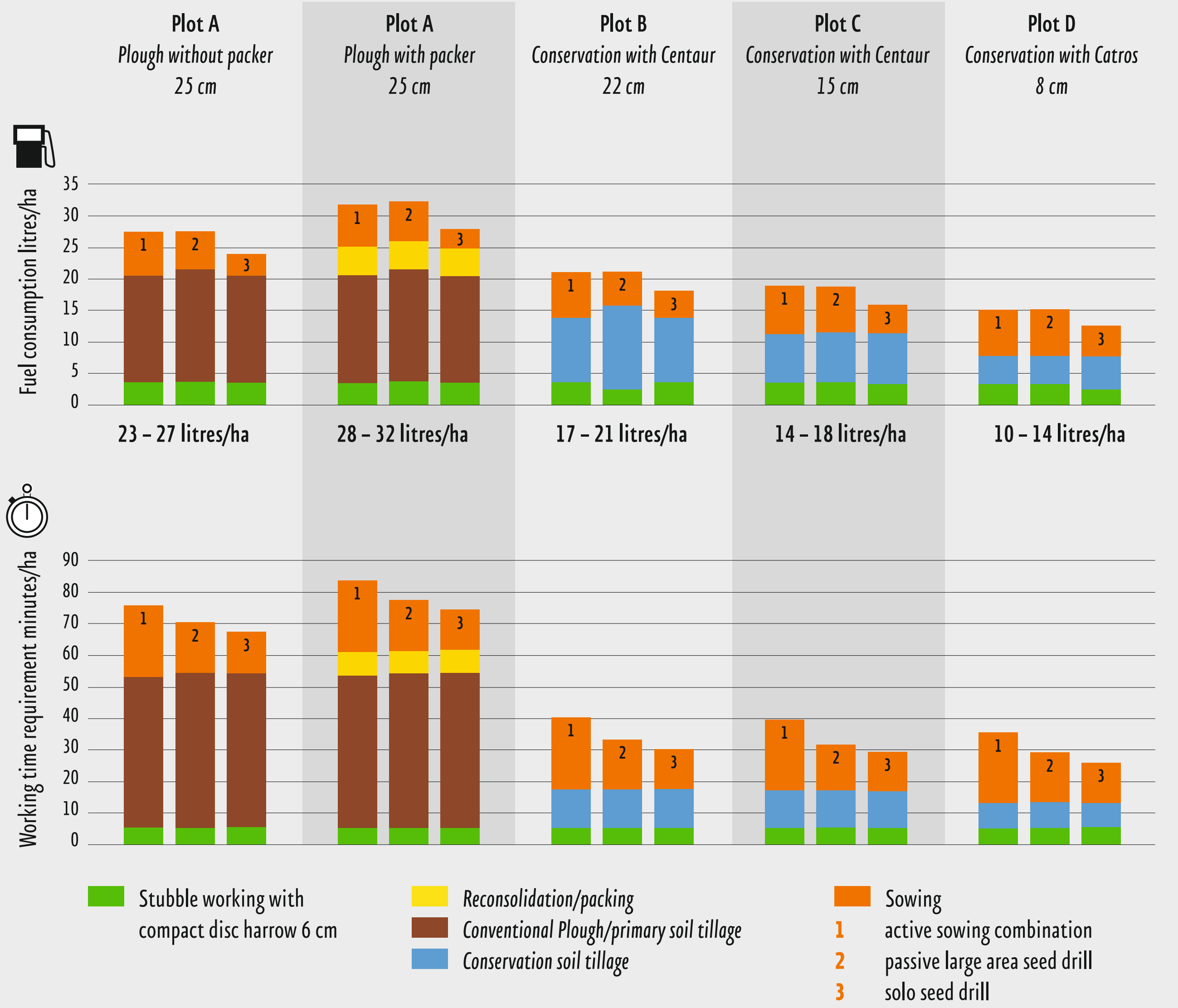
The investigations show that the different systems offer considerable fuel saving potentials (see Fig. 18). In instances of initial stubble cultivation no significant differences are shown regarding fuel consumption. The consumption data varies only slightly in the range from 3.6 to 3.9 l/ha. The values show, however, that the use of the Catros compact disc harrow, compared with the use of a standard cultivator, can result in saving potentials of 4 to 5 l of diesel/ha.

Clear differences in fuel consumption, however, show up in primary soil tillage. So, with conventional cultivation using the plough, consumption values of 17 to 17.7 l/ha and 21.5 to 22.2 l/ha (with an additional packer on the plough) were registered.

In conservation systems, on the other hand, the measurements result in significantly lower consumption figures which are between 10.2 l/ha and 4.3 l/ha (depending on implement type and intensity). This results in differences of up to 17 l/ha compared to working with the plough. Realistic and in practical operation the saving potential amounts to approx. 7 l/ha. This is shown in the direct comparison between plot A (with plough) and B (without plough), because on these plots the operational intensities were about the same. If one adds the packer operation on the plough one even gets figures of approx. 11 l/ha.

In general the fuel consumption figures of the trailed Cirrus sowing combination with its integrated compact disc harrow are low. The differences between these two systems are only 0.5 to 1 l/ha in favour of the PacTeC seed drill. Extremely low consumption values result from the use of the solo seed drill because here no seedbed preparation takes place. In general, there is only little scope by the selection of sowing technology, regarding the reduction in fuel consumption. The question for the correct mechanisation of the sowing operation is rather more determined by local site factors.

Fig. 18: **Fuel consumption and working time requirements of the systems** (results of the DLG test institute [Groß-Umstadt] and vTI [Braunschweig])



Summarising the total fuel consumption of the systems shows that operation with the plough requires approx. 7 l diesel/ha more than operation without the plough. The fuel consumption of the individual total systems is decisively influenced by the kind of primary soil tillage. So, the key for success is the choice and intensity of the primary soil tillage.

Apart from a more favourable fuel consumption then also the working times for the total systems are reduced in favour of cultivation without the plough. For a mulch sowing system it is halved, with even savings of up to 60 % being realistic.

Trials results in an overview:

Different methods and intensities in primary soil tillage result in clear differences in fuel consumption.

Depending on the method, saving potentials of 35 % down to 20 % can be achieved. For the working time required, savings of up to 60 % can be realised. The differences in the use of the different seed drills are negligible.

Statistical calculation and profitability analysis (Leipzig/Saxony)

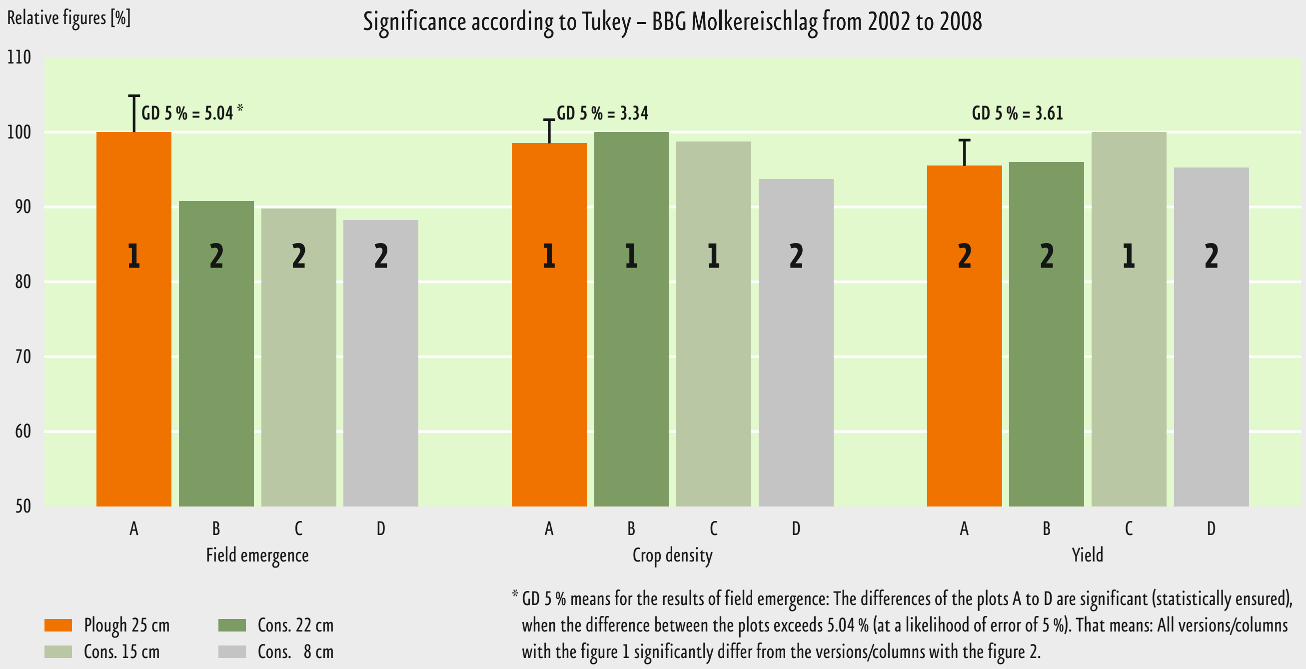
The results of a analysis that includes the most important parameters of the relevant trial years are shown in Ill. 19 for the reporting period 2002 to 2008. The statistical approach 'Tukey' was utilised. The calculations have also been carried out by vTI Braunschweig.

When considering the field emergence, a clear significance in favour of plot A is noticed. That means, over the reporting period, the plough plot proves to have the highest field emergence.

In the results of the crop density, the situation is reversed (the compensation ability of the crop has to be considered). Here the plots A – C significantly differ from D (lowest crop density). So, over the years, plot D has the lowest ear, pods and cobs figures.

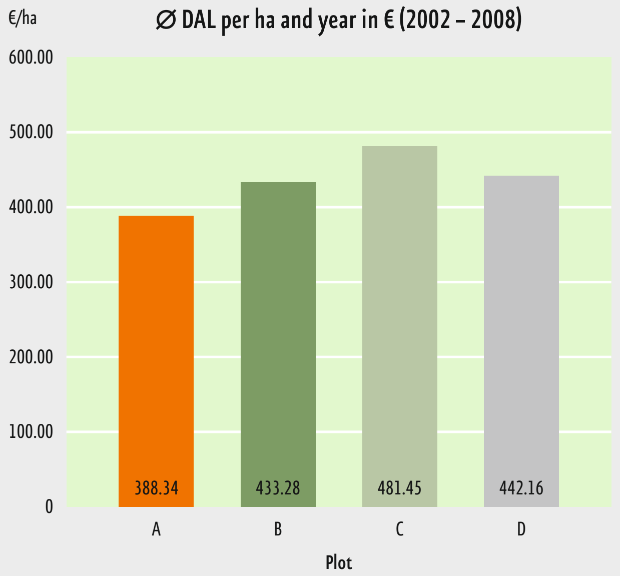
At the relative yield investigation, Plot C significantly differs from all the others. So one can concur that there is a statistically ensured yield increase by using a conservation tillage method at a 15 cm working depth.

Fig. 19: **Statistical analysis, trial site Leipzig (field Molkerei) – assessment of the entire crop rotation (2002 – 2008):**



* GD 5 % means for the results of field emergence: The differences of the plots A to D are significant (statistically ensured), when the difference between the plots exceeds 5.04 % (at a likelihood of error of 5 %). That means: All versions/columns with the figure 1 significantly differ from the versions/columns with the figure 2.

Fig. 20: Average direct and operational cost free capacity (DAL) per hectare and year – € (2001 – 2008):



Analysis of profitability

Within the framework of a master's thesis at the University of Applied Sciences, Southern Westfalia, the profitability of the methods used in Leipzig was investigated.

The calculation for the different trial years was carried out with the valid figures for the relevant actual year. The reporting period also includes the years 2002 to 2008.

The results clearly show that the revenue level is obviously higher for all conservation systems than for conventional systems.

Depending on the system, up to 100 €/ha more per year can be generated. Even the most extensive plot without the plough (Plot D), which is relatively even in terms of yield, results in, due to clearly reduced operational costs, a surplus of approximately 55 €/ha and year.

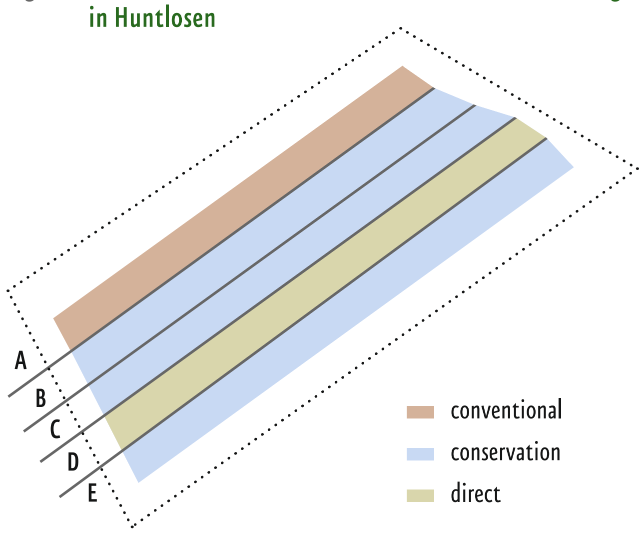
For the calculations, payments of premiums and rents have not been considered, due to big regional differences.

AMAZONE trials at Huntlosen, Lower Saxony

The Huntlosen site in Lower Saxony is representative of arable farming in mixed regions on light soils with small fields. The trials site is situated on the farm of Heiko Boning/Huntlosen. The approx. 100 ha size farm runs both an arable sector and pig fattening. Liquid manure is applied to the fields and the straw is completely removed. Besides the plough and conservation tillage plots also a direct sown plot has been investigated in Huntlosen (see Table 10).

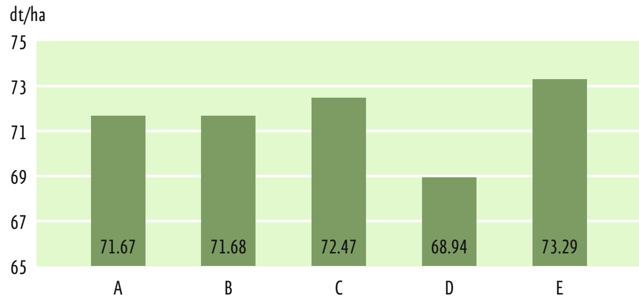
Site data	
Soil	Humus sand, 24 soil points
Climate	Annual rainfall: 750 mm
Crop rotation	Changing crop rotation with: barley, rye, triticale, rape, turnips and maize
Tramline width	12 m

Fig. 21: Division of the trial sites on the farm of Heiko Boning in Huntlosen



Plot A is conventionally cultivated with the plough, the plots B, C and E conservation tillage by mulch sowing and for plot D direct sowing.

Fig. 22: Site at Huntlosen: Average cereal yields 1995 – 2012



Trials results in an overview:

Conservation soil tillage is possible as the long term successful practice on light soils.

Mulch sowing exceeds the yield level of the plough plots.

Cereal mulch sowing resulted in the highest yields.

A broad crop rotation contributes decisively to the success of conservation systems.

Deep loosening during spring cultivations is an advantage.

Time saved by renouncing the plough (smoothing out the work peaks) is important for higher outputs in intensive farming regions.

Comment to the trials results in Huntlosen

by Dipl.-Ing. Jan Juister

Plough-less tillage is possible also on light, sandy soils. In the average of the years no decisive yield differences could be noted between mulch sowing and sowing following the plough (see Fig. 22 and Fig. 11). With mulch sowing, however, the highest gross margin was achieved. On the annual average over several years it was about 60 Euro higher than on the ploughed plot. Due to crop rotation, disease problems did not occur in the conservation tillage plots nor were any extreme changes in weed proliferation noted.

Saving working time plays an important role especially on intensively worked farms and also the reduced fuel consumption in case of conservation tillage is of great importance. The further advantages of mulch sowing, such as better traffic carrying ability of the soils, lower

Table 10: Trials variations in soil tillage, seedbed preparation and sowing, Huntlosen site

	Plot A Plough 5 cm	Plot B Mulch sowing 15 cm	Plot C Mulch sowing 22 cm	Plot D Direct sowing	Plot E Minimal mulch sowing
Mulching after maize	Flail mulcher				
Stubble working	Catros 6 cm	Catros 6 cm	Catros 6 cm	–	Catros 6 cm
Tillage	Plough 25 cm Catros	KG – AD-P Super 15 cm	KG – AD-P Super with deep loosener 22 cm	–	–
Seedbed and seeding: cereals	KG – AD-P Super			Primera DMC	Primera DMC
Seeding: maize	EDX				

Table 11: Yield results in comparison (dt/ha)

	Plot A Plough 25 cm	Plot B Mulch sowing 15 cm	Plot C Mulch sowing 22 cm	Plot D Direct sowing	Plot E Minimal mulch sowing
Winter rape 1994	24	20	21	20	–
Winter barley 1995	72	77	75	69	72
Potatoes 1996	485	479	478	467	471
Winter triticale 1997	81	72	79	70	67
Winter rye 1998	62	68	69	47	68
Winter barley 2000	75	75	75	71	73
Winter rye 2001	93	103	83	99	100
Silage maize 2002	522	466	461	444	450
Winter barley 2003	77	75	79	68	74
Stubble turnips 2004	23	25	25	21	24
Winter barley 2005	81	79	79	75	78
Winter barley 2006	71	71	76	74	74
Silage maize 2007	525	515	535	535	540
Winter barley 2008	48	46	49	49	50
Winter rape 2009	52	49	51	50	47
Winter triticale 2010	58	52	54	52	54
*Silage maize (DM) 2011**	133	144	133	128	133
*Sorghum (DM) 2011**	118	88	104	92	82
Winter barley 2012	72	70	79	85	97

*after forage rye – plot division in 2011: 50 % silage maize, 50 % sorghum

erosion and higher efficiency also had an effect in Huntlosen. It turned out that it is easier to do without deep loosening on good soils with adequate clay and humus content than on sandy soils with a low humus content or water logging.

Because of the sandy soil, Huntlosen site is rich in humus it is possible to manage without deep loosening here. Nevertheless even this soil should be annually loosened at varying depths to avoid compaction and stratification. For growing maize, quick soil warming in spring is important, so that deep loosening in spring makes sense.

A peculiarity is the year 2011. In 2011, initially as a pre-crop to maize and sorghum, forage rye was sown and harvested by mid May. In order to find out how the later sowing dates effect the yields of maize compared with sorghum, the plots were divided and were sown half with silage maize and half with sorghum.

That a deep loosening can be renounced for cereals at the Huntlosen site is also confirmed by the winter barley yields for 2012. In 2012, the very extensively worked plots of D and E achieved the highest yields.

AMAZONE trials at Petersdorf (Fehmarn), Schleswig-Holstein

The Fehmarn site in Schleswig-Holstein is representative of intensive arable farming in high yielding regions and in medium sized fields. In the years from 2000 to 2008 different mulch sowing variants (non-plough variants) with different intensities and working depths were investigated (see Table 12) and evaluated by the Johann Heinrich von Thünen-Institute (vTI) Braunschweig. The trials question was: is mulch sowing possibly sustainable even where large amounts of straw prevail?

Fehmarn is one of the most productive arable farming regions in Germany. Good soils, maritime climate without extreme variations in temperature, sufficient moisture supply and long summer days result in often extraordinarily high yields which are accompanied by very large amounts of straw. Usually the straw remains in the field, so that straw problems can be well investigated here. On the trials farm, Klaus Olderog in Petersdorf has carried out plough-less cultivation since 1990.

Site data	
Soil	Sandy clay 2.1 % humus ratio
Climate	Annual rainfall: 540 mm, average temperature: 8.3° C
Crop rotation	Winter wheat, winter wheat, winter rape

Trials results in an overview:

With wheat following wheat the yield increased with a more intensive cultivation and the deeper the soil is worked. Large amounts of straw, which could be more than 10 t/ha, remaining in the field, required good incorporation.

Rape does not require so deep a soil tillage. The yield can decrease with increasing soil tillage intensity. The precondition however, is that the soil does not have any soil compaction or patches of poor soil cultivation. This is the case on Fehmarn due to soil structure protecting cultivations and a good lime supply.

The success of mulch sowing depends decisively on the straw management. During harvest it has to be ensured that the straw is chopped into short pieces and that it is evenly distributed. Chop lengths down to about 10 cm proved to be the optimum.

Comment on the trials results in Petersdorf

by Independent lecturer Dr. Hans-Heinrich Voßhenrich, Johann Heinrich von Thünen-Institut (vTI)

The trials results from Petersdorf show that a high yield level can be maintained with mulch sowing in the long run (see Table 13 and 14). The experiences from the trials show, among other things, that it is possible to sow after cultivating to about 10 cm deep in an intensively mixed seedbed if the soil quality permits doing so without any deeper loosening. The following procedure has proved to be a success:

1. After shallow stubble cultivation with high re-consolidation optimises the volunteer grain germination.
2. Mixing and loosening, depth set accordingly, depending on site and straw incorporation.
3. Chemical weed control directly prior to sowing.
4. Sowing either active or passive, depending on farm size and site conditions.

In addition various other influencing factors must be taken into account. For instance, the crop rotation "rape after wheat" allows scope for the intensity of tillage (see Table 14). It should be ensured that the quality of seed placement is not limited by the influence of straw. Though rape, due to its strong compensation behaviour, will survive, intensive straw incorporation with sufficiently deep loosening is advisable for reasons of safety.

The rotation "wheat after wheat" presents itself similar to "rape after wheat", since also here straw in the seedbed may act as a limiting factor. For guaranteed emergence and yield the plots with a tillage depth of about 10 cm have proven reliable (see Table 13). Deeper tillage did not result in any yield increase on this high-yielding site.

Usually passive mulch sowing (Cirrus) requires one or two intensively mixing soil tillage operational passes beforehand. An active mulch sowing (rotary cultivator-combination) on the other hand, is better able to compensate for the adverse effect of the straw by a more intensive soil tillage.

Table 12: **Trial plots on soil tillage, seedbed preparation and sowing, Petersdorf site**

	Plots 1a, 1b Mulch sowing shallow	Plots 2a, 2b Mulch sowing medium deep	Plots 3a, 3b Mulch sowing with top soil deep loosening
Stubble working	Catros 5 cm deep	Catros 5 cm deep	Catros 5 cm deep
Primary soil tillage	–	Centaur 10 – 12 cm deep	Centaur 10 – 12 cm deep 20 – 22 cm deep
Seedbed preparation and sowing			
Plots a	Active sowing combination: Rotary cultivator combination (KG-combi) with RoTeC coulters, 5 – 7 cm deep		
Plots b	Passive sowing combination: Cirrus, Cirrus discs 5 – 7 cm deep		

Table 13: **Wheat yields (dt/ha) in comparison:
active (KG-combi with RoTeC coulters) and passive till and drill combination (Cirrus), Petersdorf site**

	Plots 1a, 1b Mulch sowing shallow		Plots 2a, 2b Mulch sowing medium deep		Plots 3a, 3b Mulch sowing with top soil deep loosening	
Year	Plot 1a KG-combi with RoTeC	Plot 1b Cirrus	Plot 2a KG-combi with RoTeC	Plot 2b Cirrus	Plot 3a KG-combi with RoTeC	Plot 3b Cirrus
2000	132	128	141	132	156	143
2001	97	92	93	106	98	93
2002	103	100	106	106	108	106
2003	84	95	92	92	95	92
2004	121	120	128	134	133	130
2005	107	109	113	113	115	112
2006	83	78	99	97	107	101
2007	85	87	90	92	100	88
2008	103	107	113	113	119	109
Average	**102**	**101**	**108**	**109**	**115**	**108**

Table 14: **Rape yields (dt/ha) in comparison:
active (KG-combi with RoTeC coulters) and passive till and drill combination (Cirrus), Petersdorf site**

	Plots 1a, 1b Mulch sowing shallow		Plots 2a, 2b Mulch sowing medium deep		Plots 3a, 3b Mulch sowing with top soil deep loosening	
Year	Plot 1a KG-combi with RoTeC	Plot 1b Cirrus	Plot 2a KG-combi with RoTeC	Plot 2b Cirrus	Plot 3a KG-combi with RoTeC	Plot 3b Cirrus
2000	51	47	50	49	43	43
2001	52	52	52	52	52	52
2002	42	46	46	48	41	41
2003	43	45	44	47	47	47
2004	51	56	50	56	50	50
2005	48	50	48	50	49	49
2006	49	48	50	49	50	50
2007	43	43	45	45	50	45
2008	65	46	61	47	52	48
Average	**49**	**48**	**50**	**49**	**48**	**47**

AMAZONE trials at Hasbergen-Gaste, Lower Saxony

The trial site Hasbergen-Gaste is situated at the Southern foothills of the Weser-Ems region and is climatically influenced by the mountain range of the Teutoburger Forest situated further in the South and running from West to East. The average annual rainfall is about 800 mm, whereby the rainfall distribution is normally well balanced. In the last three years, however, drought prevailed during the months of April and May.

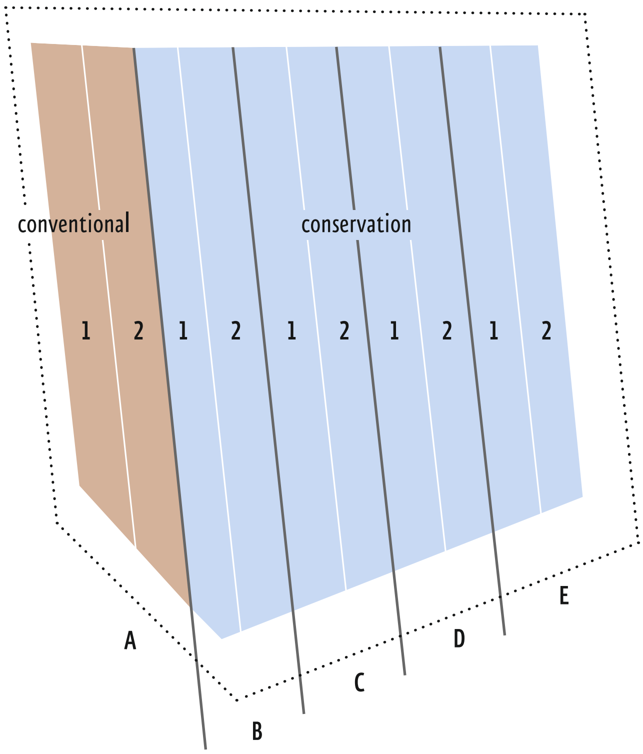
The region with predominantly sandy sites is characterised by mixed farming with animal husbandry which is reflected in the field sizes and the crop rotation. The soil conditions on the trials plot are heterogeneous. Sandy loam prevails, but there are also pure sand and pure loam areas which can clearly be recognised after drought.

Table 15 shows the layout of the trial plots which follows the classic structure of the AMAZONE trials. Primary tillage is carried out in five different intensity stages – from the conventional plots A, via conservation plots with loosening (B, C and D) to the conservation plots E without loosening, which, in respect of the level of soil tillage intensity, corresponds to direct sowing.

At first a stubble cultivation to a maximum depth of 6 cm is performed on the entire area to control weeds and volunteer grain. Sowing is carried out by means of active and passive sowing equipment adjusted to meet the site requirements. A solo seed drill is not used at this site on purpose.

Site data	
Soil	Loam, agricultural land, 60 soil points
Climate	Annual rainfall 800 mm, average temperature: 9.0° C
Crop rotation	Winter wheat, winter barley, silage maize, winter wheat, winter barley, winter rape
Tramline width	15 m

Fig. 23: Layout of the trials site on the farm of Norbert Pott in Hasbergen-Gaste



Stubble cultivation across all plots with a Catros compact disc harrow (6 cm depth)

Differentiated primary tillage to different depths with plough, mulch cultivator and compact disc harrow

Sowing with rotary cultivator/seed drill combination (KG-AD-P Super, active sowing equipment) and trailed Cirrus Special seed drill (passive sowing equipment)

Trials results in an overview:

Like on many other trials sites, the yield level in Hasbergen-Gaste is primarily influenced by the type and intensity of the primary tillage.

On this site, apart from the conventional tillage, the conservation tillage at a working depth of around 15 cm seems to be the right choice across the average of the years to suit the peculiar heterogeneity of the soil.

When the soils are ready for sowing after tillage (fine soil particles) the intensity of further cultivation during sowing is completely irrelevant.

Table 15: **Trial plots for tillage, seedbed preparation and sowing, Hasbergen-Gaste site**

	Plot A Plough 25 cm		Plot B Mulch sowing 22 cm		Plot C Mulch sowing 15 cm		Plot D Mulch sowing 8 cm		Plot E Minimal mulch sowing	
	Plot A1	Plot A2	Plot B1	Plot B2	Plot C1	Plot C2	Plot D1	Plot D2	Plot E1	Plot E2
Mulching after maize	Flail mulching machine									
Stubble working	Catros, working depth 6 cm									
Tillage	Plough 25 cm		Cenius 22 cm		Cenius 15 cm		Catros 8 cm		–	
Seedbed preparation	Catros									
Sowing	KG – AD-P Super	Cirrus Special	KG – AD-P Super	Cirrus Special	KG – AD-P Super	Cirrus Special	KG – AD-P Super	Cirrus Special	KG – AD-P Super	Cirrus Special
Sowing maize	EDX precision air seeder									

decreasing tillage intensity

Table 16: **Yield results in comparison (dt/ha), Hasbergen-Gaste site**

	Plot A Plough 25 cm		Plot B Mulch sowing 22 cm		Plot C Mulch sowing 15 cm		Plot D Mulch sowing 8 cm		Plot E Minimal mulch sowing	
	Plot A1	Plot A2	Plot B1	Plot B2	Plot C1	Plot C2	Plot D1	Plot D2	Plot E1	Plot E2
Winter wheat 2008	90	83	83	87	90	87	81	85	81	69
Winter barley 2009	84	83	80	78	84	83	81	84	76	73
Grain maize 2010	102	102	98	98	100	100	96	96	86	86
Winter wheat 2011	67	69	67	62	63	59	62	59	57	59
Winter barley 2012	89	89	81	74	77	79	77	78	87	79

The yield results were authenticated in co-operation with PD Dr. Voßhenrich from the vTI Braunschweig

Comment on trials results in Hasbergen-Gaste

by Michael Mersmann, M. Sc., AMAZONEN-WERKE

The results show that the site can provide stable, high yields both in conventional and conservation tillage (Table 16). The working intensity, however, plays a major role. So, in almost all years the plots with the least intensity of cultivation without loosening (plot E) results in significantly inferior yields. Besides the plough with a working depth of 25 cm (plots A), conservation tillage with a working depth of 15 cm (plots C) proves suitable to tap the full yield potential of the site. In 2012, also the plot E achieved high yields. Here, the reduced soil tillage intensity kept the water loss at a minimum in the very dry months of April and May with a positive result on the yields.

If one compares the results from the different sowing techniques, tendencies become also obvious, however with narrower variability. The relevant differences of yield between active and passive sowing technology are clearly smaller than the differences between the variants with differing intensities in primary soil tillage. In the years 2008, 2009 and 2012, however, the plots that received a reduced intensity of soil tillage, but a more intensive seedbed preparation, had a positive effect on the yield.

Autumn 2010 followed the crop rotation of winter wheat after maize, the critical link. The actual yields, however, show that even this crop rotation step was still successful with conservation tillage. Surely, after a pass first with the mulcher (for field hygiene) and a choice of a less susceptible variety, the first important steps had already been made beforehand. Due to the prolonged period of drought during the months March to May, the yields in 2011, across the board, were at a lower level. On all the plots the investigation by the LUFA Nord-West for mycotoxin contamination (DON and ZEA values) showed that the results were significantly below the limit values in an unverifiable range.

AMAZONE trials at Gablingen, Bavaria

In the direct vicinity of our branch in Gablingen near Augsburg, AMAZONE included in autumn 2009 an additional site in its trials. The trials are created on a 5.6 ha sized field of the farmer Georg Reinsch and follow the scheme of the trials so far. Stubble work is carried out across all plots with the Catros compact disc harrow. For primary soil tillage, the conventional method with the plough is compared with conservation methods at different working depths. Sowing is carried out with an active till and drill combination.

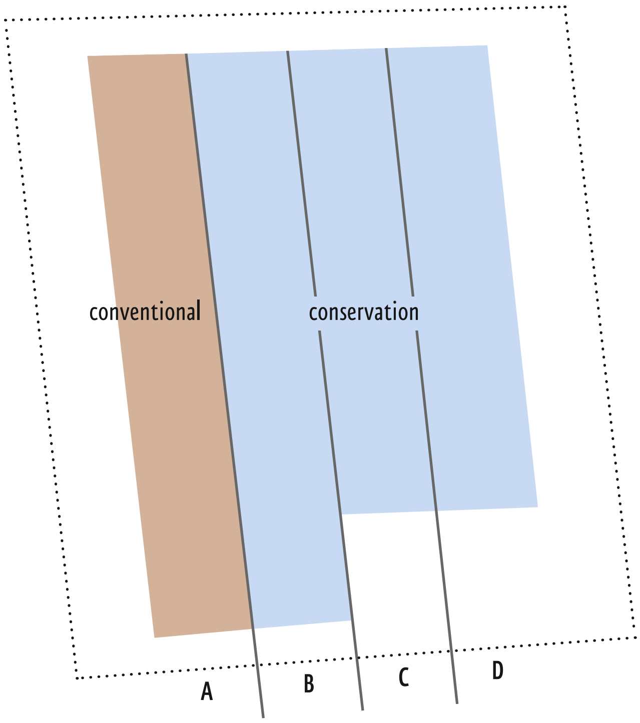
The soil conditions of the site are characterised by a shallow sandy loam of medium soil quality above gravel. The soil has a good draining effect and therefore is appropriate for conservation soil tillage. Also the rainfall level of approx. 780 mm and the high evaporation rates suggest the need for conservation soil tillage. Therefore, the aim is, above all, to answer the question as to the optimum working depth.

The four links of the crop rotation includes, among others, potatoes (grown in 2010). The rest of the crop rotation consists of winter cereals.

Also at this site, there might be a big interest from farmers in the trial results. On the one hand the ratio of conventional soil tillage in this region is still at a high level. On the other hand, crop rotations with root crops are of special interest when using a conservation system.

Site data	
Soil	Sandy loam, average soil quality
Climate	Annual rainfall 780 mm, average temperature: 8.4° C
Crop rotation	Potatoes, winter wheat, winter barley, winter wheat
Tramline width	15 m

Fig. 24: Division of the trial sites on the farm Georg Reinsch in Gablingen



Stubble work on all plots with Catros compact disc harrow at 6 cm working depth

Differentiated primary soil tillage at different working depths with the plough (25 cm), mulch cultivator (22 cm, 15 cm) and compact disc harrow (8 cm)

Sowing with a rotary cultivator-sowing combination (KG – AD-P Super, PTO-driven sowing technology)

First trial results:

The yields of the potato harvest in 2010 did not show any significant differences between the systems. Regarding the quality of product (infestation) no anomalies were noticed.

In 2011 the wheat yields are, with exception of plot C, at a uniformly high level.

The site can be cultivated with both, a conventional and also, a conservation system.

Table 17: **Trial variants in soil tillage, seedbed preparation and sowing, Gablingen site**

	Plot A Plough 25 cm	Plot B Mulch sowing 22 cm	Plot C Mulch sowing 15 cm	Plot D Minimal mulch sowing 8 cm
Stubble working	Catros 6 cm			
Tillage	Plough 25 cm Catros	Cenius 22 cm	Cenius 15 cm	Catros 8 cm
Seedbed and seeding cereals	KG – AD-P Super			

decreasing tillage intensity

Table 18: **Yield results in comparison (dt/ha), Gablingen site**

	Plot A Plough 25 cm	Plot B Mulch sowing 22 cm	Plot C Mulch sowing 15 cm	Plot D Minimal mulch sowing 8 cm
Winter wheat 2011	87	88	82	88
Winter barley 2012	93	82	76	78

The yield results were authenticated in co-operation with PD Dr. Voßhenrich from the vTI Braunschweig

At the Gablingen site an area of in total 5.6 ha is available for trials.

Comment on trials results in Gablingen

by Michael Mersmann, M. Sc., AMAZONEN-WERKE

The creation of the trials field started with sowing a catch crop in August 2009. In spring 2010 potatoes followed as a first main crop. The yield results did not show any significant differences between the variants of the differing soil tillage. Also regarding quality (infestation) no differences were noticed between variants of conventional and conservation soil tillage. For the yield of winter wheat in the trials year of 2010/2011 it was similar.

The winter barley sown in 2011/2012 showed that the crop densities in the two intensively worked plots, A and B, also resulted in the highest yields. The absolutely clean seedbed in plot A, free from any harvest residues, additionally was helpful to the development of the winter barley in the autumn and spring.

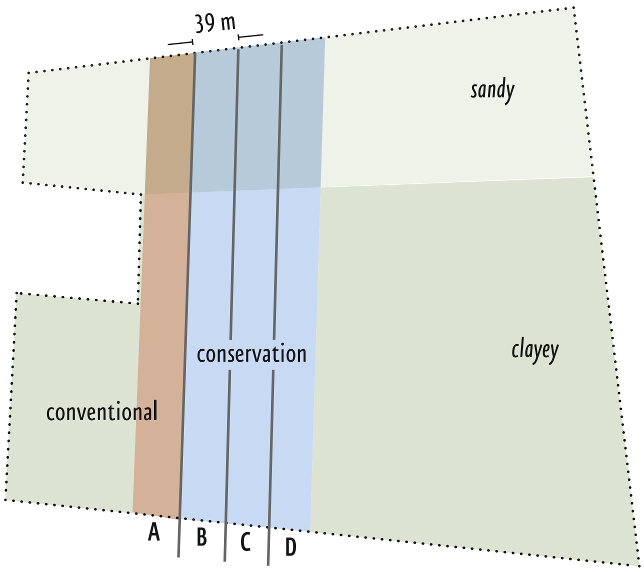
AMAZONE trials at Hellvoetsluis (Netherlands)

The Hellvoetsluis trial site (30 km to the southwest of Rotterdam) is characterised by extreme soil and climatic conditions. The clay content of the soil, a young, heavy lime marsh, varies between 30 and 60 %; the pH value is above "7" and the humus content about 5 %. These are ideal conditions for field trials for the sustainable establishment of soil saving, cost saving and conservation arable farming methods.

Due to its composition and properties, the soil can bear mechanical loads and tends hardly to suffer any structural damage, such as soil compaction damage. Its distinctive swelling and shrinking behaviour ensures a good oxygen supply in arid conditions in the summer half-year is, however, at the same time the cause of an oxygen deficiency in moist conditions in the winter half-year.

The latter defines the required tillage intensity. The high rainfall level of about 900 mm/year is finally decisive for the necessity of intensive soil loosening. According to the first estimations, working depths must be between 15 and 30 cm. It is rather unlikely that successful tillage is possible at working depth of 10 cm and less.

Fig. 25: Layout of the trials site on the farm of Hans van Strien in Hellvoetsluis



Stubble working with Catros compact disc harrow

Differentiated primary tillage to differing depths with plough, cultivator and deep loosener

Sowing with rotary cultivator and pack top seed drill (KG/AD-P Super)

Site data	
Soil	Lime marsh
Climate	Annual rainfall 900 mm, average temperature: 9.4° C
Crop rotation	Winter wheat, winter barley, winter rape
Tramline width	39 m

Trials results in an overview:

The difficult trial site in Hellevoetsluis requires increased intensity, both in soil tillage and when sowing. In most years, the soil must have the possibility to aerate and dry.

After the run-through of a complete crop rotation, the yield results show that this site can also support conservation systems. However, there is no distinct preference in the favour of a specific version.

Even though the crop rotation for the Hellevoetsluis site is rather untypical, the results are very interesting. They can also be transferred to German marsh sites.

Table 19: Trial plots for tillage, Hellvoetsluis, Netherlands site

	Plot A Plough 25 cm	Plot B Mulch sowing 22 cm	Plot C Mulch sowing 15 cm	Plot D Minimal mulch sowing 22 cm*
Stubble working	Catros, working depth 6 cm			
Tillage	Plough 25 cm Catros	Cenius 22 cm	Cenius 15 cm	Deep loosener 22 cm
Seedbed preparation and sowing in one operational pass	KG – AD-P Super			

* farm's usual cultivation with a deep loosener

decreasing tillage intensity

Table 20: Yield results (dt/ha) in comparison, Hellvoetsluis, Netherlands site

	Plot A Plough 25 cm	Plot B Mulch sowing 22 cm	Plot C Mulch sowing 15 cm	Plot D Minimal mulch sowing 22 cm*
Tillage	Plough 25 cm	Cenius 22 cm, Narrow shares	Cenius 15 cm, Inversion shares	Deep loosener 22 cm
Winter wheat 2009	105	112	110	110
Winter barley 2010	91	85	88	87
Winter rape 2011	45	48	49	50
Winter wheat 2012	89	94	91	90

The yield results were authenticated in co-operation with PD Dr. Voßhenrich from the vTI Braunschweig

The trials setup

Matched to the general trials set-up, AMAZONE has investigated in Hellevoetsluis since autumn 2008, the different soil tillage methods with the plough and the use of a cultivator at decreasing working intensity (Plots A – D).

Due to the heavy soil conditions, the otherwise usual plot with an 8 cm working depth is not considered. For this purpose, and as found on the trial farm, usual variant of working with a deep loosener was integrated into the trials.

Similar applies to sowing technology. Due to mostly moist conditions during sowing and the related, rather coarser seedbed structures, the use of passive sowing technology has been abandoned. The sowing operation is carried out in a classic way and site specific with an active PTO-driven sowing combination.

Comment on trials results in Hellevoetsluis

by Michael Mersmann, M. Sc., AMAZONEN-WERKE

After the winter wheat harvest in 2012, the four-year trials results are now available. With an untypical crop rotation for this region, winter wheat – winter barley – winter rape, the yield results do not illustrate a definite advantage for a specific method of establishment. However, it has become obvious that the yields for the conservation tillage methods have exceeded the yields of the conventionally worked areas in 3 out of the 4 years.

Here again, it is obvious, that even heavy, moist and heterogeneous sites (sandy and clay soils) can be worked with conservation tillage systems. Over the entire assessment period, the yields were stable at a high level. So the choice of working depth and sowing technology requires the highest intensity right from the beginning with minimal mulch sowing and the use of passive sowing technology on these sites already being excluded.

Besides the yield, the costs of soil tillage and cultivation play a major role. Here the systems of reduced soil tillage clearly perform more favourably. This applies especially with regard to fuel consumption and operational time.

AMAZONE trials at Auneau (France)

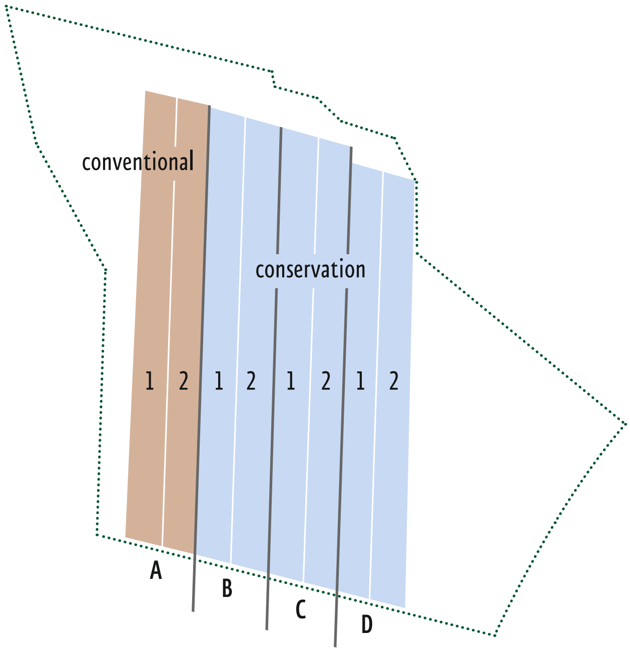
Since 2008 there has been another AMAZONE trials site in the immediately vicinity of AMAZONE Auneau. Auneau is situated near Chartres, the capital of the Département Eure-et-Loire, on the south-western edge of the Paris basin, one of the most important arable farming regions in France.

With a clay content of more than 10 %, the Auneau trials site is perfectly suited for conservation tillage. An annual rainfall of about 850 mm, however, limits the scope for reduced tillage, because excessive water contents can become a limiting factor for the oxygen supply in the soil. Hence the plough is the preference for tillage on this and other sites, since oxygen supply in the soil can temporarily be secured by topsoil-deep working. On the other hand there are several farms in the Departements around Auneau which cultivate their fields without the plough in a specific crop rotation.

Therefore the main question in the case of the trials in Auneau is whether, and how in the long term, a change to plough-less tillage would influence this site conditions. At which working depth must mulch sowing be carried out to achieve a sufficient oxygen supply and a yield level which is at least as high as a plough tillage system?

Site data	
Soil	Clay loam (24 % clay, 46 % loam, 30 % sand)
Climate	Annual rainfall: approx. 850 mm, average temperature: 10.2° C
Crop rotation	Winter wheat, winter barley, winter rape

Fig. 26: Layout of the trial areas in Auneau



Stubble incorporation across all plots with the Catros compact disc harrow (at 6 cm depth)

Soil tillage with a decreasing level of intensity from plots A to D

Sowing with a KG/AD-P Super combi and Cirrus

The trials setup

A plough plot with 25 cm working depth (plot A) is compared with various conservation plots with 22 cm, 15 cm and 8 cm working depth during the trials in Auneau (Fig. 26 and Table 21). For the sowing pass, the passive seed drill Cirrus Special is compared with active sowing combinations on the basis of a rotary harrow or rotary cultivator.

Table 21: **Trial plots for tillage, seedbed preparation and sowing, Auneau site**

	Plot A Plough 25 cm		Plot B Mulch sowing 22 cm		Plot C Mulch sowing 15 cm		Plot D Minimal mulch sowing 8 cm	
	Plot A1	Plot A2	Plot B1	Plot B2	Plot C1	Plot C2	Plot D1	Plot D2
Stubble working	Catros, working depth 6 cm							
Tillage	Plough 25 cm		Cenius 22 cm		Cenius 15 cm		Catros 8 cm	
Seedbed preparation	Catros		–					
Sowing	KG – AD-P Super	Cirrus (EDX)	KG – AD-P Super	Cirrus (EDX)	KG – AD-P Super	Cirrus (EDX)	KG – AD-P Super	Cirrus (EDX)

decreasing tillage intensity

Table 22: **Yield results (dt/ha) in comparison, Auneau site**

	Plot A Plough 25 cm		Plot B Mulch sowing 22 cm		Plot C Mulch sowing 15 cm		Plot D Minimal mulch sowing 8 cm	
	Plot A1	Plot A2	Plot B1	Plot B2	Plot C1	Plot C2	Plot D1	Plot D2
Winter rape 2009	49	49	49	49	45	45	43	43
Winter wheat 2010	75	68	75	68	65	75	57	65
Winter barley 2011	72	74	73	74	69	70	72	75
Winter rape 2012	45	50	43	35	42	55	48	30

The yield results were authenticated in co-operation with PD Dr. Voßhenrich from the vTI Braunschweig

Comment on trials results in Auneau

by Michael Mersmann, M. Sc., AMAZONEN-WERKE

With an average of 46.5 dt/ha, the rape yields in 2009 were, in total, at a high level, the wheat yields in 2010 on a rather average level. Here, the first two plots for soil tillage (A and B) achieved identical yields. Therefore, also on this site stable yields can be achieved with an intensive, conservation soil tillage. With a continuing decrease in the working depth, the yield level drops. So, the plot with the least working depth over the majority of years provides the lowest yield. This suggests that a working depth above a certain minimum is indispensible on this site.

Effects on the yield level due to the use of the different sowing systems could not be noticed in 2009. So, in 2009, both seed drills were still at the same level. In 2010, however, the active and passive sowing technology registered different yields, depending on the working depth. In 2011, the passive technology gave the highest yields. However, a clear tendency could not be derived.

In 2012, instead of the Cirrus sowing combination, the EDX precision seeder with a 45 cm row spacing without seedbed preparation was utilised. Sowing with the EDX was carried out 10 days after operation with the rotary-seed drill combination. So, the results of the sowing methods could not be directly compared with each other in 2012. In spite of the later sowing date, the highest yields were achieved with the EDX in plots A2 and C2. However, due to a wide range of variation in the yield results of the EDX, it became apparent that the preconditions have to be correct. Renouncing the seedbed preparation in conjunction with the later sowing date has, in spite of the precise EDX seed placement, a negative effect on yield in the plots B and D.

AMAZONE trials at Tickhill (South Yorkshire), Great Britain

Tickhill is located in the middle of the Great Britain near the city of Doncaster – south from Sheffield and east from Manchester. In this agricultural region medium to large field sizes prevail. The average annual rainfall at around 750 mm is clearly higher than in the South of the country, where already for many years conservation soil tillage has been practised on a broad scale.

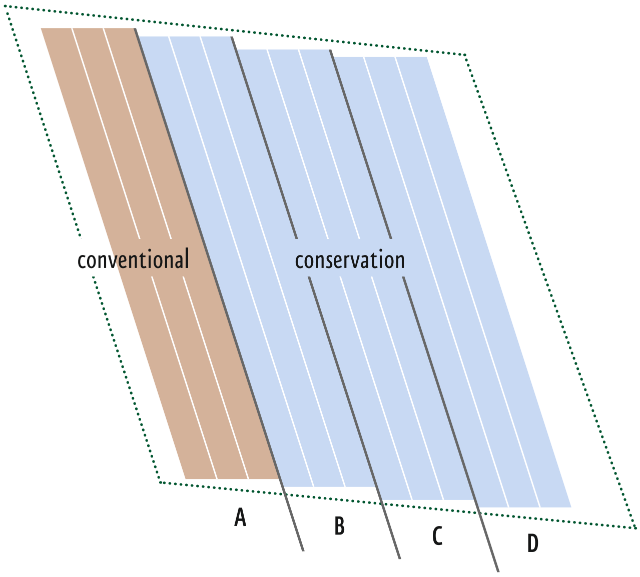
The trial site is located on a limestone formation north of the village Tickhill. The medium, clayey soils have a soil layer of up to 50 cm and rest on limestone as parent rock. Rainfall is fairly balanced throughout the year.

The trial question for the site Tickhill is whether mulch sowing is possible to sustain under the more moist conditions of this site in a close cereal-rape crop rotation. Over the longer term, it has also to be clarified as to what effects may arise regarding weeds and which hygiene management is required.

The establishment of the trial plots corresponds to the classic structure of the AMAZONE experimental methods. After harvest stubble working is initially carried out at a maximum depth of 8 cm to combat weeds and to promote the emergence of volunteer grain. Soil tillage is carried out in four different levels of intensity. It includes the conventional soil tillage with the plough (plot A) and the conservation tilling versions with deep loosening at 22 cm or 15 cm (plot B and C). In plot D soil tillage is carried out at a depth of only 8 cm. Sowing is carried out via actively and passively assisted sowing technology which is matched to the demands on this site.

Site data	
Soil	Deep limestone, grade 1 arable farm land – 60 points
Climate	Annual rainfall: 750 mm, average temperature: 9.0° C
Crop rotation	Winter wheat, winter barley, winter wheat, winter beans, winter wheat, winter oil seed rape
Tramline width	28 m

Fig. 27: Layout of the trials site in the Woolthwaite Farm in Tickhill



Stubble working across all plots with a Catros compact disc harrow (8 cm depth)

Differentiated primary soil tillage at different depths with the plough, the Cenius mulch cultivator and the compact disc harrow

Sowing with a rotary cultivator sowing combination (KG/AD-P Super), trailed Cirrus seed drill and Cayena tine seeder

Trials results in an overview:

As at many other sites, the yield levels at the trials in Tickhill depend mainly on the degree of intensity of the soil tillage.

It seems that the conservation method of soil tillage at a depth of approximately 15 cm is the right choice.

If, prior to sowing, the relevant seedbed is available then the different intensities of the following soil tillage hardly have any effect whilst sowing.

Table 23: **Trial plots for tillage, seedbed preparation and sowing, Tickhill site**

	Plot A Plough 25 cm			Plot B Mulch sowing 22 cm			Plot C Mulch sowing 15 cm			Plot D Minimal mulch sowing 8 cm		
	Plot A3	Plot A2	Plot A1	Plot B3	Plot B2	Plot B1	Plot C3	Plot C2	Plot C1	Plot D3	Plot D2	Plot D1
Stubble working	Catros, working depth 8 cm											
Tillage	Plough 25 cm – Catros			Cenius 22 cm			Cenius 15 cm			Catros 8 cm		
Seedbed preparation and sowing	KG – AD-P Super	Cirrus	Cayena	KG – AD-P Super	Cirrus	Cayena	KG – AD-P Super	Cirrus	Cayena	KG – AD-P Super	Cirrus	Cayena

decreasing tillage intensity

Table 24: **Yield results (dt/ha) in comparison, Tickhill site**

	Plot A Plough 25 cm			Plot B Mulch sowing 22 cm			Plot C Mulch sowing 15 cm			Plot D Minimal mulch sowing 8 cm		
	Plot A3	Plot A2	Plot A1	Plot B3	Plot B2	Plot B1	Plot C3	Plot C2	Plot C1	Plot D3	Plot D2	Plot D1
Winter wheat 09/10												
Seed rate	320 seed seeds/m² (Cordiale)											
Emergence plant/m²	264	260	219	456	248	275	280	308	225	336	212	384
Yield dt/ha	***127***	***136***	***133***	***138***	***142***	***124***	***135***	***134***	***136***	***123***	***119***	***98***
Winter wheat 11/12												
Seed rate	294 seed seeds/m² (Oakley)											
Emergence plant/m²	184	274	184	192	196	173	174	216	147	170	204	160
Yield dt/ha	***99***	***99***	***103***	***103***	***107***	***98***	***98***	***101***	***99***	***104***	***105***	***105***
Winter barley 12/13												
Seed rate	333 seed seeds/m² (Cassia)											
Emergence plant/m²	306	278	261	258	294	271	279	250	252	218	300	257
Yield dt/ha	***101***	***106***	***103***	***113***	***107***	***99***	***103***	***105***	***99***	***102***	***94***	***85***

All the listed results have been determined in co-operation with NIAB TAG.
In the year 2010/11 (winter beans) due to the extreme frost damage no results could be determined.

Comment on trials results in Tickhill

by Dr. Sven Dutzi, AMAZONEN-WERKE

The crop rotation, typical for this region, at the site of Tickhill consists mainly of winter cereals. The results from the first years of trial show that the yields with conservation soil tillage can compete with those from the classic plough-based system. However, also at this site, a minimum of soil tillage intensity is required.

So, the working depth of approximately 15 cm seems to be a good choice across the average of the years as well here in Tickhill, where the influence of the different sowing systems on the yield is low. It is of importance, however, that at the time of sowing the seedbed is in a good condition ready for sowing.

The first results are encouraging that the conservation soil tillage systems can be established successfully for a long term at this site. For a statistically safe investigation, the entire crop rotation has to be taken into account. Therefore additional years of trials will have to be considered initially. Also the question as regard to field hygeine (fusarium, take-all disease, blackgrass) can only then be safely answered.

AMAZONE XTill: practice-orientated trial approaches for new Strip Till methods

A system for sowing maize and soya which has already been used in America for quite some time gets more into the limelight in Europe: Strip Till. In this system, the soil is only loosened in strips with the area between the strips remaining untilled. The seed is then placed into the pre-loosened strips.

The most important advantages are a further increase of the availability of water, an increase of rain seeping away and the reduction in the danger of erosion. Also the stability of the soils is improved because, within the area between the loosened strips, a stable soil structure remains. In addition, strip-wise tillage offers the chance to reduce crop rotation-related undesirable phenomena such as volunteer rape or black grass. However, Strip Till is not equally suited for all field conditions. Heavy soils or soils which are often too wet for cultivation and poor porous soils present another special challenge.

With the XTill strip loosener, AMAZONE offers a professional machine for the strip-wise soil tillage. The XTill operational pass, as part of a split system, replaces the deep primary soil tillage – and all this at reduced costs.

The cultivation element of the XTill corresponds to the classic sequence of front cutting disc, clearing stars, loosening tine, covering discs and a press roller. Operated on the AMAZONE Vario Trail 3000 tool carrier, the XTill provides the possibility to simultaneously carry out, in conjunction with the deep loosening, an under-root fertilisation with immobile nutrients – a new option for arable farms to optimise mulch sowing methods.

Initially XTill is offered for operation at 75 cm row spacing. In future, additional solutions for row spacings from 45 cm will be available. Then AMAZONE will offer a Strip Till implement for all row crops, started with maize and rape via beets to sunflowers and soya.

Initially, AMAZONE trials will see how the operation of XTill deals with the different tractive power requirement which arises during strip-wise loosening with the XTill in comparison to a full area loosening with a conventional system. In other arable farming trials AMAZONE investigates the XTill operation in maize and rape. Additional practise tests with other row crops will follow within a short timescale.

Strip Till tests in maize

In the mixed farming regions of Western Europe the fertilisation of maize mainly is carried out via liquid

Strip Till with XTill.

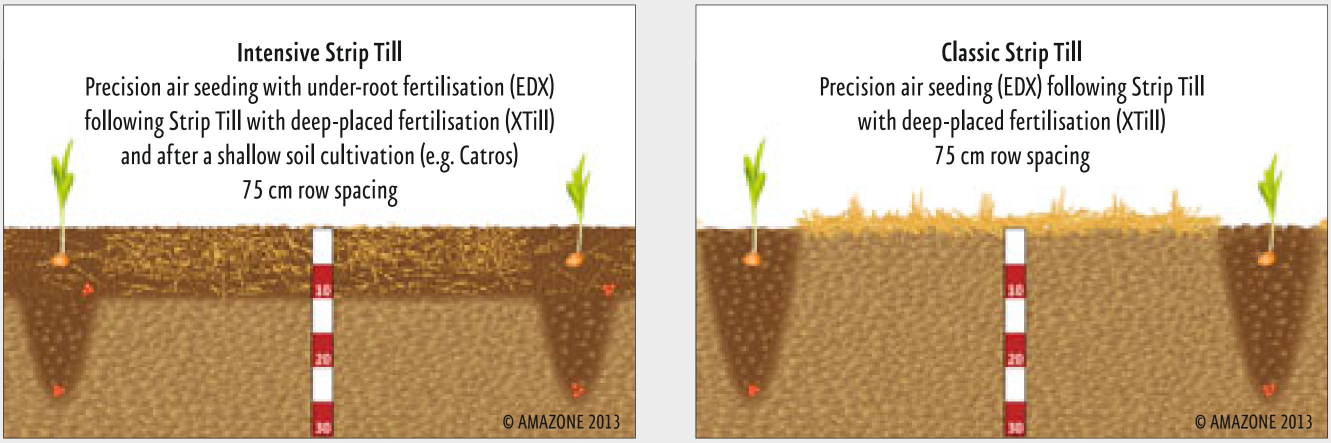


Fig. 28: **Intensive and classic Strip Till in comparison**

manure and fermented substrates. For this spectrum of operation, the company Vogelsang GmbH offer the XTill with relevant distribution technology. Here, the objective of the XTill operation is, above all, the reduction of emissions.

However, AMAZONE with the XTill is focused on the grain maize regions where one operates with mineral fertiliser. Grain maize is preferably cultivated in dry, warm climatic regions (e.g. Rhine valley, Southern France, South-East Europe, because it provides there higher profit margins than achieved with cereals. Especially in these regions, the larger availability of water, which the unloosened soil body stores additionally, can be of advantage. The under-root fertilisation with nitrogen or phosphate assists the improved growth of the plant roots to a greater depth and thus dry periods are better managed. Therefore, within the focus of the relevant trials, is the question under which conditions does reduced, strip-wise loosening ensure the highest yields.

In an additional trials series, it is investigated whether the current usual under-root fertilising (up to a depth of 10 cm) is necessary to a limited extent or not at all if the possibility exists to deposit the fertiliser in an deep root area. With this concentrated fertiliser placement the same yields can be achieved at a reduced fertiliser rate and thus the fertiliser efficiency is further increased.

Strip Till trials in rape

During the previous years, winter rape has been sown increasingly and very successfully with larger row spacings of, for example, 45 cm. As a result of the wider spacings, the individual plant can develop still stronger, show a better resistance to winter and a higher resistance to stress during drought. As a tap root crop, rape is grateful for a targeted, deep loosening with under-root fertilisation that is ensured by the Strip Till method. And thus the single under-root fertiliser rate for spring rape promises indeed the same effects such as at maize: A stress tolerant, deep root for safe yields, above all in dry years. For winter rape, under-root fertilisation, however, makes sense only with limits, because the nutrition here is mainly achieved via spring fertilisation with the fertiliser spreader.

The first trial results are promising and confirm the effects. In the years to follow, AMAZONE will further encompass the introduction of the Strip Till method for rape with its own trials. Here, the big question is asked – especially in tight crop rotations: how far it is possible to safely control weeds, crop rotation diseases, mice and slugs without additional costs.

Fig. 29: Location of the trials sites in Eastern Europe and CIS

AMAZONE trials in Eastern Europe

The excellent results and the conclusions drawn from the AMAZONE trials system in Germany plus the strong international reputation of the company were the essential reasons for establishing a trials system as well in the Commonwealth of Independent States. Here AMAZONEN-WERKE is pursuing various objectives. On the one hand, special developments for such farm sizes and conditions are tested in practice. On the other hand, modern and efficient processes are investigated on typical sites corresponding to the different agro-climatic regions. In this way AMAZONE can operate also in the new markets as a competent partner in the field of farming systems and crop production and provide farmers with the optimum advice.

Meanwhile AMAZONE is carrying out trials concerning tillage and sowing on seven sites in Eastern Europe. These trials show that the further you go east the larger becomes the influence of continental climatic conditions with a very low rainfall. Long and extremely cold winter periods, which then almost seamlessly change into hot summer periods, results in the fact that mostly only spring crops can be grown and as only a short time window is available for cultivation and sowing; tillage is carried out, not only at significantly reduced intensity, but also at very large working widths – because of the very large farm sizes.

Because of the special climatic conditions, it is important to protect the water balance of the soils; that is why direct sowing is often the optimum method. With the Primera DMC and Condor direct seed drills, AMAZONE offers two different machines which are used in the corresponding trials. From the different trial sites, we introduce to you, as an example, trials results from Vladimir in Russia and Rodina in Kazakhstan.

AMAZONE trials at Lednewo, near Vladimir (Russia)

The Lednewo site lies approx. 50 km North of Vladimir and approx. 250 km east of the capital Moscow, on the axis Moscow – Kazan.

The site is located in Oblast Vladimir and belongs to the non-black soil sites where typically animal production prevails.

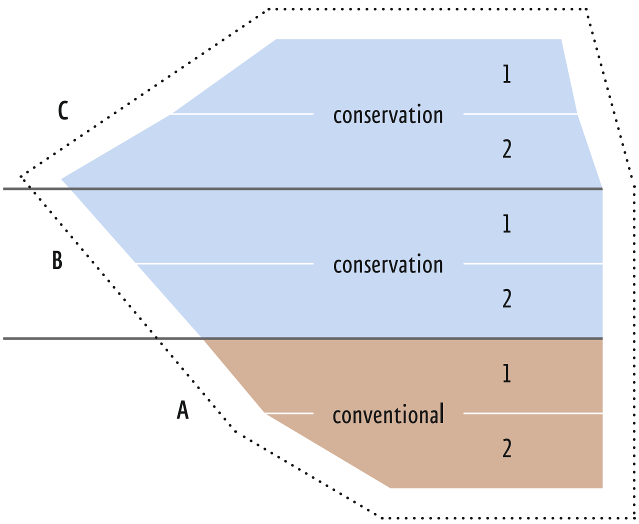
Here, the soils tend to be heavier and difficult to work. The average rainfall is approx. 650 mm/year.

The Lednewo trials site has existed since 2007. It is run in cooperation between the farm AOA Lednewo of the Russian consulting society Consultant Agro, the institute for agricultural technology and bio-system technology of the vTI Braunschweig and AMAZONE.

The trials question here is: can a conservation soil tillage system also succeed on sites with a continental climate?

Site data	
Soil	Clay, degraded black soil
Climate	Annual rainfall 650 mm, average temperature: 5.0° C
Crop rotation	Winter wheat, spring barley, spring rape
Tramline width	18 m

Fig. 30: Division of the trials site on the farm OAO Lednewo near Vladimir



Plot A is conventionally worked with the plough, the plots B and C are cultivated with a conservation mulch sowing, each with 2 seed rates (in rape with different sowing techniques).

Stubble cultivation on all fields with the Catros compact disc harrow (6 cm working depth)

Differentiated primary soil tillage at different depths with the plough, cultivator and compact disc harrow

Sowing with the trailed Cirrus sowing combination (passive sowing technology), rape also with D9 6000-TC

Field day at the trials site Lednewo (Russia) in August 2011.

Table 25: **Trial variants in soil tillage, seedbed preparation and sowing, Lednevo site**

	Plot A Plough 25 cm		Plot B Mulch sowing 15 cm		Plot C Minimal mulch sowing 8 cm	
	Plot A1	Plot A2	Plot B1	Plot B2	Plot C1	Plot C2
Stubble working	Catros 6 cm					
Tillage	Plough 25 cm Catros		Centaur 15 cm		Catros 8 cm	
Seedbed and sowing	Cirrus					

decreasing tillage intensity

Table 26: **Yield results in comparison (dt/ha), Lednevo site**

	Plot A Plough 25 cm		Plot B Mulch sowing 15 cm		Plot C Minimal mulch sowing 8 cm	
	Plot A1	Plot A2	Plot B1	Plot B2	Plot C1	Plot C2
Winter wheat 2010 seed rate seeds/m^2	500	400	500	400	500	400
Yield dt/ha	***33***	***32***	***36***	***38***	***35***	***36***
Spring barley 2011 seed rate seeds/m^2	400	350	400	350	400	350
Yield dt/ha	***27***	***27.5***	***32***	***29***	***28.5***	***25.5***
Spring rape 2012 seed rate 2.8 kg/ha	Cirrus 6001	D9 6000-TC	Cirrus 6001	D9 6000-TC	Cirrus 6001	D9 6000-TC
Yield dt/ha	***21***	***25***	***25***	***23***	***28***	***26***

The yield results were authenticated in co-operation with PD Dr. Voßhenrich from the vTI Braunschweig

First results:

The first results show that the conservation system, under the continental and arid influences, can contribute to a clear increase in the yield.

Due to, in comparison to Western Europe, the inferior volumes of straw, soil tillage can be carried out at considerably reduced intensity.

Optimum conditions at the time of sowing – both in the agronomical and agrotechnical sense – allow for a distinct reduction of the site specific seed rates without resulting in any yield losses.

Condor large area seed drill in 12 m working width.

Farm Rodina (Kazakhstan)

Site data	
Farm size	About 42,000 ha
Soil	Shallow soiled Steppe
Climate	Annual rainfall of about 240 mm on average Temperature 3° C on average
Crop rotation	Maize, spring wheat, bare fallow

In Kazakhstan the general conditions for crop farming are characterised primarily by water shortage and erosion hazards. The annual rainfall amounts only to 200 to 300 mm; in addition high evaporation rates occur at summer temperatures of up to 40° C. Steppe winds cause further drying of the soils and soil erosion.

The yield level of cereals ranges from 0.5 to 1.5 tons/ha. To enable economic farming under these conditions the farms in Kazakhstan, with acreages of 5,000 to 40,000 ha/farm, are many times larger than in Western Europe. Agricultural machinery must be able to offer particularly high work rates and thus, appropriately sized working widths.

At the area of the Rodina farm near Astana, AMAZONE is carrying out tillage and sowing trials using different methods and machinery. This is done in close co-operation with the Institute for Cereal Research "Barajew" Shortandy, Dr. Kanat Akshalov. The Institute is responsible for the implementation, rating and evaluation of the trials.

In the trials described here three methods are compared (see Table 27):

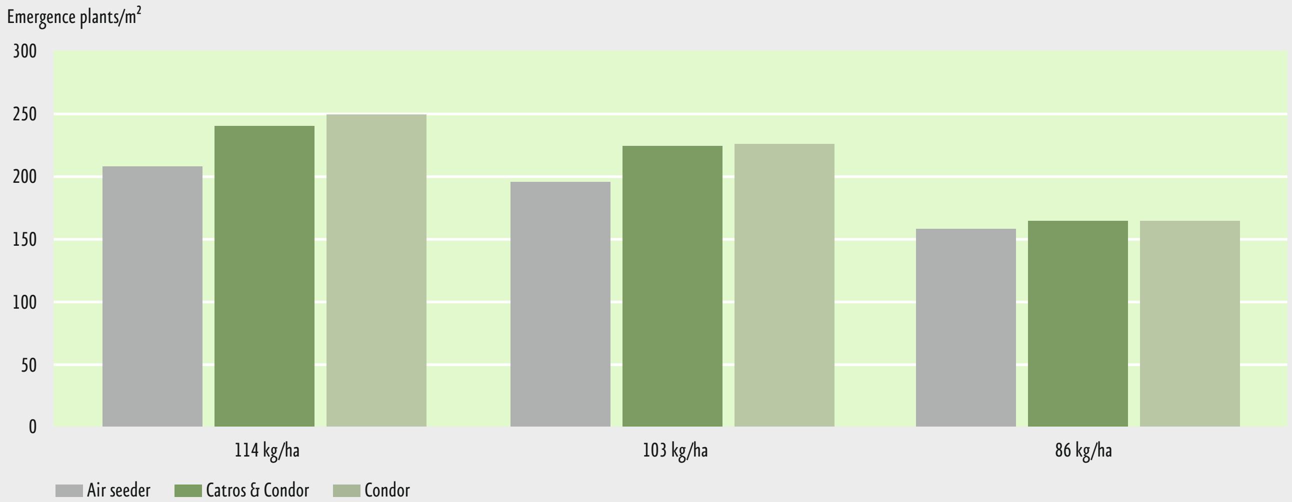
1. Traditional direct sowing with wide-cutting wing shares (air seeder)
2. Seedbed preparation with the Catros, sowing with a Condor (small chisel shares)
3. Direct sowing with the Condor (narrow chisel shares)

All plots are sown at the seed rates of 86 kg/ha, 103 kg/ha and 114 kg/ha respectively. In 2008, the

Table 27: Trial plots for tillage, Rodina site

	Conventional sowing			Minimum tillage			Direct sowing		
	Plot A1	Plot A2	Plot A3	Plot B1	Plot B2	Plot B3	Plot C1	Plot C2	Plot C3
Seed rates (kg/ha)	86	103	114	86	103	114	86	103	114
Tillage	–			Cenius 15 cm			–		
Pre-emergence herbicide treatment	only on plots sown on 24th May 2008								
Sowing	Air seeder 12 m			Condor 12 m			Condor 12 m		

Fig. 31: Germination rates of spring wheat at differing seed rates after 10 days (plants/m^2), Rodina trials site



When an air seeder is used, the stubble from the previous crop is mixed in with the soil.

Using the Condor accelerates field emergence. Apart from this, the young plants grow between the stubble of the previous crop which reduces the erosion hazard.

trials were initially carried out without any additional fertiliser. This will be also investigated in the coming years.

Sowing in 2008 was carried out on two different days (14th & 24th May). The areas sown later were additionally subjected to a pre-emergence herbicide treatment. Each of the trial plots was 24 m wide and 1,500 m long.

The general trials question is: which methods and which seed rates are suitable for Kazakhstan's dry Steppe conditions for a faster field emergence, optimum preservation and utilisation of the ground water supply and that offers erosion protection?

By means of the press wheel following the ConTeC coulters on the Condor, reconsolidation is achieved that ensures better seed-soil contact.

Comment on the trial results

by Dr. Tobias Meinel, AMAZONEN-WERKE

The first interesting result from the plots was the remarkably quick germination on the plots sown with the Condor (Fig. 31). For instance, with a seed rate of 103 kg/ha, the Condor achieved a higher germination than the traditional system with the air seeder and a seed rate of 114 kg/ha. The reasons for the generally better germination results after using the Condor is down to the good contour following ability of the coulters and the narrow openers which cause only a minimum soil movement. This reduces any drying out of the topsoil and thus more water is available to the seed. The better seed-soil contact is supported by the very good reconsolidation produced by the following press rollers on the Condor coulters.

Further development of the crops was influenced above all by the low rainfall. The total rainfall from May to July was only 35 mm, and in June, the month important for the yield, there was no rainfall at all. This resulted in increased water competition between crops and weeds.

Trial results in an overview:

Compared with the wing shares of the traditional air seeder, the good contour following and placement quality of the Condor coulters result in a significantly better germination. This results in a seed saving of up to a third.

Where the Condor is used the best yield results were achieved in combination with the lower seed rates of 83 kg/ha.

At the same time, a herbicide treatment is advisable to minimise water competition from weeds.

Erosion hazards are considerably lower where the Condor is used, because the stubble from the previous crop is not mixed into the soil.

The Condor leads to a considerable improvement in profitability, since not only are seed costs reduced by 66 %, but also fuel consumption is reduced by up to 40 %.

The yield results (see Table 28) clearly reveal that: a comparison of the results from the earlier sowing date (14th May 2008, without herbicide treatment) shows that the yields of the two plots with intensive tillage (Catros/Condor or air seeder) were higher at all seed rates than that of the direct sown plot worked with the Condor. Obviously weed competition was reduced by the more intensive soil movement.

By contrast, the positive effects of the higher field emergence of the plots sown later (24th May 2008 with herbicide treatment) were obviously retained up to the phase of yield formation. As a result of herbicide treatment there was no water competition from weeds; this explains the better yield results from the Condor.

Yields of 8.3 or 8.4 dt/ha were achieved with the lower seed rates on the Condor plots (C1, C2). This proves the extreme importance of weed control by herbicides. The fact that the yields were lower on the Condor plot C3 is due to the competitive effects within the row occurring where excessive seed rates were used. These effects do not occur on plot B3 where pre-working with the Catros took place, since the soil movement results in higher nutrient availability to the crops. Presumably, also the plots sown earlier (sowing on 14th May 2008) would have produced the same good results like the plots sown later should they have had a pre-emergence herbicide treatment. Since due to the longer vegetation phase the scarce moisture could be used more effectively for assimilation.

Altogether these trials show that by using the Condor and with reduced seed rates (about 30 %) one can achieve higher yields than with air seeders and the methods applied so far. On the costs side there are, besides the lower seed costs, diesel savings of about 1.5 l/ha compared with the corresponding air seeders (about 5 l/ha). The reduced costs converted to the total area of a farm in Kazakhstan would have an important saving effect.

Also erosion hazards are significantly reduced by the use of the Condor. Unlike traditional air seeders, which mix the stubbles of the previous crop more or less intensively into the soil, the Condor places the seed in the slit beside the stubbles and the stubbles remain where they are. In this way the wind speeds on the soil surface are considerably reduced.

Table 28: Yield results in dt/ha (spring wheat), Rodina (Kazakhstan) site, August 2008

	Conventional sowing			Minimum tillage			Direct sowing		
	Plot A1	Plot A2	Plot A3	Plot B1	Plot B2	Plot B3	Plot C1	Plot C2	Plot C3
Sowing on 14th May 2008	7.7	7.3	6.7	8.1	7.5	6.2	5.6	6.5	5.4
Sowing on 24th May 2008	6.7	7.3	6.5	8.7	8.3	8.1	8.3	8.4	5.4

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KULUNDA – international research project for innovative arable farming in the dry regions of Siberia and Northern Kazakhstan

In the framework of a big grant project from the Federal Ministry of Research and Education (Bundesministeriums für Forschung und Bildung – BMBF) KULUNDA was started in October 2011. With the global approach: "Sustainable land management" eleven German and Russian research institutes where, in total, 65 scientists carry out investigations into the long-term combat of soil erosion, humus formation and for the stabilisation of yields in the agriculturally-exploited Steppe regions of South West Siberia. In these regions, since their cultivation began in the 1950's and 1960's disastrous erosion has taken place and a massive exhaustion of the soil incurred. The main objective of the KULUNDA project is the contribution to secure global nutrition in future and to act against the CO_2 emissions caused by the human race.

AMAZONEN-WERKE supports this project with more than 500,000 Euros. The theme is the development and testing of arable farming and technical innovations for a future-orientated agriculture in the South Siberian Kulunda Steppe and other Steppe regions of Russia and Kazakhstan.

Massive wind erosion due to excessive soil tillage in the dry Steppe regions of North Kazakhstan.

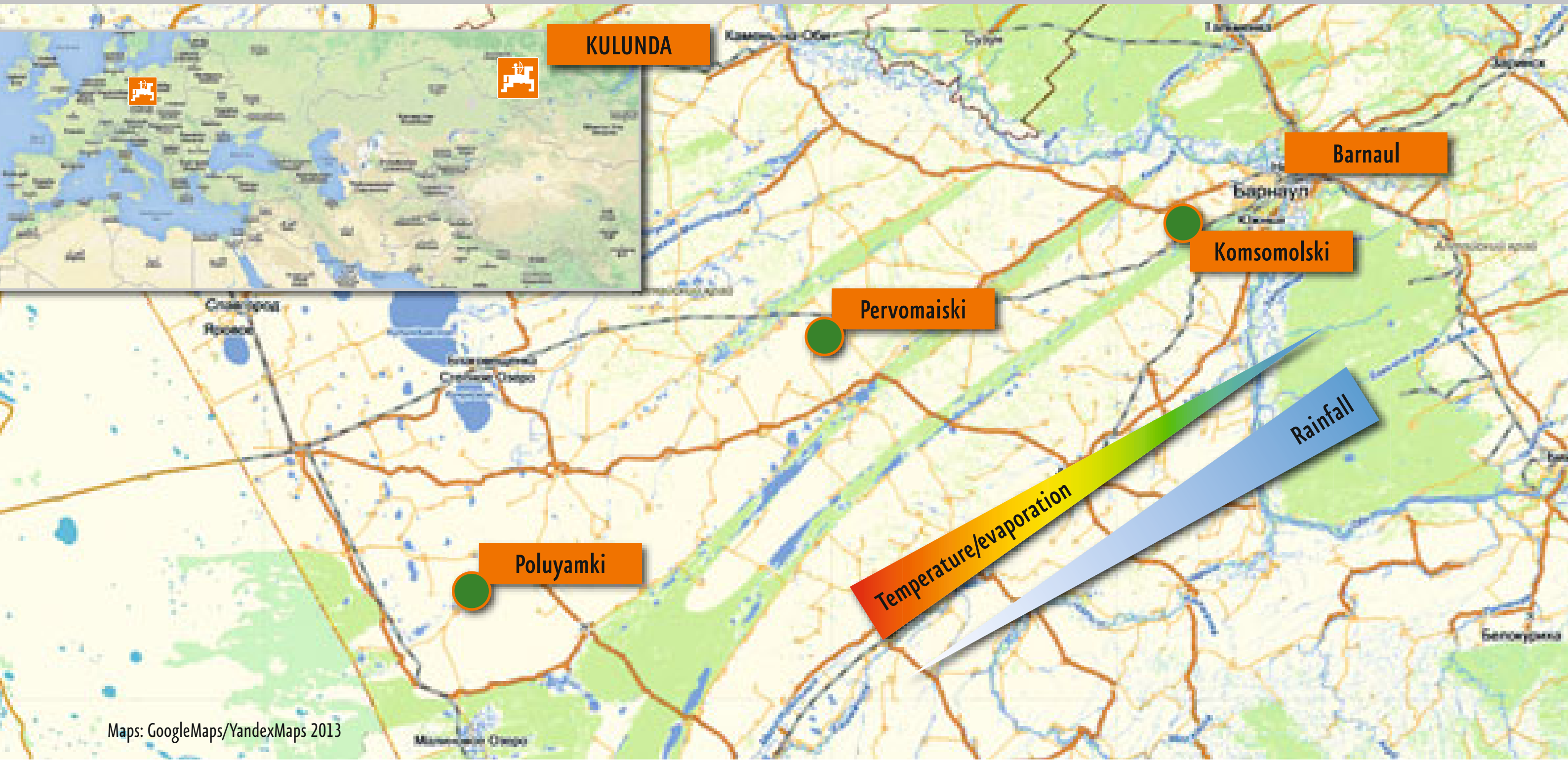


Fig. 32: The trials sites of the KULUNDA Project are located in South West Siberia along a climate gradient

The project in detail

In a close co-operation with the Governmental Agricultural University (ASAU) in Barnaul, AMAZONEN-WERKE started a perennial trials programme in 2012 with the objective to investigate the effects of conventional and modern arable farming methods regarding soil and agronomic parameters under different regional climates and on changing soils.

With the aid of innovative technologies and systems, above all direct seed drills with narrow chisel openers, the long-term stabilisation of yields, the establishment and marketability of multi-crop rotations is the intention and, in addition, the use of fertiliser and crop protection agents made more efficient and rational. Farming methods and technical solutions as they are used in the dry farming regions of South Canada shall act as a model.

In the range of technical development, in special focus are coulter systems which allow a clear fuel and time saving operation with the aid of as extensive cultivation methods as possible. By innovative fertilising methods, the optimum supply of the crop with nutrients shall be ensured.

The realisation

On three sites in the Kulundus region, field trials for several years have been established. The trials farms Komsomolski and Pervomaiski are located on humus-rich, black earth soils (Russian Tschernoseme) in the moist forest Steppe and in the typical long grass Steppe. The third site is near the Kazakh frontier and represents the basic conditions as it is found in most regions of the more extreme short grass dry Steppes of Siberia and North Kazakhstan. There, up until now, the farmers do not have to fight against the disastrous environmental damage and harvest lossed by erosion, drought and poor soils.

Especially for these trials, AMAZONEN-WERKE has developed a test machine with 3 m working width. The manoeuvrable pneumatic seed drill eases sowing on the trial plots and, due to its easy pulling ability, it can be pulled with a tractor in the 80 HP class. With the aid of this system, technical innovations can be fitted quicker and tested in field trials.

At all sites three arable farming methods are investigated. In this relationship, the comparison of the agricultural technology utilised is an important part within the monitored farming methods, which, however, include additional investigation parameters such as crop rotation, crop and climate depending sowing dates and sowing depths, row widths and seed rates, fertilising and crop protection strategies as well as straw management.

Conventional and modern cultitation methods in comparison

Method 1 is the modern direct sowing with Condor chisel openers and no further soil tillage. The four-fold crop rotation consists of spring wheat, field beans and, spring wheat and summer rape. The fertilisation is carried out directly with the seed with farm-usual CAN fertiliser. Crop protection is solely carried out chemically. Obligatory is an autumn application of a glyphosate-based product, which so far is little practised in the Altai region. Volunteer grains and late germinating weeds and weed species are thus decimated still prior to winter. This is supposed to minimise the danger of their overwintering and thus a higher weed pressure in the next spring. In addition, depending on the weed pressure in spring, a pre-emergence treatment with glyphosate or targeted in the crop with selective agents is carried out.

Method 2 is the modernised system with mainly conventional technology. Prior to sowing, initially a shallow seedbed is prepared. Sowing is carried out with conventional seed drills such as the СЗП and СЗС. The СЗП as a mechanical twin hopper seed drill that requires a particular good seedbed preparation with a tine cultivator or with a disc harrow. This machine has been designed in the 1970's especially for the dry Steppe regions of the former Soviet Union. In this concept, fertiliser application is also carried out directly together with the seed. The chemical crop protection is carried out, like in a modern system, obligatory in the autumn and in spring as a pre-emergence (glyphosate) treatment or targeted in the crop with the relevant necessary agents. Deep autumn soil tillage is omitted. Here, the four-fold crop rotation consists of spring wheat, field peas, spring wheat and spring rape.

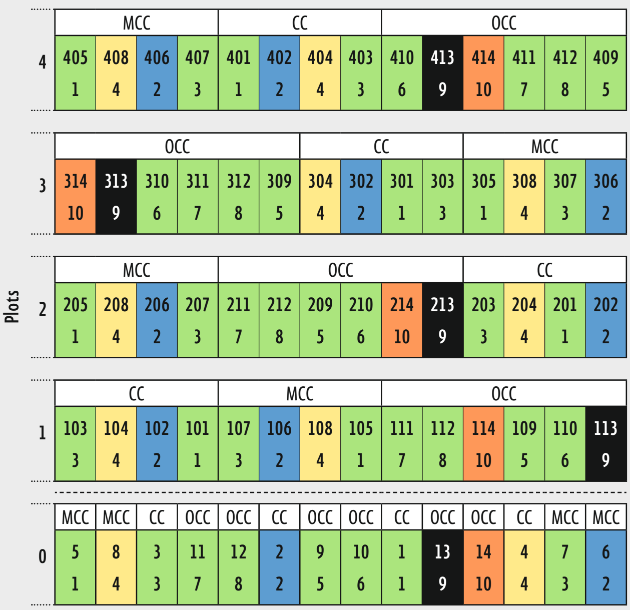
For Method 3, the conventional Soviet procedure, the intensive version has deliberately been chosen. Although since the 1980's, numerous farms in the Kulunda region no longer operate in this way, many of them have returned to this scheme due to the economic problems of the 1990's. The reason for this was the high prices for fertiliser and chemical crop protection and bad credit conditions. Until today, quite a number of farms operate in this way where for autumn soil tillage, cultivators are used that move the full area as well as in some cases also where a conventional method is utilised. In the more moist regions, seedbed preparation is carried out with drag harrows, disc harrows or shallow cultivators. The mechanical seed drills, which are utilised for sowing, mostly feature badly guided twin disc coulters or wing cultivator sowing coulters without individual

Method 1: Pneumatic seed drill 3 m with ConTeC coulters on a Belarus MTS 1221.4 (120 HP).

Method 2: Mechanical disc drill СЗП in a 7.2 m working width on a Belarus MTS 50 (50 HP).

Method 3: C3C2.1 mechanical wing coulter seed drill with 2.1 m working width on a Belarus MTS 82.1 (80 HP).

Fig. 33: Trials set-up – several year trials for arable farming systems (Komsomolski/Poluyamki)



Legend for the trial set-up:
Method 1: CC – modern cultivation procedure with direct sowing (System Condor)
Method 2: MCC – modernised procedure with conventional technology
Method 3: OCC – conventional Soviet procedure

- Spring wheat
- Spring rape
- Field peas
- Chemical summer fallow l
- Bare fallow

depth guidance. Mineral fertilising is completely omitted; crop protection is carried out exclusively mechanically. The trials crop rotation for Method 3 is a threefold one and includes spring wheat, spring wheat and fallow land. At some of the trials, the fallow land is created chemically, in others mechanically.

Illustration 33 shows the scheme of the main trials which are run in Komsomolskij and in Polujamkij. The layout of the trials in the plots 1 to 4 is incidental. The influence of the soil heterogeneity at the site is getting clearly lower from the assessment of the results. Plot 0 serves as a demonstration area (visits of project partners, field days etc.).

Trials for sowing dates, sowing depths and row spacings

At the site Polujamki (dry Steppe) plots for the investigation of sowing depth depending on the crop sown and the sowing date have been created. The objective is the collection of experience for the establishment of cereals and rape. As in continental regions, the time window for sowing in the spring is very limited and so it is paramount to place the seed in the optimum depth. In the Steppe regions of Siberia and Kazakhstan, often just a month after the melting of the snow extremely dry weather prevails. The upper soil layers dry very quickly. This requires a very good supply to the seed with soil moisture; however, also sowing too deep is not allowed to avoid wasting energy in the grain.

In addition at these sites, plots for row spacing trials with consideration of the seed rate are also being run. The trials are carried out with the ConTeC chisel opener system of the AMAZONE Condor. Here, row widths of 25 cm, 33.3 cm, 37.5 cm and 50 cm are investigated. Concurrently, in parallel with each one, a normal seed rate and a significantly smaller seed rate are compared.

As due to the increasing early summer drought in the highly continental regions, the competition of the plants within the crop further increases a trend that is developing towards lower seed rates and larger row spacings. The several years of trials should demonstrate the development of the crops at different seed rates and row widths. From an economical point of view, it is investigated how far the tractive power requirement can be reduced by larger row widths and how the efficiency can be increased due to lower seed rates and less fill times.

Outlook

With the trials in the KULUNDA Project, AMAZONE actively participates in a possible improvement of arable farming in one of the mainland regions worldwide affected most by the change of climate. Higher yields and a more cost-effective agriculture with new methods and technology can very effectively contribute to the development of this region. Although the project has only just started, the results of the season 2013 and all those to follow shall be transferred as a usable knowledge directly to universities and farmers.

The partners in the SASCHA Project

SUPPORTED BY

The SASCHA Project in West Siberia

The interdisciplinary "SASCHA – Sustainable land management and adaptation strategies to climate change for the Western Siberian corn-belt" research project deals with the reciprocal effects of climate and land exploitation change in the Tyumen region in West Siberia.

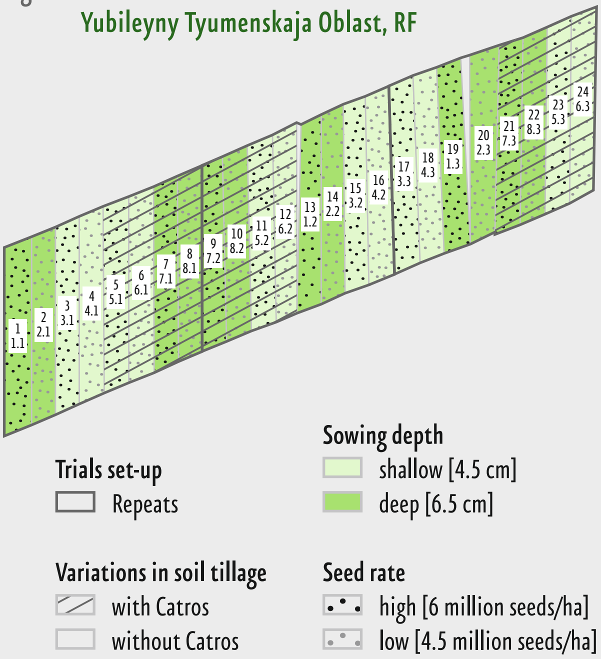
In the transition region from the forest Steppe to the pre-Taiga (see blue areas on the map), extensive arable farming is carried out whereas, in the North (see light green area on the map), mainly unusable moors and forests prevail. These organic areas are of global importance for the carbon footprint.

Due to the increasing drought in the southern regions, a shifting of cereal cultivation in a northerly direction to the moor rich regions has to be expected. This, however, would cause an extended release of greenhouse gases. In order to avoid these effects, strategies are developed in the SASCHA Project to compensate for the expansion of cereal cultivation in a northerly direction by a sustainable intensifying of the areas cultivated in the south. Here, project agriculture is the focus of, in total, seven part projects.

Project agriculture: field trials in Ishim
Spring wheat is the most usual crop in the Tyumen region. In this region the lack of water is the most important limiting factor for cereal production. Here, climate change can already be noticed and due to extremes of weather more often yield losses have resulted.

For the identification of sustainable agricultural production systems, which allow long-term stable yields

Fig. 34: Wheat trials SASCHA SP150 ZAO Plemzavod Yubileyny Tyumenskaja Oblast, RF



On the farm ZAO Plemzavod Yubileyny in Ishim field trials under practical conditions are carried out.

In the course of three years, different combinations of soil tillage and sowing systems have been compared.

Also for crop protection measures AMAZONE machinery is utilised.

even under climate change conditions, field trials under practical conditions are carried out on the farm ZAO Plemzavod Yubileyny in Ishim. Over three years, different combinations of soil tillage and sowing procedures with regard to maximising as much as possible the efficient use of water are compared.

On a 10 ha trial field, spring wheat is sown with a threefold repeat and with a fully randomised block design to demonstrate the operating possibilities of AMAZONE technology in comparison to the farm's usual procedure. The trials include each of two soil tillage techiques (with and without soil tillage with the Catros compact disc harrow), two seed rates (high & low) and two sowing depths (deep, shallow).

Outlook:

The objective of this trial, apart from the identification of the best system combinations regarding harvest quantities - and qualities, is also to demonstrate the potentials of accurate and matched production systems. In addition, the infrastructure for the intensive local monitoring will be created.

7.
Trials results from fertilisation and crop protection

AMAZONE's expertise in "Intelligent Crop Production" lies not only in tillage and sowing, but also in fertilisation and crop protection. Here the question is also how to achieve maximum yields at minimum cost and at the same time to conserve the soil and sustain its resources. On the following pages are outlined two current examples.

Fertilisation trials in Westerkappeln, Lower Saxony

The Westerkappeln site near Osnabrück is representative for arable farming in mixed regions on light soils with small field sizes. The trials site is part of the farm of Hermann Helmich. Since 2004, different tillage systems in combination with different N fertilisation strategies have been investigated here.

Results from several years concerning the application of N-stabilised fertilisers are presented as examples: six trial plots were cultivated on a field designated for mulch sowing (stubble cultivation with Catros down to 6 cm, medium deep soil tillage with Cenius to 15 cm, sowing with rotary cultivator seed drill combination) and then treated with various fertiliser types and different partial applications (see Table 29). Stabilised N fertilisers in one application (190 kg N/ha at the beginning of vegetation) once with (plot A), and once without (plot B), any sulphur content was also compared.

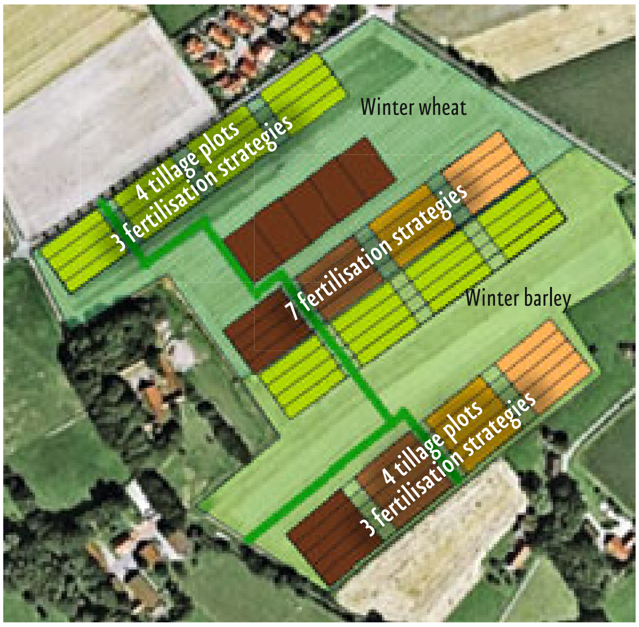
Plots C and D show nitrogen fertilisation with N-stabilised fertiliser applied over two applications. Plot C comprises a partial application with 120 kg N/ha of stabilised N fertiliser plus sulphur at the beginning of vegetation and 70 kg N/ha at growth stage 30 – 32. On plot D, 58 kg N/ha of ASS (ammonium sulphate) was spread at the beginning of vegetation and 138 kg of stabilised N/ha at stalk extension (ES 30 – 32).

The plots E and F investigate the frequently used standard programme with 3 applications of non-stabilised N fertilisers: plot E with 62 kg N/ha as ASS and 68 kg N/ha CAN (calcium ammonium nitrate) at stalk extension and 60 kg N/ha CAN at ear emergence. On plot F the complete N quantity was spread in three portions as CAN. Plot G constitutes a reference plot without any N fertilisation.

The average results from the years 2004 to 2012 clearly show that the plots with stabilised N fertiliser and Sulphur produced a yield up to 5 dt higher than that of the plots with non-stabilised fertilisers. Obviously it is advantageous to spread a relatively high first dose or only one dose with N-stabilised fertiliser. At the same time, the trials show that a sufficient Sulphur supply is important for optimum N uptake and better root growth.

Site data	
Soil type	Loamy sand/sandy loams
Kind of soil	Brown soil
Climate	Annual rainfall 800 mm, average temperature: 8.5° C
Crop rotation	Maize, winter wheat, winter barley

Fig. 35: Layout of the trials site in Westerkappeln



Trial results in an overview:

When mulch sowing methods are used, strategies with N-stabilised fertilisers produce better results than strategies with partially or non-stabilised fertilisers.

A relatively high first N application with stabilised fertilisers before the beginning of vegetation also turns out to be of advantage for mulch sowing systems.

Crop control via a two application strategy with N-stabilised fertilisers leads to optimum yields and profitability.

The results from the year 2007 in which, due to extreme dryness in April and May only a reduced Nitrogen conversion of the high-nitrate fertilisers (plots E and F) could take place, show that strategies with N-stabilised fertilisers (plots A to D) considerably reduce the risk of N shortage in case of spring drought.

2 application strategies offer more flexibility. For instance, the longer application period brings advantages in respect of a better distribution of working time capacities particularly on farms with work peaks in spring. In addition 1 and 2 application strategies are more economical. Machinery costs can be minimised by using bulk material broadcasters with wide tyres for early fertilisation. Because the relatively expensive third application (small tractor with row crop tyres for late fertilisation) is no longer necessary, the application costs can be reduced by 40 % to 50 %.

The trials show that the single-application strategy also produced maximum yields. There is, however, no possibility of correcting or adjusting the N-fertilisation in the course of the second application. Hence it may be useful, particularly on heterogeneous sites, to optimise the N-fertilisation in the course of a 2-application strategy by using sensor technology for the 2nd application.

A further trial (Table 30) focused on the question of how far the different tillage intensities in combination with different N-fertilisation strategies influence the yield. Different stabilised fertiliser types and specifications with a total N content of 190 kg/N/ha are used for fertilisation. The tillage plots comprise a plough plot and three mulch sowing plots with working depths of 22 cm, 15 cm and 8 cm.

Table 29: **Yield result of winter wheat (dt) after various fertilisation strategies (preceding crop maize)**

Plot	A	B	C	D	E	F	G
Number of fertiliser applications	1	1	2	2	3	3	0
1st. application: beginning of vegetation	190 kg N/ha Nstab+S	190 kg N/ha Nstab	120 kg N/ha Nstab+S	52 kg N/ha ASS	62 kg N/ha ASS	70 kg N/ha CAN	...
2nd. application: EC 30 – 32 stalk extension	...	...	70 kg/N/ha as Nstab	138 kg N/ha as Nstab	68 kg N/ha as CAN	60 kg N/ha as CAN	...
3rd. application: ear emergence	...	...	...	...	60 kg N/ha as CAN	60 kg N/ha as CAN	...
Year							
2004	97.1	...	...	97.8	98.2	95.9	71.2
2005	107.3	100.4	104.2	101.5	99.3	100.2	75.2
2006	103.1	92.9	101.3	93.2	99.4	93.2	76.8
2007	96.2	97.5	94.2	95.4	72.1	73.7	72.2
2008	108.9	103.7	111.9	117.1	112.9	109.1	84.2
2009	114.2	107.9	115.1	114.5	111.0	115.6	88.2
2010	108.3	112.2	106.4	103.3	99.4	101.1	70.0
2011	94.2	106.7	111.6	109.3	88.4	100.0	73.6
2012	95.3	96.1	93.8	97.9	97.0	99.1	73.2
Average	**102.7**	**102.2**	**104.8**	**103.3**	**97.5**	**98.7**	**76.0**

Nstab = N-stabilised fertiliser, S = Sulphur, ASS = Ammonium Sulphate; CAN = Calcium Ammonium Nitrate

Comment on the trial results in Westerkappeln

The average yield results from 8 harvests (Table 31) show that also in the case of this trial the plot "mulch sowing at 22 cm working depth" produces similar yields to conventional tillage with the plough. At the reduced working depths (15 cm and 8 cm) the yields of winter wheat slightly decrease at this site.

Improved traffic carrying ability of the soils after conversion to a mulch sowing system can also be noticed on the Westerkappeln site. The infiltration capacity has increased so that even heavy rainfall does not cause any problems. Because soil life is more active also straw rotting has improved.

In respect of fertilisation strategies suited best for mulch sowing systems, the following recommendations can be derived from the trials: considering the average of the individual fertilisation plots across all tillage methods one can see that plot C (1st application: 40 % sulphur, stabilised N fertiliser (120 kg N); 2nd application: 46 % stabilised N fertiliser (70 kg N)) produced the highest yield result. The plot B, also with a relatively high first application dose of a stabilised N fertiliser, reaches a medium level.

Depending on the crop development in the autumn and further weather developments in winter, the first N dose should be applied as early as possible. The first application in mid-February with stabilised N mineral fertiliser (about 120 kg/N/ha) and the second application at growth stage EC 30 – 32 with about 70 kg N/ha. It is also important here to provide a sufficient Sulphur supply along with fertilisation.

If the crops are supplied with Nitrogen in time, the risk of shortages due to dryness in the spring are considerably lower. Because the advantages that stabilised N fertilisers offer consist in the fact that they release nutrients only when the temperatures rise, they are available to the crops exactly at the time when they are needed. At the same time this produces the effect that the application times for the first and second application can be carried out more flexibly which enables a reduction in the work peaks often found in the spring.

Table 30: Trial plots for tillage. Different fertilisation strategies with N-stabilised fertilisers. Westerkappeln site

	Plot A	Plot B	Plot C	Plot D
Stubble cultivating	Catros 6 cm			
Tillage	Plough 25 cm	Cenius 22 cm	Cenius 15 cm	Catros 8 cm
Sowing	Cirrus Special			
N fertilisation	Three N-fertilisation strategies (with 190 kg total N) were compared over all tillage systems: Strategy A 1st application ASS 26 (52 kg N); 2nd application: 46 % stabilised N fertiliser (138 kg N) Strategy B 1st application 46 % stabilised N fertiliser (120 kg N); 2nd application: 46 % stabilised N fertiliser (70 kg N) Strategy C 1st application 40 % sulphurous. stabilised N fertiliser (120 kg N); 2nd application: 46 % stabilised N fertiliser (70 kg N)			

Table 31: Yield results with winter wheat (dt/ha) after silage maize. Westerkappeln site

		Plot A Plough 25 cm	Plot B Cenius 22 cm	Plot C Cenius 15 cm	Plot D Catros 8 cm	Average of all strategies
2004	Strategy A	85.8	87.8	86.2	81.5	85.3
	Strategy B	85.8	84.9	86.2	89.3	86.6
	Strategy C	87.8	85.6	86.5	90.5	87.6
	Average	**86.5**	**86.1**	**86.3**	**87.3**	**86.6**
2005	Strategy A	106.3	108.1	104.1	102.6	105.3
	Strategy B	107.0	110.3	97.1	106.7	105.3
	Strategy C	117.4	110.3	108.1	112.2	112.0
	Average	**110.2**	**109.6**	**103.1**	**107.2**	**107.5**
2006	Strategy A	97.8	99.1	98.0	96.1	97.8
	Strategy B	101.9	101.9	105.0	104.0	103.2
	Strategy C	101.5	101.9	102.5	102.5	102.1
	Average	**100.4**	**101.0**	**101.8**	**100.9**	**101.0**
2007	Strategy A	101.0	92.6	83.5	76.0	88.3
	Strategy B	91.6	85.8	86.1	81.2	86.2
	Strategy C	95.8	92.9	90.1	79.0	89.5
	Average	**94.1**	**90.4**	**86.6**	**78.7**	**87.5**
2008	Strategy A	105.8	107.8	105.4	98.4	104.4
	Strategy B	125.6	125.4	120.7	110.9	120.6
	Strategy C	116.4	115.3	115.1	117.6	116.1
	Average	**115.9**	**116.2**	**113.7**	**109.0**	**113.7**
2009	Strategy A	103.8	103.2	100.4	100.9	102.1
	Strategy B	106.1	105.5	102.4	103.0	104.3
	Strategy C	103.0	103.2	100.4	99.2	101.5
	Average	**104.3**	**104.0**	**101.1**	**101.0**	**102.6**
2010	Strategy A	117.8	118.9	115.3	111.9	116.0
	Strategy B	112.2	114.4	113.9	117.2	114.4
	Strategy C	113.9	109.4	114.7	114.4	113.1
	Average	**114.6**	**114.2**	**114.6**	**114.5**	**114.5**
2011	Strategy A	112.4	104.9	104.4	102.9	106.2
	Strategy B	109.3	111.1	106.0	106.0	108.1
	Strategy C	108.9	107.3	110.2	105.1	107.9
	Average	**110.2**	**107.8**	**106.9**	**104.7**	**107.4**
2012	Strategy A	96.8	93.2	91.0	93.6	93.7
	Strategy B	93.6	87.5	90.1	98.2	92.4
	Strategy C	91.0	90.5	92.7	98.8	93.3
	Average	**93.8**	**90.4**	**91.3**	**96.9**	**93.1**
Average 2004 – 2012		**103.5**	**102.2**	**100.6**	**100.0**	**101.6**
Average strategy A						99.9
Average strategy B						**102.3**
Average strategy C						**102.6**

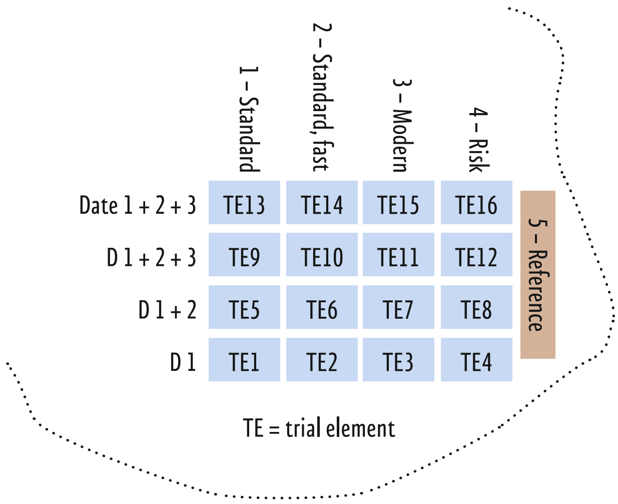
Trials into differing water rates and forward speeds in crop protection

Together with its partners: BASF, Agrotop, JUIST plant production consulting and the crop protection service department of the North Rhine-Westfalia chamber of agriculture, AMAZONE, from 2008 to 2010, has investigated the influence of different water rates and forward speeds on the effectiveness of fungicides. The field trials took place in winter wheat, at three locations: Groitzsch/Saxony, Huntlosen/Lower Saxony and Dortmund/North Rhine-Westfalia). On all sites, the trials were identical, whereby the mutual question was: what affects have different amounts of water and forward speeds on the efficiency of fungicides? Which nozzles are best suited for the safe application of plant agents?

The trials were carried out as part of large-scale trial plots utilising normal farm machinery. Applications were carried out at the normal times for BASF fungicides and using the normal amount of active agents, but using four different strategies in respect of water rates and forward speed (see Table 32).

The rating of all the trials is also carried out uniformly in respect of disease infestation, yields (dt/ha) and quality (HL, RP, Sedi, Fz, DON). For statistical evaluation, the three sites are taken into account. During the trials, an assessment of the wetting quality in different heights of the crop (see Fig. 37) was carried out additionally with the aid of water sensitive paper strips. At the Dortmund trial of the NRW chamber of agriculture, special investigations over the entire crop were carried out in addition. Here, with the aid of a fluorescent dye wetting measurements were carried out to judge the attachment quality at the different leaf levels.

Fig. 36: Layout of the 16 trial plots



Limited to 150 l of water per ha?

As a result of these trials and after many discussions with consultants and professionals, it can be inferred that, under high yield conditions such as in Germany, there is a limit at 150 l of water/ha. Below this value the risks increase.

At reduced water rates it is vitally important to observe the application conditions. The air humidity – a decisive factor for the efficacy – should be at least 50 %,

Table 32: Setup of the fungicide trials 2009

No.	Trial plot elements (TE)	Date	Nozzle type	Forward speed	Water rate in l/ha	Pressure in bar
1	**Standard**	T1/T2	Airmix 110 03	8	200	3.5
	Trial elements 1, 5, 9, 13	T3	Airmix 110 03	8	200	3.5
2	**Standard, fast**	T1/T2	TD HiSpeed 04	14	200	6.2
	Trial elements 2, 6, 10, 14	T3	TD HiSpeed 04	14	200	6.2
3	**Modern**	T1/T2	Airmix 110 025	8.5	150	3.3
	Trial elements 3, 7, 11, 15	T3	TD HiSpeed 03	14	150	6.4
4	**Risk**	T1/T2	TD HiSpeed 02	14	100	6.2
	Trial elements 4, 8, 12, 16	T3	TD HiSpeed 02	14	100	6.2
5	untreated Reference	T1/T2/T3	No application			

Application dates: T1 in EC 31/32; T2 not before EC 37/39; T3 from beginning of flowering. Treated crop: winter wheat

Artificial wheat crops with water-sensitive paper strips.

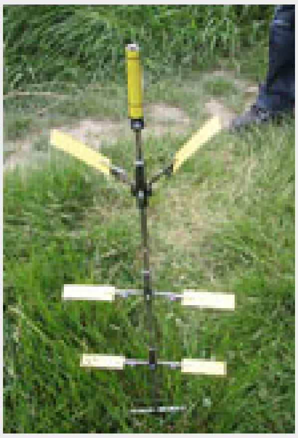
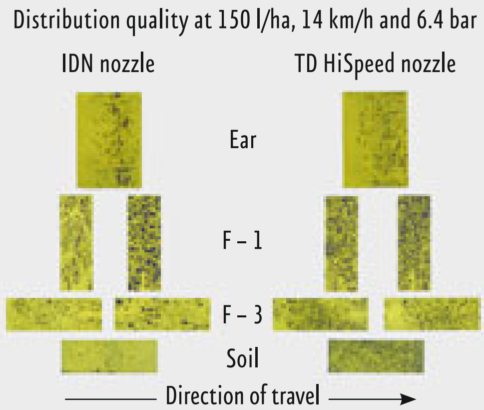


Fig. 37: Water-sensitive paper strips serve for optical assessment of the distribution quality



or better still, however, in excess of 60 %. On the other hand, the temperature obviously is not so important for most of the agents. So, within the course of a day during the main season, often only 6 to 8 operational hours with the best conditions prevail – in the early morning and in the evening.

Of course, also the choice of the right nozzle technology plays a major role here. So in arable farming practice, double flat fan nozzles are increasingly used for an improved coverage. In order to investigate during the trials the effect of these nozzles, "artificial wheat plants" were placed into the crop. Over the various leaf levels, they were fitted with water sensitive paper.

Fig. 37 shows exemplarily the effect of the double flat fan technology; the TD HiSpeed nozzle (Agrotop) compared with the IDN nozzle (Lechler). For the use of the TD HiSpeed nozzle more drops reach the rear of the ear, whereas the droplets of the IDN nozzle tend to roll off. At the leaf level F-1, the right hand paper facing in direction of the travel, the left hand paper is facing away from the direction of travel. There the TD HiSpeed nozzle shows a more even wetting of the leaves than the IDN nozzle. In the lower leaf levels, the coarse droplet characteristics of the IDN nozzle become obvious. However, here also the double flat fan nozzle manages a good penetration.

This visual assessment is confirmed by the results of the wetting measurements at the different leaf levels which have been carried out by the chamber of agriculture. Accordingly, when using the TD HiSpeed nozzle both with water amounts of 100 l/ha and also 200 l/ha an increased wetting was measured at leaf level F-1 than when using the IDN nozzle. Within the area of the lower leaf level F-3, on the other hand, the plot with the wetting with TD HiSpeed with only 100 l water/ha was clearly lower than at all other plots with higher water rates.

As an additional, important result, one can derive from the trials that a fungicide strategy with two sprayings at lower water rates shows a less long-term effect than with three sprayings. That means: only if one thoroughly looks after one's crops and so, targeted sprayings at reduced amounts of water over more applications are sufficient. However, if one intends to get away with less operational passes and only wants to spray twice, a high water rate is an advantage.

The trials also show that the biological effect of the forward speed obviously is not that decisive, but it can rather follow the farming requirements. In smaller fields the feasible limits are soon reached, whereas in bigger fields 16 to 18 km/h is no problem.

In any case it is advisable to keep informed about nozzle types and their application range when changing any application strategy. Of course, configuring any respective machinery with equipment for increasing the driver's comfort and the automation of the most important functions (DistanceControl, GPS-Switch) is also an important factor (see page 48 to 53).

8.
Professionals report on their experiences with AMAZONE machinery

In our practical reports we introduce various arable farmers who use AMAZONE machinery. The reports show the variety of conditions and the corresponding implementation of the systems in practice: whether with or without the plough – however, AMAZONE machinery is always in the frame, operating competently and offering maximum efficiency.

"Economical use of ground water …"

Henning Müller from Kirchlinteln-Deelsen in Lower Saxony is an MSc in agriculture who can look back on seven years' experience in mulch sowing. Together with his father, the 32 year old farmer runs a farm with more than 170 ha of arable land and a pig fattening unit with 2,300 stalls. In addition, the Müllers farm another 210 ha on partner farms and other contracting work, such as crop protection, sowing and harvesting. A totally new business is also actually being developed: a 500 kW biogas plant which they intend to run together with one of the partner farms.

The change to mulch sowing started when in 2004 the farm used the Cenius mulch cultivator for the first time. "After the first trials with rape proved successful, we have trialled mulch sowing with other crops and now subsequently carry it out across the farm since 2008" Henning Müller reports.

In 2011/12 the rotation on the farm was split into 36 ha winter barley, 35 ha winter rye, 25 ha winter wheat and 20 ha rape. On another 22 ha initially forage rye is sown followed by silage maize, and on 36 ha, a grass ley is then followed by silage maize. For the future it is planned to again sow grass following the silage maize, to harvest one to two autumn cuts and then use it as substrate for the biogas plant.

Müller-Deelsen GbR	
Site	D-27308 Kirchlinteln/OT Deelsen, Lower Saxony
Farm size	170 ha
Animal production	Pig fattening unit, 2,300 stalls
Average annual rainfall	700 mm, pre-summer drought in the last few years
Soil	Loamy sand to sandy loam
Average yield level	Cereals 75 dt/ha, rape 40 dt/ha, silage maize approx. 450 dt/ha
Crop rotation under cultivation 2011/12	Winter barley 36 ha Winter rye 35 ha Winter wheat 25 ha Rape 20 ha Forage rye followed by silage maize 22 ha Grass followed by silage maize 36 ha

In the spring, the sward is treated early enough with glyphosphate and then incorporated to sow subsequently maize. "In this way, we do not only harvest an additional substrate, but create at the same time, a humus enriching pre-crop for maize. That is important as we bale up to almost 100 % of the straw and the appropriate formation of soil organic matter is missing" Henning Müller considers this as the decisive advantage of the second crop.

As an advantage, Henning Müller also considers the relatively wide crop rotation because, in this way, the risk of yield losses due to an earlier or later pre-summer drought can be reduced. At the same time, excessive work peaks at sowing and harvest are temporarily evened out. "That is, for example, a very sound combine crop rotation, because we achieve a bigger time window for harvesting and can then, with 250 to 270 ha per year of our own area plus when harvesting on contract, utilise fully our 5 straw walker combine."

With the soil tillage and sowing done with the Catros, Cenius and Cirrus, it means several AMAZONE machines are used and even the fertiliser spreader and crop protection sprayer are from AMAZONE. Available tractors: two 180 HP tractors of their own and one of 230 HP from a partner farm.

Catros, Cenius and Cirrus in operation

The 5 m wide Catros compact disc harrow is already 10 years old and has probably worked about 10,000 ha already. Because rape is supposed to germinate first of all after harvest, the Catros is used here only approx. 14 days after the combine. Following cereals, however, the stubble work is done immediately after the straw is baled. If in case liquid manure is applied later – before rape or grass – a second cultivation is carried out with the Catros. Usually the operational speed is between 14 and 15 km/ha to achieve a high work rate and the appropriate mixing of the soil. Here the 180 HP tractor has a fuel consumption of 4 to 5 litres of fuel per hectare.

Prior to sowing, soil tillage is carried out to a 20 to 25 cm working depth with the 3 m wide Cenius mulch cultivator. At an operational speed of 10 to 11 km/h and a diesel consumption of between 6 and 8 l/ha, work rates of between 25 and 30 ha per day are achieved. The machine is equipped with 3-D tines, 75 mm narrow shares and a wedge ring roller. As an important advantage of the 3-D tines, Henning Müller mentions, is that

As the positive effects of a mulch sowing system, Henning Müller, above all, confirms the enormous improvement in efficiency and the fuel savings.

hardly any stones are brought to the soil surface. "Since we started to use the Cenius with its 3-D tines, collecting stones on our relatively stone-rich areas is a thing of the past." Henning Müller places great emphasise also on the wedge ring roller to ensure a reasonable re-consolidation of the soil after stubble work with the Catros and also after deep soil tillage.

The soil tillage is supplemented by a further measure. In order to prevent possible compaction on the sandy soils, and to promote rooting, all fields are worked with a subsoiler on a three year rotation.

Since 2006, a trailed Cirrus seed drill in 3 m working width is used for sowing. Usually Henning Müller operates it at 12 and 14 km/h. "I'd rather operate at 12 km/h than with very high speeds", Henning Müller says, "and so I still manage between 2.2 and 3.2 ha per hour. The machine does a perfect job and reliably places the seed at the desired depth. This is also confirmed by the farms where we sow as a contractor."

Winter barley is additionally rolled with a Cambridge roller after sowing. "Our experience shows that the field emergence is then even better" says Henning Müller.

Also the fertiliser spreader is an AMAZONE ZA-M 3000 in 27 m working width. However, it is only used for a starter application and when applying potash in rape. On cereals 250 kg/ha and on rape 40o kg/ha of a mixed fertiliser consisting of ammonium sulphate and calcium ammonium nitrate (24.10.) are applied. The further fertiliser rates are applied using pig manure and as an AUS application with the crop protection sprayer.

GPS-Switch relieves the driver

The crop protection sprayer, a UX 4200, which is also operated across several farms, is very well utilised and manages both crop protection applications and AUS fertilising over an annual area of, in total, 2,500 to 3,000 ha. In 2010 the machine was retrofitted with the GPS-Switch headland and part-width section control and combined with the GPS receiver unit already available from a parallel driving aid. The advantage of this equipment, Henning Müller sees, is the savings in the inputs plus, above all, however, that the work is clearly less stressful for the driver. "When we, for example, apply AUS, we use multiple hole nozzles and drive with speeds between 12 and 15 km/h. The driver cannot switch on and off at the headlands quite so quickly or as accurately as the GPS-Switch." Well proven also is the Super-L boom on the UX 4200, because the boom rides absolutely smoothly, even at high speeds.

In addition to soil tillage and sowing, glyphosphate treatments are carried out. So, in autumn, the rape is sprayed prior to sowing the following crop, to break down the green bridge. Further treatments are carried out on demand. For example, when barley follows wheat or grass follows winter barley.

Benefit from efficiency and fuel savings

The experiences with mulch sowing systems are good. In the course of the conversion no negative, unwanted side effects have been noticed. Only mice appeared increasingly again every now and then, so that one had to counteract that using a shotgun, but this is also the case on ploughed fields in this region.

Of positive impact, according to Henning Müller, above all, is the greater efficiency of the system and the fuel savings from which the farm has benefitted enormously. In addition, the soils meanwhile feature a fine-grained structure because more soil life has developed. Accordingly also, their traffic carrying capacity has clearly improved. In view of the actual weather conditions, Henning Müller says in conclusion: "Whether there is a climate change or not – it is absolutely clear that we should now treat ground water much more sensitively."

30 years of good experience

Georg Staudt from Martinushof in 76698 Ubstadt-Weiher converted his farm to mulch sowing 30 years ago. “Beforehand we had big problems due to water erosion. Thunderstorms and even simple light rain often resulted in capping and movement of the soil” the farmer remembers the time before the conversion. Because the site at Ubstadt-Weiher is situated in the Kraichgau, a region in the North-West of Baden-Württemberg, which, due to its hilly landscape and the prevailing loamy soil is supposed to be heavily in jeopardy from erosion.

Together with his wife, a trainee and one permanent employee, the 45 year old farmer today runs a mixed farm with, in total, 600 ha of arable farming, horse livery and a sow house with 800 stalls. The fields measure between 0.2 and 14 ha, the average size is 2 ha. The landscape around is partially flat and partially hilly.

About 200 ha grain maize, 200 ha winter wheat, 30 ha winter barley and 70 ha malting barley are grown. The crop rotation is carried out in such a way that both after winter and spring barley, and partly also after winter wheat, maize is sown. The maize is followed by winter wheat, then follows winter or spring barley. On some fields, now and then, maize is sown following maize or stubble wheat. After cereal crops, as a matter of principle, yellow mustard or phacelia are sown as catch crops, unless winter barley is sown following winter wheat.

Martinushof, Ubstadt-Weiher	
Site	D-76698 Ubstadt-Weiher/OT Zeutern, Baden-Württemberg
Farm size	600 ha
Animal production	Horse livery, sow house with 800 stalls
Average annual rainfall	600 mm, pre-summer drought from May to July
Soil	80 % light loamy soils, otherwise sandy soils and heavy clay soils
Average yield level	70 to 80 dt wheat/ha, 95 dt dry matter maize/ha
Crop rotation under cultivation 2011/12	Maize 200 ha Winter wheat 200 ha Winter barley 30 ha Malting barley 70 ha Grass and pasture land 100 ha

This relatively tight crop rotation is definitely a challenge. “To prevent infestation, we especially have to ensure that the maize straw is well mulched and can rot away. Prior to sowing winter barley which follows the wheat, it is important that the volunteer grains safely emerge so that we will not find winter wheat in the winter barley. And, for this we actually do quite well”, Georg Staudt reports.

One decisive disadvantage of the site is the relatively small field structure. “Therefore we cannot operate with very big machines. We rather have to use for many operations two smaller and, at the same time, more manoeuvrable machines in parallel.” So the machine park consists of, in total, six tractors with engine capacities of between 160 and 355 HP and as a minimum, two or even three mounted machines for the different passes are operated in parallel at operating peaks.

Stubble work and catch crop incorporation with the Catros

In the course of the grain harvest approximately half of the straw is baled, the other half is chopped and evenly distributed via the straw chopper and chaff spreader on the combine. Relatively soon after harvest a 5 m mounted Catros 5001-2 compact disc harrow for stubble work is then used. The work rate of this machine is significant, between 4 and 5 ha/hour, and on larger areas even higher.

After stubble work, Georg Staudt initially lets volunteer grains emerge and then loosens the field with the cultivator at a depth of about 20 cm. For this, either a two row or a four row cultivator with 4 and 5 m working width is available. Both cultivators are each equipped with a slug pellet spreader for the simultaneous sowing of a catch crop.

The catch crop then remains in the field until winter and then, in the period from December to January, it is incorporated into the soil with the Catros. “As we farm here in one of the warmest regions in Germany we often have no frost in the later months. However, we need the frost to be able to drive on the soils and thus better break up the catch crops” Georg Staudt explains, as to the relatively early date of this measure.

Georg Staudt of Martinushof in Ubstadt-Weiher.

Before the contractor does the maize sowing, all the fields with lighter soils are shallow worked once more with the Catros, on the heavier soils Georg Staudt uses a seedbed combination cultivator.

After the maize harvest, the stubbles are initially worked with a flail mulching machine. Like in many other regions it is also is an important measure in Kraichgau to prevent encouraging the corn borer beetle. Then a 4 m combination machine is used. It is equipped with loosening legs and cultivating discs so that soil tillage and the sowing of winter wheat can be done in one pass. If one of the two also available 3 or 4 m sowing combinations, consisting of rotary harrow and seed drill, are required, the fields have to be tilled again beforehand in order to optimally mix the maize straw into the soil.

When sowing malting barley, the time windows are especially tight. Therefore mostly all three sowing combinations are used. Beforehand, the malting barley fields also have to be worked once more with the Catros or the seedbed combination cultivator.

Problems of erosion solved

In the course of the conversion over to mulch sowing there was never any yield decrease or any other undesirable side effects. In practice the weed pressure initially was a bit higher and one had to prevent volunteer plants of the previous crop in the following crop.

And on clay soils and a winter with little frost even today problems may occur. Then these soils tend to compact so that it is difficult in spring to create an optimum seedbed for malting barley. "However, we have to live with this, because we benefit on the other hand from the many other advantages", Georg Staudt explains.

For him, such benefits include, above all, solving the problem of erosion. Firstly by the mixing in of plant residues into the top soil layers and secondly the consequent cultivation of catch drops. Therefore Georg Staudt would definitely recommend mulch sowing for erosion endangered fields. And "as additional plus points, the enormous savings on operational time and fuel costs can be added."

Surely there are also, Staudt estimates, sites where one cannot completely do without a plough. "In the end, everyone has to decide for himself, whether mulch sowing is suitable for his farm or not."

Good experiences with GPS-Switch

Both the ZA-M Ultra Hydro, and the UF 1801 crop protection sprayer from AMAZONE, Georg Staudt has used for the past two years in combination with GPS-Switch, the automatic headland and part-width section control. "We are very pleased with it. Once the fields are mapped on the headlands by the system, GPS-Switch automatically switches on and off the fertiliser spreader as it reaches the ends. Many of our fields have a conical shape, and there, GPS-Switch also automatically switches on and off the part-width sections of both these machines. On the one hand, this makes work more comfortable for the driver and, on the other hand, results in cost savings."

Catros and Cenius on a mixed farm

Westrup-Koch GbR	
Site	D-49143 Bissendorf, Lower Saxony
Farm size	690 ha
Animal production	350 dairy cows, approx. 350 calves and cattle, 10 breeding bulls
Employees	6 workers, 2 trainees
Annual rainfall	750 to 800 mm, well distributed
Altitude	75 to 150 m above sea level, somewhat hilly terrain
Average yield level	90 to 95 dt/ha wheat, 80 dt/ha barley, 40 to 50 dt/ha rape
Crop rotation under cultivation 2007	Grassland approx. 140 ha Maize approx. 130 ha Set-a-side approx. 40 ha Wheat approx. 160 ha Rape approx. 90 ha Barley approx. 80 ha Triticale approx. 22 ha

"For us, soil tillage without the plough makes sense, above all because of the increased efficiency, the protection against erosion and cost saving", this is the opinion of Dirk Westrup in D-49143 Bissendorf. At Westrup-Koch GbR, Dirk Westrup is responsible for arable farming in the general organisation. The farm cultivates almost 700 ha. Experience with soil tillage without the plough has been made over about six years.

"Our soils vary very much", Dirk Westrup says, "therefore they are cultivated differently. Partly we own sandy soils, sandy clays or silt soils." At the moment, the Westrup-Koch GbR cultivates about 140 hectares in total without the plough. Above all, on sandy and in addition, high groundwater soils the plough is only rarely not used. "Sandy soils quickly tend to compaction and as we grow here often maize and triticale in the crop rotation, which are both susceptible to fusarium, we mostly plough."

In other areas of the Westrup-Koch GbR set-up the silt containing fields, which are situated to a large extent in hilly terrain, have been cultivated without the plough for now several years: "Due to the fact that we do not plough these fields, we have clearly managed to reduce the erosion problem", Dirk Westrup confirms.

An additional criteria for decision is, what kind of crop is being grown. "Rape is partly cultivated without the plough, however, for example, with barley after wheat the plough is still used. With barley after wheat there is normally volunteer wheat in the grain which then might increase the moisture percentage when harvesting. It is then easier to sow wheat after wheat. This functions best when the wheat straw has been baled. Here also an increased risk of fusarium exists but with a targeted variety choice this can be reduced or by spraying during flowering time it can be prevented." As an additional peculiarity of the farm Dirk Westrup mentions "that we grow on 130 to 140 hectares wheat, barley and triticale as multiplication seed and so there, without using the plough, it is more difficult to keep the crops clean."

Due to the larger amounts of straw and the increased risk of fusarium after grain maize or CCM, the plough is also used. On the other hand, after forage maize, cultivations are carried out without the plough. Here the stubbles are initially worked with a flail-type mulching machine to improve rotting and to minimise the fusarium risk and then incorporated using a disc harrow or a cultivator before the next sowing operation is carried out.

Dirk Westrup from Westrup-Koch GbR in Bissendorf.

"It is also of importance to have slugs and mice under control when cultivating without the plough – in the past we have paid dearly in this respect", Dirk Westrup refers to a possible problem.

Absolutely irrespective of whether the fields are cultivated with or without the plough, Westrup-Koch GbR uses a compact disc harrow, a 5 m Catros, and as a cultivator, a 3 m Cenius. Stubble cultivation after rape is only carried out in very dry weather relatively quickly in order to ensure a guaranteed soil contact for the seed. However, in case of sufficient rainfall, they wait for about two weeks. During this time a great deal of the volunteer grains emerge which then with the first pass can be incorporated into the surface.

Stubble breaking after cereals, however, Westrup-Koch GbR carries out as quickly as possibly after the grain has been harvested. This requires observing the straw distribution previously done by the combine harvester. "In general it is good, but there are occasionally problems when the straw is still damp and is difficult to chop into short pieces." Initially slurry or chicken manure is incorporated. As it is intended to plough, the second pass is often carried out with the Catros because the work rates are higher than with the cultivator and because the mixing effect is very good. "Usually we carry out two passes in order to get a maximum of volunteer grains to emerge as we are also an intensive farm" says Dirk Westrup. For cultivations without the plough, the second pass for soil tillage is usually done with the Cenius cultivator for a deeper working depth. However, the Cenius is also used before ploughing when the soil may need to be loosened once more, for example in the wheel tracks.

Dirk Westrup judges the operational quality of AMAZONE machinery as positive. "The Catros achieves a good mixing-in of plant residues at 6 to 8 cm depth. However, an even, shallow soil tillage at 3 to 4 cm is also possible. The Cenius also operates to our entire satisfaction and we have equipped it with wing shares so that we can incorporate the straw evenly into the medium soil layers." In front of the 5 m working width Catros, tractors of 170 HP or 220 HP are used, whereas in front of the Cenius cultivator, 120 or 160 HP. Westrup-Koch GbR carries out the sowing operation mainly with a 3 m combination consisting of rotary cultivator and Pack Top seed drill with disc coulters behind a 160 HP tractor.

Besides the technology Dirk Westrup also highly regards the more far reaching AMAZONE competence for soil tillage systems. "It is good that AMAZONE is working on a continual development programme and that they support farmers in the realisation of those systems. Also in crop protection and fertilisation technology they are far ahead. From the developments in the previous years one can see that this is an innovative company."


In sloping terrain the erosion hazard has been significantly reduced.


The task of the Cenius cultivator is to work the soils deeper.

AMAZONE machinery in Hungary

B.M. Tiszamenti Kft.	
Site	Lácacséke, Hungary

Béla Kiss, employee and manager for agricultural technology:

On approximately 1,700 ha where roughly 600 ha is winter wheat, 600 ha maize, 250 ha rape, 250 ha sunflowers are grown. With an annual rainfall of 500 mm the soil qualities vary from sandy to heavy. Since 2005 for soil tillage and sowing the Catros, Centaur, KG-AD seed drill and ED precision air seeder from AMAZONE have been used. They only plough in the spring for sowing maize and sunflowers. Sowing winter wheat and rape in the autumn is carried out without the plough to save costs and time. After a short settling-in period with the new AMAZONE machinery, the employees said: "Good, effective technology that is also easy to operate."

With Catros and Cirrus on very heavy soils

"In 1997 we totally changed over to soil tillage without the plough when the machinery ring purchased a mulch sowing sugar beet drill", Stefan Ruckelshaußen remembers, who cultivates in Groß-Gerau 190 ha of arable land. Before that they still ploughed for sugar beet, spring barley and maize. "Sowing shortly after ploughing is virtually impossible because the soil is really too heavy. When we ploughed earlier there were huge clods, for a four furrow plough we needed 180 HP. So we only could plough for spring sowing. However, that had to be done really in the autumn so that the frost could break the soil down into smaller clods over winter." Sowing in the autumn, on the other hand, had already been done without the plough for a much longer period, initially with a combination of rotary harrow and seed drill.

The soil quality is mixed and changes from field to field, with a soil rating from 40 to 80 points. In the Upper Rhine rift valley – former alluvial land – here there are partly very heavy areas with an increased clay content of up to 65 %, however also some areas with clayey sand. The mostly heavy soil is the significantly important reason why Mr. Ruckelshaußen relies on conservation soil tillage. In addition there is the uneven distribution of rainfall, which is, over ten years between 500 and 530 mm/year. After a pre-summer drought, approximately from June, the most of the rain falls in the autumn. "In the autumn it is too wet, sometimes nothing can work, then the soil is very sticky, when it is loosened and then rained on again then everything is just too late."

Mr. Ruckelshaußen cultivates 65 ha of his fields organically as a separate farm but even here he manages with the aid of a special wing tine cultivator and a very wide crop rotation to work without using the plough. On the remaining 125 ha, which are not organically cultivated, the crop rotation is substantially tighter and exists at the moment of herbs (parsley), sugar beet, rape and wheat. Via the exchange of fields with partners in his machinery cooperative and other farmers cereals and root crops are cultivated in all fields in an annual rotation. "That goes superbly with soil tillage without plough, after cereals we grow either sugar beet, rape or herbs", Mr. Ruckelshaußen reports. In the long-term average yields for sugar beet are between 530 and 550 dt, 75 dt for wheat, 55 dt for spring barley and approx. 40 dt for rape.

For several years Stefan Ruckelshaußen has cultivated his fields with a Catros and sown with the Cirrus.

In order to carry out soil tillage and sowing as cheaply as possible, Mr. Ruckelshaußen relies on the advantages of a machinery co-operative. In this way, thanks to the mutual use together with three other farms on 1,100 ha in total, the 6 m Catros compact disc harrow, a 4.6 m wing tine cultivator and the 6 m working width Cirrus seed drill can be used to full capacity. For the towing tractor a 240 HP Fendt 924 from the machinery co-operation is available.

Only a few passes prior to sowing

Special attention is turned to the straw distribution from the previous crop harvest. When it is intended to cultivate herbs, as a matter of principle straw is baled from the previous crop, with all other previous crops it is usually left. The combine harvester drivers generally pay attention to an even straw distribution. One measure, for example is, that they ensure a constant sharpness of the knives.

For beet after grain, Mr. Ruckelshaußen initially carries out a stubble cultivation with the Catros to a depth of 5 to 8 cm. When the field is then greening up again, mostly the Catros is used once more to mix in emerging volunteers and straw. In the end, prior to winter, Roundup is sprayed to remedy root weeds with then no other cultivation being carried out until sowing.

For rape after wheat or barley after spring barley Mr. Ruckelshaußen initially carries out a first shallow pass with the Catros, then for the second time a bit deeper and then he sows directly with the Cirrus. The sowing operation is done mostly in combination with a pre-sowing herbicide which can be incorporated with the cultivation discs of the Cirrus.

If parsley follows cereals, it is worked one or two times with the Catros, in addition mostly the cultivator is used once more. "For parsley we have to incorporate the straw somewhat more intensively to avoid later straw residues in the product", says Mr. Ruckelshaußen with regard to the special demands of parsley.

For wheat after beet (harvested with a six row self-propelled machine), if it is not too wet, sowing is carried out directly with the Cirrus. Here the pre-cultivating discs of the Cirrus, however, are set in to a depth of 8 to 10 cm in order to loosen the surface a bit more. After rape and after parsley only Roundup is sprayed, then followed just by sowing with the Cirrus.

Minimising operational time and costs

The decisive measures for Mr. Ruckelshaußen are the number of passes with the Catros and the use of Glyphosate containing agents. The cultivator is used only there, when the straw has to be incorporated a bit deeper, such as, for example for rape or in cases where the ground is left uneven. From time to time also prior to beet on the lighter soils. When sowing cereals, rape and parsley with the Cirrus the pre-culti-

Stubble cultivating with a 6 m Catros: At 18 km/h round about 12.5 ha in just under two hours.

vating discs level the soil and at the same time provide some loose soil which is then firmed again by the wedge ring tyres.

What has changed now the plough is not used any more? “One spends clearly less time in the field. Previously, one had to sit for hours and days on the tractor, but today everything is done very quickly and the time that is saved can be used for other work”, declared Mr. Ruckelshaußen. “The work is quickly done and in cases where the weather is bad, we also work in shifts.” In this way Mr. Ruckelshaußen – when we visited him – had just stubble cultivated 12.5 hectares in barely 2 hours with the Catros at 18 km/h. Also with the Cirrus, depending on field sizes, 4 to 8 ha/hour can be managed.

In addition there is the saving on fuel: For the first stubble pass with the Catros, Mr. Ruckelshaußen only used 5 l/ha, for the second pass 7 l/ha (with the mulch cultivator 9 to 10 l/ha) and for sowing also 7 l/ha, for tillage and sowing this results in a total of around 19 l/ha. On the other hand, Mr. Ruckelshaußen did not notice any yield decreases.

Additional observations: “At the beginning of the change over we thought we would have to supply the stubbles with more nitrogen. However, we do not do this any longer because the soils are so active with so many more earthworms. Also for base fertilisation nothing has changed but the traffic carrying ability of the soils has improved.”

Regarding the time for sowing Mr. Ruckelshaußen says: “One has to approach the optimum time with care, under no circumstances should one sow too early. One has to wait until the top soil layer flows a little bit but waiting is not all that bad because of the enormous efficiency that is at our disposal once we start going.”

“Centaur mixes and deep loosens …”

Agrarprodukte Kitzen eG	
Site	D-04460 Kitzen

Hans-Uwe Heilmann, Chairman of the board.

The farm in Kitzen runs about 3,000 hectares and for more than 6 years a Centaur from AMAZONE has been used here. Uwe Heilmann: “Why did the plough once revolutionise agriculture? It inverts and it mixes but it does not do anything else. At that time when the plough was introduced, no crop protective agents were available and hardly any fertilisers, so once upon a time it brought the more nutrient rich soil layers to the top and provided a deep loosening at the working depth. However, today the Centaur does this better: Because it does not invert the soil but loosens it at the relevant required depth and mixes in the straw. We have got masses of straw which have to be incorporated and one should not bury the straw but mix it into the soil and then let the soil life do the work.”

"The effects are really put into action!"

Agricultural cooperative Kirchheilingen e.G.	
Site	D-99947 Kirchheilingen, Thuringia
Farm size	Total farmable area 3,640 ha, 3,500 ha of arable land
Animal production	450 milk cows, 900 sows, 400 sheep
Employees	Big direct marketing with several subsidiaries 115 employees in total
Annual rainfall	An average of 510 mm, badly distributed, summer droughts
Altitude	230 m above sea level, slightly hilly terrain
Soil	LÖ 2 (from loams to disintegration soils) Ø field number: 63, Ø grass land number: 34
Crop rotation under cultivation 2007	Winter wheat approx. 950 ha Peas approx. 244 ha Lucerne/Grass approx. 172 ha Spring wheat approx. 112 ha Spring barley approx. 393 ha Rape approx. 687 ha Sugar beet approx. 68 ha Feed maize approx. 207 ha Grain maize approx. 140 ha Winter barley approx. 270 ha Triticale approx. 39 ha Durum wheat approx. 108 ha Set-a-side areas ca. 70 ha (participation in the Thuringian Kulap programme A8, B and C)

Agricultural cooperative Kirchheilingen e.G. cultivates a great deal of their approximately 3,500 hectares of arable land without the plough, however, a smaller part is still ploughed. Carsten Steger, member of the management of the co-operative and at the same time responsible for the area of crop establishment, reports about the reasons and experiences.

When in 1994 the change over to conservation soil tillage began, the reason was mainly the economic constraints for constant rationalisation. The decreasing numbers of employees did not enable all areas to be ploughed in the usual way due to the operational peaks in summer. In addition there was the problem of little rainfall and unfavourable rainfall distribution: "When we plough in summer and then want to sow rape the soil moisture has disappeared. So this was a complex problem which we wanted to solve with a plough-less operation" Carsten Steger reports.

Today, approx. 65 % of the crop rotations at agricultural cooperative Kirchheilingen e.G. are carried out without the plough – that is valid for all crops which follow on from peas or rape. Also for rape (after winter barley, wheat or spring barley) normally one does not plough. The same applies to winter cereals, except for maize. For spring crops (spring barley, forage maize, beet) one normally ploughs.

For all acreages, where over many years the plough has not been used, according to Carsten Steger the following can be noticed: the yield differences between good and bad fields are not as big as in former times because the soil structure is better. The soils obviously carry traffic better, as after rain the water seeps away quicker. In an extremely dry year, such as in 2003, the highest wheat yields were still harvested. "So it is true", according to Carsten Steger, "the effects of conservation soil tillage are really put into action provided one has not done something wrong previously." He also confirms the economic advantages: "Whilst the yields hold steady – though initial difficulties due to mismanagement of straw, to slugs, mice and awn-less brome grass – not only did we reduce manpower but also diesel consumption in huge dimensions!" In this way, for example, as a comparison between the years 1999 and 2003 the diesel consumption was reduced from 345,000 litres/year to 245,000 litres/year – a 100,000 litres/year less!

The Centaur as the core machine

Today the Centaur, which is pulled by a 420 HP tracked vehicle, is the most important machine for cultivation

Carsten Steger, member of the board and farm manager at agricultural cooperative Kirchheilingen e.G.

without the plough in Kirchheiligen. This machine cultivates approx. 3,000 ha per year. For four years the farm has used a Cirrus as the "main" seed drill with help from an older Primera DMC direct seed drill.

Even when combine harvesting, the Kirchheilingen staff keeps an eye on an even straw distribution. "Straw management is very important, one has to achieve a good distribution of chaff and volunteer grains over the entire area", Carsten Steiger says. The magic formula of how to proceed after harvest does not exist, so that the soil tillage always varies. Carsten Steger explains with the aid of individual examples: When, mostly on the worse fields, winter barley follows wheat initially the Centaur is used as quickly after harvest as possible. However, a disc harrow is also used in exceptional cases, in cases where much there is much lodged grain. "This, however, is comparatively rare because when spreading fertiliser we operate with the N-sensor", Carsten Steger explains.

"We try to keep the first pass as shallow as possible, then the second somewhat deeper. Possibly also with different shares. For us, here the flexibility of the Centaur has the decisive advantage – enabling us, depending on the demands, to work shallower or deeper, to use wider or narrower shares." Whether the operational quality and working depth are correct and whether the straw has been sufficiently incorporated, is judged after a look in the field. "It always depends on the actual conditions: Is it wet or is it dry, was there lodged grain or not, it is all very complex. One really has to make one's own experiences and also one has to fall flat on one's face and then to be able to make it alright in the end."

Another example: after rape, winter wheat is sown. Here, after harvest no initial soil tillage is carried out, but a straw harrow is used. This measure is designed to distribute the straw a little and to promote the emergence of the fallen rape seeds. After three to four weeks the fields are treated with a total herbicide. In this way the basic food is taken away from mice and slugs and their breeding is reduced, at the same time the water supply is conserved. In order to destroy the mice runs, the rape fields are mulched and cultivated once all over. As rape is grown on the poorer soils there are often still wheel tracks which are removed by running an approximately 10 cm deep operation with the Centaur prior to the next sowing.

"Straw management is very important to us; one has to achieve complete distribution of chaff and volunteer grains over the whole area in the field."

There are different reasons that in Kirchheilingen one goes on ploughing in some fields. So, for example, the manure from the animal production has to be spread, in most cases before beet and maize. The approximately 500 hectares for spreading are next to the livestock sheds. For logistic reasons it is suggested to initially bale the straw and spread the manure later. "However the manure is mostly spread in unfavourable weather, so that often deep wheel tracks are left behind and so one has to plough afterwards. As our better soils are situated around the livestock sheds these areas simultaneously offer a high yield level, so that it easily pays to work here with the plough", Carsten Steger reports.

The plough is also used following grain maize: At first the field is mulched, then ploughed and then the wheat is sown. By mulching the stalks are smashed, at the same time it acts as a control measure against the corn borer beetle and prevents blockages during subsequent tillage. Carsten Steger explains that the Kirchheiligen staff use the Centaur for further tillage after mulching: "Because of fusarium – we want to have the straw here well away from the surface. We tried it with the Centaur before and it works, however, in an unfavourable year problems might arise especially if the don values then become too high, the grain becomes unsuitable for use as either foodstuff or feed."

But summarising Carsten Steger says: "Without these pressures, of course, we would like to renounce the plough here also." Looking back at the beginning of changeover, Carsten Steger remembers: "Initially, one has to learn the hard way because one underestimates certain effects – problems with slugs, mice and awnless brome grass, also mineralisation in the soil takes another course. One has to be prepared to learn all over again and again and to make compromises. If much straw prevails, I still have to work deep enough, not generally shallow because if not I get problems. Also where the co-operative grows seed grain one works without the plough: here the long crop rotation, which we practise thanks to the participation in the Thuringian A-8 programme, helps us to ensure purity of variety."

Carsten Steger is extremely satisfied with AMAZONE technology. All machines function very well – besides the Centaur and Cirrus the Primera DMC direct seed drill, precision air seeders and fertiliser spreaders are all used at Kirchheiligen. The staff from Kirchheiligen use the 6 m wide Primera DMC mostly in the smaller fields.

However, exact work rates regarding the use of AMAZONE machinery Carsten Steger does not want to commit to: "Areas and conditions are just too different. To work a 100 ha field on the level with the Centaur means the same output as a 20 ha field where I have to drive up and down hill. In any case, the 7.5 m Centaur works between 12 and 15 km/h, the hourly rate can be calculated and in normal operation we thus manage between 50 and 70 ha per day, with the 8 m Cirrus also between 50 and 70 ha."

Regarding AMAZONE and conservation soil tillage Carsten Steger thinks: "We have abeen co-operating closely with AMAZONE for a very long time and we are very pleased that AMAZONE endeavours to obtain new, actual background knowledge regarding plough-less soil tillage and that they pass on their experiences to their customers."

AMAZONE machinery in Russia

Agrofirma Kulon	
Site	Tartastan

Rafik Miftachov, General manager.

The estate runs 35,000 hectares and a dairy farm. A strongly continental climate prevails (hard winters, periods of drought in the summer); the annual rainfall is about 220 to max. 370 mm. Heavy clay/black earth soils predominate. The arable farming is carried out in the proportion of 40 % conventional and 60 % without the plough. For 4 years AMAZONE technology has been used in the form of disc harrows, seed drills, fertiliser spreaders and crop protection sprayers.

All machines have proven themselves superbly, with the sowing technology especially praiseworthy. "Exemplary in precision and handling, reliability and sowing speed, the Citan seed drill is a real sowing miracle. With an AMAZONE seed drill plant emergence appears after just four days." Also the tractor drivers regard AMAZONE technology as operator-friendly and uncomplicated.

AMAZONE machinery in Poland

Kaczmarek farms	
Sites	Poznań, Wałcz

Maciej Kaczmarek.

Together, with his cousin Rafał Kaczmarek, Maciej Kaczmarek runs two different farms with a total area of 1,260 ha. The crop rotation includes rape, rye, winter wheat and maize. The main farm with predominantly medium soils is located near Poznań, the second farm is near Wałz where loamy soils prevail.

For many years now Maciej Kaczmarek and Rafał Kaczmarek have been working with various AMAZONE machinery e.g. with the ED precision single seed drill, the UG trailed sprayer and ZA-M and ZG-B fertiliser spreaders. "In 2005 we purchased a Catros compact disc harrow with 6 m working width and a Citan large area seed drill with 9 m working width. Since that time we have tried to work our fields without the plough", Maciej Kaczmarek reports. "You always must look out for new effective solutions to increase the output and reduce the costs."

Because there is not enough farmyard manure, the straw is always chopped in all areas and remains on the field. When the soils are dry and the straw has been well distributed, Maciej Kaczmarek and Rafał Kaczmarek work their fields twice with the Catros. In case of wet soil conditions and bad straw distribution, the plough is still used. "In our conditions mulch sowing, for example, works very well after growing rape. Problems still occur after rye which is due to the mostly too long and poorly rotten chopped material", says Maciej Kaczmarek.

Independent of primary tillage, sowing is always performed with the Citan. "This seed drill works excellently under all conditions. It is not only effective and reliable but also easy to operate", is Kaczmarek's opinion of the Citan.

"Each year we learn something new ..."

Agricultural holding, Philippe Mendak	
Site	Ouzouer-sur-Trézée, France
Agricultural region	Puisaye
Soil type	Loamy, sandy soil
Farm type	Cereals
Crop rotation	Rape, wheat, sunflowers, spring barley, maize, spring barley
Annual rainfall	630 mm
Farm size	158 ha
Average field size	Consolidated, separated by groups of trees
Employees	1 employee
Machinery in use	Catros; rotary cultivator/seed drill AD 4.5 m; ED 452 precision single seeder; ZA-M fertiliser spreader

Philippe Mendak's farm is located in Ouzouer sur Trézée, in the small region La Puisaye, and covers a consolidated area of 158 hectares. The soil is sand loam down to a depth of 40 cm, in some parts down to even 100 cm. The layers below are very clayey and hydrous. "When I started off here I found out that these soils were very challenging and at the same time expensive to cultivate. To give you just one example: I had to change the plough shares every 20 hectares which cost me more than 4,500 Euros a year". In 1990 Philippe Mendak left out the ploughing pass for the first time. "Because I had very little time to plough after the maize I started sowing directly after going over with the cultivator. Although the conditions were not ideal, the result convinced me of the effectiveness of plough-less tillage."

Using a drill combination from AMAZONE (TL deep loosener, KG rotary cultivator and disc drill, at first with a working width of 3 m, later 4.5 m) instead of a plough, Philippe Mendak saved himself one pass with the tractor and also the wear and tear of the plough shares – without any reduction in the quality of work. In 2003 Philippe Mendak swapped the first part of the combination, the TL deep loosener, for a pass with a winged tine cultivator. "The low working speed and also the wear of the share of the deep loosener had brought back memories of my problems with the plough. At first I selected a cultivator with 4 m working width, 11 tines and 360 mm tine spacing to avoid over mixing the soil during deep treatment and to create a wavy profile with a depth of about 20 cm while at the same time loosening and structuring the soil."

The next difficulty was that the cultivator was not entirely suitable for mixing the straw residue into the soil following the cultivation of maize or wheat. Philippe Mendak therefore exchanged it for a disc harrow with 15 cm disc spacing. This was a further step on the way to reducing the work load. The large discs of the harrow worked faster and there was less wear and tear. What was more, soil quality improved from year to year and there were fewer problems with soil compaction. "While I was still ploughing I would walk over my fields and feel hard and lifeless soil under my feet. Now it is like walking on cotton wool." Philippe Mendak also points out, however, that this is the result of many years of paying strict attention to soil maintenance: no trailers on the fields during harvesting, tractor passes kept to a minimum and wide tyres during sowing. "Where nowadays my feet leave footprints when I walk, I can drive over with a tractor without marking the ground – and that is the most important thing for my soil."

Farmer Philippe Mendak.

Today Philippe Mendak uses the Catros at a working depth of 5 to 10 cm. "The Catros works faster than the conventional disc harrow, uses less fuel and the consolidating effect is better. This is an important advantage because it means that volunteer grain and weed seeds can germinate better."

A varied crop rotation is essential in Philippe Mendak's opinion. "Then weeds are not much more of a problem than in the days of ploughing". Nowadays the crop rotation consists of wheat, rape, winter barley, maize, spring barley and sunflowers. Prior to maize and sunflowers he sows mustard and phacelia, two frost sensitive catch crops, so that the soil is also covered in winter thus preventing weed growth.

Philippe Mendak is delighted with the last soil profiles he examined because he was able to find the fine roots of wheat even at a depth of 90 cm which proves that the soil structure is very good. Regular soil analysis has also told him that the humus ratio has risen from a former 1 to 1.5 % to today's 2 to 2.5 %.

Philippe Mendak's conclusion after 20 years of ploughless tillage speaks for itself:

- there is less work for the tractors. Formerly the main tractor worked 1,000 hours a year – nowadays only 275 hours;
- yields have risen an average of 9 %;
- soil quality has improved significantly;
- costs have been greatly reduced. Compared with the average of similar farms in the region they have dropped by 250 to 300 Euros per hectare.

"Each year we learn something new for there is no chartered path that leads to these results. Our motto is to observe the developments very carefully and to be willing to take a few risks."

"The advantages are obvious ..."

Farm Hervé and Arnaud Billet	
Site	Châtres and La Croix en Brie, France
Agricultural region	Wooded Brie
Farm type	Cereals
Crops (average yields)	Wheat (85 dt./ha) Rape (40 dt./ha) Barley (85 dt./ha) Beans (52 dt./ha) Beet (79 t/ha)
Annual rainfall	630 mm
Farm size	Approx. 500 ha
Average field size	17 ha
Employees	2 managers, 1 employee
Machinery in use	Catros 6001-2; Centaur 5 m; Cirrus 6001 Special; ZA-M Ultra; ED 602-K

Hervé Billet and his brother Arnaud Billet cultivate their two farms in Châtres and La Croix en Brie together. They additionally subcontract out to farms near to Melun in the Departement Seine-et-Marne (77). The soil on both farms, which are 25 km apart, is liable to compaction but otherwise very different: in Châtres it is loamy, hydromorphic and susceptible to capping, in La Croix en Brie, on the other hand, the soil is loamy clay that is very difficult to work.

The Billet brothers began plough-less cultivation in 1992. In order to save time during rape cultivation they reduced the three working steps, stubble cultivation, ploughing and sowing to only two: stubble cultivation followed by a combination of deep loosener, rotary harrow and seed drill.

Apart from saving time, the Billet brothers soon found that yields were increasing even in the first few years – a good reason to gradually change the other crops over to reduced tillage. This is how it came about that since 2003 the Billet brothers have been cultivating without the plough on some 90 % of their land; they continue to plough only for winter barley which they grow as a crop on contract.

To further reduce the workload, this time when sowing, the brothers replaced their 4 m wide drill combination, which worked very efficiently but could only manage 20 hectares per day, with a winged tine cultivator and a 4 m Cirrus large area drill. "Now we can use the cultivator a few hours or days before the drill and then choose the ideal time to sow up to 35 hectares a day" reports Hervé Billet.

As the Billet brothers gained more and more experience in plough-less tillage they found further aspects that could be refined and improved. For example, they were not entirely satisfied with their stubble cultivation, whereby the straw is mixed with the soil for the first time – a step that is particularly important for weed and slug control. The conventional disc harrow they were using was working too deep in the soil and, more importantly, the soil reconsolidation effect was inadequate. "We should have been working more shallowly when stubble cultivating and if necessary add another pass so that weeds germinate well and to combat slugs", they decided. They exchanged the conventional disc harrow for a Catros compact disc harrow with a working width of 6 m because it worked faster and more precisely, was more manoeuvrable and at the same time consumed less fuel. "The fact is that three passes with the Catros are equal to two with the conventional disc

Farmer Hervé Billet.

harrow", said Hervé Billet, "but we are now saving about 4 litres of fuel per hectare. What is more, the weeds emerge better because the Catros with its wedge ring roller packs the soil more effectively."

The winged tine cultivator also had its limitations in respect of mixing and levelling the soil. For this reason it was replaced with a more efficient Centaur with a working width of 5 m. "The quality of straw-soil mix using the Centaur with its 4 rows of tines, two rows of discs and the wedge ring roller is surprisingly high; the good levelling and consolidating effect also mean that afterwards we can sow faster – at up to 18 km/h. But be warned: on our kind of soil the 5 m Centaur needs at least 300 HP to work at 10 km/h", Hervé Billet pointed out.

To further increase the area covered, the 4 m Cirrus seed drill was exchanged for a 6 m version. The increased working width and 3600 litre tank boosted sowing output enormously. Later the Billet brothers acquired a new AMAZONE machine for their sugar beet seed: the ED precision single seeder with 12 rows with combined mineral fertiliser applicator. "This technique allows us to work at higher speeds and achieves a remarkably even sowing depth. The combination with fertiliser, which is unusual for sugar beet in this area, saves us a day's work and accelerates emergence of the beet plants", explained Hervé Billet.

Today tillage and sowing are organised as follows on the Billet farms: stubble cultivation with the Catros is performed twice for all crops – once immediately after harvesting and a second time when the harvest residue and weeds have emerged. Depending on the location, a third stubble cultivation is carried out for late sown crops. When wheat is sown following a crop of sugar beet the soil is prepared just using the Centaur.

Otherwise the soil for wheat and rape is worked with the Centaur a few days before sowing; deep tillage for spring crops (beet, spring barley, beans) takes place in winter; further cultivation with the Catros is carried out only a few hours before sowing.

Deeper tillage is necessary for weed control and also to ensure that harvest residues are well mixed with the soil. It also serves to remove any compaction caused by vehicle tyres. Over the years the problem of soil compaction has, however, become less and less significant: on the one hand due to better technology (soil tillage machinery, suitable tyres) and on the other due to the great improvement in soil quality. After 17 years of plough-less tillage the stability of the soils has in fact become much better: they have become less susceptible to heavy rain and water circulation has also improved in the loamy clay soil.

In the next few years the Billet brothers plan to reduce deep tillage even further in favour of superficial soil preparation. If, however, regulations come into force requiring the soil to be cultivated also in the winter, the Billets plan to grow a catch crop before each spring crop and to adjust soil cultivation accordingly: “We must then do the deep tillage in the autumn and sow a cover crop which will be worked into the soil with the Catros in spring before sowing or we can sow a cover crop directly after stubble cultivating and then work this catch crop intensively into the soil the next spring.”

9.
Results: optimised application concepts to develop on

The end user reports show how differently and flexibly tillage and sowing are handled on the farms. Some farm managers rely completely on conservation tillage systems, others only partially. Irrespective of this and of farm structure, soil types and crop rotation, all practitioners successfully use AMAZONE machinery.

As to which system is used, above all depends on the individual farm situation. On the one hand the conservation soil tillage offers, in addition to the ecological benefit, such as improved soil structure or being less sensitive to erosion, also economical advantages! So in many areas, not only equally high but sometimes even higher yields than with conventional soil tillage with the plough are possible but also clear cost savings can be realised.

Never the less, many farms totally or at least partly still operate with the plough and many reasons speak out for this flexibility. So, above all, the growing of fusarium susceptible crops in tight crop rotations makes the use of the plough preferable. Additional benefits are the relatively safe yield, the simple removal of weeds and volunteer grains and a residue-free seed horizon without physio-sanitary risks to the following crop.

Simultaneously, further on-going development in the management of soil tillage shows the continuing fluid-

ity with an increasing interest in what is, for Europe, the still relatively new Strip Till system. As a mulch sowing system, matched to European field conditions, this strip-wise cultivation offers a huge potential. With its inherent reduced energy costs, the soil is only loosened at the targeted area around the plant and the fertiliser is applied very efficiently and accurately in that strip, where the plants can take it up directly. Thus, a Strip Till system unifies the economical objective of cost reduction alongside the environmental objectives, such as protection against erosion, elimination of compaction issues, humus formation and a reduction in CO_2 emissions. However, the wide scale introduction of Strip Till systems into tight crop rotations, orientated on achieving an economical optimum, is a challenge. Any investment in the relatively new system chains only makes sense where a high proportion of row crops within large acreage units are grown. AMAZONE will also intensively encompass the further development of the Strip Till system within the framework of the 3C concept.

On the basis of the 3C crop establishment concept, with AMAZONE machinery the optimum technology is also at your disposal for the operations of stubble cultivating, primary tillage and sowing, both for conventional and for conservation soil tillage systems. AMAZONE meets the various demands with a wide range of working widths and capacities. In addition, a large number of machines allow the multi-functional use for several operations so that even smaller size farms are able to make optimum use of the technology. All the machines are optimised regarding their robustness, operational performance, operational safety and operating comfort as well as the fuel saving potential.

At the same time AMAZONE assists its customers with a comprehensive advice; offering concrete recommendations around the operation of its machinery and systems. Amongst other material, AMAZONE provides different leaflets and brochures which you can order via your AMAZONE sales partner or download via the AMAZONE InfoPortal on the internet (www.amazone.de). In addition, the AMAZONE video portal (www.amazone.tv) provides you with a quick access to more than 250 AMAZONE films based around the different topics.

Conventional soil tillage

Conservation soil tillage

Strip Till systems

Epilogue of the editor

The central idea for this documentation of Intelligent Crop Production by AMAZONE was to bring together theory and practice. My job as a freelance agricultural journalist was to provide editorial support: to compile information from a multitude of sources and to present the concepts of the solutions found.

This would not have been possible without active support from many quarters and all the preliminary work that was needed. Many thanks therefore to the practitioners and scientists, who performed, evaluated and prepared reports on the numerous AMAZONE field trials and to the AMAZONE staff who developed the concepts for optimum deployment of the machinery. I also thank the scientists who gathered and compiled the information for the second part of this book.

Special thanks go to all the farmers who allowed us to report on their practical experience in this documentation. One fact that was confirmed over and over again during our visits to the farms was that there is no simple answer to the question of what is the most economic farming procedure. The statements made by the practitioners rather show that farming concepts will continue to develop on the basis of new insight and experience.

This is why AMAZONE too will continue to refine and expand their solutions and procedures for every aspect of the 3C crop establishment concept. As in the past, they will focus on cooperation with farming practice and science. For this reason you, the reader, is cordially invited to provide feedback: if you have any suggestions, requests or questions about 3C – the crop establishment concept, the experts from AMAZONE are at your disposal. Write to AMAZONE, for example by email to 3C@amazone.de or simply call them on: +49 (0)5405 501-0.

Yours
Franz-Peter Schollen, Coesfeld

Intelligent crop production

Part II

Soil tillage from a scientific viewpoint

PD Dr. habil. Joachim Brunotte
Thünen Institute for Agricultural Technology
(TI, formerly FAL Braunschweig)

PD Dr. habil. Claus Sommer, Braunschweig

AMAZONE

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1. Fundamentals

1.1 Maintaining soil productivity

Agriculture uses the environmental resources of soil, water and air and produces low-cost high-quality food. Therefore agriculture has a particular responsibility to nature and sustainable agricultural production is required which guarantees:

1. conservation and improvement of soil fertility,
2. safeguarding of competitiveness combined with the strengthening of rural areas
3. maintenance of the stability and functional reliability of the social systems in rural areas.

Since the Federal Soil Protection Act (BBodSchG) came into effect, preventive soil protection has been the essential principle of today's agriculture in Germany. That means: the productivity of the soils (productive function) and their natural functions (habitat and regulatory function) must be preserved, because soils are a scarce and non-renewable resource.

Tillage constitutes the essential mechanical intervention in the complex "climate-soil-plant" system. As a rule, the growing and harvesting of crops is impossible without a certain measure of tillage: favourable germination and growth conditions must be provided for drilling and planting, crop care can be performed mechanically, harvesting of tubers and root crops also involves human intervention in the soil structure. If these measures and harvesting procedures, carried out in the course of the growing season, result in an unfavourable soil structure in some areas, tillage will be necessary again for the following crop.

Hence tillage in the broadest sense is necessary to preserve soil fertility – understood as the site-specific sustained productivity. At the same time it is necessary to provide for the protection of further, indispensable soil functions (buffer and filter capacity).

In the past, mechanical weed control and the drilling equipment available primarily determined the form of tillage: to bury weeds and make a "clean start" and for trouble-free coulter passage the plough had to be used every year. For these reasons the major part (> 50 %) of the arable area in Germany is still ploughed today; however, there are large differences from region to region and in crop rotation.

Whereas plough-less methods after leaf crops (rape, sugar beet, potatoes) already reach shares of up to 90 %, depending on the region and atmospheric conditions; tillage without plough, e.g. for sugar beet in areas threatened by erosion, reaches around 75 %. Ploughless cultivation of cereals following cereals remains limited to individual farms, but covers still, around 30 % of the arable land in regions with an average rainfall and average straw yields, whereas mulch sowing methods have been limited so far mainly to regions where soil erosion and nitrate displacement constituted a

serious problem. Today they are an attractive option also to all other farms because of the lower labour costs and premium payments for ecologically sound management.

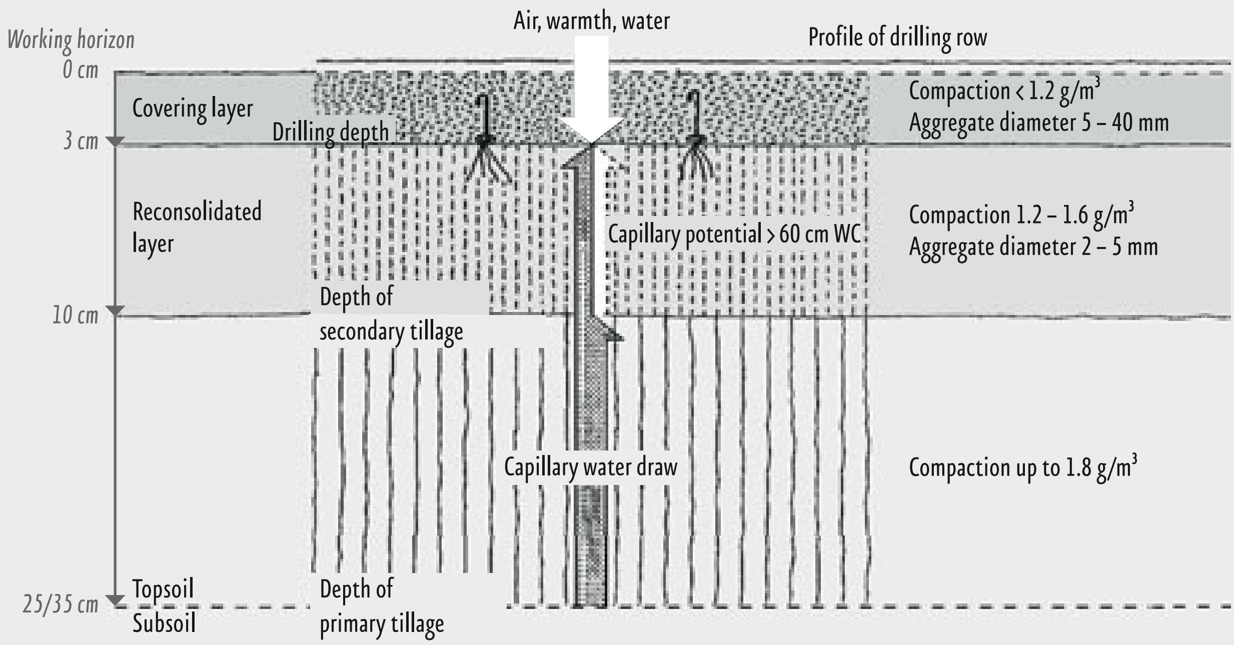
1.2 Aims of soil tillage

Today soil protection, reduction of disease potentials and cost saving are the most important demands made on arable farming. Where permitted by location, crop rotation, infection potentials and soil moisture, the plough will reduce in importance, and instead mulch sowing methods will expand. Since, in these cases, large amounts of organic residues of the preceding crop must often be incorporated into the surface, optimum lateral distribution of the straw by the combine harvester is of great importance. It influences not only the quality of straw incorporation, but also the crop emergence and the yield development of the following crop.

To provide good growth conditions one main target of tillage consists in creating a physically favourable soil structure in the topsoil with an undisturbed transition to the subsoil. The contradiction between a.) the soil as crop site and b.) the soil as "road" for machinery and transport vehicles, almost rules out the description of an "optimum" soil structure by means of quantitative data. Among the parameters which influence crop growth, soil moisture plays an important part. Particularly in cases of wet harvesting conditions where the soil can be compacted by heavy harvesting equipment, so much so, that the root growth of the following crop is impaired.

Primary tillage is intended to positively influence the air, water and temperature balance in the soil and the soil resistance. Against the background of cost saving and soil protection the extent of annual deep soil loosening must be carefully considered. Today soil loosening in heterogeneous areas, for example, can be performed site-specifically and, moreover, crop yield at the end of a growing season does not correlate to the tillage intensity.

Fig. 1: Structure of an ideal seedbed for sugar beet/maize after different tillage methods on hills threatened by erosion (according to IfL, Bonn)



Germinating seeds and crops need a loose, non-capped covering layer; the radicals need an easily accessible, water-conducting soil. The corresponding tillage requirements are shown in figure 1. Today seedbed preparation does not only involve loosening, levelling and reconsolidating; in addition, the aims regarding soil protection must be pursued by leaving organic residues on the surface or by shallow incorporation of such residues.

1.3 Side effects of plough based tillage

Tillage interferes in the complex soil system and tries to generate a positive influence on physical, chemical and biological processes for the growth of the following crop. Today the farmer can choose between ploughing and plough-less tillage systems.

Traditionally, the plough offers certain advantages. In a wet autumn e.g. it can be used to turn up dry soil which extends the time available for cultivation. Harvest residues are ploughed in and thus the risk of infection from crop borne diseases is reduced. On the other hand, however, the plough does not meet the requirements of soil protection. Despite all efforts to carry out site and crop-specific tillage, various problems become apparent.

Soil erosion problem: site (angle and length of slope) and climate (probability of erosive rainfall occurring) are responsible for the soil erosion hazard; this cannot be influenced by the farmer. In addition, however, soil erosion depends directly and indirectly on soil tillage. A ploughed field with a fine crumb structure, for example, will promote surface capping and thus soil erosion when heavy rainfall occurs. The high energy of the rain drops is transmitted to the topsoil and destroys it. (Fig. 2a and 2b). The silt produced clogs the water-conducting pores (Fig. 2c) so that rain water ends up running off on the surface (Fig. 2d).

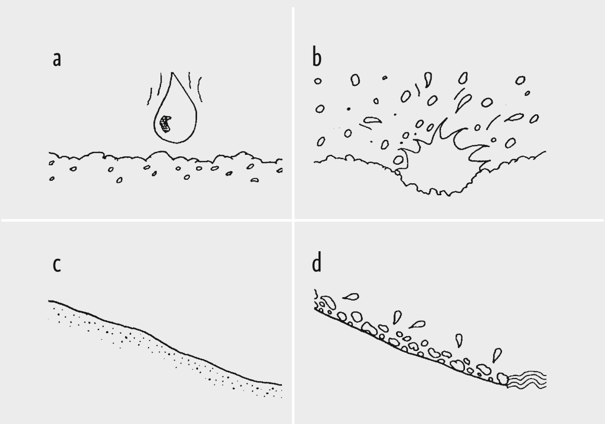
Preventive action is possible by leaving crop residue on the surface which absorbs the energy of the rain drops and thus protects the surface crumbs. Also erosion by wind can only be reduced by leaving crop residue on the surface. Crop residues can be produced by cultivating catch crops (such as a catch crop mix of openly sown phacelia, mustard, oil radish) or by leaving harvest residues on the surface.

Soil compaction problems: On the one hand, the soil is tilled to create favourable physical conditions, e.g. by loosening compacted soil. On the other hand, tillage always involves travelling on the ground and thus can cause harmful soil compaction. In addition, tractors, harvesting machines and haulage vehicles have become bigger and bigger as a result of economies of scale. Such loads cause mechanical stress on the soil which is relieved only with increasing tillage depth.

Travelling on the soil involves a particular risk after deep loosening of the soil structure. To limit any negative effects after ploughing, as a rule the packer on the plough is used for reconsolidation. Also, ploughing on land with a wider working width (i.e. more than 8 furrows) reduces the soil pressure in the top soil layer.

One fundamental approach of preventing soil compaction is based on the increase of the soil load bearing capacity. This is achieved by the use of non-inversion equipment such as a cultivator or Paraplough. After working with these implements the soil is more solid than after the plough, without impairment to any soil

Fig. 2: **Development of the erosion process (acc. to Derpsch et al., 1988)**



functions. In this way the soil is strengthened to bear high loads. This is supported by the selection of suitable carrier vehicles and the use of wide radial tyres which can be operated with low tyre inflation pressures.

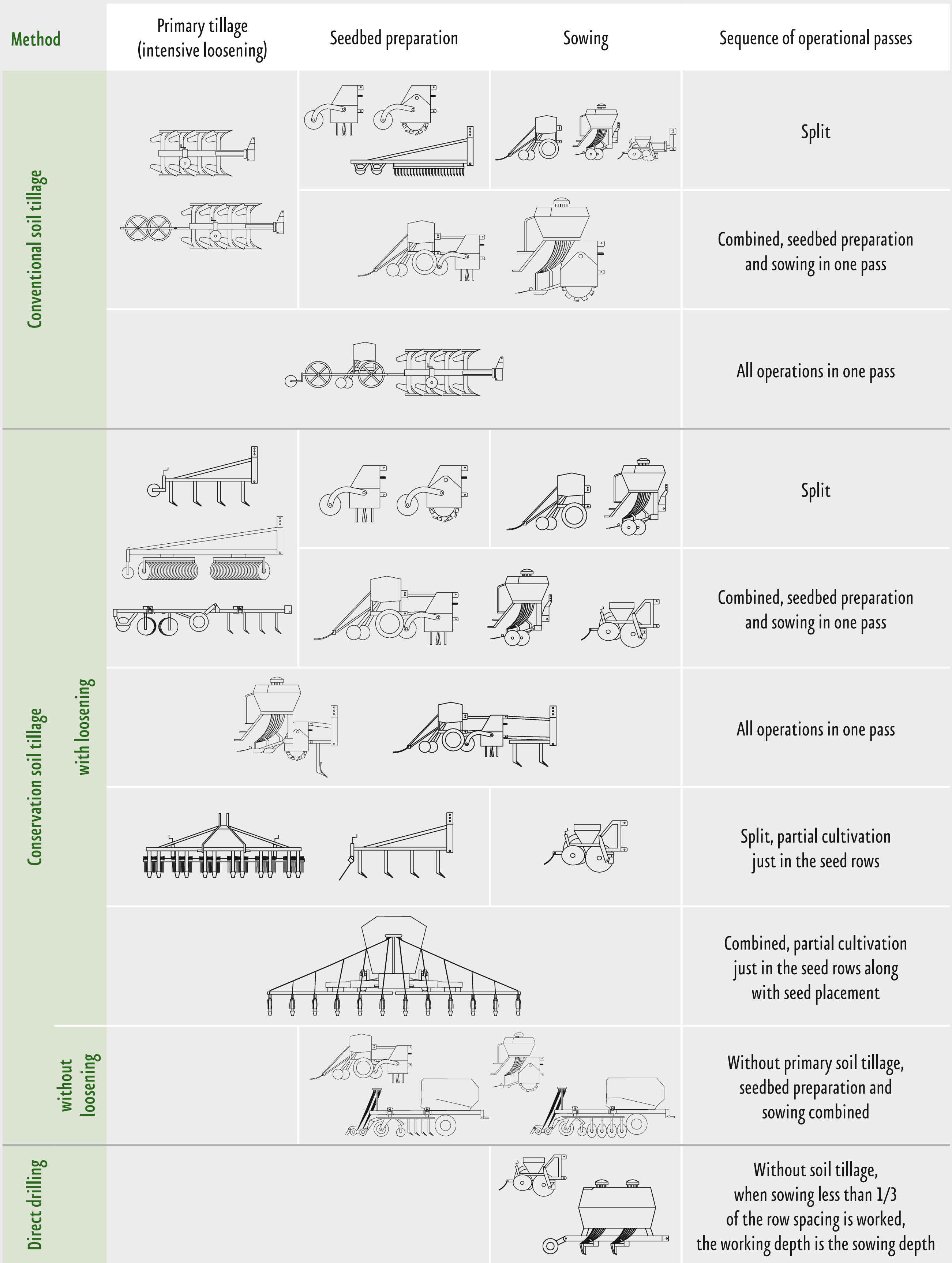
Leaching: Today 70 % of the drinking water in Germany is abstracted from groundwater so the filtering of the water is the most important regulating function of the soil. Leaching (nutrients, pesticides) from agricultural areas may impair drinking water quality. On conventionally cultivated land there is the risk of leaching due to surface runoff and soil erosion. Mulch sowing methods mitigate the increase in nutrient concentrations in water – however pesticides must not be applied before intense rain to prevent them from getting into waters via the macropore flow.

Biological activity: To preserve the natural productivity of the soil, bacteria, fungi and soil insects and worms must be able to perform their activities undisturbed. Ploughing in autumn or spring, for example, causes a serious decrease in the earthworm density. The intense shifting of soil layers by the plough, just at a time of high earthworm activity, e.g. deprives the earthworms of their food resources in straw and other organic residues.

Conclusion: Even if there are various advantages (simpler sowing techniques, mechanical weed control, lower infection potential for crop diseases on the soil surface) that speak in favour of the use of the plough, these are accompanied by the disadvantages of higher costs and the higher risks of soil erosion, surface capping and soil compaction.

Mulch sowing methods, however, allow more soil protection and cost savings at the same time. They show a way of how to solve field hygiene problems by using the latest stubble cultivation technology combined with less susceptible varieties and a less stringent crop rotation – an approach of "Integrated Crop Production".

Fig. 3: Overview of soil tillage and sowing systems (KTBL, 2013)



1.4 Tillage methods

Enhancements in crop production and agricultural engineering coupled with a change in general conditions has led to a basic discussion of the common tillage methods in recent years. This discussion was accompanied by the multiple use of terminology which often provoked overlaps and thus misunderstandings.

Scientists, consultants and agriculturists in Germany agreed on the following three definitions (KTBL, 2013) which – besides tillage intensity – takes the main objectives such as soil protection into account (Fig. 3):

Conventional soil tillage with the plough: the annual inversion of the topsoil with the plough is the essential characteristic of conventional tillage. Weeds and organic residues are buried in the soil. A loose field surface free from residues is created which permits trouble free use of conventional sowing equipment (suffolk coulters).

Non-inversion tillage (also called "conservation tillage"): the plough is not used and the residues of the previous and/or catch crop remain on the soil surface. Thus, conservation soil tillage is characterised by two principles:

1. Reduction of the usual intensity of primary tillage in respect of type, depth and frequency of the mechanical intervention: non-inversion, gentle loosening is intended to create a stable soil structure and thus serve as preventive protection against compaction.

2. Leaving crop residues near or on the soil surface: the goal is a year-round cover on a sound soil structure as preventive protection against surface capping and erosion. Here the sowing operation is defined as 'mulch sowing' because it is carried out into an existing layer of organic matter or into a mixture of mulch and soil. When the working depth is more than 10 cm, this is called mulch sowing with loosening (MSmL), when the working depth is less than 10 cm; this is called mulch sowing without loosening (MSoL).

A transition to direct sowing is offered by the newly defined "Strip Till" system where the strip-wise cultivation means that any loosening is not carried out across the full area but only partially in strips; loosening down to the maximum depth of top soil. Here organic or mineral fertiliser can also be placed in or to the side of the strip and the seed can be sown simultaneously or in a separate operational pass.

Direct drilling: is defined as cultivation without any kind of tillage since the last harvest. Seed drills with disc, tine or chisel coulters are used.

On the basis of this classification Fig. 3 shows a selection of machines for the three tillage systems. The operational passes of primary tillage, seedbed preparation and sowing reveal the trend that

- tillage intensity decreases,
- soil compaction increases,
- costs decrease.

2. Practical implementation

2.1 Starting in plough-less tillage

Basic system changes require high expenditure and involve risks. A gradual changeover to new systems of soil tillage, however, provides the possibility of gaining experience and reduces the conversion risk. In addition there is the fact that today almost all modern machinery solutions can be used universally after the plough and in plough-less tillage systems, so that step-by-step conversion to the cheaper plough-less system is possible.

For many farms, cultivation without the plough following leaf crops (rape, sugar beet, potatoes) is a sensible entrance into new cultivation systems. The higher reliance on the quality of mix of the straw and on seedbed preparation represents the cultivation of rape following cereals without the plough. If cereals are sown following cereals good straw distribution, short chop lengths and a very precise stubble working with an excellent incorporation of straw are compulsory for the successful utilisation of a system without plough. During the course of conversion in the method of soil tillage, the plough becomes an exception or is possibly omitted completely. Model farms with the relevant knowhow are meanwhile increasing in all the arable farming regions. If the plough is then selectively utilised again in the crop rotation, e. g. for cereals after cereals or cereals after silage maize, specific positive effects, such as the improved carrying capacity, the increase of the earthworm activity and the protection against capping on the surface are reduced again for a short period, however they recover relatively quickly when returning to mulch sowing.

2.2 Basic principles of straw distribution and stubble cultivation

2.2.1 Straw distribution requirements

Increasing straw yields (up to 12 t/ha), plus wider working widths of combine harvester headers (up to 12 m) as well as harvesting on slopes often hamper the ability to achieve an even straw distribution. In extreme cases it may be that there is too much straw in the middle behind the combine harvester (up to 20 t/ha), which is not present in the outer areas of the combine harvester width. This is a problem for both mulch sowing and for the plough, because in the areas with too much straw the crop emergence and root development of the following crop are impaired.

Usually, combine harvester manufacturers supply the potential for precise straw distribution – what is important, however, is the correct adjustment to be made by the driver. Often it is sufficient to reduce the straw inlet holes to the chopper in the centre and to enlarge those at the edge, or to reduce the speed of the chopper. One alternative can be, to install knives in the outer range of the chopper to achieve a higher wind speed or to attach an additional centrifugal spreader on working widths of more than 8 m. When making any new investment, one should select, instead of a simple chaff spreader, such systems where the chaff is distributed out to the sides via the chopper so that it is better distributed together with the material flow of the straw.

When leaving a long stubble, straw distribution does not constitute such a problem, since the straw remains where it has grown. To ensure, however, proper stubble cultivation and sowing for the following crop, the long stubble must subsequently be chopped by a mulch mower. As a result the savings achieved by leaving a longer stubble are compensated for by the operation costs of the mulch mower. Nevertheless, harvesting with long stubble can make sense in critical situations (problem of number of cases) to start harvesting two hours earlier in the morning, or to work two hours longer at night. Appropriate logistics are required also to support these additional harvesting hours.

2.2.2 Straw incorporation requirements

Once the straw has been evenly distributed, the time interval available before the following crop and the selected tillage system (with/without plough) determine the further strategy. If cereals are followed by a winter crop (rape/cereals), accelerated straw decomposition is important. If a spring crop follows (sugar beet, maize, potatoes, peas, cereals), decelerated straw decomposition must be aimed at for the purpose of soil protection (see Fig. 4).

Generally the rotting speed is determined by:
- the degree of straw splitting (counter blade and serrated knives on combine harvester chopper can increase the degree of straw splitting),
- the straw length (10 cm long straw takes more time to rot than 3 cm long straw) and
- the incorporation depth (straw left on the soil surface takes longer to rot and provides the best protection against soil moisture loss, see Fig. 5).

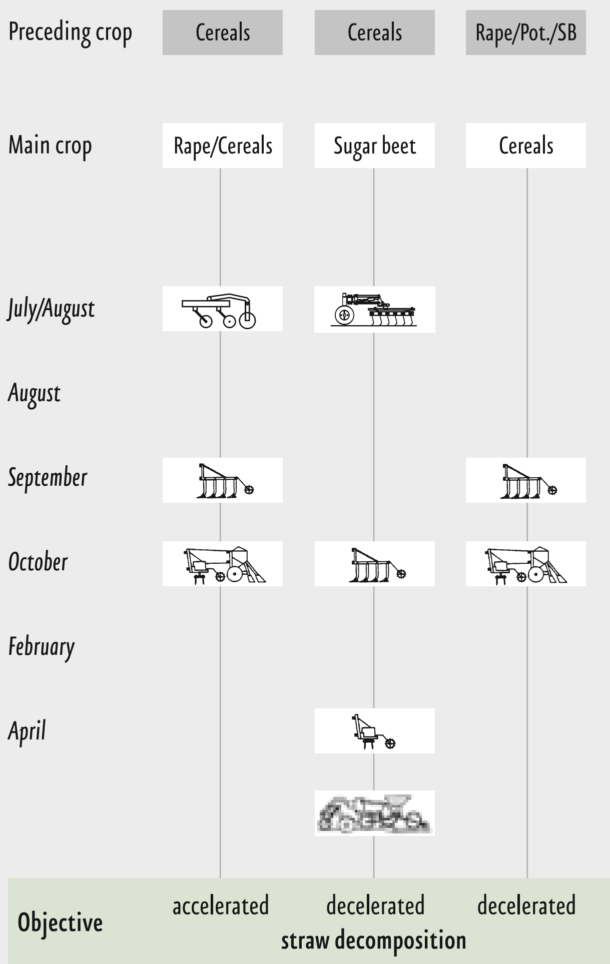


Fig. 4: Operational passes of conservation tillage in case of different crop rotation

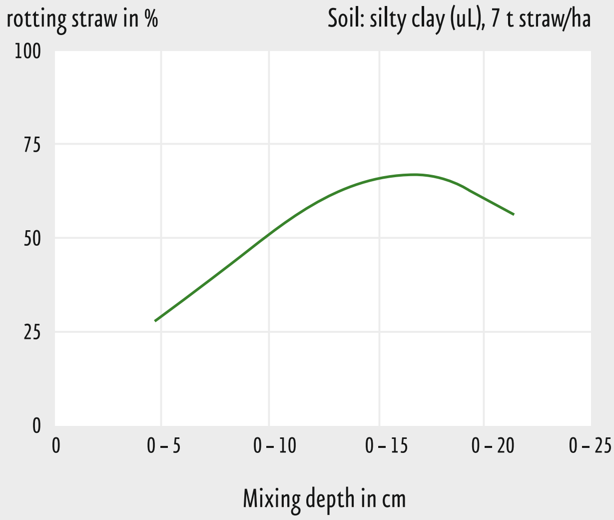


Fig. 5: Straw rotting in relation to mixing depth (according to Köller)

Fig. 6: Placement of straw and seeds in case of different tillage systems and climates

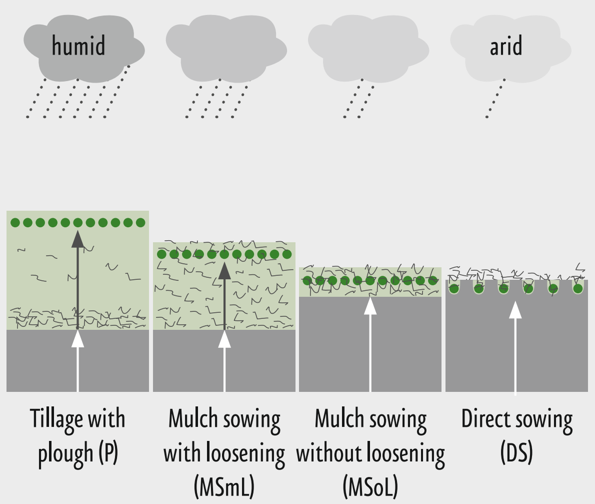
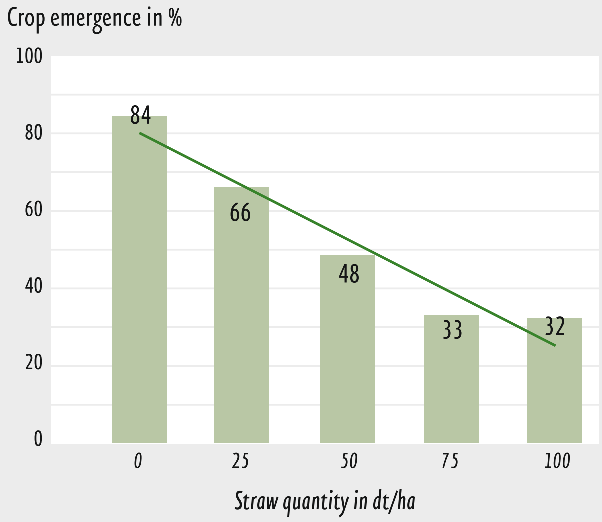


Fig. 7: Crop emergence in relation to straw quantity (according to H. Voßhenrich, 1997)



In case of short-term crop rotation in autumn, three possible strategies of straw processing are available within the plough-less system (see Fig. 6):

1. Separation of straw and seeds: This is done by direct drilling with ripping shares such as chisel, tine or goose-foot shares. The straw remains on the soil surface, at the same time the seeds are placed into contact with the capillary water – optimum evaporation protection exists. Usually chemical straw decomposition products do not influence germination and crop emergence.

   The situation is similar in cases of sowing after shallow tillage. Here, however, the seeds are covered by a mixture of straw and soil; in wet conditions there is the risk of soil capping preventing plants from rooting properly.

2. Incorporation of straw near to the surface: To prevent any physical-mechanical damage during seed placement, emergence and early development in case of mulch sowing without loosening (MSoL) (see Fig. 7), the straw should be chopped to less than 1 cm. Technically, however, this is very complicated and expensive. At the present state of technology mulch sowing without loosening (MSoL) can only be recommended if straw yields are less than 5 t/ha or for spring crops.

3. Thinning effect: At sites with high straw yields (up to 12 t/ha) and in case of short time spans to the cultivation of the following crop, mulch sowing with loosening (MSmL) is best suited. At the present state of technology concerning straw processing and distribution, only this method allows the farmer to minimise physical damage by the straw via a "thinning effect". The soils must be tilled deeper for optimum straw incorporation, although the soil structure does not require loosening. The following rule of thumb applies: an incorporation depth of 1 cm (moist conditions) to 2 cm (dry conditions) per 1 t yield/ha should be aimed at – only this will accelerate straw decomposition.

2.2.3 Quality of straw incorporation with different equipment

As a result of the extensive demands made on straw management today it is not enough just to "make the field black" by stubble cultivation. In fact, "precision stubble management" is required.

Against this background, incorporation quality and energy demand of various stubble cultivation equipment have been tested in field conditions. The widely used wing-tine cultivator (3 m working width, 43 cm tine spacing, concave discs, and cage roller) served as reference for shallow and deep tillage. Alternatively, a mounted compact disc harrow (5 m working width, wedge ring roller) was used for shallow tillage, followed by a 4-stagger cultivator (3 m working width, 23 cm tine spacing, inversion shares, star tiller) for deep tillage. The 3rd variant was a semi-mounted tine & disc combination cultivator (3 m working width, 20 cm tine spacing, inversion shares, wedge ring roller) for shallow and deep tillage. Since crumbling and mixing requires high travelling speeds, tractors with a tractive power of 120 kW (160 HP) were used.

For the evaluation after tillage several profile pits were dug; subsequently straw coverage in the profile wall and on the surface is rated by means of a grid. Fig. 8 shows the quality of shallow straw incorporation by means of the straw distribution in the profile wall (Fig. 8.2). It is particularly remarkable that – despite its flat adjustment – the wing-tine cultivator works 10 to 15 cm deep which is due to the coulter tips. The topsoil profile shows zones with high and zones with low straw concentrations, i.e. a heterogeneous picture of straw incorporation. The compact disc harrow on the other hand is able to work extremely shallowly which leads to a high emergence of volunteer grain. At the same time it leaves most of the straw on the surface achieving coverage of 78 %.

Also the tine & disc combination cultivator achieves better shallow tillage compared with the wing-tine cultivator, which is due to the larger number of tines and the narrow-cutting inversion shares. More tines and the following twin-row arrangement of concave discs result in a very intensive straw mixing. In connection with reconsolidation by means of the wedge ring roller this machine achieves the highest emergence of volunteer grains (Fig. 9).

In case of all variants the first pass had to be carried out slightly deeper because of combine harvester tracks. The 2nd deeper pass (at half topsoil depth) produced the “straw thinning effect” and constituted the primary tillage for the mulch sowing system (Fig. 8.2, 8.3).

The straw decomposition rates from the 1st pass (Fig. 8.2) to the 2nd pass (Fig. 8.3) are clearly visible. In instances of all system variants, the degree of straw coverage in the profile wall decreases (Fig. 8.2: more black and dark-brown squares; Fig. 8.3: more orange and yellow squares).

To achieve high straw decomposition rates, the straw residues should be repositioned in the soil from time to time to create new decomposition conditions for the microorganisms. Consequently, one single intensive stubble working pass is not as effective as two passes at an interval and at different working depths, which are carried out with machinery working less intensively. The decisive point is that the straw and soil are remixed once again.

Fig. 8: Incorporation quality of wheat straw (shallow and deep) with different implements (Adenstedt, IT 3 V 68, 2002, FAL/IBB, Voßhenrich, Ortmeier, Brunotte)

Fig. 8.1:
Straw/stubble distribution
Rating of straw/harvest residue incorporation
Grid 4.0 x 4.0 cm

Fig. 8.2:
Straw/stubble distribution
Incorporation with different implements: shallow incorporation

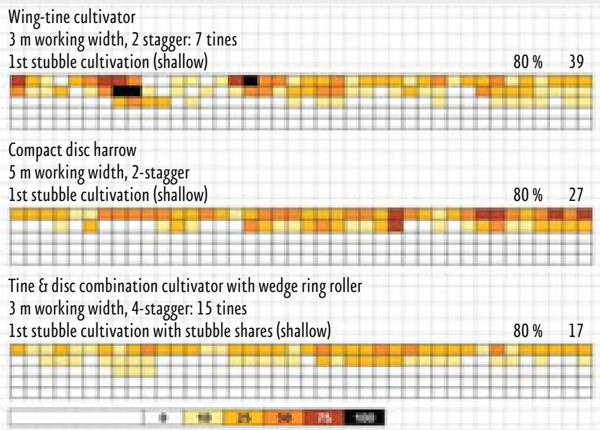


Fig. 8.3:
Stubble distribution
Incorporation with different implements: deep incorporation

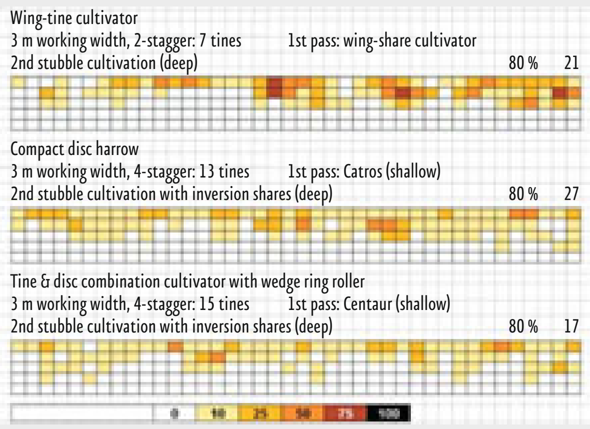
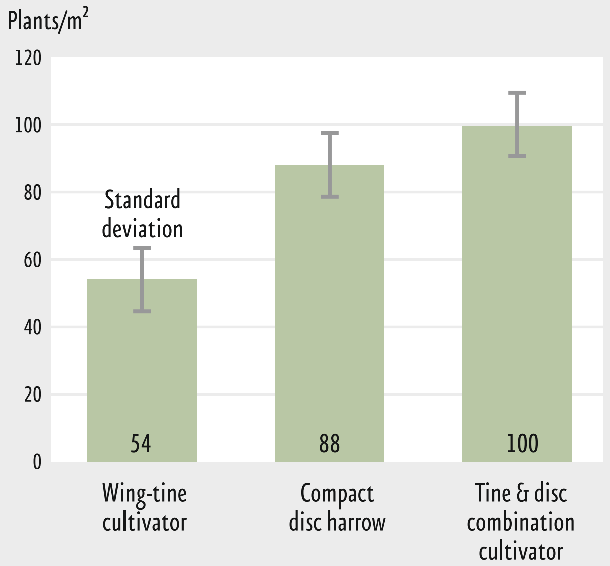


Fig. 9: Emergence of volunteer grains after different shallow stubble cultivations



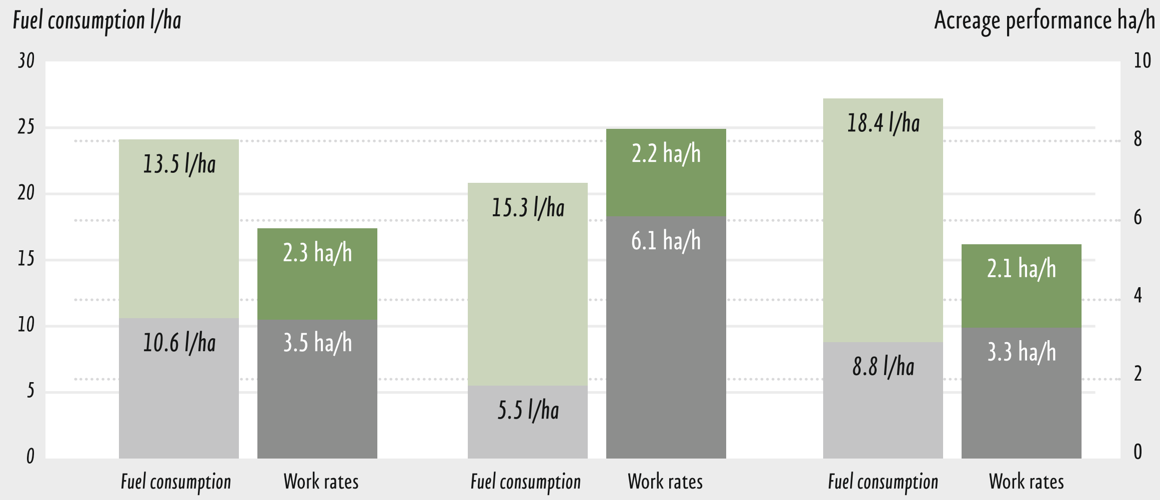
To achieve a high emergence of volunteer grains and weed seeds it is important to combine intensive straw incorporation with systematic reconsolidation. As shown by Fig. 9, the tine & disc combination cultivator achieves the best results, followed by the compact disc harrow which leaves a little bit more straw in the seed placement area. The result of the wing-tine cultivator differs widely because it works too deeply and leaves a lot to be desired in respect of crumbling and reconsolidation. Apart from this it should be mentioned that particularly in case of moist soil conditions narrow-cutting shares are preferable because wing shares may easily cause smearing of the soil.

2.2.4 Fuel consumption and work rates of the different techniques

During the 1st shallow operational pass the fuel consumption of the wing-tine cultivator is the highest, because the tines penetrate the soil deeply in case of full-area tillage (see Fig. 10). This is, however, to the benefit of the machine during the 2nd pass in which it reaches the lowest fuel consumption value of 13.5 l/ha only compared with the other cultivators.

The compact disc harrow achieves a very favourable fuel consumption value even at 5 m working width, and with 6.1 ha/h the highest work rates. It is followed by the 4 stagger cultivator with a fuel consumption of 15.3 l/ha and work rates of 2.2 ha/h in case of deep tillage; this value is about the same as those for the other cultivators. The tine & disc combination cultivator achieves a very even straw incorporation which is nearly equal to a secondary tillage in case of mulch sow-

Fig. 10: Fuel consumption and output performance in instances of shallow and deep stubble cultivation with different implements



2nd stubble cultivation	Wing-tine cultivator – 3 m	4-stagger cultivator/ inversion shares – 3 m	Tine & disc combination cultivator/ inversion shares – 3 m
1st stubble cultivation	Wing-tine cultivator – 3 m	Compact disc harrow – 5 m	Tine & disc combination cultivator/ inversion shares – 3 m

ing; this, however, with a higher demand of tractive force and an average work rate comparable to that of the wing-share cultivator.

2.2.5 Recommendations for straw management

1. Transverse distribution of straw is often insufficient where combine harvesters with a working width of more than 6 m are used. The combine harvester driver should optimise guide plates and fan speed accordingly. One field method of checking straw distribution is to rake the straw together in one swath with a coarse rake transversely to the travelling direction of the combine harvester and over three working widths. The evenness of the transverse swath will indicate the quality of transverse distribution. When buying a new combine harvester, one should specify equipment which also distributes the chaff via the chopper.

2. A straw rake that can redistribute the straw to a certain extent, causes, however, decelerated straw decomposition, because the straw is distributed only on the surface.

3. In case of straw incorporation, either straw and seeds must be separated (direct sowing), or a straw thinning effect in the topsoil must be aimed at – in particular in case of high straw yields.

4. A universal machine for stubble cultivation and primary tillage attached to the tractor as trailed machine is not available up to today. As far as the functions are concerned the tine & disc combination cultivators with exchangeable share systems meet these requirements to a large extent; but unfortunately the working width cannot be adjusted to the working depth to make full use of the tractor power during both working passes. That is why it is better to use special machinery with optimum working widths for each pass, instead of a universal machine for all passes.

5. Mounted special machines with different working widths, e.g. a compact disc harrow (5 m) followed by a 3 or 4 stagger cultivator (3 m), are suited best for meeting the requirements of stubble cultivation and primary tillage with a tractor power of 180 HP.

6. Target-orientated stubble cultivation plays an essential part in integrated tillage. By even straw incorporation in the soil, the goals of soil protection can be reached and, on the other hand, the infection potential for crop diseases minimised.

2.3 Seedbed preparation and drilling after conventional tillage

Conventional tillage with the plough provides a completely cleared field. There are two approaches to minimise the undesired side effects such as soil erosion and soil compaction:

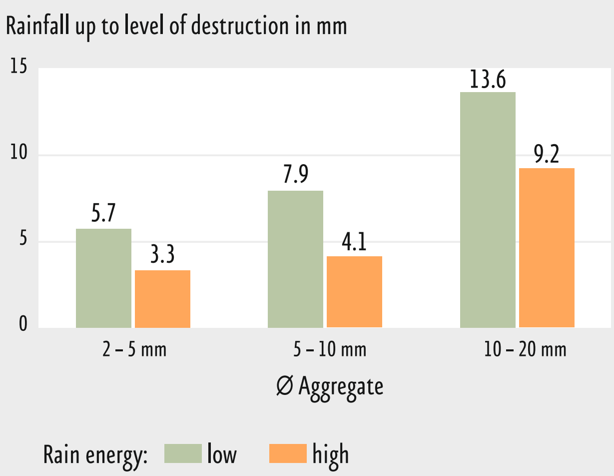
1.) If no harvest residues lie on the surface the effect of surface capping causing erosion can be reduced – to a limited extent – by coarse soil aggregates (see Fig. 11).

The figure shows that in instances of heavy rain only 3.3 mm of rainfall is required to destabilise aggregates of 2 to 5 mm, to destroy aggregates of 10 to 20 mm, 9.2 mm of rain is required.

At the same time we know that a rough seedbed hampers rainwater runoff more than a fine seedbed (see Fig. 12). On the other hand, the aggregates in the seedbed must show a certain degree of fineness (i.e. be smaller than the respective seed diameter) to provide the supply of moisture for germination via an optimum soil-seed contact.

To maintain the big soil aggregate on the surface and the finer particles in the seed horizon, machinery and tine speeds have to be selected carefully. In this context it must be ensured that the tine speed of powered rotary harrows and cultivators can be reduced via gears on the machine and/or via lower engine or PTO speeds. As a rule a spring-tine harrow with seed drill will do on sand and loamy sand. Clayey loam and clay sites require the use of rotary harrow and/or rotary cultivator (4 to 6 m/s tine speed at 5 km/h travelling speed, i.e. 250 to 290 rotor revs/min.). Higher travelling speeds require higher rotor speeds.

Fig. 11: **Amount of rain water (mm) required for aggregate (loam) destruction dependent on the precipitation energy (according to Czeratzki, 1966)**



In view of the goal of optimum crumb distribution (coarse on the surface, fine in the seed horizon underneath) the "on-grip" tines of the rotary cultivator have the following effects:

- Coarse aggregates are conveyed to the surface, small ones run down to the seed horizon (see Fig. 13). By placing the seed in the area of the fine soil a good seed-soil contact is achieved ("demixing effect"). Trailing tines, however, e.g. of rotary harrows, press the bigger soil aggregates down and leave most of the fine soil on the surface.
- "On-grip" tines pull themselves into work particularly in firm conditions. In wet conditions, however, it may happen that they pull moist clods to the soil surface.
- The power requirement at the PTO shaft is about the same for "on-grip" tines or a little bit lower than for trailing tines (Fig. 13).

2.) Another approach to reduce the undesired side effects of ploughing is by reconsolidation. The soil is reconsolidated by a packer on the plough and a packer roller attached to the tillage implement which reduces the negative effects of excessive loosening. As packers on the soil tillage implement, cage, tooth packer and wedge ring rollers along with other open, bar type rollers are available. Cage rollers and tooth packer rollers act on the entire surface covered by their working width. Whereas the cage roller mainly crumbles the soil and ensures depth control of the implement, the tooth packer roller also reconsolidates the soil.

The wedge ring or knife profile rollers, however, due to their undulating design carry out two opposing functions:

A. They reconsolidate the soil in strips where subsequently the coulters are running in a pre-consolidated zone with an even placement depth (see Fig. 14). Due to the reconsolidated strips the sowing is well provided with capillary water – even under arid conditions.

B. In the space between the reconsolidated strips bigger soil aggregates are left which reduce surface capping. In addition there is a loose soil layer which results in an increase in water infiltration (2.5 times higher

Fig. 12: Surface runoff for different levels of seedbed coarseness (according to Helming, 1992)

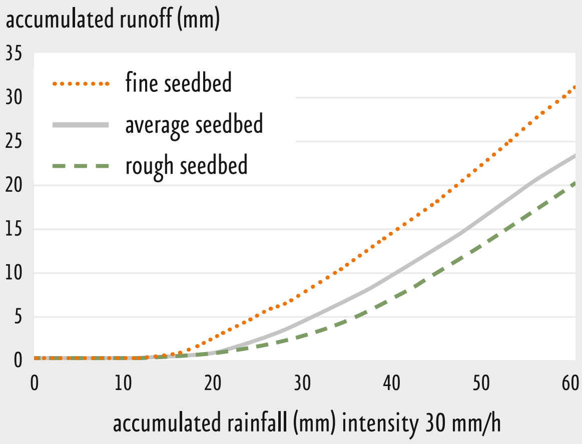
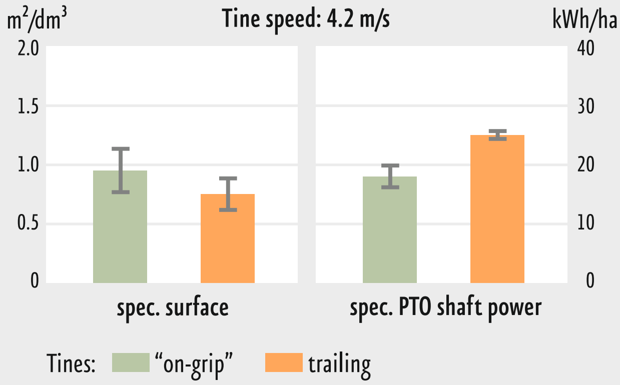


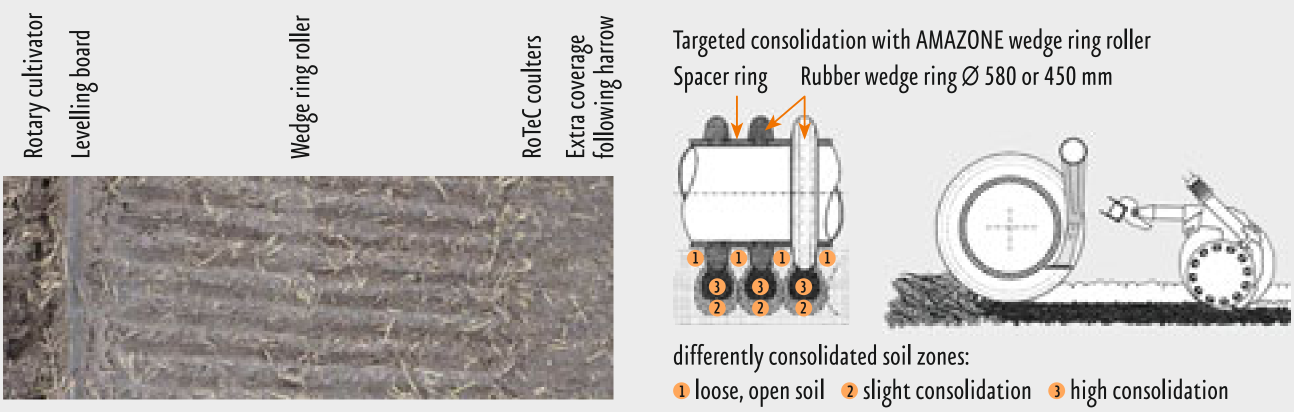
Fig. 13: Surface of aggregates (measure for coarseness) and power requirements of trailing and "on-grip" tines on the rotary cultivator (example) (according to Herberg, 1988)



than in the reconsolidated area). Thus even large amounts of rainwater can drain away in the unrolled, loose areas. But be careful: on silty soils, the tine speed of any PTO driven harrow should be reduced by selectable speed gearboxes or engine revs because they are renowned for aggregates which are heavily prone to capping. After drilling the coarser aggregates from the unrolled areas are distributed over the entire field by means of a special harrow (Exact following harrow) (see Fig. 14).

Reconsolidation in strips which combines high plant emergence with a high water infiltration capacity is called **"targeted heterogeneity".** It is based on the finding that under arid conditions the soil should be more compact than under moist conditions. Since one cannot foresee the weather conditions of the next vegetation period at the time of cultivation in autumn or spring, tillage or reconsolidation of the soil in strips – alternating compacted and loose or coarse and fine – offers the crop the chance to choose for itself the conditions that are better for it in each case. The new system of working in strips (i.e. Strip Till) additionally integrates the primary soil tillage and the fertiliser application in one pass.

Fig. 14: Working sequence of a combination of rotary cultivator, wedge ring roller and RoTeC coulters



2.4 Effects of conservation tillage

In addition to the yield capability, other important functions of the soil require promotion and protection, such as, for example, the water filtration and storage capacity. Conservation tillage constitutes a conception which aims at the reduction of tillage costs and simultaneously in more soil protection. In the interest of the farmer and according to the soil protection act "good professional practice" should make provisions against detrimental soil changes. That means

- tillage must be adapted to suit the local conditions,
- soil erosion, soil compaction and elemental losses must be avoided,
- soil structure, humus content and biological activity must be promoted.

One key to reaching these goals is the reduction of tillage intensity (deep loosening does not automatically mean intensive tillage, if e.g. narrow chisel shares across the full area or in strips are used). This applies to both, primary tillage and seedbed preparation.

Whereas gentle loosening aims at cost saving and better traffic carrying ability, mulch sowing (see table 1), (both across the full area or partially) with or without seedbed preparation is the only possibility for the effective prevention of capping and soil erosion by wind or water (see Fig. 16).

2.4.1 Mulch sowing reduces surface capping and soil erosion

By "mulch" it is understood that residues will remain on the soil surface. The soil erosion hazard is particularly high in cases of crops like sugar beet, maize and potatoes which are grown in wide rows. These spring crops can be preceded by a catch crop so that residues from the catch crop and/or from the preceding crop are available. If, however, cereals are grown after cereals or rape, only the residues from the preceding crop can be used as mulch.

Generally one can say that the effect of preventive protection against surface runoff and soil erosion increases with the degree of surface coverage by organic residues (see Fig. 15). The stems protect the soil aggregates against the direct influence of wind and water. This prevents surface capping; infiltration via the pores is maintained and thus soil erosion reduced. This applies accordingly to wind erosion.

Using the example of maize, figure 17 shows how site-specific tillage and different degrees of coverage (BDG) as protection against surface capping and erosion can be reached by a systematic use of machinery.

In addition, the figure shows that different tillage methods and the growing of catch crops lead to different degrees of coverage. For reasons of clarity, the

Fig. 15: The higher the coverage rate, the larger the protection against surface runoff and erosion (according to Roth et al., 1990)

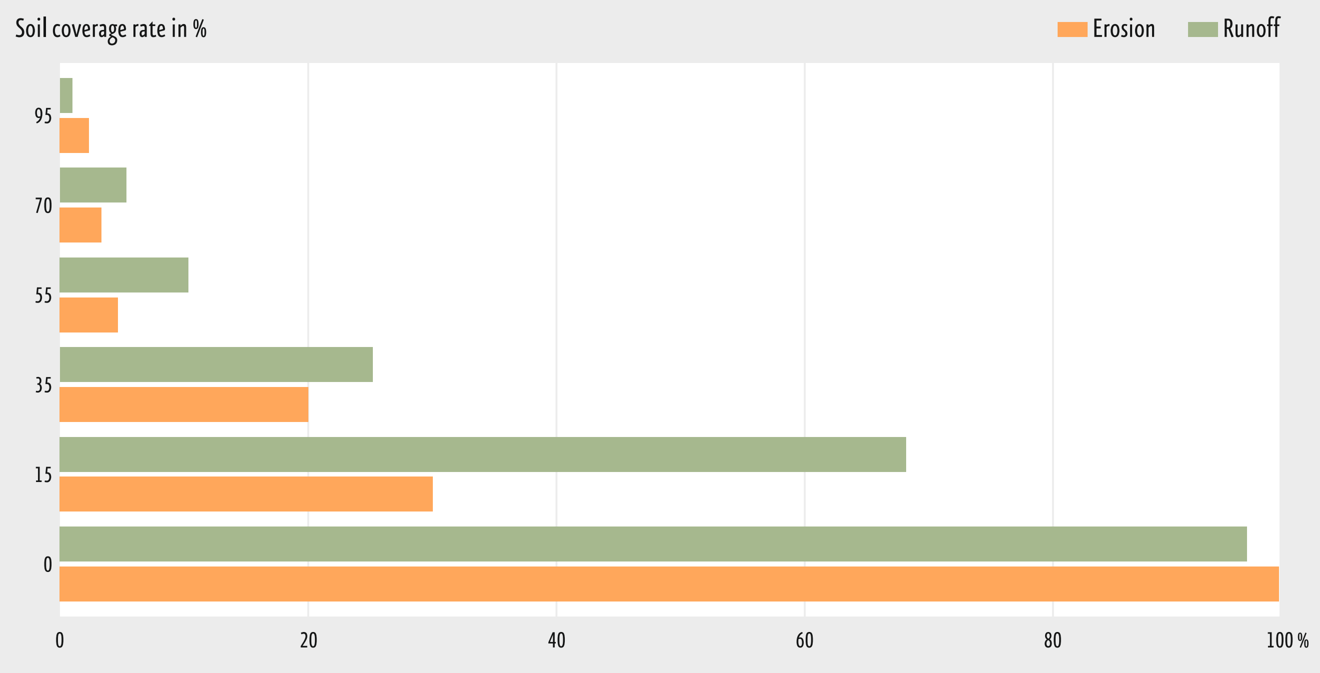


Table 1: Definition of mulch sowing with seedbed preparation and of mulch sowing without seedbed preparation

Scope	Mulch sowing		
Designation	with seedbed preparation		without seedbed preparation
Definition	residues of the preceding and/or catch crop shallowly incorporated over the full area	residues of the preceding and/or catch crop incorporated shallowly in strips	left with residues of the preceding and/or catch crop on the soil surface
Objective	soil stability, soil coverage prevention of capping and erosion cost saving		
Drilling equipment	conventional equipment and enhancements (roll disc coulters, seed coulter rail etc.)		conventional equipment (disc, chisel, goose foot coulters) after mulching and/or shredding

Fig. 16: The problem of soil erosion and approaches to a solution (according to Sommer, 1997)

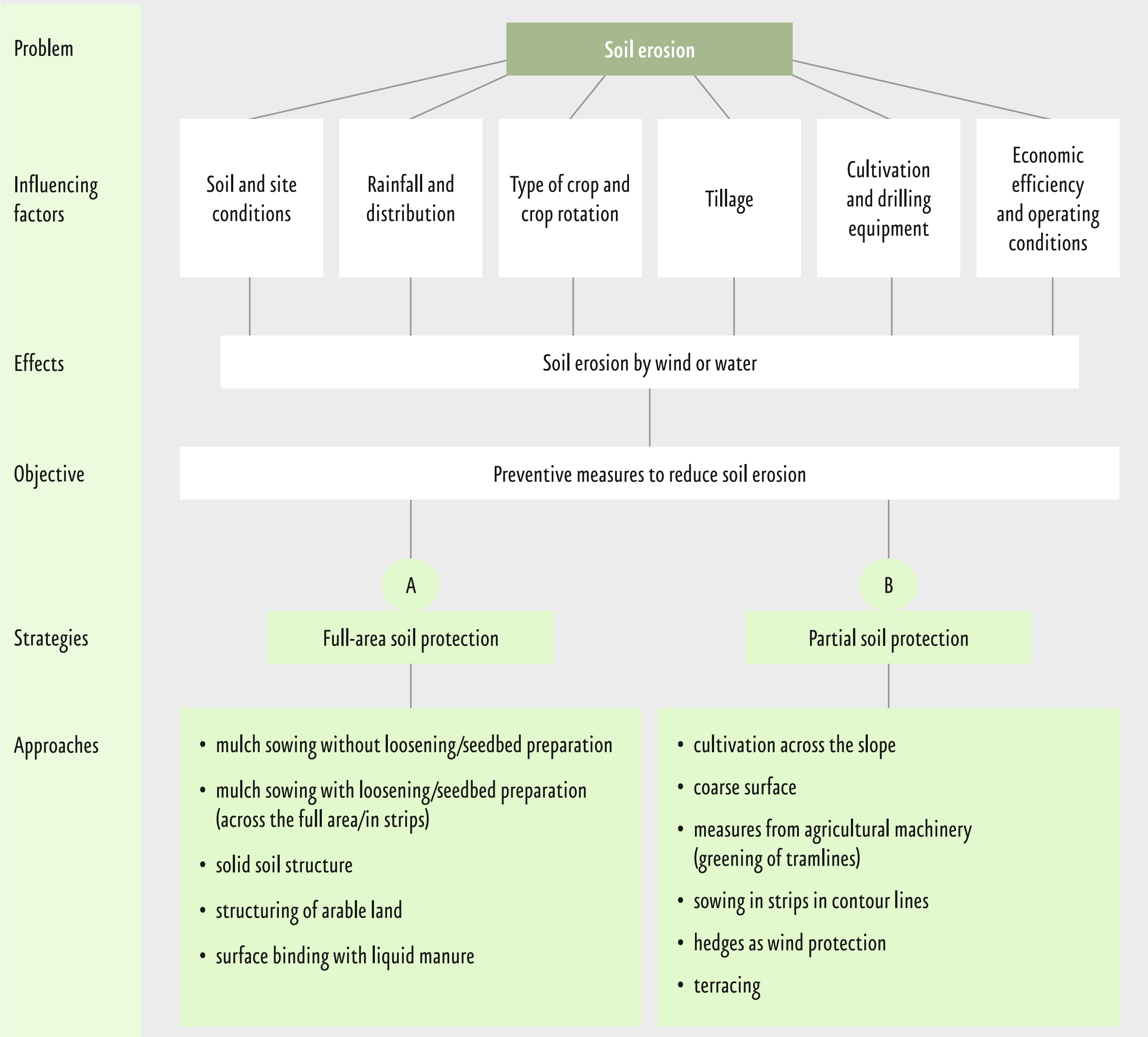
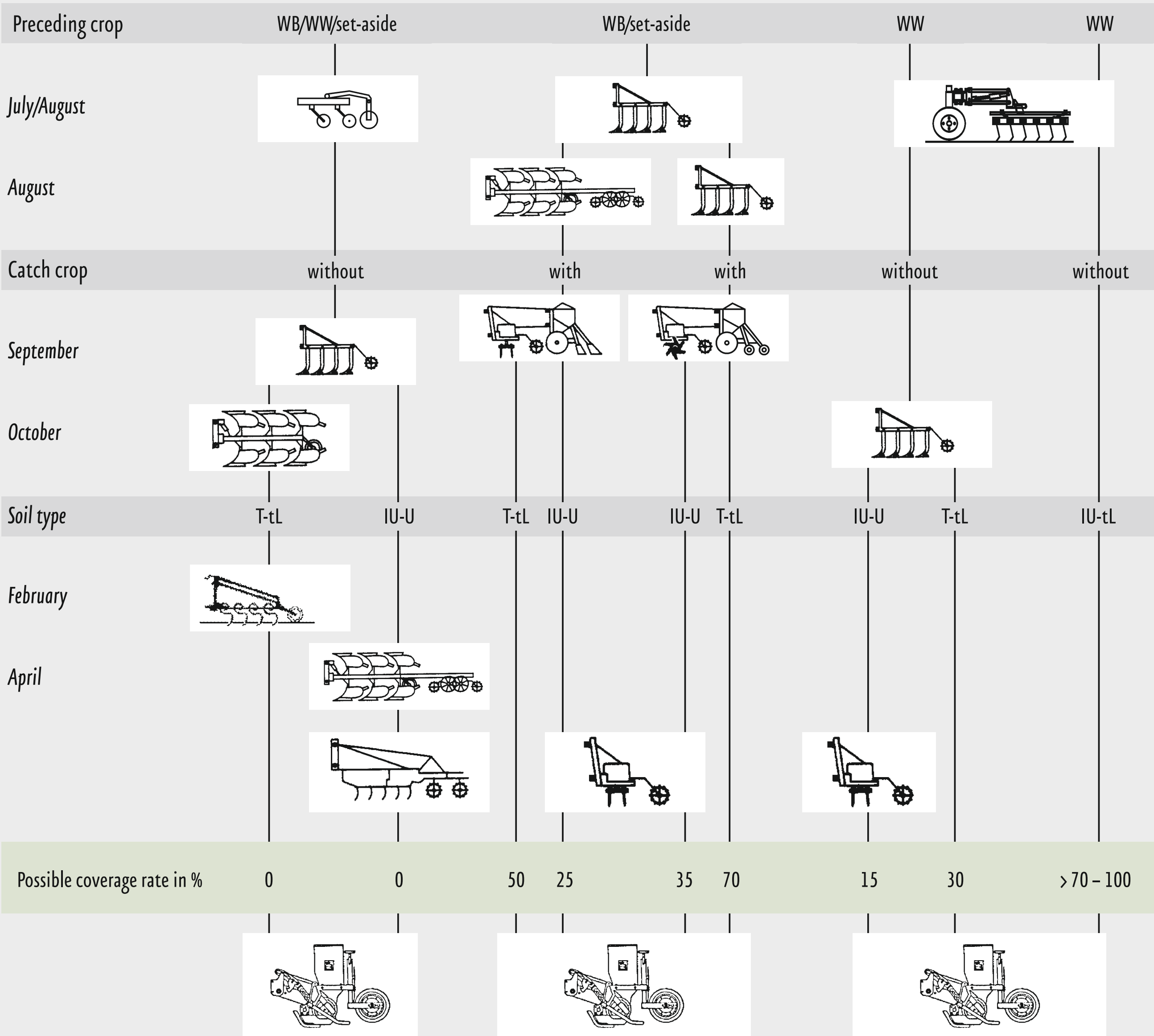


Fig. 17: **Implements used for conventional and conservation tillage for maize**



Problem	Conventional sowing with seedbed preparation	Conventional sowing without seedbed preparation	Mulch sowing without seedbed preparation	Mulch sowing with seedbed preparation	Mulch sowing without seedbed preparation	Mulch sowing with seedbed preparation	Mulch sowing without seedbed preparation	Direct sowing
Surface capping	–	–	xx	x	xx	o	x	xx
Soil erosion	o	–	xx	x	xx	o	x	xx
Soil compaction	x	–	x	x	xx	x	xx	xx
Nitrate leaching	–	–	xx	xx	xx	o	o	x
Costs	x	o	o	–	x	x	xx	xx

Problem solution: xx very good x good o satisfactory – unsatisfactory

Soil types: L, l = loam T, t = clay U = silt; cereal types: WB = Winter Barley, WW = Winter Wheat operation in strips is not shown in Illustration 17. The worked (15 – 30 %) and unworked strips (50 – 70 %) show very different degrees of surface coverage.

If phacelia is grown in clay soils, preceded by winter barley and after the plough – as is often done in practice – and then no seedbed preparation is performed in spring, 50 % coverage can be reached with the residues of the catch crop.

In the case of mustard which can also be grown without ploughing, one should use the rotary cultivator after stubble cultivation instead of a rotary harrow, since its “on-grip” tines convey fresh soil to the surface and thus enable good straw mixing.

If winter barley or winter rye is grown before maize, then often the sowing of a catch crop has to be omitted, since it cannot sufficiently mature in the autumn. Instead, the straw residues of the preceding crop must be used as surface protection. In this case the straw management must be completely changed: in October only one pass with the cultivator should be carried out at the depth necessary for this location.

On the basis of straw mulch, an average coverage of 30 % at least can be reached (Fig. 17), if only one stubble cultivation pass is performed and the rotary cultivator (tine speed 4.5 m/s) is used only once. Due to the “on-grip” tines swath formation by straw and/or catch crop residues does not necessarily occur even in cases of high residue volumes. This is more likely to happen when a rotary harrow with trailing tines is used, because the organic material is turned into the soil passing under the tines and leaves the tines of the implement always at the same point. In case of dry soil conditions the combination of rotary cultivator + wedge ring roller + precision single seeder can be used after conventional and conservation primary tillage.

In the instance of any damaging compaction, e.g. following a harvest under moist conditions, it makes sense to carry out an additional loosening in front of the rotary cultivator. After this mechanical loosening then a catch crop (catch crop mixture/fodder radish) with its roots can provide the biological stabilisation without having to travel on the field a second time for sowing. Coverage rates of at least 70 % can be reached with straw and catch crop residues.

Using a deep loosener first also improves the incorporation quality from the rotary cultivator. The soil slices rising at the soil guide plates fall onto the loose straw and are mixed with it (see Fig. 18). Nevertheless the straw thinning effect (at 8 t/ha) in the topsoil is not sufficient – as field emergence results of rape on Fehmarn have shown. An additional preceding pass with the heavy-duty cultivator to a depth of 20 cm made the plant emergence rise by 20 % (see Fig. 19).

If conservation tillage with deep loosening is performed, the topsoil must be reconsolidated by means of the packer roller. The wedge ring roller is better suited for this purpose than the tooth packer roller, since the latter pulls the straw-soil mixture up again by the teeth penetrating the soil and thus reduces reconsolidation in the seed placement zone.

Tests have shown that straw residues in the seed horizon and on the surface also influence coulter movement

Fig. 18: **Deep loosener, rotary cultivator and wedge ring roller during stubble cultivation**

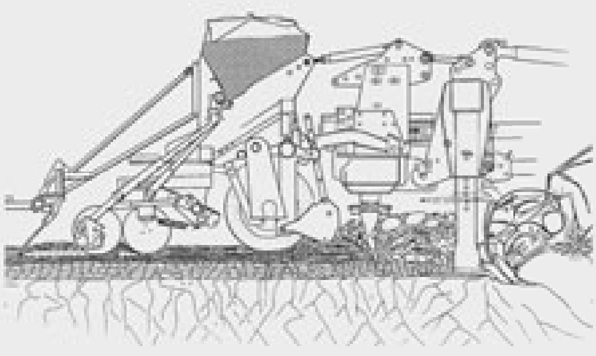


Fig. 19: **Crop emergence in cases of conservation tillage, with and without a heavy-duty cultivator (according to Voßhenrich, 1996)**

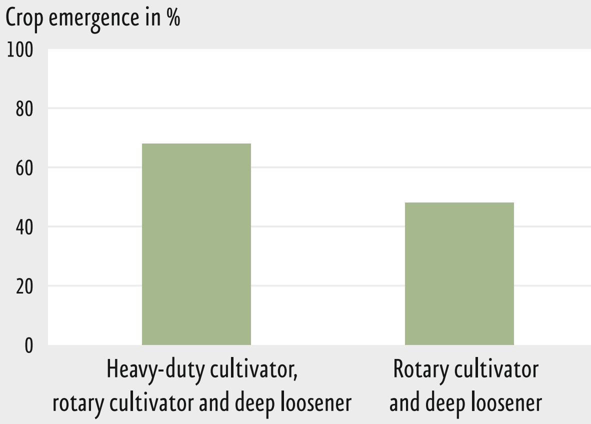


Fig. 20: Placement depths for wheat seeds when using roll disc coulters, after different tillage processes

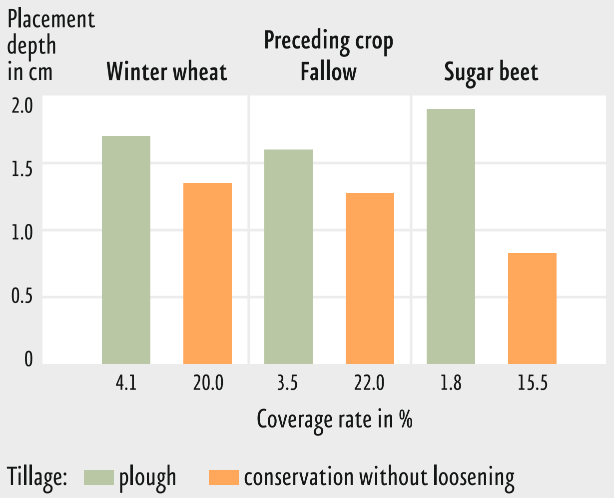
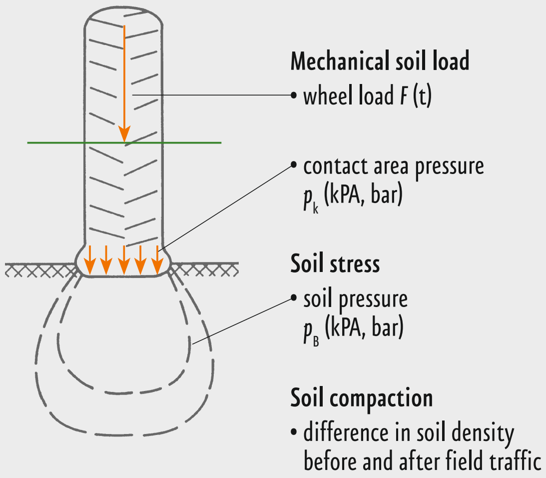


Fig. 21: Load, stress and compaction of the soil (according to Sommer, 1997)



of the seed drill. The disc coulters of an AMAZONE seed drill are mounted at an angle of 7°. The selected angle constitutes a compromise between intended straw removal to improve the seed-soil contact and the desired soil transport at high travelling speeds. An inclined coulter tends less to roll over the straw residues than a coulter or a double disc coulter running straight in the travelling direction. Despite its inclination the placement depth of a disc coulter in instances of mulch sowing with a high level of organic residual matter is lower than after conventional tillage with the plough (see Fig. 20).

The lower placement depth must not necessarily result in a lower plant emergence. It may, however, lead to the exposure of roots when the soil is thawing, which in turn may result in crop losses if UAN solutions are used in conjunction with herbicides. For these reasons disc coulters must be adjusted slightly deeper or operated at a higher pressure for mulch sowing.

2.4.2 Gentle soil loosening reduces harmful soil compaction

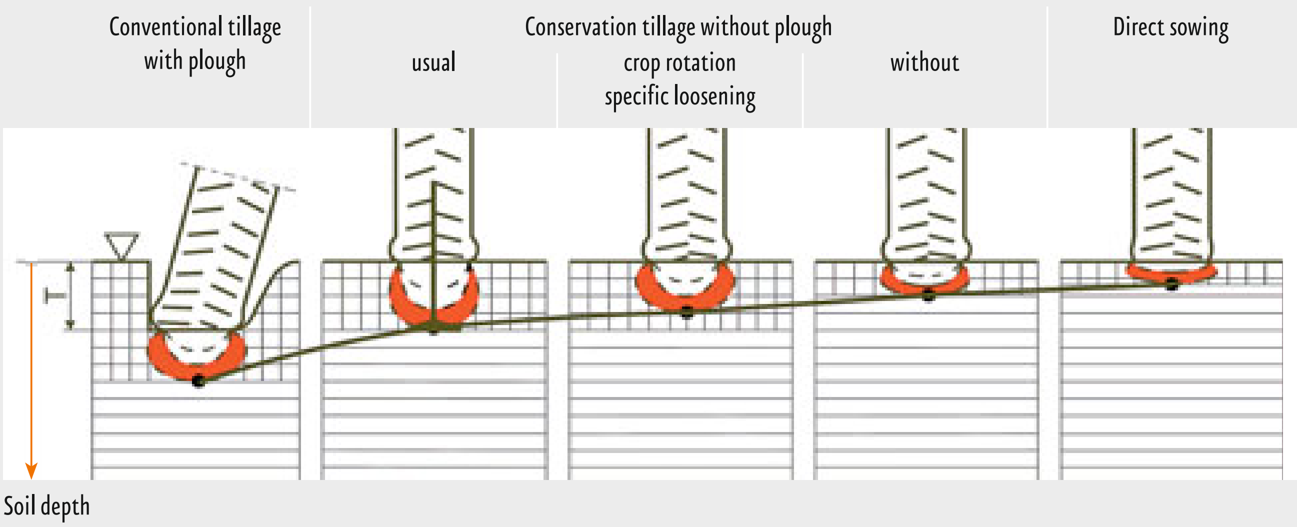
Soil compaction is generally defined as an "increase in soil density". When the possibilities of preventive soil protection are discussed, the structural changes caused by field traffic are in the foreground.

The soil pressure is indicated either by the wheel load or the surface pressure in the contact area by the running gear/soil in kPa (100 kPa = 1 bar) (see Fig. 21). As a result of these loads, field traffic produces mechanical stress, the course of which is represented by lines of equal vertical stress ("pressure bulbs") (see Fig. 22).

This stress results in an increase in soil density which is primarily to the disadvantage of the coarse pores and thus influences soil ventilation and infiltration. The higher the soil bearing capacity, i.e. the soil density, or the drier the soil during field traffic, the lower are the consequences of compressive stress. Any stress that exceeds the inherent stability of the soil structure may result in a change of the soil functions. If the specific parameters fall below a certain threshold, e. g. in air capacity (< 5 Vol.-%) or of the saturated water conductivity (< 10 cm/day) and if the field structure response at packer density, earth worm activity or root growth reaches critical levels, then damaging soil compaction may prevail (Lebert et al., 2004).

The effects caused by the inappropriate use of machinery on soil structure are as old as the mechanisation of agriculture. The operation of mechanical implements

Fig. 22: **Depth effect on soil pressure from differing soil tillage systems**



for facilitating work in agriculture would have been bound to fail if the increase of yield capability of the soil would have suffered. Therefore, since the middle of the 20th century, there has been a continuous investigation into the soil and load tests are carried out which describe the important interactions between machine and soil and help to assess their likelihood and sensitivity to compaction. Such investigations are the basis for the arrangement and specification of recommendations for the preventive soil protection (aid, 2013).

As an example, a status survey from southern Lower Saxony (Brunotte et al., 2008) was taken and looked at a time horizon of 50 years which illustrates the development in agricultural technology. Whereas in 1952 several individual operational passes using a harrow and a roller resulted in a high travelling frequency of the tractor and increased the compaction of the soil, by 1982, through the combination of operational passes by means of combining implements in conjunction with an increased efficiency by larger working widths, quite a number of passes are saved, resulting in reduced compaction in the top soil. The development from 1982 to 2002 did not result in any further progress.

With regards to the top soil and the subsoil, the base top soil compaction in 1982 is apparent. By subsoiling and ploughing – sometimes with high wheel slip and in moist conditions – significant compaction at the transition from topsoil to subsoil occurred. The investigations in 2002 – another 20 years later – proved that this trend has not continued. (Fig. 23). Reasons for this reduction are:

- The reduction in working depth for reasons of cost
- Cultivations carried out in reasonable soil moistures thanks to better efficiency
- Extension of soil tillage systems without the plough by travelling on the soil surface
- Technical improvements in details (radial ply tyres with lower internal pressure around 1 bar and wheel slip control when ploughing)

Fig. 23: **Soil density/pore volume at 144 locations in southern Lower Saxony – comparison (Ruhm 1983; according to Ruhm cited by Sommer 1985; Brunotte et al., 2008)**

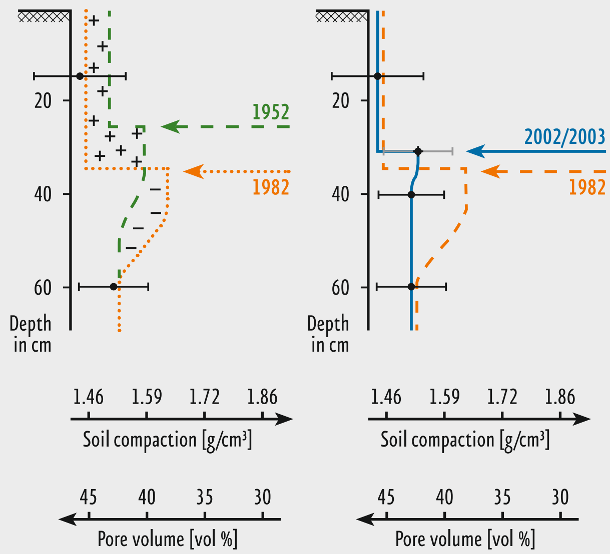


Fig. 24: Comparison of the wheel loading on land side/furrow side from rear tractor wheels during the ploughing operation. Mean values from each 6 successive measured passes (Brunotte et al., 2012)

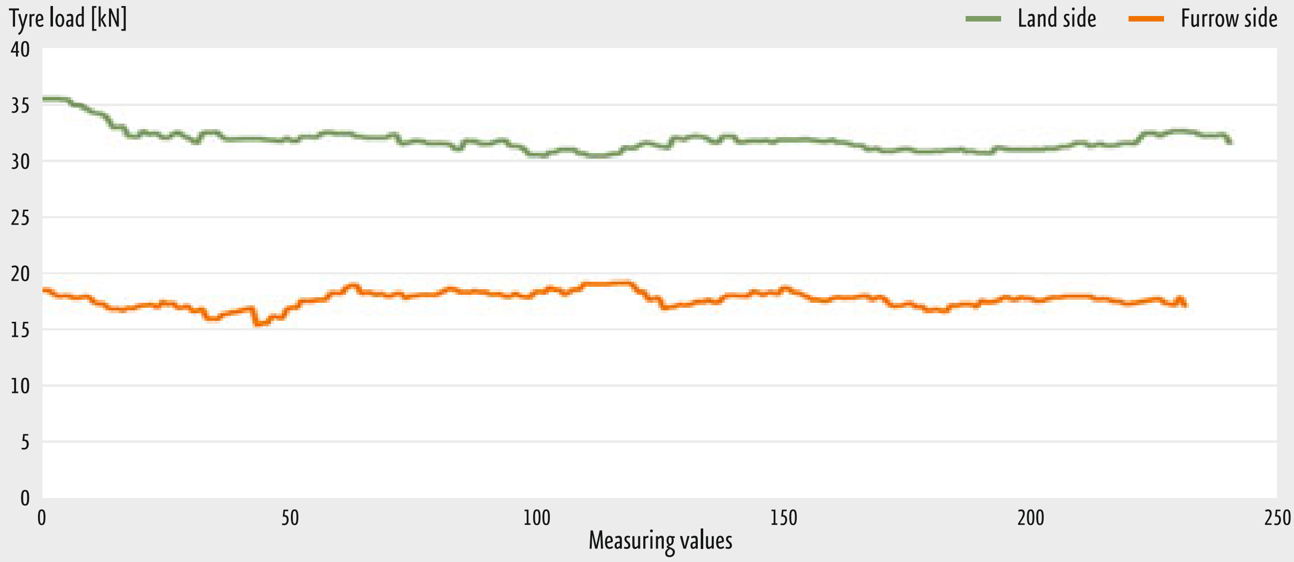
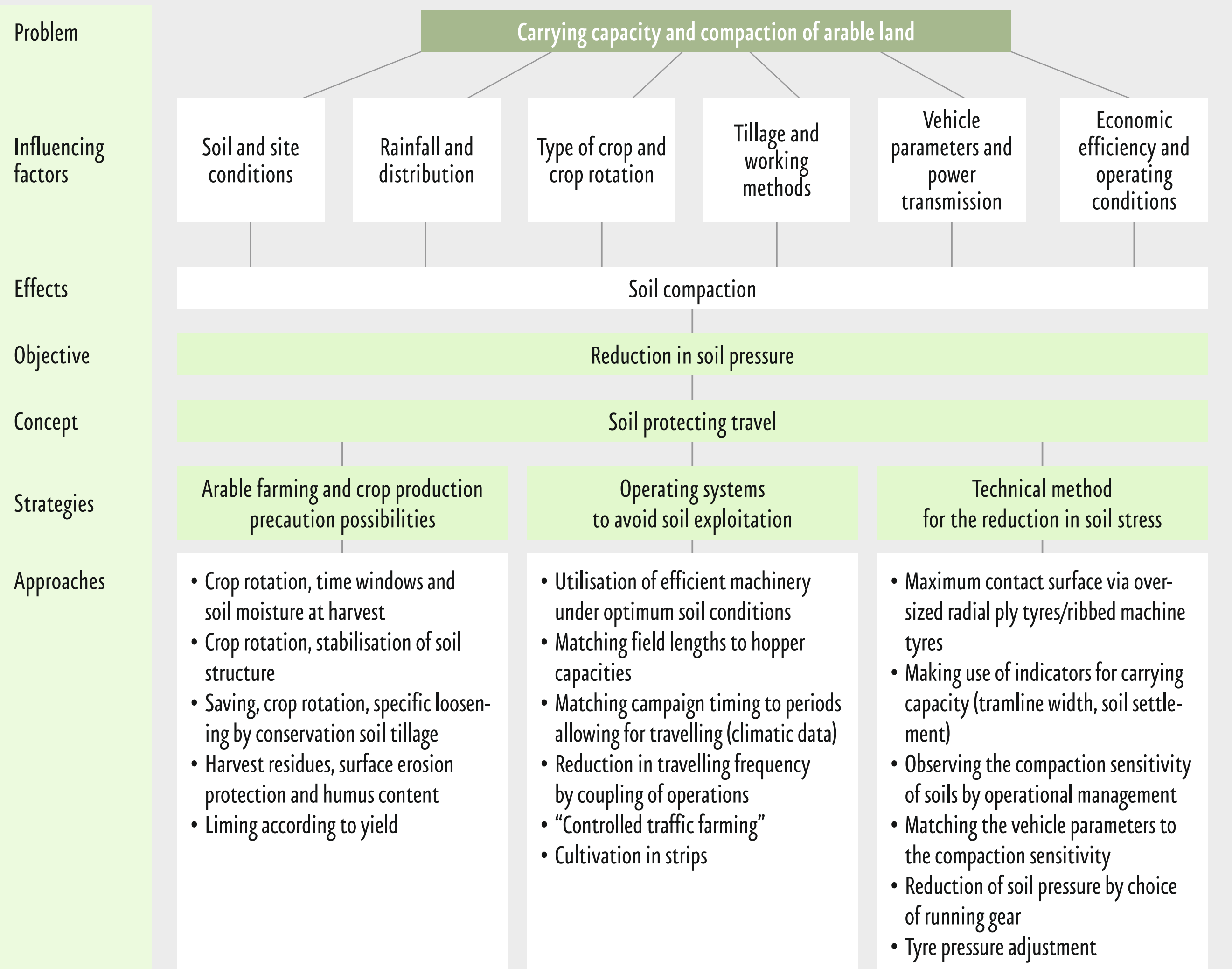


Fig. 25: The problem of soil compaction and approaches to a solution (Sommer, 1998b, adjusted according to Brunotte, 2008)



• Wider ploughs (> 4 furrows) result in a weight transfer to the land wheel and in the lightening of the furrow wheel (Fig. 24)

Throughout Germany approximately 50 % of the fields are still ploughed – with strong regional differences – the effect of the plough tractor on the top soil base is of great importance. By the adaption of ultrasonic sensors in the wheel rim, the Thünen Institute for Agricultural Technology (Braunschweig) was the first worldwide to succeed in on-line tyre deflection measuring. As this highly correlates with the supporting load, the dynamic wheel load during the ploughing operation can be measured. The measurements show a surprising tendency; not at the edge of the furrow but higher loads prevailed on the land wheel (Fig. 24). So instead of the expected ratios of the furrow wheel load/ land wheel load of 60/40, the measurements resulted in a ratio of 40/60. The reason for the unexpected relief of the furrow wheel is the combination of tractor and plough. On 2 and 3 furrow ploughs the acting point of the effective weight of the tractor is shifted in the direction of the furrow wheel whereas, on 4 and 5 furrow ploughs, the acting point of the vertical force moves on to the side of the land wheel. Therefore, these measurements provide an additional explanation for the soil conditions in the top soil base (Brunotte et al., 2012).

Traffic carrying ability can be improved by not necessarily loosening the topsoil every year, but just crop rotation specific (Fig. 25) utilising mulch tillage equipment (e.g. chisel openers). Less loosening of the soil structure would render reconsolidation superfluous, possibly resulting in a huge cost saving, especially from the decreased fuel consumption.

Using a combination of pre-loosener, rotary cultivator and wedge ring roller helps to realise this conception. In the course of crop rotation, however, the right time for non-inversion loosening must be carefully considered. That means the lifting tines of the deep loosener should only be used if there actually is harmful compaction and under favourable, i.e. dry soil conditions. At the same time biological stabilisation by catch crops is possible.

Using sugar beet as an example, (crop rotation SB-WW-WW) trials concerning this aspect have shown that loosening could be reduced without any yield loss. The positive effect of conservation tillage without loosening compared with conventional tillage resulted in cost saving. In addition, there was an increase in the soil bearing capacity (represented by means of the front axle of a 6-row beet harvester, Fig. 26).

Reduction of the contact surface pressure is the main technical option to reduce the soil pressure. Greater tyre widths in the form of twin tyres or wide-base tyres increase the contact area and result in a reduction of pressure propagation to the soil depth while the wheel load remains the same (Fig. 27). This leads to a lower

Fig. 26: **Track depth of beet harvester with increasing hopper filling and after different tillage processes (tyres: 800/65R32 XM28, tyre inflation pressure: 2.4 bar, contact area: 6,600 cm², contact area pressure: 1.24 bar)**

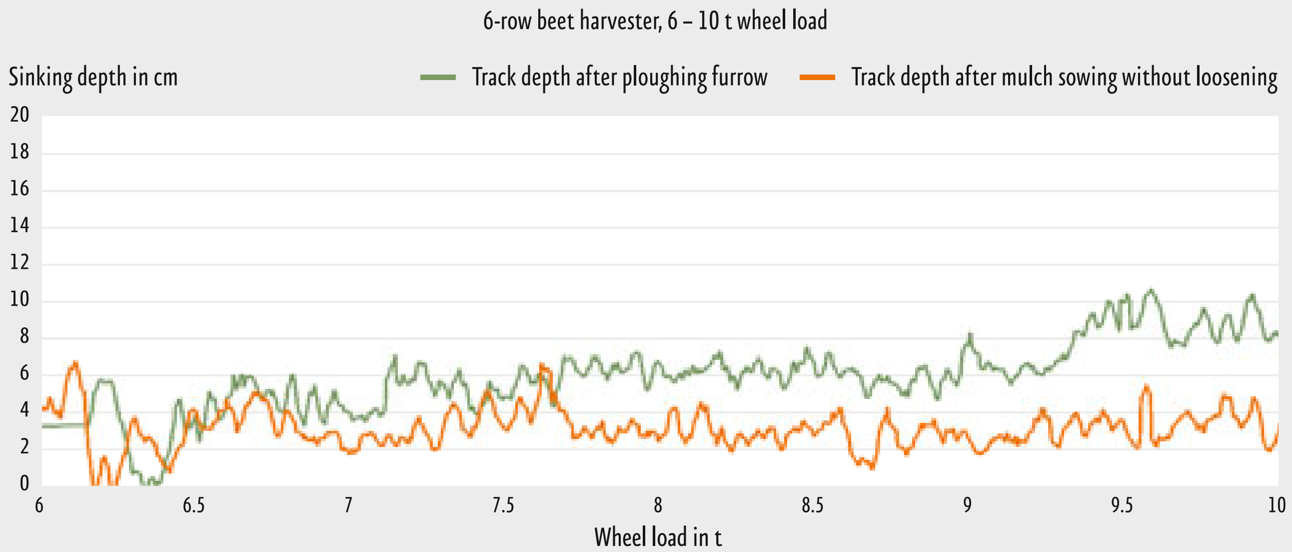


Fig. 27: **Wide-base tyres reduce pressure propagation to the soil depth only if the wheel load remains unchanged (according to Söhne, 1961)**

soil pressure in the topsoil. If at the same time the wheel load is reduced, e.g. for a cultivating tractor, by using a trailed sprayer instead of a mounted sprayer, soil pressure at a depth will also decline.

Enhancement of working methods is another measure for soil conservation. Changing to the tramline system e.g. for sugar beet or potatoes, will provide sufficient space for wider tyres for cultivation work. This permits a reduction of the tyre inflation pressure to 1 bar and provides – combined with the measures mentioned above – better conditions for soil-conserving field traffic. In addition, the risk of lined erosion decreases as a result of the flatter tracks. The same applies to the creation of wider tramline tracks for cereals: If you close three instead of two rows on the seed drill during drilling, you can use a 16.9 or 18.4" tyre. For an additional reduction of lined erosion e.g. AMAZONE seed drills offer the option to create intermittent tramlines. Intermittent tramlines mean alternate sowing and then not sowing of cereals in the tramline so that the tramlines are still visible but the risk of water erosion is reduced because the erosion-effective slope length is interrupted. This is an actual recommendation derived from the Soil Protection Act (BbodSchG) which plays an important role especially during application in the autumn season.

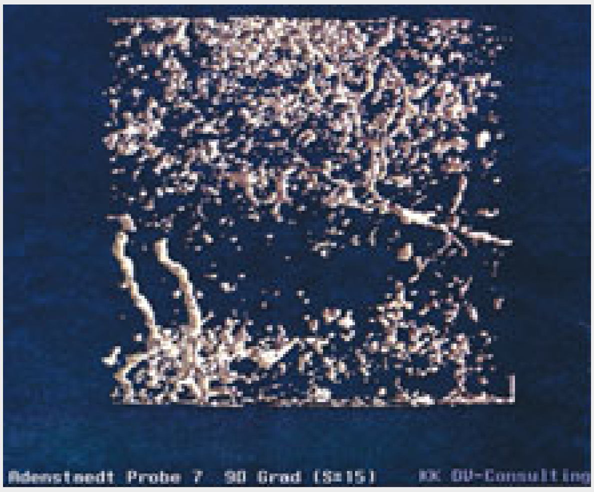
Whether and by how far loosening of the tramlines is necessary as repair measure can be determined by means of the track depth on the one hand and the earthworm activity in the tramline on the other hand. If any earthworm activity is recognisable in the tramline (organic residues drawn into the ducts), deep mechanical loosening (30 cm) is not necessary. The large rope worm (lumbricus terrestris) is able to displace the soil at 1.5 bar. That means those who execute cultivation measures at a tyre inflation pressure <1.5 bar (corresponding to the soil pressure at a depth of 10 cm) protect soil life.

2.4.3 Promotion of biological activity

The goal of tillage must not only be to create favourable soil physical conditions for crop growth, but also to enhance the biological development and decomposition potential. A plough furrow e.g. has a particularly detrimental effect on earthworms when performed in autumn or spring, because the earthworms are particularly active at these times. So ploughing is better car-

Fig. 28: **Three-dimensional visualisation of the macropore area after X-ray computer tomography (according to Rogasik et al, 1994)**

Fig. 28a: **Soil tillage with the plough**

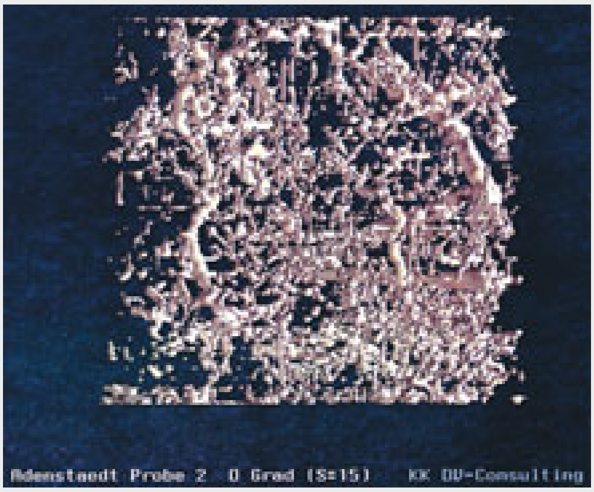


top

Plough pan

bottom

Fig. 28b: **Soil tillage without the plough**



ried out in summer when the worms have withdrawn to deeper, moister soil horizons. The use of non-inversion cultivators does not disturb the soil structure as much as ploughing.

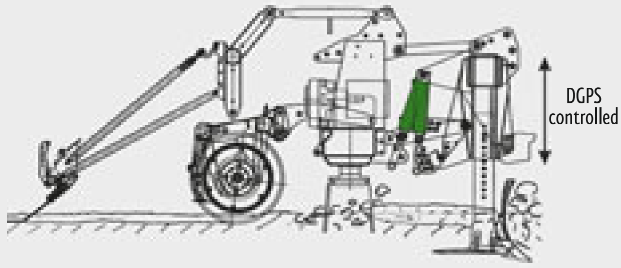
In addition it is important to offer the earthworms a wide range of food on the soil surface by means of the mulch sowing methods at the times of high activity. This promotes particularly the activities of the large rope worm which thereby

- increases the water absorption capacity of the soil,
- promotes ventilation and
- causes incorporation of organic materials without extensive tillage work.

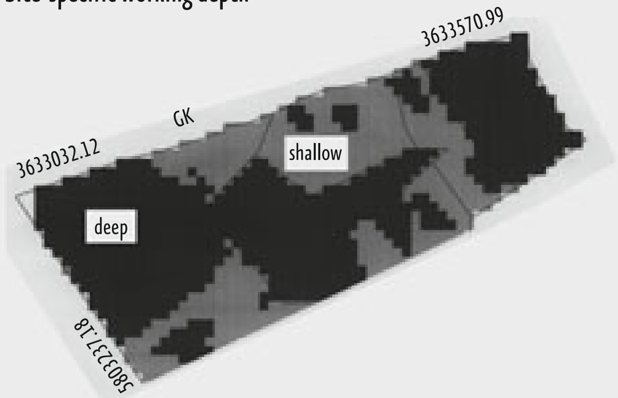
X-ray computer tomography inspections show the porosity of a crumb after ploughing and after mulch sowing (Fig. 28). After ploughing vertical pores can be cut off at the topsoil base (tractor wheel base) so that the infiltration of excessive rainfall is interrupted, (Fig. 28a). That is different in case of mulch sowing: here the biogenic vertical pores with their high continuity can be well recognised. They form the pathways for water, oxygen and roots (Fig. 28b).

Fig. 29: Site-specific tillage in the collaborative "pre-agro" project (Voßhenrich et al. 2000)

Test machine for site-specific tillage
Project partner: AMAZONEN-WERKE



Site-specific working depth



Project partners:
Universität Kiel
TU München
Agri-Con etc.
Agric. enterprise: Täger-Farny

Information levels:
Boring rod samples
State soils evaluation
Conductivity (EM38)
Relief

2.5 The soil determines the tillage intensity

Considering the tillage systems in the order of "tillage with plough", "conservation tillage with/without deep loosening", "Strip-wise soil tillage (Strip Till)" and "direct sowing" the demands on the farmer increase with the decreasing intensity of tillage. Besides optimum straw management (see chapter 2.2), the soil conditions at a site are of decisive importance. Oxygen supply which is most important for plant growth has always a limiting effect. To ensure adequate oxygen supply the share of air-conducting coarse pores in the soil should also be at least 10 % in the winter.

In the framework of the "pre-agro" project promoted by the German Federal Ministry of Education and Research in which AMAZONE had been involved as a project partner, Voßhenrich and Sommer (2002) described instructions for activities according to which the tillage intensity is dependent on the kind and type of soil (Fig. 29).

Due to their fine particle size, sandy soils have a tendency for compaction which might possibly affect root growth. They therefore require topsoil-deep loosening. Clay, however, is a stabilising component in the soil structure. Favourable conditions exist from a clay content of about 15 % so that one can do without soil loosening provided the soil is not affected by ground water or backwater. The third limiting factor, besides soil kind and type, is the humus content of the soil. Loosening is required if the humus content is 1 % or less, as frequently found at loamy sites in the hilltop areas after plough tillage for years.

Only a few sites fully meet all the requirements that can be met for tillage without soil loosening. For many sites the solution consists in the site-specific variation of the working depth within an area. Adjustment of the cultivator from shallow to deep or from deep to shallow can either be performed by hand or controlled via satellite. As tests have shown this so-called "site-specific tillage" offers the advantage of an up to 40 % reduction of working time and energy consumption during primary tillage and precludes the usual risk of consistently shallow tillage. Here also an operation in strips represents an intermediate position because it works the strips shallow to deep; leaving the gaps in between unworked as much as possible. How in this way the development of root growth, nutrition dynamics, soil moisture level and pest infestation are influenced has to be clarified by further field trials.

Direct sowing, however, as a system without any stubble cultivation, requires consistently suitable soil conditions within an area to fulfil the afore-mentioned criteria for doing without loosening. It is successfully used world-wide at appropriate sites. It requires, however, special sowing equipment to place the seeds into the soil with disc, tine or chisel coulters. As a rule disc coulters work trouble-free but are unable to cut straw (so-called "hair-pinning" effect). Tine coulters are ideal by their good placement quality, but are prone to blockages. So both systems require good chaff quality and straw distribution.

In case of perfect straw management and a yield level of up to about 7 t straw/ha direct sowing coulters are able to clear the sowing groove of straw. If tine or chisel coulters are used, the coulters move under the straw layer and place the seeds in the capillary fringe of the soil. Any heaps of straw which may be produced are subsequently distributed by a straw harrow behind the machine.

3. Effects on fertilisation and plant protection

3.1 Adjustment of fertilisation strategies

Main features of mulch sowing are the organic residues on or near the soil surface and the higher density of the topsoil as a result of the reduced intervention intensity by tillage. This promotes the biological activity particularly that of earthworms, and influences the air, water and temperature balance of the soil and thus the availability of nutrients via a changed pore system (fewer coarse pores, more medium pores, higher pore continuity).

3.1.1 Nitrogen dynamics

Accumulation of organic matter in the top 10 cm of the soil leads to a lower mineralisation intensity.

In autumn the micro-organisms need nitrogen for the natural production of protein in their own bodies which is then not available to the crop. An initial dose of 20 – 30 kg N/ha may be useful here to ensure that the cereal crops are strong enough for the winter. Also in spring slightly increased fertilisation of low-till areas with 10 – 20 kg N/ha is advisable to compensate for the lower ventilation, the higher water content and slower warming.

If in the following months April, May and June high temperatures and moist conditions lead to higher mineralisation, these nitrogen quantities can be saved again. C. van Ouwerkerk showed by means of results from Holland that the yield level of a site can be fully utilised by site-specific tillage and fertilisation. When changing from plough based tillage of an arable area to conservation tillage or direct sowing, depending on the site, slightly higher nitrogen rates may be necessary in the first three years in order to reach the same yield level as with plough based tillage. (Meisinger et al., 1985).

Altogether the residual nitrogen amounts remaining in the soil after harvesting decrease due to reduced tillage intensity. This leads to lower nitrate displacement and reduces the impact on ground water during the fallow period. This benefit can be additionally supported by growing catch crops in autumn.

3.1.2 Phosphate and potash supply in case of mulch sowing

In case of conservation tillage a certain accumulation of potash and phosphate occurs in the upper soil layers. This is due to the lower mobility of the nutrients (Drew and Saker, 1978). The mixing effect caused by a high earthworm activity and the higher root density of the crops in the upper 5 cm counteract this development in instances of sufficient soil moisture. In case of permanent plough-less tillage without loosening or direct sowing annual basic fertilisation in small amounts (in-

Fig. 30: Depletion of subsoil using phosphorous as an example – comparison between plough and mulch sowing (Dr. Bodo Hofmann, Bernburger Ackerbautagung, 2006)

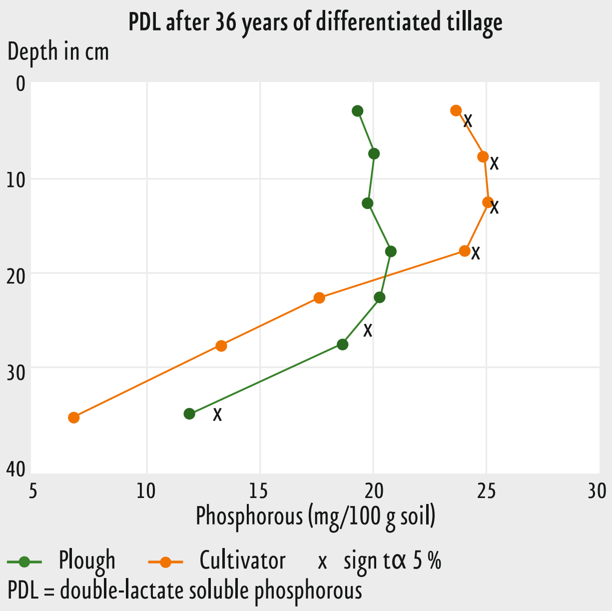
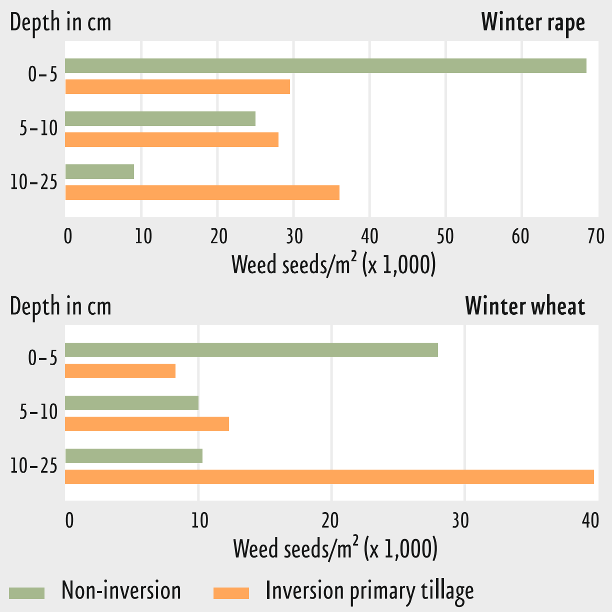


Fig. 31: Influence of primary tillage on the vertical distribution of weed seeds in the soil depending on the variety (Zwerger, 1998)



stead of every three years) is advisable to avoid excessive salt concentrations and too high a change in the ph value.

Mulch sowing in dry sites for years (e.g: "Magdeburger Börde", black earth in Ukraine) causes nutrient depletion (e.g. phosphorous, potash) in the subsoil and nutrient accumulation in the topsoil (Brunn, 2009). When the topsoil dries out this may lead to a lack of nutrients. For this reason systematic deep fertilisation should be performed to ensure that the crops can take up nutrients from the moist subsoil (Fig. 30).

3.2 Weed, disease and pest control

3.2.1 Weed control

The business environment and the target to preserve the natural balance forces us to use pesticides in a biologically useful and economically justifiable manner. Thus pesticides must be used according to the rules of "good professional practice", i.e. the principles of "Integrated Plant Protection" must also be followed here.

Consequently weed control must be such that the development of the crops is encouraged and the weed "competitors" are reduced to an economically justifiable extent (economic loss threshold) keeping, however, intervention into the ecosystem as low as possible.

Besides site, crop rotation, crop species, crop management (sowing date, sowing system, seed rate) the tillage system is a decisive factor for the composition and density of a weed flora (Fig. 31 and Table 2).

In case of non-inversion tillage a high potential of weeds and grass weeds remains on the surface which can be controlled mechanically by multiple cultivation. This will reduce in particular broadleaf weeds in succeeding crops. If, for reasons of soil protection, a high degree of soil coverage is required, weeds and weed grasses must be treated with non-selective herbicides a couple of days before sowing.

Table 2: **Special characteristics and measurement of weed control after different tillage methods**

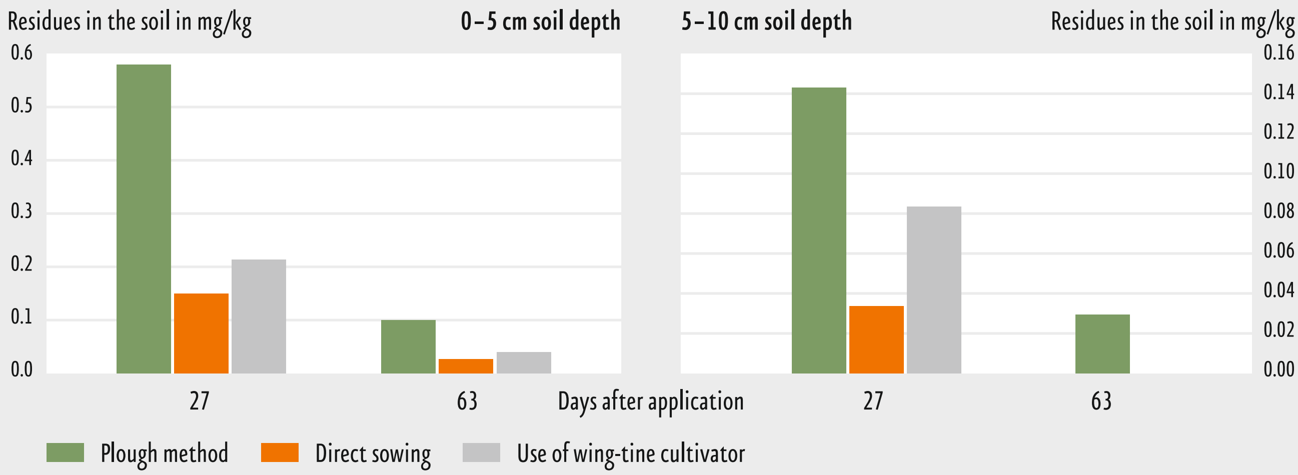
Measures	Effects on weed development
Plough buries grass weeds deeply in layers	80 – 90 % of the buried seeds die. By inversion, however, perennial weeds germinate increasingly in the 2nd year (Fig. 31).
Intensive stubble cultivation and primary tillage	Perennial species (couch grass, creeping thistle) are restrained as a rule because they constantly reshoot. If mechanical measures are not sufficient, targeted herbicide application is necessary.
Repeated incorporation in the upper soil layer	Reduces weed emergence in the main crop.
Moist conditions during tillage	Negative for success of control measures: new emergence of weeds, weed grasses and volunteer grain is promoted.
Non-inversion tillage	A high weed share in the preceding crop leads to excessive weed density in the following crop (Zwerger, 1998).
Mulch sowing	In case of short-term crop rotation increase in grass weeds (slender meadow foxtail, sterile brome) possible.
Soil herbicides reduced efficacy and decomposed faster due to mulch layer	Foliar-active products (glyphosate, growth hormones sulphur ureas) are more effective due to systemic effect.
Catch crop cultivation	Growth with high coverage rates causes good weed suppression (Garbe, 1986).
Direct sowing	Unwanted vegetation must be destroyed before next sowing exclusively by non-selective products since no tillage is carried out.

Grasses which are difficult to control require special plant protection management. As a result of the organic residues in the upper soil zones foliar herbicides must increasingly be used because under dry conditions the effectiveness of soil herbicides is reduced due to these residues.

At first, inversion tillage with the plough is an effective method of mechanical weed control because the weed seeds are buried in the soil. In the long run, however, this measure is not effective because in the following year the weed seeds are ploughed to the surface again.

When nutrients and herbicides are applied to areas cultivated by non-inversion methods the risk of displacement by macropore seepage (in particular through earthworm ducts) is often discussed. This risk exists when these products are applied to water-saturated soils immediately before a heavy thunderstorm. These conditions are, however, very rare in practice; in fact the increased microbial activity leads to an accelerated decomposition by the micro-organisms and increased sorption after reduced tillage provides for less displacement in the soil (Fig. 32).

Fig. 32: **Residue concentration of the active substance metamitrone in 0–5 and 5–10 cm soil depth (Düring and Hummel, 1992)**



3.2.2 Disease and pest control

Plough-less tillage furthers the following factors as a result of the organic residues (above all stubble and straw residues) on the soil surface (Table 3):

- the development of diseases, since direct infection of the emerging crop by residues of the preceding crop is possible;
- the distribution of pests, since due to the reduced intervention intensity the habitats of certain pests are not affected.

Altogether the reduced intervention intensity as a result of the mulch layer leads to changes in the occurrence of diseases and pests which requires indirect and direct control strategies.

The most important problems "Fusarium", "DTR", "viruses" and "Agriolimacidae" are discussed below (with the collaboration of Dr. Elisabeth Oldenburg, Julius-Kühn-Institut (JKI), Institute for Plant Protection in Field Crops and Grassland, Braunschweig, formerly FAL).

3.2.2.1 Fusarium spores

The problem that cereals and maize are infested with mycotoxin-forming Fusarium spores has recently been discussed mainly in connection with plough-less tillage systems and short grain maize rotation intervals. Fusarium infections are, however, the result of a multi-factor event in which influences caused by the weather and a multitude of other factors of the entire production system play a part and interact (Fig. 33).

Since the mycotoxins contained in the harvested product can be removed only partly by the subsequent cleaning and manufacturing processes, preventive measures are of particular importance. These include crop rotation frequency, variety selection, tillage and plant protection measures.

Crop rotation

In instances of short crop rotation intervals with a high proportion of cereals, in particular with maize, plant types which are particularly susceptible to infestation with Fusarium spores succeed each other. If the maize or cereals proportion is reduced within an extended crop rotation system e.g. by including grain legumes, the fungus will find significantly fewer suitable crops and

Table 3: Disease and pest occurrence and control after different tillage methods

Diseases/Pests	Occurrence and control
Parasitic foot rot and take-all	Infection of wheat after mulch sowing lower than after conventional sowing. Accelerated decomposition of straw residues due to increased microbial activity and antagonistic micro-organisms ("antiphytopathogene potential") hampers reproduction of harmful fungi (Bräutigam, 1994).
Fusarium types	Partly found on wheat and maize after non-inversion tillage. Crop rotation system, less susceptible varieties and targeted fungicide application are remedies. In case of mulch sowing following maize, re-chopping of the maize stubble is one of the most important measures to ensure faster rotting of the straw.
DTR Speckled leaf blotch (Drechslera tritici-repentis)	Ear bodies in the straw residues infect the young wheat crop under moist conditions. Targeted fungicide strategies in EC 31/32 and EC 49/51 with curative and prophylactic means keep the pests within limits (Bartels and Rodemann, 1998).
Mice	Particularly in case of conservation tillage without loosening and direct sowing. Targeted control by loosening measures (destroys build up) and placing of toxic baits.
Slugs in cases of winter rape, sugar beet and cereals	Appear increasingly in soil cavities (also after ploughing on clay soils), in case of permanently green vegetation cover and under moist conditions. Remedy: properly reconsolidated soils, application of UAN or rolling pass at night, application of molluscicides.
European corn borer	Fostered by non-inversion systems, damage to following winter wheat. Effective control by stubble chopper on header attachment, intensive shallow incorporation by PTO-driven implement and use of Trichogramm ichneumon wasps. In the short term, the plough is one of the safest combat measures. In regions with intensive maize cultivation re-chopping of the maize stubble is the most important control measure against the European corn borer.

Fig. 33: Factors influencing the mycotoxin content in cereals (Brunotte/Oldenburg, 2002)

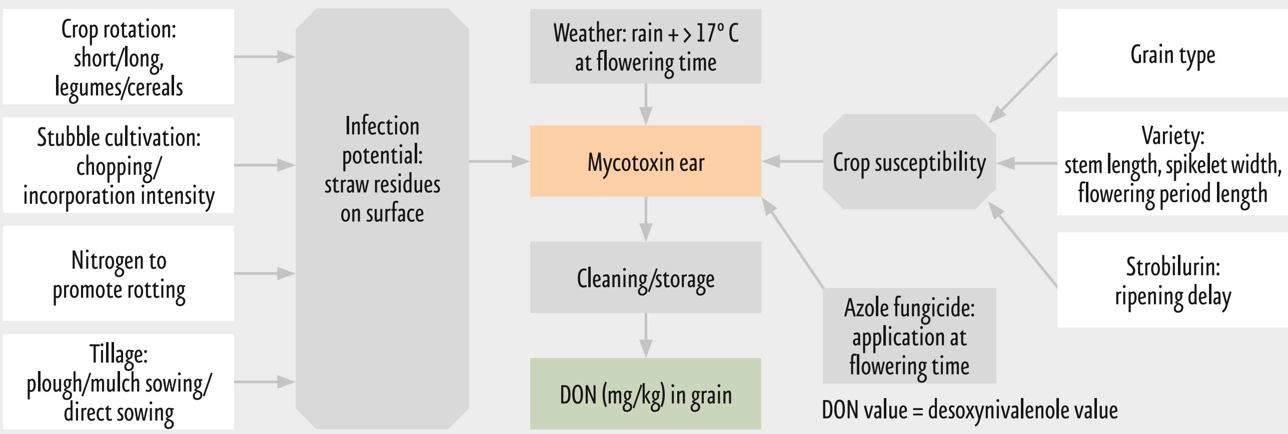
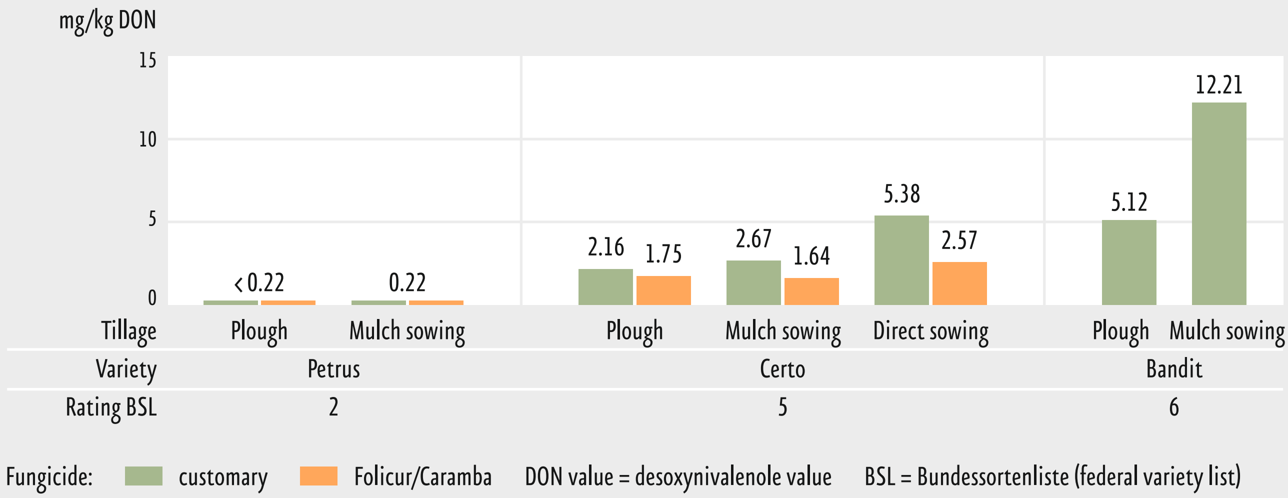


Fig. 34: Mycotoxin contents of wheat dependent on variety, tillage and fungicide application (Brunotte, Oldenburg, 2002)



crop residues which its needs for growing, reproduction and persistence.

Variety selection

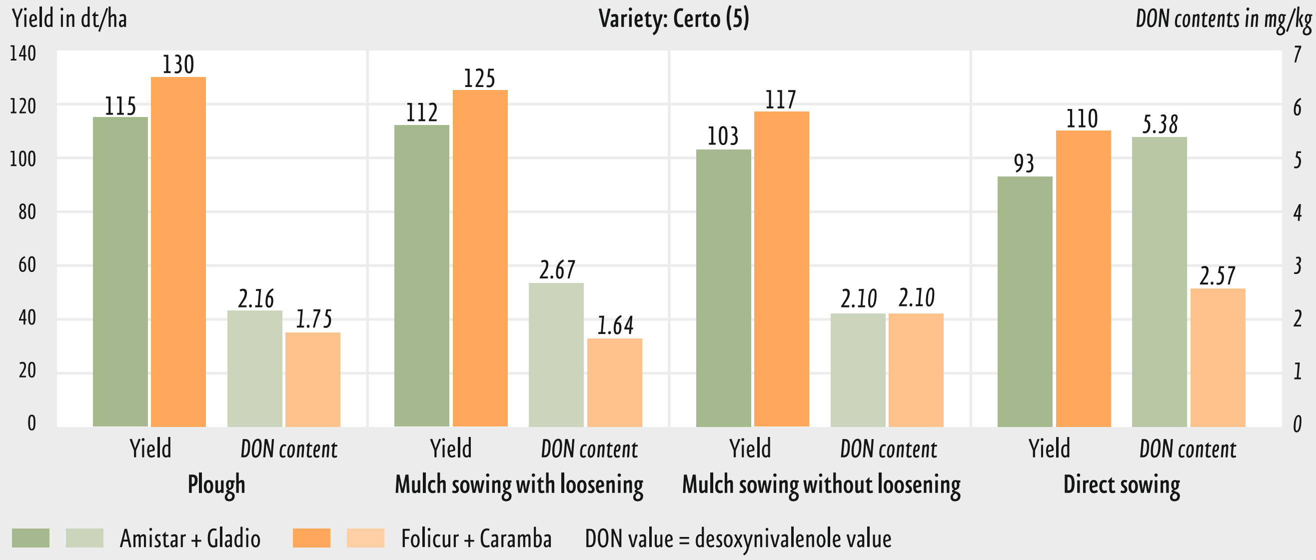
Varieties which are completely resistant to Fusarium spores have not been available so far. As a result of recent efforts by breeders to improve the resistance level to Fusarium there are new varieties which are less susceptible to Fusarium infections (infection classes 2 – 3 of the Federal variety list). Compared with susceptible varieties, a significantly lower ear infestation and significantly lower mycotoxin contents in the grain are to be expected even in case of a high infection hazard (Fig. 34).

Tillage

Fusarium spores overwinter mainly on the dead, not yet rotten harvest residues, in particular of maize and cereals. Where the plough is used, the harvest residues are brought deeper into the soil so that at first there is no infection potential on the surface. In compacted areas, however, incomplete rotting takes place so that viable spores adhere to the material ploughed up again in the following years and can cause a new infection.

In case of conservation methods harvest residues remain in soil layers near or on the soil surface as protection against surface capping and erosion and thus constitute an increased infection hazard to the following crop. As a result, direct sowing is the method with the greatest risk potential in respect of Fusarium infestation. To reduce the infection hazard emanating from the crop residues optimum chopping and even distribution of the harvest residues on the soil surface and in the topsoil must be ensured to accelerate rotting. Two

Fig. 35: **Effects of different tillage systems and targeted flowering spraying in case of wheat on yield and DON content (loamy site, Brunotte/Oldenburg, 2002)**



tillage passes with the tine & disc combination cultivator are a possible solution here.

In addition, the potentially higher infestation risk as a result of conservation tillage methods can be significantly reduced by extended crop rotation systems, by avoiding maize preceding cereals and by selecting less susceptible cereals varieties (Fig. 33, 34). Fig. 34 shows the effects of specific variety selection, different tillage systems and targeted foliage spraying with a fungicide reducing Fusarium.

Crop protection methods
Absolutely effective fungicides against Fusarium have not been available so far. Presently azole fungicides with the active ingredients tebuconazole, prothioconazole or metconazole show the best effectiveness against Fusarium infection – with lower infestation rates and reduction of the toxin contents of 50 to 70 % (Fig. 34 and 35). Usually the yield increases by the reduction of Fusarium infected shrivelled grain – according to studies in 2002 by 13 – 17 dt/ha (Fig. 35). To achieve optimum efficiency rates, precisely timed application within a time slot of one week from the start of flowering, during which infection takes primarily place, is of particular importance.

If Fusarium infection occurs in the course of the flowering period (rainfall + temperatures > 17° C), the azoles mentioned above must be applied within 32 hours. The higher the concentration of the azoles in the spraying solution, the better the result. This is the reason why in practice the amount of water is often reduced. To achieve perfect spraying of the grain, application is carried out with twin-type flat fan jet nozzles (injector nozzles) and adjuvants and at high travelling speeds (Brunn 2009).

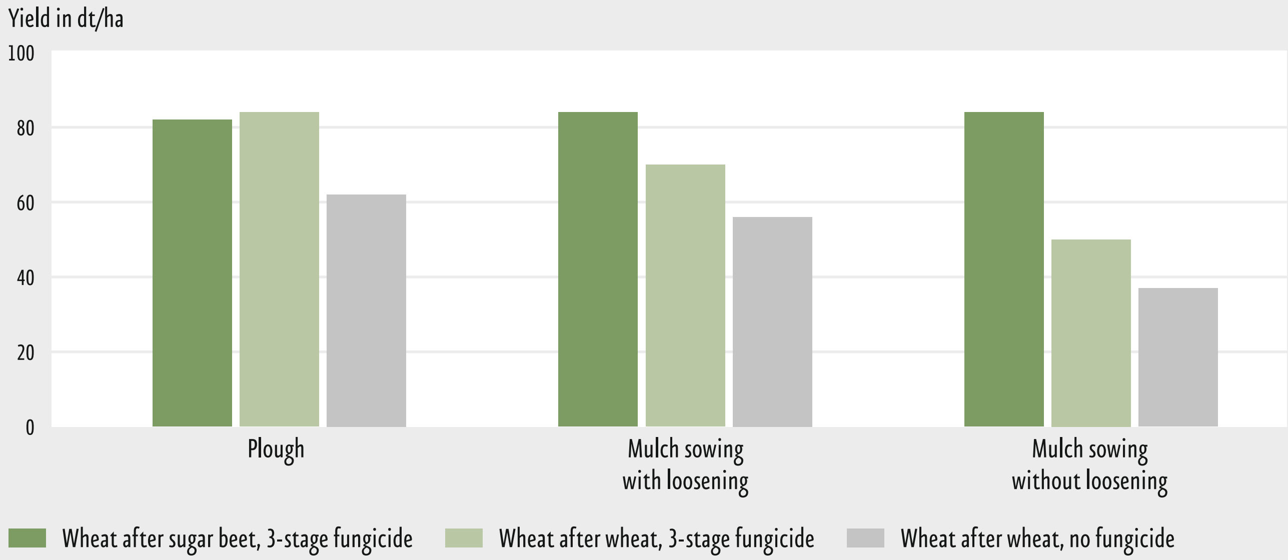
3.2.2.2 DTR – Speckled leaf blotch
Like the Fuseria pathogens, the pathogens of DTR can survive on the harvest residues. If rotting of the straw produced is accelerated by optimum chopping and incorporation, this will lead to the decomposition of the organic substance which will deprive the harmful organisms from their natural resources.

Primary infection in early spring is caused by aeciospores. The spreading of the disease causes damage to the leaves and thus leads to a loss of assimilation area. This reduces the thousand-grain weight and results in a high share of shrivelled grain and corresponding profit cuts.

To avoid this, varieties featuring a high resistance level while permitting optimum yield development should be selected. Besides preventive measures such as straw incorporation and specific variety selection, the upper leaf layers can be protected by targeted fungicide application (development state GS 37/39 and 55/59) up to grain fill to restrict the disease. For this purpose, products containing strobilurins should be combined with azole/morpholine products.

Fig. 36 shows the influence of preceding crop, tillage and fungicide application on the yield which correlates

Fig. 36: Yield of winter wheat depending on tillage system, preceding crop and fungicide application, Mariensee 1998 (Kreye and Garbe, 2001)



to the green residual leaf area. In case of wheat following sugar beet there is no infection potential in the soil because there are no straw residues. The infection potential increases with the increase in residues on the surface (plough › MSmL › MSoL), the yields decrease simultaneously, particularly if no fungicide treatment is carried out. So targeted fungicide application has a positive effect on the yield.

3.2.2.3 Viruses

During the last year, viruses (wheat and barley dwarf virus) increasingly occurred particularly on farms utilising mulch and direct sowing methods (Brunn 2009). Here the "green bridge" which aphids and cicadae need to survive should be broken by well-timed tillage. Also targeted use of insecticide seed dressings against aphids and cicadae should be included depending on their occurrence.

3.2.2.4 Agriolimacidae

Slugs (Spanish and red slug, grey field slug) today constitute a permanent problem not only in rape and sugar beet but also in cereals. The slugs partly comprise three generations/year and being hermaphrodites they achieve huge reproduction rates. They use opportunities to move such as cavities (among others clay soils after ploughing), earthworm ducts and straw layers. That means that reduced tillage – without targeted reconsolidation – tends to promote the development of slugs (Table 3).

Preventive measures include again the right tillage system. Optimum straw management, targeted reconsolidation and sufficient fine soil in the seed placement area are important components of a strategy to destroy the cavities that slugs use to move around in. Cultivation passes performed at different times will destroy the habitats of the slugs again and again. This also includes subsequent rolling of the seedbed. Everything which encourages the early development of the crops is at the same time a preventive measure against slugs.

If these preventive measures do not help, you can only react with slug pellets. The best results are achieved if the pellets are spread already when the crops have emerged. The active ingredients Metaldehyde, Methiocarb and Thiodicarb are the most effective. When selecting the products their rain resistance and on the other hand the protection of earthworms and ground beetles (which eat the slug eggs) should be taken into account.

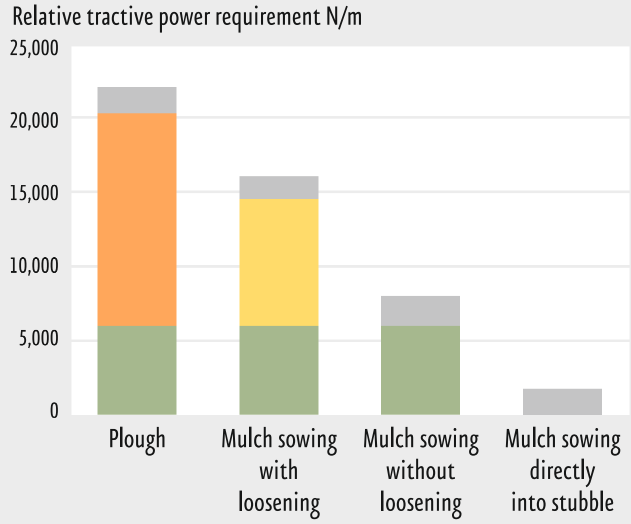
4. Cost and benefit in comparison

4.1 System costs – overview

Numerous comparisons between conventional and conservation (mulch sowing) tillage systems make it clear that the final conclusion as to the question for the yield advantage cannot be answered in a single sentence. The fact is not ploughing is more common on 'heavy' and low-yielding soils, often in order to limit costs, than on deep marshy and loamy soils. In practice, often both systems are used within a crop rotation: so, for example, wheat stubbles are ploughed and then after the following sugar beet crop wheat is sown by means of mulch sowing or the field is ploughed for winter barley following winter wheat to avoid unwanted volunteer problems.

Actual measured performance data provides a more precise assessment basis for an economic examination than general calculation data. Fig. Abb. 37 e.g. shows the specific tractive power requirement for the various tillage systems with a loamy site. Plough-based systems require a tractive power of 22,000 N/m for stubble

Fig. 37: Specific tractive power requirement for different tillage systems; loamy site



	Working depth	Forward speed
Twin row tine cultivator 1996	$\bar{t}$: 20 cm	$\bar{V}_R$: 7.1 km/h
4-furrow plough with packer	$\bar{t}$: 26–27 cm	$\bar{V}_R$: 6.1 km/h
Deep cultivator	$\bar{t}$: 26–27 cm	$\bar{V}_R$: 5.8 km/h
Rotary cultivator	$\bar{t}$: 9–10 cm	$\bar{V}_R$: 6.5 km/h
Rotary cultivator directly in stubble	$\bar{t}$: 9–10 cm	$\bar{V}_R$: 5.5 km/h

Fig. 38: Fuel consumption in l/ha for stubble cultivation, primary and secondary tillage at different sites (according to Kreye, Garbe)

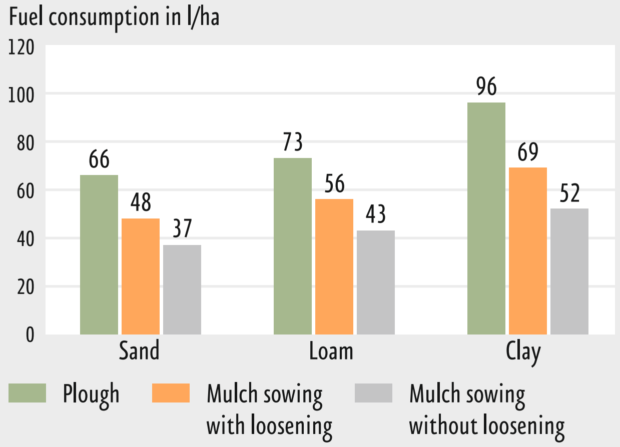
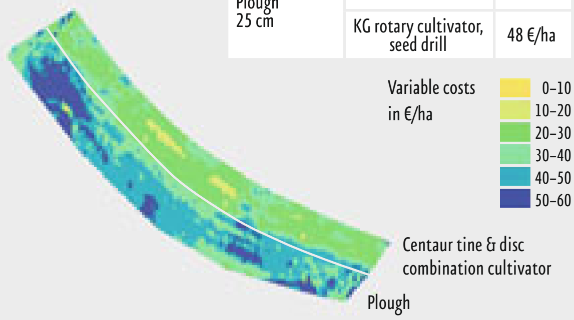


Fig. 39: Variable costs of plough and mulch sowing

At the time of the study the variable costs consisted of fuel costs to the amount of 0.63 €/l and labour costs to the amount of 16 €/h. Plough-less tillage offers significant cost advantages over plough tillage.

Tillage	Drilling	Variable costs
Centaur tine & disc combination cultivator 20 cm	KG rotary cultivator, seed drill	29 €/ha
	Cirrus seed drill	27 €/ha
Plough 25 cm	Cirrus seed drill	44 €/ha
	KG rotary cultivator, seed drill	48 €/ha

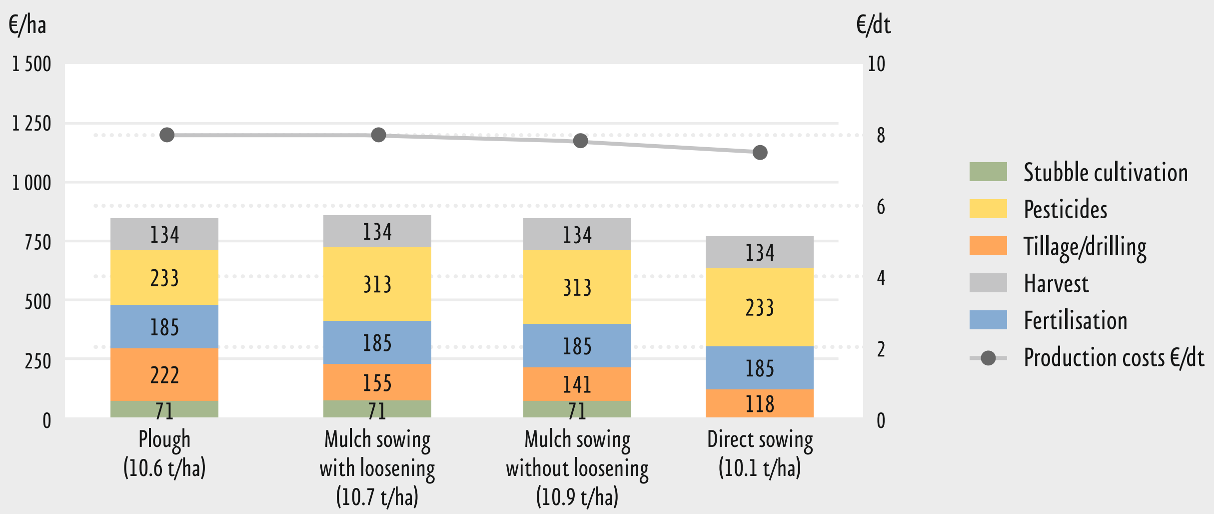


cultivation, ploughing and working a field. Whereas mulch sowing systems without loosening require only 8,000 N/m; i.e. the saving amounts to about 64 %.

Fuel consumption is still of particular high importance. Fig. 36 shows the fuel consumption values for stubble cultivation and primary and secondary tillage at three different sites (sand, loam, clay). Measurements were carried out by means of a flow meter (PLU) (2 measured values/sec). The result shows that fuel consumption at the clay site was highest. This is due to the fact that during loosening (with the plough or plough-less with a blade cultivator) an enormous soil resistance must be overcome and a high amount of seedbed preparation is required to create a field ready for sowing. Compared with plough tillage, mulch sowing without loosening (MSoL) requires only half the amount of fuel. From this it follows that loosening should only be performed at sites where it actually has an effect on the yield.

For savings concerning the variable costs a diagram (Fig. 39) has been drawn up during tests in eastern Holstein (Schleswig-Holstein, Germany). Whilst the yields were identical (three-year average of plough sowing and mulch sowing) the costs for fuel and labour were significantly lower in case of mulch sowing. The diagram also takes into account the influences of different soil types at this site which also have an effect on the variable costs.

Fig. 40: Tillage systems and production costs of wheat after wheat at a loamy site (1999 – 2002)



Besides diesel consumption and labour costs, competitiveness plays an important part in system selection. For this purpose income and costs must be compared. Fig. 40 shows, by way of example, the production costs of wheat following wheat at a loamy site for the tillage processes; plough sowing, mulch sowing with and without loosening and direct sowing. The absorption costing is based on the assumption that the machines are used to capacity at the depreciation threshold. Farm-specific costs such as rent, calculated contractor gains and overheads are not taken into account, since they vary considerably from farm to farm and are not influenced by the tillage system. In addition, the calculation was based on prices of 11 €/dt of wheat and urea costs < 1 €/kg N.

The highest costs of 8 €/dt arise in case of plough tillage and in case of mulch sowing with loosening. Mulch sowing without loosening costing 7.80 €/dt is a little bit cheaper – as a result of a comparable yield and slightly reduced costs. Obviously loosening was not yield-effective here; shallow straw incorporation, however, led to the result that no negative effects occurred during crop emergence and growth.

Direct sowing produces a slightly lower yield which is, however, more than compensated for by the cost saving. Although the result of direct sowing is thus positive it cannot be generally recommended. On the one hand, exclusively chemical measures are available for weed control, which e.g. in case of mulch sowing is performed mechanically by tillage. On the other hand, the disease hazard emanating from the straw residues is the highest in the case of direct sowing. And thirdly, the achievable optimum soil protection is not absolutely necessary at a medium level.

Under the moderate climatic conditions in Central Europe one should choose between mulch sowing with and mulch sowing without loosening depending on the site, because with these methods soil protection is realised and the infection potential for diseases is restricted within the meaning of integrated arable farming. Thus both targets – competitiveness and environmental compatibility – can be reached with these methods.

4.2 Cost-benefit analysis

An overall assessment of the various tillage systems requires more than just considering yields, market prices and costs. Since the target of arable farming today is not only competitiveness but also environmental compatibility, a more comprehensive assessment in the form of an overall cost-benefit analysis is required. In the approach shown here the positive contribution of the mulch sowing method to erosion control is assessed by using sugar beet as an example. The calculation is

Table 4: **Single-farm benefit-cost comparison concerning erosion protection, data in €/ha per year (according to Brunotte et al., 1995)**

Method	Benefit				Cost	Comparison
Tillage method	Catch crop green manure	Savings: machinery, seed	Inversion/ re-drilling, fertilisers, pesticides	Soil value maintenance	(+ increase) (– decrease)	(+ benefit) (– cost)
Method 1: conventional sowing with seedbed preparation	0	0	0	0	0	0
Method 2: mulch sowing with seedbed preparation (straw)	0	20	4	8	–25	+57
Method 3: mulch sowing with seedbed preparation (catch crop)	90 40 to 145	20	4	8	+50	+72 (+22 to +127)
Method 4: mulch sowing without seedbed preparation (catch crop)	90 40 to 145	20	4	13	+30	+97 (+47 to +152)

based on the data of an enterprise with a crop rotation system of sugar beet and cereals, cultivating erosion prone loamy soils, with more than 200 m in field length, 5 to 12 % slopes and an annual rainfall of 750 mm.

The benefit of the measures against soil erosion comprises of the following factors:

- **Green manure effect:** in the medium term, growing a catch crop before the mulch sowing of sugar beet has a positive effect on the yields of the following crops, i.e. sugar beet and wheat.
- **Protection of plant populations:** mulch sowing methods protect the young crops in cases of intense rainfall events so that the costs for inverting and re-drilling are saved. Thus mulch sowing is a kind of 'insurance' for the emerging crops.
- **Maintenance of soil value:** compared with ploughless methods, one long-term benefit of mulch sowing consists in lower depreciation rates of the soil fertility.
- **Cost:** catch crop cultivation carried out every three years costs 90 €/ha (30 €/ha/year). The straw mulch method saves 75 €/ha (25 €/ha/year).

In a benefit-cost comparison the overall analysis of the measures used for the reduction of erosion leads to the following results (Table 4):

1. By mulch sowing with seedbed preparation (System 2), because the straw residues provide a benefit, in comparison with a plough-less system (System 1) and so reducing the risk that any such inversion might be necessary, of an improved maintenance of soil values and lower operating costs. In total the benefit amounts to 57 €/ha per year.
2. Mulch sowing with seedbed preparation on the basis of a catch crop (method 3) compensates for the additional costs for catch crop cultivation by the green manure effect. Inversion risk and maintenance of the soil value are comparable to the straw mulch variant (method 2), so that an overall benefit of 72 €/ha per year results.
3. In case of mulch sowing without seedbed preparation on the basis of catch crop (method 4) green manure effect, inversion risk and maintenance of the soil fertility add up to the highest benefit value of 97 €/ha per year.

This comparison shows that despite the increasing necessity to save costs a way of land utilisation is possible which offers chances for competitive and at the same time environmentally compatible farming. An example of the erosion reduction measures is in the form of a catch crop which shows that the green manure effect compensates for the expense and has a positive effect also in the medium term.

To increase the acceptance of these measures among farmers a financial incentive still makes sense. The European Modulation for example leads to a redirection of premium payments e.g. to agricultural projects protecting the environment. Thus it is also a measure for the reorientation of agricultural policy.

4.3 Competitiveness and environmental compatibility

To achieve the target of a competitive, and at the same time environmentally compatible agriculture, various measures concerning the problems of soil erosion, soil compaction and biological activity addressed in the German soil protection act are of particular importance. These include crop rotation, variety selection, field design and tillage with a defined employment of machinery. So agriculture has various practical solutions to reduce negative influences on the environment.

Crop rotation and crop type influence, among other things, the supply of organic substances, the periods available for tillage, maintenance and harvest (equipment available, consideration of sensitive soil conditions). They also determine whether a catch crop can be grown and the period of soil coverage (cereals, slow growing row crops).

Type, frequency and intensity of tillage have a decisive influence on the costs of the production processes, and also on the hazard potential concerning soil erosion, soil compaction and interference in biological activities. Decades of experience and the machinery available speak in favour of tillage with the plough. Ploughing is the safest method of excluding unwanted vegetation within a short time; crop yields can be achieved with a minimum of management work.

Leaving the cost analysis out of consideration there is hardly any reason to use other tillage methods in respect of the soil production function. If, however, the control and habitat function of the soil is taken into account one will soon encounter unwanted side effects such as soil erosion and harmful compaction caused by tillage, sowing, crop protection/fertilising and harvesting measures.

Numerous tests have shown that the problems mentioned above could be effectively solved by direct sowing but then, however, chemical weed control is paramount. Apart from this, according to present knowledge it is not possible to do permanently without soil loosening under the moderate climatic conditions in Central Europe and with the present farming methods.

Considering crop yields, soil protection and input costs, a tillage system should be selected which involves a level of intensity of mechanical intervention between that of the plough (high intensity) and that of direct sowing (zero intensity): conservation soil tillage – carried out across the whole area or in strips. With its components of gentle loosening and mulch sowing it comes closest to meeting the requirements of Integrated Crop Production. It is based on the idea that tillage is not only aimed at the following crop, but also takes long-term aspects of environmental compatibility into account.

In the past, the formulation of certain soil condition steps (optimum consolidation) has hardly led to an optimisation of yields. Since under dry weather conditions the consolidation may be higher, and under moist conditions it may be lower. But because tillage is mostly performed at a time when one cannot yet foresee the weather development for the vegetation period to come one must try to create a “targeted heterogeneity”, i.e. a sequence of vertical, denser or looser compartments between which the crops can find their optimum way, using appropriate tillage equipment. Seed drills on wedge ring rollers used in combination with trailed or PTO-driven rotary harrows and cultivators show the right way.

Soil protection, an important aspect of environmental compatibility, can also be realised best with the mulch sowing method. Residues on the surface (from preceding and/or catch crops) reduce surface capping and thus the intensity of surface runoff and soil erosion. The use of harrows with spring-mounted discs or PTO-driven implements should be targeted help to create different coverage rates of residues and to protect the surface against the consequences of intense rain.

Of course, non-inversion tillage influences weed development and the occurrence of diseases and pests. Preventive measures of Integrated Crop Protection and targeted chemical control strategies provide solutions.

Gentle soil loosening, e.g. by means of cultivators, avoids excessive soil loosening and thus creates a solid structure to prevent harmful compaction. Crop-specific performance of this operational pass (i.e. only once during crop rotation) will not only increase the soil bearing capacity, but also can save costs.

4.4 Economics and ecology in harmony

Ecologically founded demands to preserve the environment result in an increase in production prices in almost every case we know. Fortunately, agricultural crop production is an exception. By the appropriate adoption of a plough-less soil tillage system, however, possibly interrupted by the occasional use of the plough, it is possible to maintain the yield level, to reduce production costs and at the same time to fulfil environmental demands.

However, it is not the target to lock farms to a strict system of mulch sowing with or without loosening or direct sowing, and to derive therefore from the effects they have on costs and environmental compatibility. In fact, the point is to apply the methods site and crop-specifically. It may be sufficient e.g. to gently loosen the topsoil only once per crop rotation. Flexible use of equipment and application of methods adjusted to the conditions are important. Depending on the size of the farms they may have their own machines or use them in co-operation with others.

In summary the following is to be stated: Mulch sowing shows a way of how to operate not only competitively but also in an environmentally friendly manner by the targeted and useful employment of modern machinery, and thus lays the basis for integrated arable farming, with economics and ecology in harmony.

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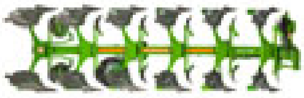
Note: If no sources are stated under the figures and tables they originate from the studies of the authors J. Brunotte and C. Sommer.

AMAZONE machinery overview

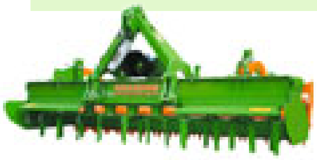
Soil tillage

Cayron plough



Cayron 200 5	Power requirement to 240 hp	40, 45, 50 cm furrow width	Stepped adjustment
Cayron 200 5+1	Power requirement to 240 hp	40, 45, 50 cm furrow width	Stepped adjustment
Cayron 200 V 5	Power requirement to 240 hp	30 – 55 cm furrow width	Hydraulic vari-width
Cayron 200 V 5+1	Power requirement to 240 hp	30 – 55 cm furrow width	Hydraulic vari-width

KE rotary harrows

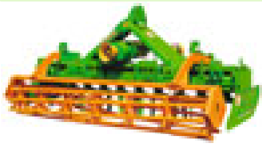


KE 2500 Special	Power requirement to 140 hp	Working width 2.50 m	Rigid
KE 3000 Special	Power requirement to 140 hp	Working width 3.00 m	Rigid
KE 3000 Super	Power requirement to 180 hp	Working width 3.00 m	Rigid
KE 3500 Super	Power requirement to 180 hp	Working width 3.50 m	Rigid
KE 4000 Super	Power requirement to 180 hp	Working width 4.00 m	Rigid

KG rotary cultivator · KX

KG 3000 Special	Power requirement to 220 hp	Working width 3.00 m	Rigid
KG 3500 Special	Power requirement to 220 hp	Working width 3.50 m	Rigid
KG 4000 Special	Power requirement to 220 hp	Working width 4.00 m	Rigid
KG 3000 Super	Power requirement to 300 hp	Working width 3.00 m	Rigid
KG 3500 Super	Power requirement to 300 hp	Working width 3.50 m	Rigid
KG 4000 Super	Power requirement to 300 hp	Working width 4.00 m	Rigid
KG 4001-2	Power requirement to 300 hp	Working width 4.00 m	Hydraulic folding
KG 5001-2	Power requirement to 300 hp	Working width 5.00 m	Hydraulic folding
KG 6001-2	Power requirement to 300 hp	Working width 6.00 m	Hydraulic folding
KX 3000	Power requirement to 190 hp	Working width 3.00 m	Rigid

SW cage rollers · PW tooth packer rollers · KW wedge ring rollers



SW 2500	Working width 2.50 m	Diameter 420 mm	Rigid
SW 3000	Working width 3.00 m	Diameter 420 mm	Rigid
SW 3000	Working width 3.00 m	Diameter 520 mm	Rigid
SW 3500	Working width 3.50 m	Diameter 520 mm	Rigid
SW 4000	Working width 4.00 m	Diameter 520 mm	Rigid
PW 2500/3000	Working width 2.50 m/3.00 m	Diameter 420 mm	Rigid
PW 2500/3000	Working width 2.50 m/3.00 m	Diameter 500 mm	Rigid
PW 3500/4000	Working width 3.50 m/4.00 m	Diameter 500 mm	Rigid
PW 3000/3500/4000	Working width 3.00 m/4.00 m	Diameter 600 mm	Rigid
KW 2500	Working width 2.50 m	Diameter 520 mm	Rigid
KW 3000	Working width 3.00 m	Diameter 520 mm	Rigid
KW 3000	Working width 3.00 m	Diameter 580 mm	Rigid
KW 3500	Working width 3.50 m	Diameter 580 mm	Rigid
KW 4000	Working width 4.00 m	Diameter 580 mm	Rigid

Catros compact disc harrows

Catros/Catros$^+$ 3001	Power requirement from 90 hp	Working width 3.00 m	Rigid
Catros/Catros$^+$ 3501	Power requirement from 105 hp	Working width 3.50 m	Rigid
Catros/Catros$^+$ 4001	Power requirement from 125 hp	Working width 4.00 m	Rigid
Catros/Catros$^+$ 4001-2	Power requirement from 125 hp	Working width 4.00 m	Hydraulic folding
Catros/Catros$^+$ 5001-2	Power requirement from 150 hp	Working width 5.00 m	Hydraulic folding
Catros/Catros$^+$ 6001-2	Power requirement from 180 hp	Working width 6.00 m	Hydraulic folding
Catros/Catros$^+$ 3002-T	Power requirement from 80 hp	Working width 3.00 m	Rigid
Catros/Catros$^+$ 3502-T	Power requirement from 100 hp	Working width 3.50 m	Rigid
Catros/Catros$^+$ 4002-T	Power requirement from 120 hp	Working width 4.00 m	Rigid
Catros/Catros$^+$ 7501-2T	Power requirement from 240 hp	Working width 7.50 m	Hydraulic folding/trailed
Catros/Catros$^+$ 9001-KR	With KR coupling frame	Working width 9.00 m	Hydraulic folding/trailed
Catros/Catros$^+$ 12001-KR	With KR coupling frame	Working width 12.00 m	Hydraulic folding/trailed
Catros/Catros$^+$ 4001-2TS	Power requirement from 120 hp	Working width 4.00 m	Hydraulic folding/trailed
Catros/Catros$^+$ 5001-2TS	Power requirement from 170 hp	Working width 5.00 m	Hydraulic folding/trailed
Catros/Catros$^+$ 6001-2TS	Power requirement from 180 hp	Working width 6.00 m	Hydraulic folding/trailed

Soil tillage

Cenius mulch cultivator

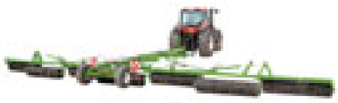
Cenius 3002 Special/Super	Power requirement from 100 hp	Working width 3.00 m	Rigid
Cenius 3502 Special/Super	Power requirement from 140 hp	Working width 3.50 m	Rigid
Cenius 4002 Special/Super	Power requirement from 170 hp	Working width 4.00 m	Rigid
Cenius 4002-2 Special/Super	Power requirement from 170 hp	Working width 4.00 m	Hydraulic folding
Cenius 3002-T Special/Super	Power requirement from 125 hp	Working width 3.00 m	Rigid
Cenius 3502-T Special/Super	Power requirement from 140 hp	Working width 3.50 m	Rigid
Cenius 4002-T Super	Power requirement from 160 hp	Working width 4.00 m	Rigid
Cenius 4002-2T Special/Super	Power requirement from 150 hp	Working width 4.00 m	Hydraulic folding

Cenius 4003-2TX	Power requirement from 200 hp	Working width 4.00 m	Hydraulic folding
Cenius 5003-2TX	Power requirement from 250 hp	Working width 5.00 m	Hydraulic folding
Cenius 6003-2TX	Power requirement from 300 hp	Working width 6.00 m	Hydraulic folding
Cenius 7003-2TX	Power requirement from 350 hp	Working width 7.00 m	Hydraulic folding

Centaur cultivator/disc cultivator combinations

Centaur 3001 Super	Power requirement from 150 hp	Working width 3.00 m	Rigid
Centaur 4001 Super	Power requirement from 200 hp	Working width 4.00 m	Rigid
Centaur 4001-2 Super	Power requirement from 200 hp	Working width 4.00 m	Hydraulic folding
Centaur 5001-2 Super	Power requirement from 250 hp	Working width 5.00 m	Hydraulic folding

AW land rollers



AW 6600	Power requirement from 80 hp	Working width 6.60 m	Hydraulic folding
AW 7800	Power requirement from 110 hp	Working width 7.80 m	Hydraulic folding
AW 9400	Power requirement from 130 hp	Working width 9.40 m	Hydraulic folding
AW 12200	Power requirement from 150 hp	Working width 12.20 m	Hydraulic folding
AW 15400	Power requirement from 180 hp	Working width 15.40 m	Hydraulic folding

Sowing technology

D9 mounted gravity seed drills

D9 2500 Special	Working width 2.50 m	Seed hopper capacity 360 l	Rigid
D9 3000 Special	Working width 3.00 m	Seed hopper capacity 450 to 850 l	Rigid
D9 3000 Super	Working width 3.00 m	Seed hopper capacity 600 to 1000 l	Rigid
D9 3500 Super	Working width 3.50 m	Seed hopper capacity 720 to 1200 l	Rigid
D9 4000 Super	Working width 4.00 m	Seed hopper capacity 830 to 1380 l	Rigid
D9 60 Super	Working width 6.00 m	Seed hopper capacity 1200 to 2000 l	Rigid
D9 9000-KR	Working width 9.00 m	Seed hopper capacity 1800 to 3000 l	With KR coupling frame
D9 12000-KR	Working width 12.00 m	Seed hopper capacity 2490 to 4140 l	With KR coupling frame

AD pack top gravity seed drills

AD 2500 Special	Working width 2.50 m	Seed hopper capacity 360 l	Rigid
AD 3000 Special	Working width 3.00 m	Seed hopper capacity 450 to 850 l	Rigid
AD 3000 Super	Working width 3.00 m	Seed hopper capacity 600 to 1000 l	Rigid
AD 3500 Super	Working width 3.50 m	Seed hopper capacity 720 to 1200 l	Rigid
AD 4000 Super	Working width 4.00 m	Seed hopper capacity 830 to 1380 l	Rigid

AD-P · Avant pneumatic seed drills

AD-P – 303 Special	Working width 3.00 m	Seed hopper capacity 750 to 1500 l	Rigid
AD-P – 353 Special	Working width 3.50 m	Seed hopper capacity 750 to 1500 l	Rigid
AD-P – 403 Special	Working width 4.00 m	Seed hopper capacity 750 to 1500 l	Rigid

AD-P – 303 Super	Working width 3.00 m	Seed hopper capacity 1500 to 2000 l	Rigid
AD-P – 403 Super	Working width 4.00 m	Seed hopper capacity 1500 to 2000 l	Rigid

Avant 4000	Working width 4.00 m	Seed hopper capacity 1500 to 2000 l	Rigid
Avant 4000	Working width 4.00 m	Seed hopper capacity 1500 to 2000 l	Hydraulic folding
Avant 5000	Working width 5.00 m	Seed hopper capacity 1500 to 2000 l	Hydraulic folding
Avant 6000	Working width 6.00 m	Seed hopper capacity 1500 to 2000 l	Hydraulic folding

Sowing technology

Cirrus · Citan · Cayena · Condor · Primera DMC pneumatic seed drills

Cirrus 4002	Working width 4.00 m	Seed hopper capacity 2200 to 2800 l	Hydraulic folding

Cirrus 3003 Compact	Working width 3.00 m	Seed hopper capacity 3000 l	Rigid
Cirrus 6003-2	Working width 6.00 m	Seed hopper capacity 3600 l	Hydraulic folding
Cirrus 6003-2C	Working width 6.00 m	Seed hopper capacity 4000 l	Hydraulic folding

Citan 6000	Working width 6.00 m	Seed hopper capacity 3000 l	Hydraulic folding
Citan 8000	Working width 8.00 m	Seed hopper capacity 5000 l	Hydraulic folding
Citan 9000	Working width 9.00 m	Seed hopper capacity 5000 l	Hydraulic folding
Citan 12000	Working width 12.00 m	Seed hopper capacity 5000 l	Hydraulic folding
Citan 12001-C	Working width 12.00 m	Seed hopper capacity 8000 l	Hydraulic folding
Citan 15001-C	Working width 15.00 m	Seed hopper capacity 8000 l	Hydraulic folding

Cayena 6001	Working width 6.00 m	Seed hopper capacity 3600 l	Hydraulic folding
Cayena 6001-C	Working width 6.00 m	Seed hopper capacity 4000 l	Hydraulic folding

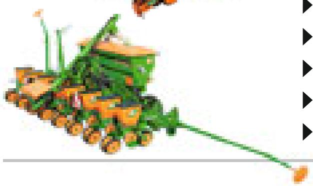
Condor 12001	Working width 12.00 m	Seed hopper capacity 8000 l	Hydraulic folding
Condor 15001	Working width 15.00 m	Seed hopper capacity 8000 l	Hydraulic folding

Primera DMC 3000	Working width 3.00 m	Seed hopper capacity 4200 l	Rigid
Primera DMC 4500	Working width 4.50 m	Seed hopper capacity 4200 l	Rigid
Primera DMC 602	Working width 6.00 m	Seed hopper capacity 4200 l	Hydraulic folding
Primera DMC 9000	Working width 9.00 m	Seed hopper capacity 4200 l	Hydraulic folding
Primera DMC 12000	Working width 12.00 m	Seed hopper capacity 6000 l	Hydraulic folding

EDX · ED pneumatic precision air seeders

EDX 6000-2	Working width 6.00 m	Number of sowing units 8 to 16	Hydraulic folding
EDX 6000-2C	Working width 6.00 m	Number of sowing units 8	Hydraulic folding
EDX 6000-2FC	Working width 6.00 m	Number of sowing units 8 to 16	Hydraulic folding

EDX 6000-TC	Working width 6.00 m	Number of sowing units 8 to 16	Hydraulic folding
EDX 9000-TC	Working width 9.00 m	Number of sowing units 12 to 20	Hydraulic folding



ED 302	Working width 3.00 m	Number of sowing units 4 to 10	Rigid
ED 452	Working width 4.50 m	Number of sowing units 6 to 12	Rigid
ED 452-K	Working width 4.50 m	Number of sowing units 6 or 7	Hydraulic folding
ED 602-K	Working width 6.00 m	Number of sowing units 8 to 12	Hydraulic folding
ED 9002-KR	Working width 9.00 m	With KR coupling frame	Hydraulic folding
ED 12002-KR	Working width 12.00 m	With KR coupling frame	Hydraulic folding

Fertilisation technology

ZA-X Perfect fertiliser spreader

ZA-XW Perfect 502	Hopper capacity 500 to max. 700 l	Working width 10 to 18 m
ZA-X Perfect 602	Hopper capacity 600 to max. 850 l	Working width 10 to 18 m
ZA-X Perfect 902	Hopper capacity 900 to max. 1700 l	Working width 10 to 18 m
ZA-X Perfect 1402	Hopper capacity 1400 to max. 1750 l	Working width 10 to 18 m

Fertilisation technology

ZA-M fertiliser spreader

ZA-M 1001 Special	Hopper capacity 1000 to max. 1500 l	Working width 10 to 36 m
ZA-M 1201	Hopper capacity 1200 to max. 2700 l	Working width 10 to 36 m
ZA-M 1501	Hopper capacity 1500 to max. 3000 l	Working width 10 to 36 m
ZA-M 2201	Hopper capacity 2200 l	Working width 10 to 36 m
ZA-M 2501	Hopper capacity 2500 l	Working width 10 to 36 m
ZA-M 2701	Hopper capacity 2700 l	Working width 10 to 36 m
ZA-M 3001	Hopper capacity 3000 l	Working width 10 to 36 m
ZA-M 1001 Special Profis	Hopper capacity 1000 to 1500 l	Working width 10 to 36 m
ZA-M Profis	Hopper capacity 1500 to max. 3000 l	Working width 10 to 36 m

ZA-TS fertiliser spreader

ZA-TS 1700	Hopper capacity 1700 l	Working width 18 to 54 m
ZA-TS 2000	Hopper capacity 2000 l	Working width 18 to 54 m
ZA-TS 2200	Hopper capacity 2200 l	Working width 18 to 54 m
ZA-TS 2700	Hopper capacity 2700 l	Working width 18 to 54 m
ZA-TS 3200	Hopper capacity 3200 l	Working width 18 to 54 m
ZA-TS 4200	Hopper capacity 4200 l	Working width 18 to 54 m

ZG-B large area bulk material and fertiliser spreader

ZG-B	Hopper capacity 5500 and 8200 l	Working width 10 to 36 m

ZG-TS large area bulk material and fertiliser spreader

ZG-TS 5500	Hopper capacity 5500 l	Working width 18 to 54 m
ZG-TS 8200	Hopper capacity 8200 l	Working width 18 to 54 m

Plant protection systems

UF mounted sprayers

UF 901	Nominal tank capacity 1050 l	Working width 12 to 28 m	Hydraulic/manual folding
UF 1201	Nominal tank capacity 1350 l	Working width 12 to 28 m	Hydraulic/manual folding
UF 1501	Nominal tank capacity 1720 l	Working width 12 to 28 m	Hydraulic/manual folding
UF 1801	Nominal tank capacity 1920 l	Working width 12 to 28 m	Hydraulic/manual folding
FT 1001	Hopper capacity 1000 l		

Self-propelled sprayers

Pantera 4502	Nominal tank capacity 4800 l	Working width 24 to 40 m	Hydraulic folding

UG trailed sprayers

UG 2200 Special	Nominal tank capacity 2400 l	Working width 15 to 28 m	Hydraulic folding
UG 3000 Special	Nominal tank capacity 3200 l	Working width 15 to 28 m	Hydraulic folding
UG 2200 Super	Nominal tank capacity 2400 l	Working width 15 to 28 m	Hydraulic folding
UG 3000 Super	Nominal tank capacity 3200 l	Working width 15 to 28 m	Hydraulic folding

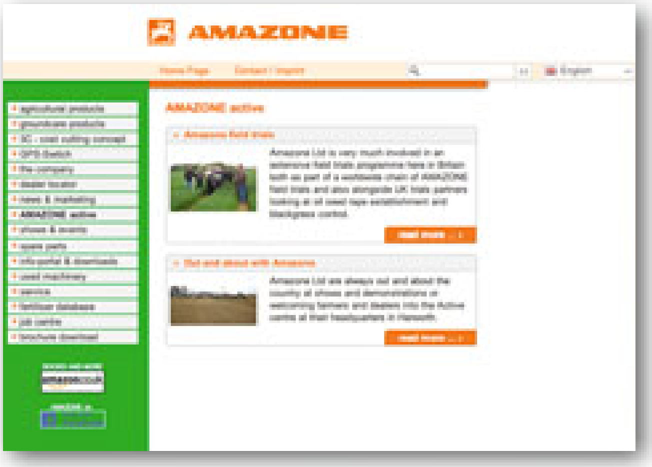
UX trailed sprayers

UX 3200 Special	Nominal tank capacity 3600 l	Working width 18 to 28 m	Hydraulic folding
UX 4200 Special	Nominal tank capacity 4600 l	Working width 18 to 28 m	Hydraulic folding
UX 3200 Super	Nominal tank capacity 3600 l	Working width 18 to 36 m	Hydraulic folding
UX 4200 Super	Nominal tank capacity 4600 l	Working width 18 to 40 m	Hydraulic folding
UX 5200 Super	Nominal tank capacity 5600 l	Working width 18 to 40 m	Hydraulic folding
UX 6200 Super	Nominal tank capacity 6600 l	Working width 18 to 40 m	Hydraulic folding
UX 11200	Nominal tank capacity 12000 l	Working width 24 to 40 m	Hydraulic folding

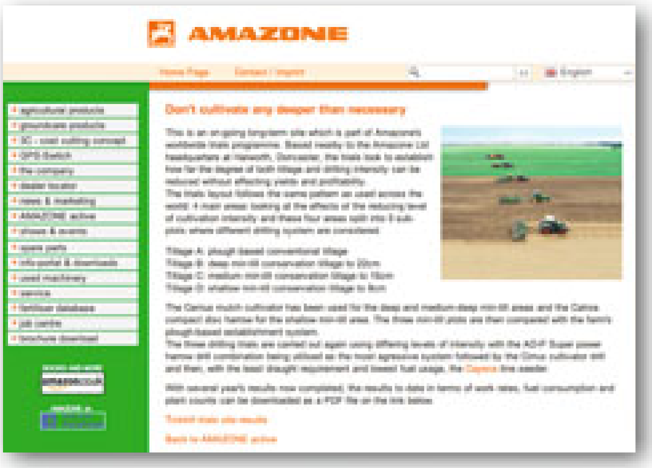
Further information at www.amazone.de · www.amazone.co.uk

Product brochures, videos, instruction manuals, test reports and other information can be downloaded from the **Info-Portal** at the AMAZONE website (www.amazone.co.uk).

The **"AMAZONE.TV" Video Portal** (www.amazone.tv) provides you with the access to more than 250 films and clips from AMAZONE. In addition to footage of different AMAZONE agricultural machinery you can also access films about the AMAZONE company as well as many different specialist subjects, such as, for example Precision Farming, robotics, soil tillage or crop protection.



The latest reports from the AMAZONE field trials sites and further information about AMAZONE's **ACTIVE Farming Concept** can be found on the AMAZONE website at www.amazone.de/activefarming



As part of our **ACTIVE Programme** we organise events on all aspects of "Intelligent Crop Production" in our ACTIVE centres at Hasbergen-Gaste, Hude and Leipzig. We hold meetings on specific themes in locations close to the AMAZONE trials sites in various regions of Germany.

The AMAZONE website contains reports and information about all AMAZONE events.

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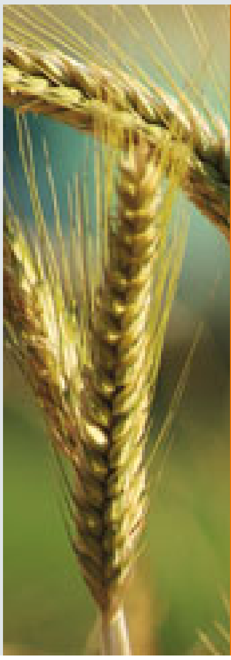
Part I
3C – the crop establishment concept

In Part I of '3C – the crop establishment concept', AMAZONE has formulated various basic rules for the successful combination of techniques when using soil tillage equipment and seed drills, as well as the accompanying fertilisation and crop protection measures. In this book, the background and, above all, the advantages and disadvantages of both conventional and conservation soil tillage methods; including the new Strip Till system are discussed. Influences of the various soil and climatic conditions on mechanisation are illustrated by the different combinations of system used in the diverse agro-climatic zones from Western Europe to Siberia. For this, AMAZONE carries out long-term field trials at different international sites and introduces here the current results. In conclusion, there is also international feedback on the use of a variety of AMAZONE equipment in the field.



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Part II
Soil tillage from a scientific viewpoint

PD Dr. habil. Joachim Brunotte from the Thünen Institute for Agricultural Technology (TI, formerly FAL Brunswick) and PD Dr. habil. Claus Sommer, Brunswick, describe how it is possible to compete not only economically, but also in an environmentally-friendly manner through the targeted use of modern equipment technology as part of a conservation soil tillage approach. Therefore, it is essential to sustain the soil performance in the long term, for example, by minimising capping and soil erosion, reducing harmful compaction and encouraging biological soil activity. These agricultural scientists also present the basic principles of conservation soil tillage and demonstrate how these can be successfully put into practice in ways that are appropriate to local conditions. The authors also discuss the possible pitfalls and explain how fertilisation strategies should be adapted and how weeds, diseases and pests should be counteracted.

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