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Compatibility of Agricultural Management Practices and Types of Farming in the EU to enhance Climate Change Mitigation and Soil Health

Overview of technological innovations in soil management

D4.451

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The CATCH-C project aims at identifying and improving the farm compatibility of sustainable soil management practices for farm productivity, climate-change mitigation, and soil quality. The project is carried out by a consortium of 12 partners, led by Stichting Dienst Landbouwkundig Onderzoek (DLO), The Netherlands.

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Executive summary

The Catch-C project addresses three major goals of better soil management: productivity, mitigation of climate change, and soil quality. The potential of soil management practices to contribute to these respective goals has been extensively analyzed in other outcomes (Work Package 3). Ideally, practices can contribute to productivity, climate and soil quality all simultaneously. In reality, however, such practices rarely exist and there are often tradeoffs between these three major goals. This report focuses on practices that we expect contribute to improving soil quality. Commonly recognized examples are reduced tillage, the application of organic inputs (manures, composts), crop rotation, the cultivation of green manures and catch and cover crops, the retention of crop residues on the field, and the use of low-impact machinery.

Besides assessing the biophysical merits of these practices, the Catch-C project also aims to identify barriers against the adoption of better practices. Such barriers may relate to farmers' perception (Work Package 4), to the legal context (Work Package 5), or to practical (technical or agro-ecological) difficulties associated with the introduction of better practices (Work Package 4). This report is about resolving barriers of latter category: practical barriers.

The adoption of sustainable practices on a given farm requires specific tinkering to make them fit within the current context. It is this process of resolving local difficulties or barriers that we refer to as 'innovation'. Innovations, then, are assemblies - of ideas, instruments, procedures, tips and tricks, etc. - that enable the adoption of better soil management practices.

This report compiles 81 examples of such innovations. Given the geographical spread of their origins, they cover a wide variety of European farming systems. Some practices may be well established in one region, but still innovative in another. The purpose of this overview is to make locally developed ideas and techniques accessible to a wider European audience, in order to facilitate better soil management. The format of 'collected fact sheets' is to encourage the use of this information by projects or organizations dedicated to disseminating innovations in European agriculture.

Each innovation is described by a separate, illustrated fact sheet, following a standard structure that summarizes the principle of operation, the main advantages, and the type of practice that the innovation aims to support (e.g. reduced tillage, or incorporation of crop residues).

The fact sheets also specify to which goals the innovation contributes, and gives key references for more information. The fact sheets are grouped by categories of soil management practices (crop rotation, tillage, nutrient management, ...). Summary tables are included that list the main characteristics of each innovation (Tables 3 and 4).

1 Introduction

1.1 Best management practices (BMPs)

The Catch-C project addresses three major goals of better soil management: productivity, mitigation of climate change, and soil quality. The project aims to assess the potential of practices to contribute to these respective goals (WP3). Ideally, management practices can be identified, that contribute to productivity, climate and soil quality all simultaneously. In reality, however, such practices rarely exist and there are often tradeoffs between these three major goals (see deliverables D3.324, D3.334, D3.344, D3.354, D3.364, D3.371). Moreover, different stakeholders have different priorities, and farmers have to work with practical constraints that may render a generally attractive practice less attractive in a particular case. Strictly speaking, best practices can be defined – at best- only for particular goals, in particular environments.

Despite these shortcomings, we still maintain the concept of BMP to be consistent with the terminology used in the project work plan (DoW). In our current, more colloquial use of the term, a BMP is a practice that contributes to (aspects of) soil quality. Commonly recognized examples are reduced tillage, the application of organic inputs (manures, composts), crop rotation, the cultivation of green manures and catch and cover crops, the retention of crop residues on the field, and the use of low-impact machinery. These BMPs often contribute to soil quality, sometimes also to productivity and climate. These examples are rather broad categories, and a long list of more closely defined management practices (MPs) was developed in WP3. It is included here in Appendix 1.

Besides assessing the biophysical merits of BMPs, the Catch-C project also aims to identify barriers against the adoption of better practices. Such barriers may relate to farmers' perception (WP4), to the legal context (WP5), or to practical (technical or agro-ecological) difficulties associated with the introduction of better practices (WP4). This report is about resolving such practical barriers.

1.2 Innovations to overcome barriers

Changes in agriculture and its context (e.g. markets, policies, natural environment) challenge the farming community to continuously innovate their business (Daane 2010). "Innovation means putting ideas, knowledge, and technology to work in a manner that brings about a significant improvement in performance or product quality" (Asenso-Okyere & Davis 2009). A similar definition was proposed by Adams (1983): "Agricultural innovations are defined as new ideas, practices or techniques which provide the means of achieving sustained increase in farm productivity and income." Adoption, then, is "a mental decision by farmers to make full use of new idea(s) as the best cause of action" (Ornan et al., 2010).

Now it can be hardly claimed that reduced tillage, the use of organic inputs, crop rotation, green manures, etc. are innovations. Such practices are as old as agriculture itself. Their adoption on a given farm, however, always requires specific tinkering to make them fit within the current context (climate, soil type, cropping system, scale, mechanization, etc.). It is this process of resolving local difficulties or barriers that we – in this project - refer to as 'innovation'. The resulting innovations are assemblies - of ideas, instruments, germplasm, instructions and procedures, software, tips and tricks, etc. - that enable the adoption of better soil management practices. In the end, of course, we do recognize that our distinction between existing practices (MPs, BMPs) and innovations remains somewhat arbitrary.

This report compiles innovations to overcome barriers to the successful adoption of BMPs for soil management. Given the geographical spread of their origins - the Catch-C partner countries - they cover a wide variety of European farming systems. Many of these innovative developments involve facilitating the farm workflow and associated equipment (machinery, sensors, and associated software). They are often local and consequently not yet within reach of the wider farming community. Some practices may be well established in one region, but still innovative in another, as recognized by Gildemacher & Wongtschowski (2013) in their definition of innovation.

Innovations may sprout from farming practice itself as well as from focused research efforts. Innovations for end-users are not often covered in the scientific literature. We relied, therefore, on a mixed approach in compiling this report: inquiries with experiment stations, advisors and their knowledge platforms, commercial parties as well as scientists. As a consequence, not all information contained here could be scientifically validated by the project team. However, we include in all fact sheets the key references that have served as our sources.

1.3 This report – fact sheets for innovation in soil management

The purpose of this overview is to make locally developed ideas and techniques accessible to a wider European audience, in order to facilitate better soil management. We chose the format of 'collected fact sheets' to encourage the use of this information by projects or organizations dedicated to disseminating innovations in European agriculture. Still, as the fact sheets were drafted from a particular national or regional context, further testing and verification may be needed for application elsewhere. In some cases, similar innovations were collected from different regions, as for example with 'strip tillage'. In such cases we have retained the separate sheets, showing local variations of the same basic technique.

Each innovation is described in a separate fact sheet, following a standard structure of seven points: "Related to MP"; "Related to FTZ"; "Key points"; "What is it?"; "How does it work / is it applied?"; "Advantages and applications of the innovation"; and "References". A brief explanation is given below:

- "Related to MP": lists Management Practices addressed/supported by the innovation. An extensive list of management practices (MPs) was drafted in WP3 and is included here in Appendix 1. Innovations that do not respond to an already defined MP (i.e. not listed in App.1), are marked as MP 'not-coded'.
- "Related to FTZ": lists the zones where the innovation is already applied by some farmers (see Figure 1 and Table 1). Our codes of farm types and biophysical environments (so called FTZ-units) follow the classification laid out in WP2 (deliverable D2.242); the major FTZ units that constitute the geographical frame of the project are depicted in Figure 1.
- "Key points": one to three highlights of the innovation.
- "What is it?": a short description of the innovation.

- “How does it work / is it applied?”: the principle of the method/technique is explained.
- “Advantages and applications of the innovation”: summarizes all advantageous aspects and possible applications of the innovation described.
- “Contribution to CATCH-C major goals”: This section also shows to which of the Catch-C major goals of better soil management (productivity, climate, soil quality) the innovation is intended to contribute.
- “Reference”: sources of information (e.g. webpages, famer journals, etc.).

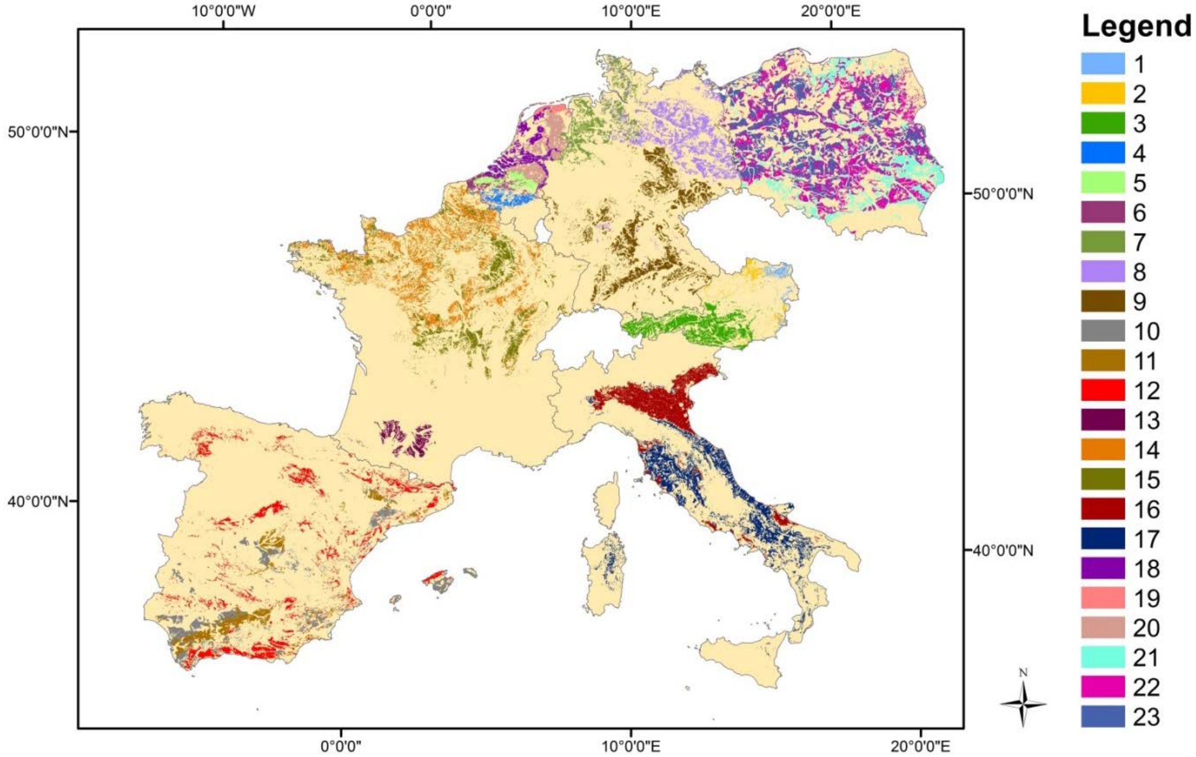

Figure 1: Selected major FTZs for each participant country in Europe as defined in Catch-C Work Package 2, see also Deliverable D2.242

Table 1: Major FTZs and land use for each participant country as defined in Catch-C Work Package 2, see also Deliverable D2.242 and Appendix 2 for ENZ, SL and TXT definitions

ID	Country	FTZ	Land use
1	Austria	ENZ8_SL3+1_TXT2	Arable / cereal, permanent crops
2	Austria	ENZ6_SL3_TXT3	Mixed farms
3	Austria	ENZ5_SL5_TXT2	Dairy cattle / permanent grass
4	Belgium	ENZ7_SL2_TXT3	Arable / specialized crops
5	Belgium	ENZ7_SL1_TXT1	Dairy farming / permanent grassland
6	Belgium	ENZ7_SL1_TXT2	Mixed farms (pigs and horticulture)
13	France	ENZ12_SL3_TXT4	Arable farms
14	France	ENZ7_SL2_TXT3	Dairy cattle
15	France	ENZ7_SL2_TXT2	Arable farms
7	Germany	ENZ4_SL1_TXT1	Arable and mixed farms
8	Germany	ENZ6_SL1_TXT1	Arable / cereal / Mixed farms
9	Germany	ENZ6_SL2+3_TXT3	Arable farms

16	Italy	ENZ12_SL1_TXT1+2+3	Arable / cereal
16	Italy	ENZ12_SL1_TXT1+2+3	Dairy cattle / temporary grass
17	Italy	ENZ12_SL3_TXT2, ENZ12_SL4_TXT2+3	Arable / cereal
21	Poland	ENZ6_SL2_ TXT3	Arable / cereal
22	Poland	ENZ6_SL2_TXT1	Mixed farms
23	Poland	ENZ6_SL1_TXT1	Dairy cattle / Other
10	Spain	ENZ13_SL1+2+3+4_TXT4	Arable / Cereals
11	Spain	ENZ13_SL2+3+4_TXT3	Permanent crops
12	Spain	ENZ11_SL5_TXT2	Sheep and goats / Others (pigs) + Beef and mixed cattle / Permanent grass
12	Spain	ENZ12_SL2+3+4_TXT2	Sheep and goats / Others (pigs) + Beef and mixed cattle / Permanent grass
12	Spain	ENZ13_SL2+3_TXT1	Sheep and goats / Others (pigs) + Beef and mixed cattle / Permanent grass
12	Spain	ENZ13_SL2+3+4+5_TXT2	Sheep and goats / Others (pigs) + Beef and mixed cattle / Permanent grass
18	The Netherlands	ENZ7_SL1_TXT2+3	Arable / specialized
19	The Netherlands	ENZ4_SL1_TXT2+3	Arable / specialized + cereals
20	The Netherlands	ENZ4+6+7_SL1_TXT0+1	Arable / specialized
20	The Netherlands	ENZ4+7_SL1_TXT1	Dairy cattle / permanent grass

1.4 Structure of this report: sorting of the fact sheets by management category

The innovations documented in the separate fact sheets differ widely in local relevance (national, regional, local) and in their degree of introduction in practice (from testing on experiment farms to introduction with advances farmers to full scale establishment). It was not possible to order all fact sheets in a clear hierarchical structure that respects these differences. Instead, we have organized them by the broad categories of management practices (as established in WP3, see Table 2).

Table 3 gives a concise overview of all innovations covered by the report. Besides a short description of the innovation, the management practices (MPs) they support are listed in the table (see MP codes in Appendix 1). If the innovation refers to a specific crop, the crop is also represented in the table.

Next, Table 4 lists the contributions of the innovation to our goals of sustainable soil management, here split into their components (productivity, C sequestration / GHG reduction, (biological) soil health, chemical soil fertility, physical soil fertility). Additional aspects (side effects) are also mentioned in the Table 4.

Table 2: List of categories of management practices (a full list of management practices is included in Appendix 1)

Category of management practices	Sub-category of management practices
A. Rotation	A1.Crop rotation
	A2. Intercropping / green manure / catch crop
B. Grassland management	
C. Tillage	
D. Nutrient management	D1. Mineral fertilizer
	D2. Organic fertilizer
	D3. Residue management
	D4. Nutrient classification
E. Crop protection	E1. Crop protection - weeds
	E2. Crop protection - pests
F. Water management	F1. Water management - irrigation
	F2. Water management - drainage
G. Other	

2. Overview of technological innovations

Table 3: Overview list of innovations

	Name of technological innovation	Description	Related crops	Related to MP
Category A. "Rotation"				
A.1	Rotation of cereals with lucerne (alfalfa) in a dairy farm	Rotation of a 3-years ley of lucerne with maize in an intensive dairy farm	Maize	MP3 Rotation with legume crops
A.2	Short rotation of grass combined with maize	Grass is cropped for three years and followed by three years of maize	Maize	MP6 Rotation with grassland
A.3	Crop rotation diversification	The alternation of subsistence, cash and green manure/cover crops with different characteristics, cultivated on the same field during successive years, and following a previously established sequence	Various crops	MP8 Rotation with cover/catch crops + MP9 Rotation with green manures
A.4	Intercropping / green manure / catch crops	Growing of two or more crops in proximity to promote interaction between them	Various crops	MP8 Rotation with cover/catch crops + MP9 Rotation with green manures
A.5	Fast growing cover crops (as green manures)	Seed mixture of summer cover crops with fast growing to improve soil fertility and to conserve nutrients containing in slurry	Various crops	MP9 Rotation with green manures
A.6	Cover crops (as green manures) for maize	Seed mixture of summer / winter cover crops to support mycorrhization of maize roots and to improve soil structure	Maize	MP9 Rotation with green manures
A.7	Cover crops (as green manures) for potato rotations	Seed mixture of summer cover crops for fast shading	Potato	MP9 Rotation with green manures
A.8	Nematodes reducing cover crops (as green manures)	Seed mixture of summer / winter cover crops to protect against nematodes	Potato, sugar beet	MP9 Rotation with green manures
A.9	Soil structure improving cover crops (as green manures)	Seed mixture of summer cover crops with intensive root growth	Winter / spring rapeseed	MP9 Rotation with green manures
A.10	Cover crops (as green manures) for sugar beet rotations	Seed mixture of summer cover crops specialized to sugar beet	Sugar beet	MP9 Rotation with green manures
A.11	Cover crops (as green manures) for water protection areas	Seed mixture of summer / winter cover crops without legumes and with or without crucifers	Winter / spring rapeseed	MP9 Rotation with green manures
A.12	Catch crops as green manures	A leguminous secondary crop is sown between two main summer crops to maintain the soil covered during winter	Maize	MP9 Rotation with green manures

	Name of technological innovation	Description	Related crops	Related to MP
A.13	Green manure to reduce beet cyst nematodes	Growing green manure type that is resistant to beet cyst nematodes for a full season or in fall only	Sugar beet	MP9 Rotation with green manures
A.14	Green manure online decision support system	Use the online system to choose the optimal green manure for control of nematodes	Potato	MP9 Rotation with green manures
A.15	Use of green manure to limit potato cyst nematodes	Growing green manure type that is not a host to potato cyst nematodes	Potato	MP9 Rotation with green manures
A.16	Soil coverage detection	Object based image to analyze and evaluate the soil coverage and could be used for the quantification of soil erosion	Various crops	MP8 Rotation with cover/catch crops + MP9 Rotation with green manures
A.17	Early harvest maize to establish grass	Early harvest of maize to allow timely establishment of green manure or grass ley before winter	Maize	MP 'not-coded' Use of early maturing maize varieties
A.18	Early-maturing maize with ryegrass	Cultivating early-maturing silage maize varieties in combination with a ryegrass cover crop	Maize	MP 'not-coded' Use of early maturing maize varieties
A.19	Underseeding under maize with herbicide I	Underseeding under maize (Lolium perenne and Lolium multiflorum) with adapted herbicide application	Maize	MP 'not-coded' Undersowing of green manure within maize
A.20	Underseeding under maize with herbicide II	Underseeding under maize (Festuca rubra) with adapted herbicide application	Maize	MP 'not-coded' Undersowing of green manure within maize
A.21	Undersowing of a green manure under maize after maize sowing	Undersowing of a green manure (Lolium perenne) under maize after maize sowing	Maize	MP 'not-coded' Undersowing of green manure within maize
A.22	Undersowing of a green manure within maize at the same time as maize sowing	Undersowing of a green manure tall fescue (Festuca arundinacea) within maize at the same time as maize	Maize	MP 'not-coded' Undersowing of green manure within maize
A.23	Underseeding under maize combined with mechanical weed control and herbicide banding	Underseeding under maize (Italian and/or perennial ryegrass) in combination with mechanical weed control and herbicide banding	Maize	MP 'not-coded' Undersowing of green manure within maize + MP41 Mechanical weeding
Category B. "Grassland management"				
B.1	Rational grazing planning combined with cultivated areas for feeding the livestock	Annual grasslands in the dehesa system are used primarily for livestock grazing		MP11 Permanent grazing

	Name of technological innovation	Description	Related crops	Related to MP
Category C. "Tillage"				
C.1	Use of specific machinery that allow non-inversion tillage	Non-inversion tillage machinery chisel plow and deep tillage sub soiler		MP17 Non-inversion tillage reduced tillage + MP18 Non-inversion tillage minimum tillage
C.2	Compact disc harrow for residues management	Compact device with high strike capacity for shallow cultivation		MP17 Non-inversion tillage reduced tillage + MP18 Non-inversion tillage minimum tillage
C.3	Stubble cultivator for shallow residues and seedbed management	Universal cultivation tool for reduced tillage		MP17 Non-inversion tillage reduced tillage + MP18 Non-inversion tillage minimum tillage
C.4	Disc harrows with 2 rollers for small farms and fields	Passive tillage tool to incorporate crop residues at small fields		MP17 Non-inversion tillage reduced tillage + MP18 Non-inversion tillage minimum tillage
C.5	Strip till	Only a partial area of the entire surface is cultivated in strips – the space for further planting/seeding - whereas up to 80% of soil surface remain untreated	Various crops	MP17 Non-inversion tillage reduced tillage + MP18 Non-inversion tillage minimum tillage
C.6	Strip tillage	A less than full-width tillage of varying intensity that is conducted parallel to the crop row direction (no more than 30% of the soil surface is disturbed by this practice, leaving most of the previous crop's residue intact	Various crops (e.g. wheat, maize, sugar beet)	MP17 Non-inversion tillage reduced tillage + MP18 Non-inversion tillage minimum tillage
C.7	Strip till	Only strips are processed before seeding, usually at smaller depth than traditional plowing, the reminder of the field remains undisturbed	Corn, sorghum, sunflower as example	MP17 Non-inversion tillage reduced tillage + MP18 Non-inversion tillage minimum tillage
C.8	Strip till drill	Strip till drill is a one- or two-pass technique that creates a seed bed only where it is needed rather than across the entire field (either one-pass targeted seed-bed preparation and sowing or cultivation and slurry application ahead of a separate sowing operation)		MP17 Non-inversion tillage reduced tillage + MP18 Non-inversion tillage minimum tillage

	Name of technological innovation	Description	Related crops	Related to MP
C.9	Bio strip till	Combination of strip till and growing of special catch crops for improving soil structure		MP17 Non-inversion tillage reduced tillage + MP18 Non-inversion tillage minimum tillage
C.10	Vertical tillage	Application of soil cultivation tools to soil loosening in strips without horizontal moving of soil.		MP17 Non-inversion tillage reduced tillage + MP18 Non-inversion tillage minimum tillage
C.11	Smart till	Vertical tillage tool to loosening whole surface without horizontal moving of soil		MP17 Non-inversion tillage reduced tillage + MP18 Non-inversion tillage minimum tillage
C.12	Deep non-inversion tillage	Non-inversion tillage at the same depth or deeper than ploughing depth	Maize, sugar beet, horticultural crops	MP17 Non-inversion tillage reduced tillage + MP18 Non-inversion tillage minimum tillage
C.13	Non-inversion spring tillage technique to incorporate grass sod before maize sowing	No inverting soil tillage is needed to destroy the grass sod	Maize	MP17 Non-inversion tillage reduced tillage + MP18 Non-inversion tillage minimum tillage
C.14	Non-inversion spring tillage technique to incorporate green manures after maize	No inverting soil tillage is needed to destroy the green manure after maize	Maize	MP17 Non-inversion tillage reduced tillage + MP18 Non-inversion tillage minimum tillage
C.15	Non-inversion tillage to reduce volunteer potatoes on clay soils	Before winter using a fixed tine cultivator up to the depth of the plough layer to facilitate freezing of volunteer potatoes	Potatoes	MP17 Non-inversion tillage reduced tillage + MP18 Non-inversion tillage minimum tillage
C.16	Tramlines	Farming system built on permanent wheel tracks where the crop zone and traffic lanes are permanently separated	Cereals, sugar beets, corn	MP24 Controlled traffic farming
C.17	DGPS-RTK to drive over the field	Tractors are equipped with a differential global positioning system (DGPS) and a real time kinematic (RTK) which allows them to drive on specified positions with an accuracy of 1 cm	Maize, potato, onion as examples	MP24 Controlled traffic farming
C.18	Low tire pressure in controlled traffic systems	When a wheel based vehicle enters the field the tire pressure is adjusted to the weight on the tire and to the specific field operation at hand		MP24 Controlled traffic farming

	Name of technological innovation	Description	Related crops	Related to MP
C.19	Precision ploughing	The DGPS system corrects the ploughing to plough in exact rows		MP24 Controlled traffic farming
C.20	Improved fertilizer spreading techniques by variable rate technology at field borders or spreading jobs	Using a DGPS based description map to shut down fertilizer application pipes automatically when spreading on borders instead of the field and to prevent application overlap between passages		MP24 Controlled traffic farming + MP26 Mineral N application
C.21	Use of finger weeder	Use of finger weeder: inter and intra row weed control combined with ridging and deridging	Maize	MP24 Controlled traffic farming + MP41 Mechanical weeding
Category D. "Nutrient management"				
D.1	Biochar application	Carbon-rich product to improve soil functioning and to increase carbon sequestration		MP Organic fertilizer application
D.2	CULTAN fertilization	Controlled Uptake Long Term Ammonium Nutrition fertilization as point injection	Various crops	MP26 Mineral N application
D.3	App to determine optimal nitrogen fertilization for winter rape in spring	Use of app with image analysis to determine optimal nitrogen fertilization for winter rapeseed in spring	Winter rapeseed	MP26 Mineral N application
D.4	Fertigation with mineral fertilizer	Technique that allows the application of water and fertilizers simultaneously through the irrigation system to apply the necessary nutrients to plants	Various vegetables as example	MP26 Mineral N application + MP27 Mineral P application + MP28 Mineral K application
D.5	Compost to improve soil fertility	Compost to improve soil fertility		MP29 Plant compost application
D.6	On-farm composting	Farm compost is made of feedstock which can be found on the farm: wood chips and bark, manure, straw, grass clippings, crop residues, etc.		MP29 Plant compost application + MP30 Bio-waste compost application + MP31 Sludge compost application
D.7	Compost application as soil amendment and fertilizer	Distribution of organic matter from a mixed composting of urban organic wastes		MP30 Bio-waste compost application
D.8	Top dressing of maize with bovine slurry	Bovine or pig slurry distributes to maize when the crop is well established and actively growing (top-dressing)	Maize	MP33 Cattle slurry application

	Name of technological innovation	Description	Related crops	Related to MP
D.9	Fertigation of maize with bovine slurry using a ranger irrigation system	Irrigation of maize using slurry mixed with water, in some of the irrigation events before the flowering stage	Maize	MP33 Cattle slurry application + MP54 Sprinkler irrigation
D.10	Manure processing (solid-liquid separation)	Manure separation into a solid and a liquid fraction after which both fractions can be applied to land separately or further processed		MP33 Cattle slurry application + MP34 Poultry manure application + MP35 Pig slurry application
D.11	Application of slurry in winter wheat on clay soils in the spring	Slurry is injected into the clay soil in winter wheat between 1th February and the end of April	Winter wheat	MP33 Cattle slurry application + MP34 Poultry manure application + MP35 Pig slurry application
D.12	Components in direct seeders for residue management	Soil is not tilled in the spring before planting to conserve soil moisture in the seedbed		MP36 Return of crop residues
D.13	Maintain organic matter content of the soil by the incorporation of straw	After harvest straw residues are chopped and incorporated into the soil		MP36 Return of crop residues
D.14	Manganese sensor to adapt fertilization	Technical device to evaluate the manganese supply of the youngest developed leaf and the missing amount of manganese fertilizer/surface unit	Cereals	MP 'not-coded' Soil analysis (Development and adoption of fertilization plans)
D.15	Soil nutrient sensor to adapt fertilization	The soil sensor evaluates different nutrient contents e.g. nitrogen to adapt the fertilization to the crop needs and to reduce nutrient losses by leaching or emissions		MP 'not-coded' Soil analysis (Development and adoption of fertilization plans)
D.16	Digestate and its solid / liquid separation products	The waste product from biogas production which is used to replace fertilizers or used as soil improver	Potato, sugar beet, maize, onions	MP 'not-coded' Application of digestate (from biogas plants)
D.17	Liquid fraction of digestate as fertilizer	Use of liquid digestate distributes as an organic fertilizer	Cereals	MP 'not-coded' Application of digestate (from biogas plants)
D.18	DGPS-RTK to apply slurry in rows in maize	A tractor equipped with differential global positioning system (DGPS) and a real time kinematic (RTK) injects manure in the first field operation and sows maize seeds in a second field operation shortly after manure injection	Maize	MP 'not-coded' Row application of fertilizer + MP24 Controlled traffic farming

	Name of technological innovation	Description	Related crops	Related to MP
D.19	Soil scanner	Non-invasive method to measure soil heterogeneity		MP 'not-coded' Use of smart N indicators to yearly adapt N fertilization or precision farming
Category E. "Crop protection"				
E.1	Désherbinage	Combination of a sprayer on a hoeing machine that enables targeting the row, while inter-row is hoed	Maize	MP41 Mechanical weeding + MP24 Controlled traffic farming
E.2	Autonomous robot	An electrically driven tracked module / robot combined with different agricultural precision applications (e.g. discs for hoeing)		MP41 Mechanical weeding + MP24 Controlled traffic farming
E.3	Vegetated buffer strips using double seeded density crop	The crop itself is used as a buffer strip just increasing the seeding density and changing the sowing direction		MP44 Patches or stripes of natural vegetation
E.4	Integrated pest management (IPM)	Process of the balanced use of cultural, biological, chemical procedures that are environmentally compatible and economically feasible to reduce pest populations to tolerable levels	Various crops	MP 'not-coded' Integrated weed management (only post-emergence)
E.5	Cultural weed control	Long-term weed management strategy based on the practical application of the ecological concept of 'maximum diversification of disturbance'	Various crops	MP 'not-coded' Integrated weed management (only post-emergence)
E.6	Weed detection using UAV to adapt herbicide application	Small unmanned aircraft vehicle with a modified RGB camera to detect weed	Various crops and grassland	MP 'not-coded' Integrated weed management (only post-emergence)
E.7	Weed detection using weed app to recommend herbicides	Using app with detailed herbicide recommendations for important crops and grassland	Wheat as example	MP 'not-coded' Integrated weed management (only post-emergence)
E.8	Underseeding under maize combined with mechanical weed control and herbicide banding	Underseeding under maize (Italian and/or perennial ryegrass) in combination with mechanical weed control and herbicide banding	Maize	MP41 Mechanical weeding + MP 'not-coded' Undersowing of green manure within maize

	Name of technological innovation	Description	Related crops	Related to MP
Category F. "Water management"				
F.1	Combined Centre Pivot with mobile drip tubes	Combined irrigation system with mobile drip tubes to conserve water	Potatoes as example	MP53 Drip irrigation
F.2	Centre Pivot / Linear irrigation system	Centre Pivot / Linear irrigation system		MP54 Sprinkler irrigation
F.3	Combined Centre Pivot-Linear irrigation system	Combined centre pivot-linear irrigation system		MP54 Sprinkler irrigation
F.4	Precision Irrigation - Variable Rate Irrigation	Site-specific centre pivot irrigation system for variable rates with individual control of each nozzle	Various crops	MP54 Sprinkler irrigation
F.5	Water management systems with treatment of low quality waters	Irrigation with treated wastewater for crop production with adopting appropriate on-farm management strategy	Various crops	MP53 Drip irrigation + MP54 Sprinkler irrigation
F.6	Leaf clamp to improve and to optimize irrigation scheduling and amount	Magnetic non-invasive patch clamp pressure probe to measure very small leaf turgor changes in real time	Various crops	MP53 Drip irrigation + MP54 Sprinkler irrigation
Category G. "Other practices"				
G.1	Soil Bioengineering	Use of engineering design principles with biological and ecological concepts with various construction material to control erosion and flooding		MP 'not-coded' Soil conservation practices (other than mentioned, e.g. dams for gully control)
G.2	Low pressure tires / caterpillars	Specific tires or caterpillars added to wheels		MP 'not-coded' Reducing soil compaction (by use of low pressure tires)
G.3	Management to reduce and minimize soil compaction	Several aspects to avoid soil compaction		MP 'not-coded' Reducing soil compaction (by use of low pressure tires)

Table 4: Technological innovations and contribution to major goals

	Name of technological innovation	Productivity	C sequestration GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
Category A. "Rotation"							
A.1	Rotation of cereals with lucerne (alfalfa) in a dairy farm	x		x	x	x	Increase of dairy farm self-sufficiency; reduction of mineral fertilizer supply
A.2	Short rotation of grass combined with maize	x	x	x	x	x	Reduced losses of nutrients to the environment
A.3	Crop rotation diversification	x	x	x	x	x	
A.4	Intercropping / green manure / catch crops	x	x	x	x	x	Economic
A.5	Fast growing cover crops (as green manures)	x		x		x	
A.6	Cover crops (as green manures) for maize	x		x	x	x	
A.7	Cover crops (as green manures) for potato rotations	x		x		x	
A.8	Nematodes reducing cover crops (as green manures)	x		x		x	
A.9	Soil structure improving cover crops (as green manures)	x		x		x	
A.10	Cover crops (as green manures) for sugar beet rotations	x		x		x	
A.11	Cover crops (as green manures) for water protection areas	x		x	x	x	Reduced leaching to the environment
A.12	Catch crops as green manures	x		x	x	x	Reduction of mineral fertilizer supply

	Name of technological innovation	Productivity	C sequestration GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
A.13	Green manure to reduce beet cyst nematodes	x	x	x	x	x	
A.14	Green manure online decision support system	x	x	x	x	x	
A.15	Use of green manure to limit potato cyst nematodes	x	x	x	x	x	
A.16	Soil coverage detection					x	
A.17	Early harvest maize to establish grass	x	x	x	x	x	Reduces emissions of herbicides to the environment
A.18	Early-maturing maize with ryegrass		x		x	x	Lower soil compaction risk
A.19	Underseeding under maize with herbicide I	x	x			x	Reduction of nitrogen and herbicides to the environment
A.20	Underseeding under maize with herbicide II	x	x			x	Reduction of nitrogen and herbicides to the environment
A.21	Undersowing of a green manure under maize after maize sowing	x	x		x	x	Reduced emissions of nitrogen to the groundwater
A.22	Undersowing of a green manure within maize at the same time as maize sowing	x	x		x	x	Reduced emissions of nitrogen to the groundwater
A.23	Underseeding under maize combined with mechanical weed control and herbicide banding		x		x	x	Erosion control; Prevents nitrate leaching
Category B. "Grassland management"							
B.1	Rational grazing planning combined with cultivated areas for feeding the livestock	x				x	

	Name of technological innovation	Productivity	C sequestration GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
Category C. "Tillage"							
C.1	Use of specific machinery that allow non-inversion tillage			x		x	Economic aspects
C.2	Compact disc harrow for residues management	x	x	x	x	x	Better distribution of crop residues and economical aspect
C.3	Stubble cultivator for shallow residues and seedbed management	x	x	x	x	x	Better decomposition of post-harvest residues
C.4	Disc harrows with 2 rollers for small farms and fields	x	x	x	x	x	Better distribution of crop residues
C.5	Strip till	x	x	x		x	
C.6	Strip tillage	x	x	x		x	Reduces soil erosion
C.7	Strip till	x	x	x		x	Enables better soil warming in spring
C.8	Strip till drill	x		x	x	x	Economic aspects
C.9	Bio strip till	x		x	x	x	Economic aspects
C.10	Vertical tillage	x		x	x	x	Economic aspects
C.11	Smart till	x		x	x	x	Economic aspects
C.12	Deep non-inversion tillage		x	x		x	Reduced soil erosion
C.13	Non-inversion spring tillage technique to incorporate grass sod before maize sowing		x	x		x	
C.14	Non-inversion spring tillage technique to incorporate green manures after maize		x	x		x	
C.15	Non-inversion tillage to reduce volunteer potatoes on clay soils	x	x	x		x	

	Name of technological innovation	Productivity	C sequestration GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
C.16	Tramlines	x				x	
C.17	DGPS-RTK to drive over the field	x	x			x	Energy use; pesticide use; nutrient use
C.18	Low tire pressure in controlled traffic systems	x	x	x		x	
C.19	Precision ploughing	x				x	Energy saving of following cultivation practices
C.20	Improved fertilizer spreading techniques by variable rate technology at field borders or spreading jobs		x			x	Reduced emissions of fertilizers to the environment
C.21	Use of finger weeder	x		x			Reduced emissions of herbicides to the environment
Category D. "Nutrient management"							
D.1	Biochar application		x				
D.2	CULTAN fertilization	x	x				
D.3	App to determine optimal nitrogen fertilization for winter rape in spring	x	x				Economic and environmental aspects
D.4	Fertigation with mineral fertilizer	x	x		x	x	Economic aspects
D.5	Compost to improve soil fertility	x	x	x	x	x	
D.6	On-farm composting	x	x	x	x	x	
D.7	Compost application as soil amendment and fertilizer	x	x	x	x	x	
D.8	Top dressing of maize with bovine slurry	x	x	x	x		
D.9	Fertigation of maize with bovine slurry using a ranger irrigation system	x	x	x	x		

	Name of technological innovation	Productivity	C sequestration GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
D.10	Manure processing (solid-liquid separation)	x	x		x		
D.11	Application of slurry in winter wheat on clay soils in the spring	x	x		x		
D.12	Components in direct seeders for residue management		x	x	x	x	Environmental aspects
D.13	Maintain organic matter content of the soil by the incorporation of straw	x	x	x	x	x	
D.14	Manganese sensor to adapt fertilization	x					
D.15	Soil nutrient sensor to adapt fertilization	x	x		x		
D.16	Digestate and its solid / liquid separation products	x	x		x	x	Due to digestion process digestate free of diseases and weed seeds, which will decrease pesticide use compared to the use of slurry
D.17	Liquid fraction of digestate as fertilizer	x	x	x	x	x	Reduction of mineral fertilizer use
D.18	DGPS-RTK to apply slurry in rows in maize	x	x			x	Improves nutrient use efficiency
D.19	Soil scanner	x	x		x	x	Reduction of nutrient losses to the environment
Category E. “Crop protection”							
E.1	Désherbinage	x		x		x	Cost reduction
E.2	Autonomous robot	x				x	Reduces compaction

	Name of technological innovation	Productivity	C sequestration GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
E.3	Vegetated buffer strips using double seeded density crop					x	Environmental impact reduction, runoff and erosion control
E.4	Integrated pest management (IPM)	x	x	x	x	x	Economic aspects
E.5	Cultural weed control	x	x	x	x	x	Economic aspects
E.6	Weed detection using UAV to adapt herbicide application	x					Reduction of herbicides and economic aspects
E.7	Weed detection using weed app to recommend herbicides	x					Economic and environmental aspects
E.8	Underseeding under maize combined with mechanical weed control and herbicide banding		x		x	x	Erosion control; Prevents nitrate leaching
Category F. "Water management"							
F.1	Centre Pivot / Linear irrigation system	x					Economic aspects
F.2	Combined Centre Pivot-Linear irrigation system	x					Economic aspects
F.3	Precision Irrigation - Variable Rate Irrigation	x					Economic aspects
F.4	Combined Pivot with mobile drip pipes	x					Economic aspects
F.5	Water management systems with treatment of low quality waters	x		x	x	x	Economic aspects
F.6	Leaf clamp to improve and to optimize irrigation scheduling and amount	x					Economic aspects

	Name of technological innovation	Productivity	C sequestration GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
Category G. "Other practices"							
G.1	Soil Bioengineering		x	x	x	x	Economical, landscaping and aesthetic aspects
G.2	Low pressure tires/caterpillars					x	Reduces soil pressure and fuel consumption
G.3	Management to reduce and minimize soil compaction	x				x	Reducing soil compaction

The transnational compilation of fact sheets about innovation as presented here includes and summarizes 81 technological innovations, collected from eight CATCH-C countries. Table 3 lists an overview about each assembled innovations and their relation to Best Management Practice and if specified to relevant crops.

A. Rotation

The category of management practices called “Rotation” contains 21 innovations. Most of these - except three - include the cultivation of a green manure as management practice. Many of the innovations are defined for a specific crop. Half of the innovations for “Rotation” refer to maize, and mostly describe the undersowing of a catch / cover / green manure crop. Additionally, catch crops between maize cultivation and further rotation issues for this crop are mentioned. The number of technological innovations relevant to maize reflects the importance of this crop in several European farming systems. For potatoes and sugar beets, six innovations about cover crops to reduce nematodes have been collected. The innovations about green manure are tailored to address specific tasks or demands. Soil coverage detection is also related to MP 8 and 9 (catch crops / green manure), but the implementation is more technical.

All innovations summarized under “Rotation” mainly contribute to three goals, first of all productivity. Also biological soil health and physical soil fertility are frequent. Further aspects are the reduction of nutrient / nitrogen losses by leaching into the environment, and the associated reduction in greenhouse gas emissions.

B. Grassland management

This category is represented here by only one innovation which describes a management practice from Spain, relevant to systems with permanent grazing.

C. Tillage

Most of the technological innovations of this category are related to minimum / reduced tillage. Eleven fact sheets represent non-inversion tillage practices. Four of them describe different machines for non-inversion tillage and residue management (e.g. chisel, disc harrow) to conduct shallow cultivation, showing their advantages in comparison to conventional tillage. A second part in the category “Tillage” belongs to controlled traffic farming. A few technological innovations are also connected to other MPs (e.g. nutrient management, mechanical weed control) with controlled traffic.

The “Tillage” related innovations mainly focus on the goal of “physical soil quality”. It is followed by “soil biological health” which is promoted by the non-inversion tillage. Controlled traffic farming related innovations also support “productivity”. The mentioned technological innovations in the “Tillage” category summarize and contribute many different other aspects e.g. reduction of soil erosion, better distribution of crop residues, energy savings and economic benefits.

D. Nutrient management

The category “Nutrient management” includes many different fertilizers (mineral, organic, residues and nutrients). Due to that fact, around 20 fact sheets reflect different kind of MP related innovations. Innovative ways for organic fertilizers are mostly represented by compost based on different organic materials, or digestates. Furthermore, this category has also combination with other categories of management practices. E.g. fertilizer application combined with controlled traffic farming or fertigation as a combination of irrigation with either mineral fertilizer or slurry. Three sensor based innovations to analyze nutrients are proposed, to support better dosage of nutrient inputs. All innovations summarized under “Nutrient management” obviously contribute to productivity. The compost related innovations contribute to a wider set of major CATCH-C goals. Efficient N management obviously contributes also to climate change mitigation, by reducing N losses and thereby potential N2O emissions.

E. Crop protection

“Crop protection” is reflected by seven fact sheets of innovation. Weed detection and control are characterized by innovative procedures and strategies. Therefore several various crops are related to these innovations. The more technical based sheets include weed detection by unmanned aircraft vehicles or by a weed smartphone app. All these innovations in this compilation are related to an integrated weed management (only post emergence). Two further mentioned technological innovations relate to two other MPs – mechanical weeding and controlled traffic.

F. Water management

This category of management practice is represented by six innovations mostly related to various crops. Four of them improve and / or adapt irrigation systems to conserve water or to optimize local field area conditions. The use of low quality water is another point of innovative development within this category of water management. A further description improves irrigation by a leaf clamp and measurement of turgor and water status, respectively. This method monitors directly (instead of the more common indirect by assessment via soil moisture measurement) and is a step forward to control and to schedule irrigation.

All assembled technological innovations for “water management” combine productivity and economic aspects as goals.

G. Other practices

Three innovations related to reducing soil compaction and to soil conservation practices as MPs are contained in this category. These innovations consequently promote “physical soil fertility”.

3. FACT SHEETS
Technological innovations

Category: A. ROTATION

A.1 Rotation of cereals with lucerne (alfalfa) in a dairy farm

Related to MP: MP3 Rotation with legume crops

Related to FTZ: ENZ12_SL1_TXT1+2+3 - Dairy cattle/ temporary grass

Key points

- Lucerne is a valuable source of proteins for dairy cows, that can be used as a forage instead of other sources of proteins which are normally purchased from outside the farm

What is it?

Rotation of a 3-years ley of lucerne with maize (widely used as a single crop in livestock farms), in an intensive dairy farm

Figure 2: Lucerne (http://naturewatch.wikia.com/wiki/ Datei:Saat-Luzerne.jpg)

How does it work / is it applied?

- Lucerne is sown in late summer in light soils, or early spring in heavy-textured soils, using 30-40 kg ha^{-1} of seeds
- Soil pH should not be lower than 6.0, otherwise N fixation will be limited
- Fertilization of 300-400 kg ha^{-1} of K_2O is needed at sowing and then 100-150 kg ha^{-1} every year in spring, after the first cut, as mineral fertilizer or manure. No P is generally needed, as soils of livestock farms are generally rich in P
- Sowing is made on a well-prepared seed-bed, then cultipaker to improve soil contact (the seed is very small)
- With irrigation, 4-5 cuts per year are performed to have a high-quality forage: the harvest date must be chosen depending on the cultivar; the criterion is to cut when the flowers are just visible, mowing at > 5 cm height; with a more mature crop, forage quality and digestibility are lower; gentle harvesting to reduce leaf losses; do not compact the soil
- In 3 years, irrigated lucerne can yield 40 t ha^{-1} of dry matter and 800 kg ha^{-1} of fixed N, corresponding to 5000 kg of forage crude proteins
- 350 kg ha^{-1} of N is left into the soil after 3 years, 270 kg of which from N-fixation; 100-120 kg ha^{-1} are released in the first year after lucerne. Consequently, subsequent fertilization to maize can be reduced.

Advantages and application of the innovation

- reduction of farm-gate N surplus

- reduction of weeds in subsequent maize
- erosion control
- N supply to subsequent crop
- increase in biodiversity, in the field and for the landscape
- various utilizations are possible: cut for feeding housed animals, haymaking, ensiled, dehydrated forage, grazing

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
x		x	x	x	1)

1): increase of dairy farm self-sufficiency; reduction of mineral fertiliser supply

Reference:

Sistema foraggero più efficiente se si coltiva erba medica. Speciale Erba medica - L'Informatore Agrario num. 01, pag. 36 del 09/01/2014
Dalla semina alle stalle, tecniche per medica di qualità - Speciale Alimentazione zootecnica - L'Informatore Agrario num. 09, pag. 49 del 27/02/2009
Erba medica da fieno, scelta giusta per fare reddito. L'Informatore Agrario num. 01, pag. 68 del 06/01/2012

A.2 Short rotation of grass combined with maize

Related to MP: MP6 Rotation with grassland

Related to FTZ: ENZ4+7_SL1_TXT2+3   Arable / specialized + cereals

Key points

- Improves yield of both crops,
- N stocks built up during the grass phase are exploited by the maize phase,
- Stimulates regularly resowing the sod

What is it?

- Grass is cropped for three years and followed by three years of maize

How does it work / is it applied?

- Grass is cropped for three years and then incorporated to growth maize,
- Three year old sod decomposes and supplies sufficient but not excessive amounts of nutrients to maize crop as older sods do supply excessive amounts,
- First-year' s maize is therefore not fertilized,
- Second year maize is economically fertilized, that is less than the standard allowed application rate,
- As only part of the allowed N input quota is used on maize, the remaining (un-used),
- N quota is retained for later use (i.e., during the grass phase). This N is necessary to build up the grass sod again after maize,
- Third year maize is an early ripening variety (by 15 September harvested) that enables the new grass sod to be established in September.

Advantages and application of the innovation

- Improves yield of maize,
- No yield reduction of grass thanks to early autumn establishment of the grass ley,
- Reduced herbicide use by sod establishment during autumn (when weed pressure is less than in spring),
- Enables a balanced nutrient balance of maize and grass
- Prevents that mineralization from incorporated sods exceeds N uptake capability of maize, and thus reduces N losses,
- Reduces specific maize-related diseases (that occur in continuous maize cropping),
- Improves nutrient use efficiency of manure and fertilizers,
- Positive effect on organic matter balance.

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertili-ty	Physical soil fertility	Other aspects
X	X	X	X	X	1)

1) Reduced losses of nutrients to the environment

Reference:
edepot.wur.nl/283954

A.3 Crop rotation diversification

Related to MP: MP8 Rotation with cover/catch crops + MP9 Rotation with green manures

Related to FTZ: ENZ13_SL1+2+3+4_TXT4 - Arable / Cereals

Key points

The key to a successful rotation is one that alternates between a cereal and a broadleaf. An oilseed-cereal-pulse-cereal rotation allows for a diversity of crops and prevents similar crops from being grown back-to-back. There are many advantages to this basic rotation.

What is it?

Crop rotation is the alternation of subsistence, cash and green manure/cover crops (GMCCs) with different characteristics, cultivated on the same field during successive years, and following a previously established sequence. The principal objective of crop rotation is to contribute to the achievement of a production that is profitable and sustainable, maintaining soil fertility and health.

Figure 3: Crop rotations (http://soilquality.org/ practices /row_crop_rotations.html)

How does it work / is it applied?

<u>Aspects to take into account in order to establish crop rotations</u> Crop rotations should be designed so that plans can be adjusted to consider up to date information on crop prices, soil moisture storage, or other factors influencing crop decisions.

- Always include green manure/cover crops (GMCCs), prioritizing the production of biomass to improve soil cover and organic matter content.
- The same species should never be sown on the same field in the following season.
- The GMCCs utilized should be adapted to the region's microclimate, to the soil, and to the farmer's production system, and should result in important benefits for cash crops.
- In order to plan crop rotations, the effects of one crop on the following should be taken into account, considering:
  - Compatibility with the following crop.
  - Degree of resistance to attack by pests and diseases.
  - Biomass production.
  - Root system.
  - Nutritional requirements.

<u>Proposed production systems with crop rotations</u>

- The proposals were developed utilizing the following aspects as basic fundamentals for the maintenance and recuperation of soil fertility:
- Add to the soil the greatest quantity of organic matter possible.
- Assure permanent vegetative soil cover, live or dead.

- Don’t plow the soil; that is to say, practice No-Tillage.
- Use green manure/cover crops.
- Apply lime and fertilizers to correct eventual deficiencies and to increase the production of biomass.
- Utilize agrochemicals that are specific or of low toxicity to control pests and diseases, and only when necessary.

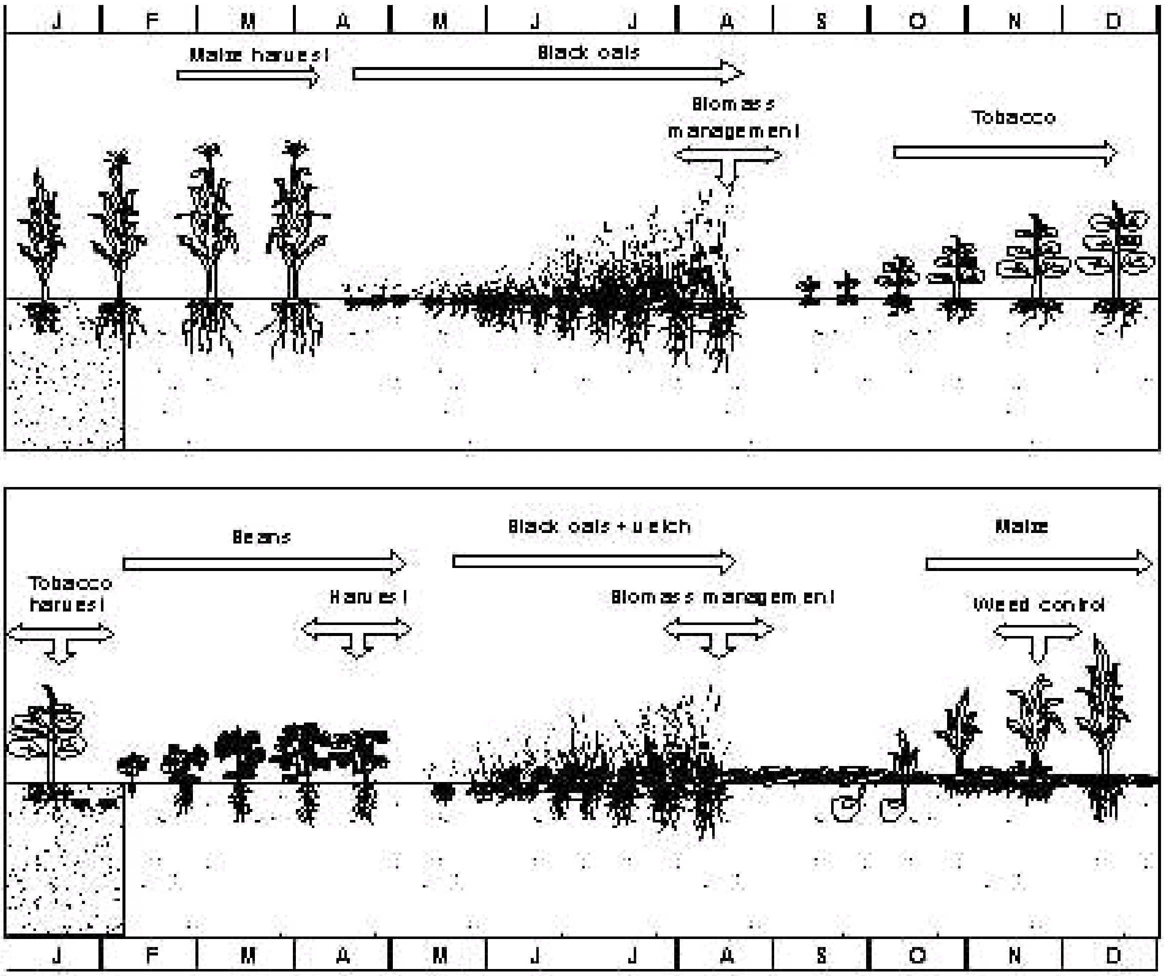

Figure 4: An example of crop rotation to maintain soil fertility and break pathogen carry-over (http://www.fao.org/ag/ca/1b.html)

Advantages and application of the innovation

- Appropriate crop rotation increases organic matter in the soil, improves soil structure, reduces soil degradation, and can result in higher yields and greater farm profitability in the long-term.
- Increased levels of soil organic matter enhances water and nutrient retention, and decreases synthetic fertilizer requirements.
- Better soil structure in turn improves drainage, reduces risks of water-logging during floods, and boosts the supply of soil water during droughts.
- Moreover crop rotation effectively delivers on climate change mitigation. Incentivizing leguminous production in Europe will also reduce our dependency on imported soy protein feeds

whose cultivation leads to large negative environmental and social externalities such as greenhouse gas emissions and displacement of indigenous people.

- Crop rotation is used to control weeds and diseases, and limit insect and other pest infestations and as a result significantly reduce pesticide use.
- Leguminous crops in the rotation fix atmospheric nitrogen and bind it in the soil, increasing fertility and reducing the need for synthetic fertilizers and the use of pesticides.

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
X	X	X	X	X	

Reference:
http://aprodev.eu/files/Trade/crop%20rotation%20briefing_pan_ifoam_aprodev_foee_fina.pdf
http://www.magrama.gob.es/es/ministerio/servicios/publicaciones/Asociaciones_y_Rotaciones_tcm7-187413.pdf
http://www.fao.org/fileadmin/user_upload/agp/icm12.pdf
http://www.fao.org/ag/ca/1b.html
http://soilquality.org/practices/row_crop_rotations.html

A.4 Intercropping, green manure, catch crop

Related to MP: MP8 Rotation with cover/catch crops + MP9 Rotation with green manures

Related to FTZ: ENZ13_SL1+2+3+4_TXT4 - Arable/Cereals
ENZ13_SL2+3+4_TXT3 - Permanent crops

Key points

- The practices of cover cropping, intercropping and green manuring can serve a number of important functions in cropping systems.
- These practices are grown mainly to prevent erosion of soil by wind and water but are useful to perform other important functions in cropping systems which:
  - improve soil quality and moisture-retention capacity
  - add fertility and cycle plant nutrients
  - aid in pest management

What is it?

Intercropping is the growing of two or more crops in proximity to promote interaction between them. Green manure or catch crop refers to a crop sown before or after the main crop and which main goal is respectively build fertility or fix the amount of residual nitrate in the soil from leaching. In addition, intercrops, green manure and catch crops present a wide range of benefits including protecting the soil against erosion, combating pests or weed growth. As many of the benefits are shared amongst the three terms, they are often used indistinctly.

How does it work / is it applied?

- The agronomic advantages of intercropping are a result of multiple crops grown at the same time but competing for different ecological niches (e.g. maize and legume) or multiple crops grown consecutively.
- It is important to choose the right crop for each situation. A wide range of plants, each with different benefits can be selected. Determine the challenge or combination of challenges of the farm (e.g. nitrate leaching or soil erosion) to tailor the needed crop (intercrop, green manure or catch crop).
- Species selection also depends on the nitrogen release rate: species with a high C/N ratio release N slower, and vice versa (see Table 5)
- Determine the time of sowing and killing of intercrop. Effectiveness of a catch crop depends on fast establishment, the time chosen for termination of the catch crop and crop specific properties like growth rate, rooting depth and root density. By choosing crops capable of fast establishment and with deep rooting systems the efficiency can be improved (Thorup-Kristensen 2004).
- Use caution in situations, where the cover or catch crop vegetation could deplete soil moisture prior to seeding the succeeding main crop.

Table 5: Root growth and C/N ratio of green manures and catch crops

Root Growth	High C/N (slow release of nitrogen)	Medium C/N (medium release of nitrogen)	Low C/N (fast release of nitrogen)
Deep root system	Chicory (*Cichorium intybus*)	Yellow mustard (Sinapis Alba)	Fodder radish (*Rapanus Sativus Olieformis*) Yellow mustard (*Sinapis Alba*) Woad (*Isatis tinctoria*)
Shallow root system	Perennial rye grass (*Lolium perenne L.*)	Rye	Rye

Advantages and application of the innovation

- Protection of the environment: protects aquifers from nitrate leaching, reduces herbicide or pesticide use by suppressing weeds and pests, reduces runoff and sediment generation
- Reduces fertilizer use
- Type of intercrop can be selected as a function of the objective.
- Introduce higher level of biodiversity and
- increase sunlight capture, Drying and warming the soil
- Adding organic matter to the soil and improving soil structure
- Increasing the supply of nutrients available to plants (particularly by adding nitrogen to the system by fixation)
- Providing supplementary animal forage

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
X	X	X	X	X	1)

1): Economical aspects

Costs may include seed bed preparation, seed, planting and killing the vegetation. In case the catch/ cover crop is harvested the costs for harvest may be counter balanced by the value of the forage. In structural damages etc. there might also be costs related to reductions in yield in the main crops.

A number of disadvantages can also be identified:

- Direct costs of seed and extra cultivations
- Lost opportunities for cash cropping
- Extra work at busy times of the year
- Exacerbated pest and disease problems (due to the ‘green bridge’ effect)
- Potential for the green manures to become weeds in their own right

References:

http://www.organicresearchcentre.com/manage/authincludes/article_uploads/iota/technical-leaflets/green-manures-leaflet.pdf
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A.5 Fast growing cover crops (as green manures)

Related to MP: MP9 Rotation with green manures

Related to FTZ: ENZ4_SL1_TXT1 - Arable and mixed farms
ENZ6_SL2+3_TXT3 - Arable farms
ENZ6_SL1_TXT1 - Arable / cereal and mixed farms

Key points

- Improvement of crop rotations and soil fertility
- Fast growing cover crop mixture to conserve nutrients containing in slurry

What is it?

- Seed mixture of summer cover crops with fast growing
- Possible mixture composition I:
  - 30 % *Avena sativa* L. (oat)
  - 25 % *Avena strigosa* L. (sand oat)
  - 12 % *Fagopyrum* MILL. (buckwheat)
  - 8 % *Helianthus annuus* L. (sun flowers)
  - 5 % *Camelina sativa* L. (false flax)
  - 5 % *Linum usitatissimum* L. (flax)
  - 5 % *Phacelia tanacetifolia* L. (phacelia)
  - 5 % *Raphanus sativus* L. (Tillage Radish)
  - 5 % *Brassica carinata* A.Braun (Abyssinian mustard)
- Possible mixture composition II:
  - 15 % *Pisum sativum* L. (pea)
  - 15 % *Trifolium alexandrium* L. (Alexandrian clover)
  - 15 % *Ornithopus sativus* L.(Serradella)
  - 15 % *Phacelia tanacetifolia* L. (phacelia)
  - 20 % *Fagopyrum* MILL. (buckwheat)
  - 20 % *Vicia sativa* L. (common vetch)

Figure 5: Fast growing mixture of cover crops (http://www.dsv-saaten.de/zwischenfruechte/terralife/biomax.html)

How does it work / is it applied?

- Fast growing above-ground biomass mixture without legumes
- Recommended for husbandry farms to recycle and conserve nutrients contained in slurry
- Also recommended for water protection areas
- Due to good deep root growth nutrients “recycling” in deep layers
- mixture is beneficial for mulch / direct seed tillage and a source of food for earth worms and other soil living creatures

- Abyssinian mustard stabilizes the mixture in period of drought as the plant is well adapted to heat and dryness
- Tillage Radish: very thick taproot (bio drilling taproot) to penetrate soil compaction layers; non-winter hardy cover crops, winterkills when temperature drop to the mid-teens; helps to improve drainage and air movement deep in the soil and also to warm soil in the spring through the voids and channels left by Tillage Radish decay
- Optimal sowing: Beginning of August to beginning of September
- Sowing amount: 20 – 40 kg/ha
- Crops rotations: Recommended for water protection areas and legume rotations
- Sowing: combined with harvester (recommended) or with drilling equipment
- N-Fertilization: 30 – 60 kg/ha
- Use as green manure: mid of September to end of November

Advantages and application of the innovation

- higher biomass and root yield for enrichment of soil organic matter
- enhancement of biodiversity and biological activity (earth worms, mycorrhiza)
- provision of nutrients for subsequent crops
- competition against weeds
- protection of soil against erosion and leaching

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
X		x		x	

Reference:
http://bsv-saaten.de/landwirtschaft/geovital/ms-100-s/
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Bloch, R. & Bachinger, J.(2010): Anpassung an den Klimawandel im Praxistest – Innovationen im Ökologischen Landbau. Forschungsreport 2: 18-21 p.
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A.6 Cover crops (as green manures) for maize

Related to MP: MP9 Rotation with green manures

Related to FTZ: ENZ4_SL1_TXT1 - Arable and mixed farms
ENZ6_SL2+3_TXT3 - Arable farms
ENZ6_SL1_TXT1 – Arable / cereal and mixed farms

Key points

- Improvement of crop rotations and soil fertility
- Cover crop mixture (partly winter hardy) for intensive maize rotations

What is it?

Figure 6: Mixture of cover crops for maize (http://www.dsv-saaten.de/zwischenfruechte/terralife/maispro.html)

- Seed mixture of summer / winter cover crops to support mycorrhization of maize roots and to improve soil structure
- Possible mixture composition I:
  - 32 % *Pisum sativum* L. (pea)
  - 30 % *Secale cereale* L. (winter rye)
  - 10 % *Sorghum* L. (sorghum)
  - 7 % *Vicia pannonica* L. (Hungarian vetch)
  - 5 % *Phacelia tanacetifolia* L. (phacelia)
  - 4 % *Trifolium incarnatum* L. (Italian clover)
  - *4 % Linum usitatissimum* L. (flax)
  - 2 % *Trifolium resupinatum* L. (Persian clover)
  - 2 % *Trifolium hybridum* L. (Swedish clover)
  - 1 % *Camelina sativa* L. (false flax)
  - 1 % *Guizotia abyssinica* (L.F.) CASS. (ramtil)
  - 1 % *Raphanus sativus* L. (Tillage Radish)
  - 1 % *Helianthus annuus* L. (sun flowers)
- Possible mixture composition II:
  - 50 % *Vicia sativa* L. (common vetch)
  - *20 % Trifolium alexandrium L. (Alexandrian clover)*
  - 13 % *Phacelia tanacetifolia* L. (phacelia)
  - 10 % *Trifolium resupinatum* L. (Persian clover)
  - 7 % *Guizotia abyssinica* (L.F.) CASS. (ramtil)

How does it work / is it applied?

- Mixture enhances mycorrhization of maize roots to improve soil structure
- Soil is more water stabile and soil tillage will be easier
- a good establishment of the cover crop mixture supports a soil tillage with very shallow depth (sowing depth of maize) in spring

- due to the shallow tillage capillarity is preserved and water availability for germination
- in region with higher drought in spring: cover crops must be killed very earlier with tillage or herbicides to reduce water consumption of the cover crops
- winter hardy components of the mixture provide soil protection against erosion until spring
- Phacelia mobilizes organic bound phosphors for subsequent maize
- Tillage Radish: very thick taproot (bio drilling taproot) to penetrate soil compaction layers; non-winter hardy cover crops, winterkills when temperature drop to the mid-teens; helps to improve drainage and air movement deep in the soil and also to warm soil in the spring through the voids and channels left by Tillage Radish decay
- Mixture is also applicable for sowing as flowering strips
- Optimal sowing: end of July to end of August (as blooming mixture - end of April to end of May)
- Sowing amount: 25 – 45 kg/ha
- Crops rotations: Recommended for maize rotations, rape rotations and pasture (cattle + sheep)
- Sowing with drilling equipment or combined with harvester
- N-Fertilization: 30 – 50 kg/ha
- Use as green manure: beginning of September to end of November and beginning of April to end of May

Advantages and application of the innovation

- higher biomass and root yield for enrichment of soil organic matter
- enhancement of biodiversity and biological activity (earth worms, mycorrhiza)
- provision of nutrients for subsequent crops
- competition against weeds
- protection of soil against erosion and leaching

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertili-ty	Physical soil fertility	Other aspects
x		x	x	x	

Reference:
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A.7 Cover crops for potatoes

Related to MP: MP9 Rotation with green manures

Related to FTZ: ENZ4_SL1_TXT1 - Arable and mixed farms
ENZ6_SL2+3_TXT3 - Arable farms
ENZ6_SL1_TXT1 – Arable / cereal and mixed farms

Key points

- Improvement of crop rotations and soil fertility
- Cover crop mixture for potato rotations

What is it?

- Seed mixture of summer cover crops for fast shading
- Possible mixture composition I:
    - 48 % *Lupinus angustifolius* L. (lupine) or 60 % Tillage Radish (TR) instead of lupine (sub-optimal growing on soil with higher pH values)
    - 18 % *Vicia sativa* L. (common vetch)
    - 10 % *Avena strigosa* L. (sand oat)
    - 9 % *Guizotia abyssinica* (L.F.) CASS. (ramtil)
    - 6 % *Linum usitatissimum* L. (flax)
    - 5 % *Ornithopus sativus* L.(Serradella)
    - 4 % Trifolium squarrosum L. (squarrose clover)
- Possible mixture composition II:
    - 40 % *Lupinus angustifolius* L. (lupine)
    - 20 % *Fagopyrum* MILL. (buckwheat)
    - 20 % *Raphanus sativus* L. (oil radish)
    - 10 % *Pisum sativum* L. (pea)
    - 5 % *Phacelia tanacetifolia* L. (phacelia)
    - 5 % Trifolium alexandrium L. (Alexandrian clover)

Figure 7: Mixture of cover crops for potatoes (http://www.dsv-saaten.de/zwischenfruechte/terralife/solarigol.html)

How does it work / is it applied?

- Good root penetration
- Higher biodiversity
- Voids and channels by lupine and flax which are used by potatos
- Lupine reudces infestation of tobacco rattle virus
- Positive effect by common vetch to soil bacteria and plant protection against pathogen
- Flax improves silicon availability, especially for sandy soils
- A good establishment of the cover crop mixture supports a shallow soil tillage in spring

- Optimal sowing: Mid of July to 20th of August (possible beginning March), with TR - End of July to end of August
- Sowing amount: 30 – 60 kg/ha, with TR - 30 – 35 kg/ha
- Crops rotations: Recommended for potato rotations and rape rotations, pasture (cattle + sheep); with TR - limited recommended for rape rotations
- Sowing depth: 1 – 2 cm
- Sowing with drilling equipment or combined with harvester
- N-Fertilization: 40 - 60 kg/ha
- Use as green manure: mid of October to end of November
- Tillage Radish: very thick taproot (bio drilling taproot) to penetrate soil compaction layers; non-winter hardy cover crops, winterkills when temperature drop to the mid-teens; helps to improve drainage and air movement deep in the soil and also to warm soil in the spring through the voids and channels left by Tillage Radish decay

Advantages and application of the innovation

- higher biomass and root yield for enrichment of soil organic matter
- enhancement of biodiversity and biological activity (earth worms, mycorrhiza)
- provision of nutrients for subsequent crops
- competition against weeds
- protection of soil against erosion and leaching

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
x		x		x	

Reference:

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Schmid, M. (2013): Mehr Abwechslung auf Maisflächen. Landwirtschaftliches Wochenblatt 15: p. 22-24.

A.8 Cover crops (as green manures) to reduce nematodes

Related to MP: MP9 Rotation with green manures

Related to FTZ: ENZ4_SL1_TXT1 - Arable and mixed farms
ENZ6_SL2+3_TXT3 - Arable farms
ENZ6_SL1_TXT1 – Arable / cereal and mixed farms

Key points

- Improvement of crop rotations and soil fertility
- Cover crop mixture for reduction of nematodes in sugar beet and potato cultivation

What is it?

Figure 8: Mixture of cover crops to reduce nematodes (http://www.dsv-saaten.de/zwischenfruechte/terralife/betasola.html)

- Seed mixture of summer / winter cover crops to protect against nematodes
- Possible mixture composition I:
    - 43 % *Vicia sativa* L. (common vetch)
    - 22.5 % *Avena strigosa* L. (sand oat)
    - 8.5 % Raphanus sativus Black Jack (oil radish)
    - 8.5 % Raphanus sativus Radetzky (oil radish)
    - 8.5 % Raphanus sativus Reset (oil radish)
    - 24 % *Pisum sativum* L. (pea)
    - 18 % *Lupinus angustifolius* L. (lupine)
    - 13 % *Avena strigosa* L. (sand oat)
    - 6 % *Trifolium alexandrium L.* (Alexandrian clover)
    - 3 % *Guizotia abyssinica* (L.F.) CASS. (ramtil)
- Possible mixture composition II:
    - 50 % *Fagopyrum* MILL. (buckwheat)
    - 30 % Raphanus sativus Reset (oil radish)
    - 20 % *Sinapis alba* L. (white mustard)

How does it work / is it applied?

- Biodiversity and improvement of soil structure
- Plant protection against nematodes
- Three resistant Oil radish varieties
    - Nematode resistant radish helps to reduce sugar beet nematodes (Heterodera schachtii and Trichodorus)
    - Multi resistant radish is additional resistant against root knot nematodes

- Sand oat reduces root nematodes (Pratylenchus)
- Voids and channels by lupine which are used by sugar beets and potatos
- Positive effect by common vetch to soil bacteria and plant protection against pathogen
- Optimal sowing: End of July to end of August
- Sowing amount: 35 – 40 kg/ha
- Crops rotations: Recommended for sugar beet and potato cultivation, rape rotations, legumes rotations, water protection areas and pasture (cattle + sheep),
- Sowing with drilling equipment or combined with harvester
- N-Fertilization: 40 – 70 kg/ha
- Use as green manure: mid of September to end of November

Advantages and application of the innovation

- higher biomass and root yield for enrichment of soil organic matter
- enhancement of biodiversity and biological activity (earth worms, mycorrhiza)
- provision of nutrients for subsequent crops
- competition against weeds
- protection of soil against erosion and leaching

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertili-ty	Physical soil fertility	Other aspects
x		x		x	

Reference:
http://www.agravis.de/media/pflanzen/pflanzen_pdf/saatgut/zwischenfruechte/topsoil/pdf_topsoil_nemafern.pdf
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Schlathölter, M. (2014): Immer ein Gewinn für Pflanzenernährung und –gesundheit - Zwischenfrüchte ergänzen das Pflanzenschutz- und Düngungsmanagement, sodass die Folgekultur(en) profitieren und die Input-Kosten reduziert werden können, praxisnah 3:20-23 p.
Schmid, M. (2013): Mehr Abwechslung auf Maisflächen. Landwirtschaftliches Wochenblatt 15: p. 22-24.

A.9 Cover crops (as green manures) for soil structure

Related to MP: MP9 Rotation with green manures

Related to FTZ: ENZ4_SL1_TXT1 - Arable and mixed farms
ENZ6_SL2+3_TXT3 - Arable farms
ENZ6_SL1_TXT1 – Arable / cereal and mixed farms

Key points

- Improvement of crop rotations and soil fertility
- Cover crop mixture for strong root growth to stabilize soil structure

What is it?

- Seed mixture of summer cover crops with intensive root growth
- Mixture composition:
    - 60 % *Lupinus angustifolius* L. (lupine) or Tillage Radish (TR, *Raphanus sativus* L.) instead of lupine (sub-optimal growing on soil with higher pH values)
    - 8 % *Fagopyrum* MILL. (buckwheat)
    - 6 % *Linum usitatissimum* L. (flax)
    - 6 % *Avena strigosa* L. (sand oat)
    - 5 % *Camelina sativa* L. (false flax)
    - 5 % *Ornithopus sativus* L.(Serradella)
    - 5 % *Helianthus annuus* L. (sun flowers)
    - 4 % Trifolium squarrosum L. (squarrose clover)
    - 1 % *Phacelia tanacetifolia* L. (phacelia)
- Possible mixture composition II:
    - 60 % *Vicia sativa* L. (common vetch)
    - 25 % Trifolium alexandrium L. (Alexandrian clover)
    - 8 % *Phacelia tanacetifolia* L. (phacelia)
    - 8 % *Helianthus annuus* L. (sun flowers)

Figure 9: Mixture of cover crops for soil structure (http://www.dsv-saaten.de/zwischenfruechte/terralife/rigol.html)

How does it work / is it applied?

- Intensive root growing is equal to a biological tillage
- Fast covering and shading for other plants
- Rooting with fine roots in A horizon
- Developed root gaps could be used by following crops for a fast root growth
- Good above-ground biomass production
- Good humus and nutrient accumulation by legume fraction

- Tillage Radish: very thick taproot (bio drilling taproot) to penetrate soil compaction layers; non-winter hardy cover crops, winterkills when temperature drop to the mid-teens; helps to improve drainage and air movement deep in the soil and also to warm soil in the spring through the voids and channels left by Tillage Radish decay
- Optimal sowing: End of July to 20th of August; with TR End of July to 25th of August
- Sowing depth: 1 -2 cm
- Sowing amount: 25 – 55 kg/ha; with TR 20 – 22 kg/ha
- Crops rotations: Recommended for rape rotations and legume rotations; with TR limited recommended for rape rotations
- Sowing with drilling equipment or combined with harvester
- N-Fertilization: 30 - 50 kg/ha
- Use as green manure: mid of October to end of November
- Soil: Applicable for every soil except soils with a poor availability of iron (e.g. pH > 7) => cover crops with TR is recommended

Advantages and application of the innovation

- higher biomass and root yield for enrichment of soil organic matter
- enhancement of biodiversity and biological activity (earth worms, mycorrhiza)
- provision of nutrients for subsequent crops
- competition against weeds
- protection of soil against erosion and leaching

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
x		x		x	

Reference:

http://www.dsv-saaten.de/zwischenfruechte/terralife
http://www.dsv-saaten.de/zwischenfruechte/terralife/rigol.html
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Stadler, M. & Preschl, C. (o.J.): Bodenleben und Zwischenfruchtanbau. Amt für Ernährung, Landwirtschaft, und Forsten Pfaffenhofen a. d. Ilm: p. 17.

A.10 Cover crops (as green manures) for sugar beets

Related to MP: MP9 Rotation with green manures

Related to FTZ: ENZ4_SL1_TXT1 - Arable and mixed farms
ENZ6_SL2+3_TXT3 - Arable farms
ENZ6_SL1_TXT1 – Arable / cereal and mixed farms

Key points

- Improvement of crop rotations and soil fertility
- Cover crop mixture for sugar beet cultivation and to improve soil structure

What is it?

- Seed mixture of summer cover crops specialized to sugar beet
- Possible mixture composition I:
  - 25 % *Vicia sativa* L. (common vetch)
  - 24 % *Pisum sativum* L. (pea)
  - 18 % *Lupinus angustifolius* L. (lupine) or 25 % Tillage Radish (TR) instead of lupine (sub-optimal growing on soil with higher pH values)
  - 13 % *Avena strigosa* L. (sand oat)
  - 10 % Trifolium alexandrium L. (Alexandrian clover)
  - 6 % *Phacelia tanacetifolia* L. (phacelia)
  - 4 % *Guizotia abyssinica* (L.F.) CASS. (ramtil)
- Possible mixture composition II:
  - 50 % Trifolium alexandrium L. (Alexandrian clover)
  - 20 % *Raphanus sativus* L. (oil radish)
  - 20 % *Phacelia tanacetifolia* L. (phacelia)
  - 10% *Lepidium* L. (pepperweed)

Figure 10: Mixture of cover crops for sugar beets (http://www.dsv-saaten.de/zwischen-fruechte/terralife/betamaxx.html)

How does it work / is it applied?

- Intensive root growing to improve soil structure
- Voids and channels by lupine which are used by sugar beets
- Positive effect by common vetch to soil bacteria and plant protection against pathogen
- Cover crop mixture supports non-plough tillage in the following year with sugar beets
- Improvement of positioning of seeds
- Decrease of root damages normally forced by soil compaction

- With Lush growing it is recommended to do a roll or mulch application in drill direction of the sugar beets in autumn (dry weather conditions)
- No incorporation of green cover crops
- Optimal sowing: End of July to mid of August, with TR End of July to end of August
- Sowing amount: 15 – 45 kg/ha, with TR 30 – 35 kg/ha
- Crops rotations: Recommended for sugar beet cultivation, rape rotations and pasture (cattle + sheep), with TR limited recommended for rape rotations
- Sowing with drilling equipment or combined with harvester
- N-Fertilization: 30 – 50 kg/ha
- Use as green manure: end of September to end of November
- Tillage Radish: very thick taproot (bio drilling taproot) to penetrate soil compaction layers; non-winter hardy cover crops, winterkills when temperature drop to the mid-teens; helps to improve drainage and air movement deep in the soil and also to warm soil in the spring through the voids and channels left by Tillage Radish decay

Advantages and application of the innovation

- higher biomass and root yield for enrichment of soil organic matter
- enhancement of biodiversity and biological activity (earth worms, mycorrhiza)
- provision of nutrients for subsequent crops
- competition against weeds
- protection of soil against erosion and leaching

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertili-ty	Physical soil fertility	Other aspects
x		x		x	

Reference:

http://www.dsv-saaten.de/zwischenfruechte/terralife
http://www.dsv-saaten.de/zwischenfruechte/terralife/betamaxx.html
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http://www.kws.de/aw/KWS/germany/Produkte/KWS-AckerFit/KWS-AckerFit-Mischungen/~fpwy/KWS-AckerFit-Ruebe/
http://www.planterra-saaten.de/landwirtschaftliche-mischungen/zwischenfruchtmischungen/product/zwh-4021-vitalis-plus/
Brockerhoff, H. (2013): Zwischenfruchtanbau im Wandel? Zwischenfrüchte bieten viele Vorteile. Zuckerrüben-journal 2: 11-13 p.
Landwirtschaftskammer NRW (2014): Empfehlungen zum Pflanzenbau und Pflanzenschutz im Rheinland und in Westfalen-Lippe. p.5.
Schmid, M. (2013): Mehr Abwechslung auf Maisflächen. Landwirtschaftliches Wochenblatt 15: p. 22-24.
Schmidt, A. & Gläser, H. (2013): Anbau von Zwischenfrüchten - Auswertung der Versuchsanlagen 2012/13 in Sachsen. Sächsisches Landesamt für Umwelt, Landwirtschaft und Geologie (LfULG).
Stadler, M. & Preschl, C. (o.J.): Bodenleben und Zwischenfruchtanbau. Amt für Ernährung, Landwirtschaft, und Forsten Pfaffenhofen a. d. Ilm: p. 17.

A.11 Cover crops (as green manures) for water protection areas

Related to MP: MP9 Rotation with green manures

Related to FTZ: ENZ4_SL1_TXT1 - Arable and mixed farms
ENZ6_SL2+3_TXT3 - Arable farms
ENZ6_SL1_TXT1 – Arable / cereal and mixed farms

Key points

- Improvement of crop rotations and soil fertility
- Cover crop mixture for water protection areas and rape rotation

What is it?

- Seed mixture of summer / winter cover crops without legumes and with or without crucifers
- Possible mixture composition:
  - 38 % *Avena strigosa* L. (sand oat)
  - 14 % *Phacelia tanacetifolia* L. (phacelia)
  - 12 % *Fagopyrum* MILL. (buckwheat)
  - 10 % *Linum usitatissimum* L. (flax)
  - 10 % *Helianthus annuus* L. (sun flowers)
  - 10 % *Sorghum* L. (sorghum)
  - 5.5 % *Guizotia abyssinica* (L.F.) CASS. (ramtil)
  - 0.5 % *Carthamus tinctorius* L. (safflower)

Figure 11: Mixture of cover crops for water protection area (http://www.dsv-saaten.de/zwischenfruechte/terralife/aquapro.html)

How does it work / is it applied?

- Recommended for water protection areas as the mixture not produces nitrogen
- Protection against leaching
- Application for narrow rape rotations or before brewing barley
- Improvement of Soil structure dynamic
- Good humus accumulation
- Optimal sowing: End of July to mid of August (for early sowing until 31.05. mixture without buckwheat)
- Sowing amount: 20 - 25 kg/ha
- Sowing depth: max. 1-2 cm
- Crops rotations: Recommended for narrow rape rotations and legume rotations
- Sowing: combined with harvester (recommended) or with drilling equipment
- N-Fertilization: 0 - 50 kg/ha
- Use as green manure: end of September to end of November

Advantages and application of the innovation

- higher biomass and root yield for enrichment of soil organic matter
- enhancement of biodiversity and biological activity (earth worms, mycorrhiza)
- provision of nutrients for subsequent crops
- competition against weeds
- protection of soil against erosion and leaching

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertili-ty	Physical soil fertility	Other aspects
x		x	x	x	1)

1) reduced leaching / environmental aspects

Reference:

http://bsv-saaten.de/landwirtschaft/geovital/mulchsaat-aqua-save/
http://www.dsv-saaten.de/zwischenfruechte/terralife
http://www.dsv-saaten.de/zwischenfruechte/terralife/aquapro.html
http://www.freudenberger.net/Produkt-Details.asp?lang=de&mode=vproduct&prodid=415
Schmidt, A. & Gläser, H. (2013): Anbau von Zwischenfrüchten - Auswertung der Versuchsanlagen 2012/13 in Sachsen. Sächsisches Landesamt für Umwelt, Landwirtschaft und Geologie (LfULG).
Schmidt, A. & Gläser, H. (2014): Anbau von Zwischenfrüchten - Auswertung der Versuchsanlagen 2013/14 in Sachsen. Sächsisches Landesamt für Umwelt, Landwirtschaft und Geologie (LfULG).
Zimmermann, C., Pekrun, C. Schiefer, R., Jacobs, O., Weiß, K. Gall, C. & Köller K. (2011): Zwischenfrüchte mit dem Mähdrescher säen. Erste Erfahrungen mit der Mähdruschsaat – Innovation 2: p. 18-19.

A.12 Catch crops as green manures

Related to MP: MP9 Rotation with green manures

Related to FTZ: ENZ12_SL1_TXT1+2+3 - Arable/ cereal
ENZ12_SL3_TXT2, ENZ12_SL4_TXT2+3 - Arable/ cereal

Key points

- addition of fresh organic matter to the soil
- protection from environmental pollution (nitrate leaching, P runoff)
- nutrients mobilization from the soil and beneficial to soil life

What is it?

A leguminous secondary crop is sown between two main summer crops, to maintain the soil covered during winter. The secondary crop is then destroyed in spring before sowing the summer crop again.

How does it work / is it applied?

- Sowing a secondary winter crop after harvesting a summer crop like maize
- The secondary crop is a leguminous because an extra N amount is fixed by symbiotic bacteria
- Best species are:
  - Winter vetch (*Vicia villosa* Roth.)
  - Crimson clover (*Trifolium incarnatum* L.)
  - Egyptian/beerseem clover (*Trifolium alessandrinum* L.),
  - Cock's head (*Hedysarum coronarium* L.)

Figure 12: Winter vetch (www.agraria.org)

Figure 13: Crimson clover (www.statebystategardening.com)

Figure 14: Cock's head (http://theresagreen2.wordpress.com/flora/vetches-trefoils-clovers/)

- No fertilizer is applied
- Minimum tillage is performed
- The crop is then cut, chopped and incorporated into the soil in spring

Herbicide treatments reduce the secondary crop regrowth

Advantages and application of the innovation

- Reduction of fertilizer use (because nutrients from the soil are mobilized and converted to an easily-available form for the main crop)
- Net N addition because of N fixing (40 - 120 kg ha^{-1} of N)
- Beneficial effects on the soil OM content and soil physical properties
- Reduction of water and nitrogen deep percolation, reduction of soil erosion, reduction of soil structure disruption by winter rain

Disadvantages and application of the innovation

- Sowing the main crop can be difficult due to impediments for large catch crop biomass
- Timing for tillage can be tight
- weed problems can be increased because of regrowth of the secondary crop
- Sowing the catch crop is a cost
- Water consumption increases; for this reason this practice is not recommended in rainfed cropping systems with low rainfall

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertili-ty	Physical soil fertility	Other aspects
x		x	x	x	1)

1): reduction of mineral fertilizer supply

Reference:

http://www.coldiretti.it/organismi/INIPA/area%20formazione/cd%20probio/files/06_prod_vegetale/06_08_prod_vegetale.htm
http://www.aiablombardia.it/index.php/coltivareterra/74-sovescio
Sovescio di leguminose nella fertilizzazione del girasole. L'Informatore Agrario num. 30, pag. 52 del 20/07/2001

A.13 Use of green manure to reduce beet cyst nematodes

Related to MP: MP9 Rotation with green manures

Related to FTZ: ENZ4+6+7_SL1_TXT0+1 – Arable / specialized

Key points

- Reducing beet cyst nematodes,
- Breaking up impermeable soil layers,
- Improved soil structure,
- Reduced nitrogen losses to groundwater,
- Production of organic matter.

What is it?

- Choose a green manure type that is resistant to beet cyst nematodes. Grow it for a full growing season (for 80% reduction of beet cyst nematodes) or in the fall only (for 30% reduction). Reductions are additional to the natural nematode decay when no beet crop is present.

How does it work / is it applied?

Theory:

- Roots of resistant crops lure nematodes but they can't multiply or form cysts on these crops,
- Reduction works best when soil temperature is high and nematodes are active.

Sowing:

- Beet cyst nematode resistant green manures: specific varieties of white mustard (Sinapis alba cultivars Achilles and Abraham) and fodder radish (Raphanus sativus cultivars Corporal and Terranova),
- Good weed control is necessary as beet cyst nematodes also flourish on most cruciferous weeds, such as Chenopodium,
- Seed bed preparation is necessary,
- Sowing of white mustard with pneumatic spreader at rates of 20 kg/ha (after half August) with a small N-application of 30 kg/ha,
- Sowing of fodder radish with pneumatic spreader at rates of 30 kg/ha (after half August) with a small N-application of 30 kg/ha,
- White mustard and fodder radish are frost sensitive and will die during an average Dutch winter.

In spring:

- After mild winters, a pre preparation before ploughing might be needed to kill off the green manure,

Figure 15: An overview of a screening trial of green manures and the effects on nematodes (left) and roots of a resistant fodder radish (right) www.innoseeds.nl/groenbemesters /Bladrammenas. aspx)

	Heterodera schachtii Witte bietencysteaaltje	*Heterodera betae* Gele bietencysteaaltje	*Meloidogyne hapla* Noordelijk wortelknobbelaaltje	*Meloidogyne chitwoodi* Maïswortelknobbelaaltje	*Meloidogyne fallax* Bedrieglijk maïswortelknobbelaaltje	*Pratylenchus penetrans* Wortellesieaaltje	*Ditylenchus dipsaci* Stengelaaltje	*Trichodorus primitivus* Trichodorus primitivus	*Trichodorus similis* Trichodorus similis	*Paratrichodorus pachydermus* Paratrichodorus pachydermus	*Paratrichodorus teres* Paratrichodorus teres
	Z D ZA K	Z D	Z D	Z D	Z	Z D ZA	Z D ZA K	Z D ZA	Z D ZA	Z D ZA	Z D ZA
Bladrammenas	▽▽ R	?	●●	▽ R	● R	●●●	?	●●●	●●	●●	●
Gele mosterd	▽▽ R	?	●	●●	●●	●●●	?	●●●	●●●	●●●	●
Italiaans raaigras	▽	▽	▽	●●	●●●	●●●	●	●●●	●●●	●●●	●●●
Rogge	▽	▽	▽	●●●	●●	●●	●●	?	●●●	●●●	●●●
Bladkool	●●●	?	?	?	?	?	?	?	?	?	?
Witte klaver	▽	?	●● R	●● R	●● R	●●●	●●●	?	?	?	●●●
Afrikaantje	▽	▽	▽	▽	▽	▽▽	?	?	?	?	?
Japanse haver	?	?	?	?	?	▽	?	?	?	?	?

Legenda Vermeerdering	
?	volledig onbekend
▽▽	actieve afname
▽	natuurlijke afname
●	weinig
●●	matig
●●●	sterk
R	rasafhankelijk
s	serotype afhankelijk
? i	? enige informatie

Legenda Schade	
(wit)	Onbekend
(groen)	geen
(geel)	weinig
(oranje)	matig
(paars)	sterk

Legenda Grondsoorten		
D	Dalgrond	
K	Klei	
Z	Zand	
ZA	Zavel	

Figure 16: An overview of the effects of different green manures on a variety of nematodes, including beet cyst nematodes (*Heterodera chatchii* and *Heterodera betea*). R = variety dependent, ∆∆ = active decrease, ∆ = natural decline, • = little, •• = moderate, ••• = strong (Brochure of Telen met Toekomst)

Advantages and application of the innovation

- Contributes to the reduction of beet cyst nematodes,
- Soil protection (soil erosion by wind and water),
- Storage of nutrients, especially N,
- Positive effect on the humus balance,

- Less need for deep soil cultivation due to improved soil quality and breakthrough of impermeable soil layers by the root system,
- Activates soil fauna,
- Improves yield of following crop,
- On clay soils additional transpiration by green manure facilitates ploughing in the fall (drier soil conditions).

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
X	X	X	X	X	1)

1) Natural reduction of nematodes

Reference:

http://www.kennisakker.nl/kenniscentrum/handleidingen/teelthandleiding-groenbemesters
http://www.kennisakker.nl/kenniscentrum/document/rassenbulletin-groenbemesters
http://www.joordens.nl/?ipag=70
http://www.joordens.nl/?ipag=36
Brochure Telen met Toekomst: Groenbemesterkeuze bij schadelijke aaltjes in aardbei, prei, Chinese kool, peen, sla en asperge. [Green manure choice by damaging nematodes in raspberries, leeks, Chinese cabbage, carrots, lettuce and asparagus]

A.14 Use of online decision support system to choose green manures for control of nematodes

Related to MP: MP9 Rotation with green manures

Related to FTZ: ENZ4+6+7_SL1_TXT0+1 – Arable / specialized

Key points

- Select specific green manures to address your specific nematode problems
- Breakthrough of impermeable soil layers
- Improved soil structure
- Reduced losses of N to groundwater
- Production of organic matter

What is it?

- Use the online system www.nemadecide.com to choose the optimal green manure for your own farm

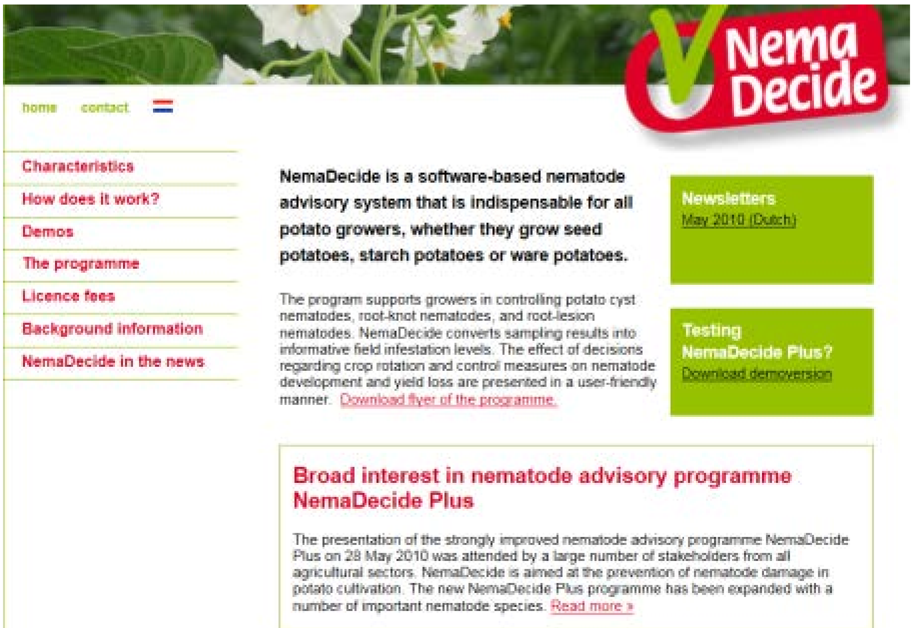


Figure 17: Main web page www.nemadecide.com allows a demonstration of the program to control nematodes

How does it work / is it applied?

Theory:

- Nematodes have an extensive host plant range,
- When no host is cropped, population decreases gradually over time,
- An online system is available to select green manures that reduce nematode populations or at least avoid promoting them.

Usage:

- The online system is available through www.nemadecide.com/en/index.php
- The online system is available in English
- The program supports growers in controlling potato cyst nematodes, root-knot nematodes, and root-lesion nematodes
- Use this online advisory system when planning your green manures

Advantages and application of the innovation

- Contributes to the reduction of nematodes in the crop rotation,
- Improves yields due to reduced nematode populations,
- Soil protection by the green manure soil cover (soil erosion by wind and water),
- Storage of nutrients, especially N, and reduced leaching,
- Positive effect on the humus balance,
- Less need for deep soil cultivation due to improved soil quality and breakthrough of impermeable soil layers by root system,
- Activates soil fauna,
- Improves yield of following crop,
- On clay soils additional transpiration by green manure facilitates ploughing in the fall (drier soil conditions).

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
X	X	X	X	X	1)

1) Natural reduction of nematodes

Reference:
http://www.nemadecide.com/en/index.php
http://www.nemadecide.com/resources/ND_Waar%20Staan%20We%20Nu_LMolendijk%2028052010.pdf

A.15 Use of green manure to limit potato cyst nematodes

Related to MP: MP9 Rotation with green manures

Related to FTZ: ENZ4+6+7_SL1_TXT0+1 – Arable / specialized

Key points

- Grow a green manure that does not increase potato cyst nematodes
- Breakthrough of impermeable soil layers
- Improved soil structure
- Reduced losses of N to groundwater
- Production of organic matter

What is it?

- Choose a green manure that is not a host to potato cyst nematodes

How does it work / is it applied?

Theory:

- Potato cyst nematodes have a large range of host plants
- Select a green manure that is not a host
- Nematode population decreases as host is not available

Sowing:

- Green manures that are no host of potato cyst nematode: Italian rye-grass (Lolium multiflorum) or English rye-grass (Lolium perenne)
- Good weed control is necessary, as potato cyst nematodes also grow well on almost all cruciferous weeds, such as Chenopodium.
- Seed bed preparation is necessary
- Sowing of Italian rye-grass with pneumatic spreader at rates of 30 kg/ha (after half August) with a small N-application of 30 kg/ha.
- Sowing of English rye-grass with pneumatic spreader at rates of 20 kg/ha (after half August) with a small N-application of 30 kg/ha.

In spring:

- After mild winters a pre preparation might be needed before ploughing.

Figure 18: Grasses (English rye-grass to the left, Italian rye-grass to the right) are an excellent green manure to control potato cyst nematode (www.kennisakker.nl)

Advantages and application of the innovation

- Contributes to the reduction of potato cyst nematodes
- Soil protection (soil erosion by wind and water)
- Storage of nutrients, especially N
- Positive effect for the humus balance
- Less deep soil cultivation is needed due to improved soil quality and breakthrough of impermeable soil layers by root system
- Activates soil fauna
- Improves yield of following crop
- On clay soils additional transpiration by green manure facilitates ploughing in the fall (drier soil conditions)

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
X	X	X	X	X	1)

1) Natural reduction of nematodes

Reference:

http://www.kennisakker.nl/kenniscentrum/handleidingen/teelthandleiding-groenbemesters

http://www.kennisakker.nl/kenniscentrum/document/rassenbulletin-groenbemesters

A.16 Object based image analysis

Related to MP: MP8 Rotation with cover/catch crops + MP9 Rotation with green manures

Related to FTZ: ENZ5_SL5_TXT2 - Dairy cattle / permanent grass
ENZ8_SL3+1_TXT2 - Arable / cereal, permanent crops
ENZ6_SL3_TXT3 - Mixed farms

Key points

- Object based image analysis
- Evaluation of the aspired soil coverage of 30% (crop residues)
- Reduction of erosion

What is it?

- The object based image (see FS Weed detection using UAV to adapt herbicide application) can be used to analyze and evaluate the soil coverage and could be used for the quantification of soil erosion

How does it work / is it applied?

The object based image analysis is used for the evaluation of the soil coverage with crop residues. Not pixels but objects which consist of pixels with the same characteristics are analyzed. All the analyses are performed with the software “Cognition” of Trimble. Therefore a vertically picture of a 1 m^2 soil surface is taken by a digital camera. The software uses an algorithm which segments the picture in objects. The objects are separated in different classes by use of given rules. These classes are: “shadow”, “vegetation”, “crop residues”, “stones” and “undefined”. All the objects which cannot be classified are assumed as soil.

Advantages and application of the innovation

- Easy handling of the equipment
- Evaluation of the soil coverage by vegetation and/or crop residues
- Evaluation of the distribution of crop residues
- Assessment of soil erosion risk

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
				x	

Reference:

Liebhard, P., Kamptner, J. and Strauss, P. (2014): Einfluss der Saatbettbereitung bzw. Mulchsaat auf den Bodenbedeckungsgrad mit organischer Substanz zur Erosionsverminderung. ALVA Tagungsband, 66-68.
Bauer, T. and Strauss, P. (2013): A rule-based image analysis approach for calculating residues and vegetation cover under field conditions. Catena, 363-369.

A.17 Early harvest of maize to allow timely establishment of green manure or grass ley before winter

Related to MP: MP ‘not-coded’ Use of early maturing maize varieties

Related to FTZ: ENZ4+7_SL1_TXT1 - Dairy cattle / permanent grass

Key points

- An early ripening maize variety is cropped to establish a green manure or grass sod in the fall,
- Reduced herbicide use compared to establishment of grass sod in the spring,
- Improved productivity and quality of first year grass sod compared to establishment of grass sod in the spring.

What is it?

- Maize is harvested before 15 September which allows the establishment of a green manure of the grass sod in the fall

How does it work / is it applied?

- An early ripening maize variety is chosen
- Maize is harvested before September 15
- Seed bed preparation followed by seeding of winter rye (*Secale cereale* ‘Humbolt’ or ‘Rheidol’) or grass (*Lolium perenne*) to establish the sod,
- Application in grass/maize rotations

Advantages and application of the innovation

- Yield of maize is not much lower (-11% to +15%) compared to standard maize variety,
- Reduced herbicide use compared to establishment of the sod in the spring,
- Sod establishment in the fall provides higher grassland productivity in following year,
- Improved nutrient uptake by green manure/ catch crop (reduced leaching),
- Positive effect on organic matter balance compared to green manures after late ripening maize varieties.

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertili-ty	Physical soil fertility	Other aspects
X	X	X	X	X	1)

1): Reduces emissions of herbicides to the environment

Reference:

http://www.wageningenur.nl/upload_mm/5/5/8/903347f8-7b7b-4d33-9a58-c2cbdf9d28c9_PPO-RassenBulletin_Ultravroege%20snijmais2014_Small.pdf.
edepot.**wur**.nl/294812
http://www.naktuinbouw.nl/sites/naktuinbouw.eu/files/Nationale%20RL2011.pdf

A.18 Cultivating early-maturing silage maize varieties in combination with a ryegrass cover crop

Related to MP: MP ‘not-coded’ Use of early maturing maize varieties

Related to FTZ: ENZ7_SL2_TXT3 - Arable / specialized crops
ENZ7_SL1_TXT1 - Dairy farming / permanent grassland

Key points

- Reduced risk for soil compaction
- Better development of cover crop

What is it?

- Sowing early-maturing silage maize varieties which can be harvested in the second half of September.

How does it work / is it applied?

- Early-maturing maize varieties mature faster compared to the medium and late-maturing maize varieties which are generally sown. Consequently those early-maturing varieties can already be harvested in the second half of September in mostly good weather conditions;
- As harvest is more likely to occur in good weather conditions, the risks for soil compaction is reduced;
- Due to the early harvest date, the ryegrass cover crop can be sown (at a normal rate of 20 kg/ha) earlier which results in better development, soil cover and nutrient uptake before the winter period and a heavier cut in spring.

Advantages and application of the innovation

- Positive effect for soil organic matter;
- Better soil cover during winter (protection against soil erosion by wind and water);
- Better trafficability at maize harvest;
- Less dirt on the roads;
- Reduced soil compaction risk;
- Improved cover crop development → less nitrate leaching;
- Early-maturing varieties tend to have lower yields than later types which are the main bottleneck for a high adoption rate, although lower compaction may lead to higher yields in the longer term.

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
	X		X	X	1)

1) Lower soil compaction risk

Reference:

Latre, J., Stoop, T., Haesaert, G., Verheyen, J., Coomans, D., Rombouts, G. (2007). Mogelijkheden van grasinzaai in maïs of gras/rogge inzaai na maïs met het oog op bodembedekking, reductie herbicide input en reststikstof. Landbouwcentrum voor Voedergewassen vzw. 8p.

De Vliegher, A., Latré, J., Carlier, L. (2009). *Lolium multiflorum* as a catch crop in maize. Proceedings of the 15th European Grassland Federation Symposium, Brno (Czech Republic), 83-86.

A.19 Underseeding under maize (*Lolium perenne* and *Lolium multiflorum*) with adapted herbicide application

Related to MP: MP 'not-coded' Undersowing of green manure within maize

Related to FTZ: ENZ4_SL1_TXT1 - Arable and mixed farms

Key points

- Whole year greening
- Improvement of soil quality
- Soil protection (water, nutrients, erosion)

What is it?

- Sowing with 15 – 20 kg / ha at a growing height of 50 – 70 cm of maize (6-leaves-stage)

How does it work / is it applied?

Under seeding:

- Sowing with pneumatic spreader without soil tillage or with a late slurry application, i.e. seeds are filled into the barrel by the injector
- Under normal conditions until ripening of maize – slow development of under seeds
- With better light conditions and after harvest the under seeds growing will be intensified
- In the case of drought – under seeds will wither and no water competition with maize will occur

Herbicide application:

- No compatibility difficulties with B 235 (Bromoxynil) and Peak (Prosulfuron) or Triketone (Mikado, Callisto, Clio and Laudis) or Calaris (Terbutylazin + Mesotrione) or Sulfonyle Cato, Milagro/Samson/Kevin, Principal and MaisTer
- 2 – 3 weeks between sowing of under seeds and herbicide application
- For narrow maize rotations: splitting application
    - First herbicide application with worst compatibility e.g. Gardo Gold with max. 1,0 l/ha at 2 – 3 leaves stage of maize
    - Second herbicide application with better compatibility (see above) mid of May – beginning of June

In spring:

- Chemical kill of underseeds with 50 – 60 % of e.g. Roundup TURBOplus, 2,65 kg/ha

Advantages and application of the innovation

- Soil protection (soil erosion by wind and water)
- All-year greening
- Storage of nutrients (~40 kg N / ha)

- A better trafficability at the maize harvest
- Less dirt at the roads
- Positive effect for the humus balance
- Yield neutrality

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soi l fertility	Physical soil fertility	Other aspects
x	x			x	1)

1) Reduction of nitrogen and herbicides to the environment

Reference

https://www.lwk-niedersachsen.de/index.cfm/portal/2/nav/183/article/16858.html
http://www.dsv-saaten.de/data/pdf/2d/01/00/DSV_Maisuntersaaten.pdf
Menne, C. (2014): Etablierung von Untersaaten auf Naturland Betrieben in Brandenburg – Auswertung von Anbauveruschen in Brandenburg. Naturland Nachrichten 1: 40-43 p.

Figure 19: Early undersowing under maize (row width 75 cm) (http://www.dsv-saaten.de/data/pdf/2d/01/00/DSV_Maisuntersaaten.pdf)

A.20 Underseeding under maize (*Festuca rubra*) with adapted herbicide application

Related to MP: MP 'not-coded' Undersowing of green manure within maize

Related to FTZ: ENZ4_SL1_TXT1 - Arable and mixed farms

Key points

- Whole year greening
- Improvement of soil quality
- Soil protection (water, nutrients, erosion)

What is it?

- Sowing with 5 – 7 kg / ha before or with the sowing of maize

How does it work / is it applied?

Under seeding:

- Sowing with seed drill to separate maize and festuca rubra roots without a harroweeder to detect soil structure
- Maize sowing with 75 cm row distance with two rows of festuca rubra

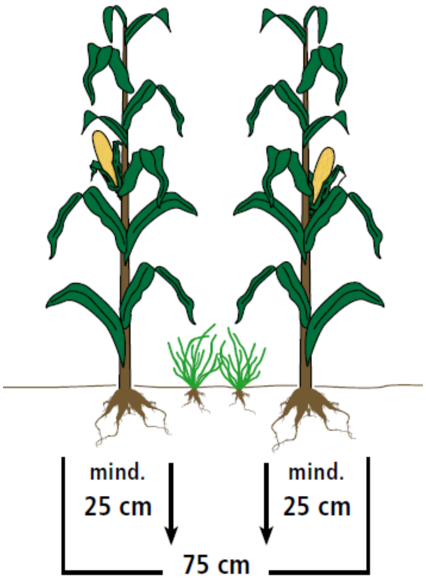


Figure 20: Row width for early undersowing (http://www.dsv-saaten.de/data/pdf/2d/01/00/DSV_Maisuntersaaten.pdf)

Herbicide application:

- No use of soil based herbicide and Sulfonyle (Cato, Milagro/Samson/Kevin, Principal and MaisTer)
- Only use of a mixture (Stomp Aqua, Callisto/Mikado and e.g. B 235) at first
- Second application with a combination of Mikado/Callisto, B235 and Peak

Figure 21: Roots of undersowing grass (http://www.dsv-saaten.de/data/pdf /2d/01/00/DSV_Maisuntersaaten.pdf)

In spring:

- Chemical kill of underseeds with up to 100 % (e.g. Roundup TURBOplus, 2,65 kg/ha)

Advantages and application of the innovation

- Soil protection (soil erosion by wind and water)
- All-year greening
- Storage of nutrients (~40 kg N / ha)
- A better trafficability at the maize harvest
- Less dirt at the roads

- Positive effect for the humus balance
- Yield neutrality

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
x	x			x	1)

1) Reduction of nitrogen and herbicides to the environment

Reference

https://www.lwk-niedersachsen.de/index.cfm/portal/2/nav/183/article/16858.html
http://www.dsv-saaten.de/data/pdf/2d/01/00/DSV_Maisuntersaaten.pdf
Menne, C. (2014): Etablierung von Untersaaten auf Naturland Betrieben in Brandenburg – Auswertung von Anbauveruschen in Brandenburg. Naturland Nachrichten 1: 40-43 p.

Figure 22: Early undersowing under maize (row width 75 cm) (http://www.dsv-saaten.de/data/pdf/2d/01/00/DSV_Maisuntersaaten.pdf)

A.21 Undersowing of a green manure under maize after maize sowing

Related to MP: MP ‘not-coded’ Undersowing of green manure within maize

Related to FTZ: ENZ4_SL1_TXT2+3 – Arable / specialized + cereals

Key points

- Maize harvest normally too late to establish cover/catch/green manure crops (NL)
- Improved late-season N-interception by green manure
- Reduced losses of N to groundwater
- Better ride-ability of the soil at harvest

What is it?

- Sowing of 20 kg / ha of Lolium perenne together with the last mechanical weeding event in the maize crop

How does it work / is it applied?

Undersowing:

- Sowing with a weeding machine equipped with a pneumatic spreader, a fertilizer spreader or regular pipe sowing machine for grass; the pipes at the maize rows should be blocked,
- Preferable sown in the afternoon when maize is warmed up and more flexible to prevent the breaking of the young maize plants,
- Sowing when maize is about 40 to 60 cm high, normally 6 weeks after sowing,
- Green manure development is slow and marginal until maize crop is harvested,
- Competition between maize and green manure is limited due to the limited development of the green manure,
- In case of drought, the green manure is wilting much faster than maize so no competition for water occurs,
- After harvest of maize green manure growth is accelerated due to better light conditions.

In spring:

- Harrow green manure in early spring depending on temperature, preferably at beginning of March,
- Standard treatment to kill green manure if needed:
  chemically with Roundup,
  incorporation by ploughing or
  non-inversion tillage by mulching in late winter to facilitate decomposition and disking, harrowing or milling green manure just before spring growth is initiated,
- Mowing in the early spring as cattle feed,
- Fencing and grazing cattle.

Special attention is needed:

- When sowing and weed control is done by a contractor let them know **NOT** to use soil herbicides for weed control (which is common) as the green manure will die too.

Figure 23: Green manure stand of an undersown green manure in maize at the end of the cropping season (left, http://www.farmwest.com/book/export/html/840) compared to a green manure stand in December of a green manure sown after harvest (right, http://commons.wikimedia .org/wiki/File:2004_0609_ Italian_ryegrass_cover_crop.jpg)

Advantages and application of the innovation

- No effect on yield of maize,
- Improved N-uptake compared to sowing after maize harvest,
- Reduced N-losses to groundwater,
- Improved organic matter production compared to sowing after harvest,
- A better ride-ability at the harvest of maize,
- No soil cultivation needed after harvest of maize,
- No time pressure on sowing green manure any more as in standard practice, green manure sowing after harvest is often delayed due to unfavorable weather conditions.

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
X	X		X	X	1)

1): reduced emissions of nitrogen to the groundwater

References:
http://edepot.wur.nl/5506
http://edepot.wur.nl/297103

A.22 Undersowing of a green manure within maize at the same time as maize sowing

Related to MP: MP ‘not-coded’ Undersowing of green manure within maize

Related to FTZ: ENZ4_SL1_TXT2+3 – Arable / specialized + cereals

Key points

- Maize harvest normally too late to establish cover/catch/green manure crops (NL)
- Improved late-season N-interception by green manure
- Reduced losses of N to groundwater
- Better ride-ability at harvest

What is it?

- Sowing of 20 kg / ha of slow germinating tall fescue together with maize sowing

How does it work / is it applied?

Undersowing:

- In one field operation maize and tall fescue (Festuca arundinacea) are sown,
- Chemical weed control is done when tall fescue is still small (<10 cm length) which then only kills aboveground biomass of green manure,
- Green manure regrowth is from below ground biomass and will be slow
- Green manure development is slow and limited until maize crop is harvested,
- Competition between maize and green manure is limited due to the slow development of the green manure,
- In case of drought, the green manure will wilt much faster than maize, so no competition for water occurs,
- After harvest of maize green manure growth is accelerated due to better light conditionsIn spring:

- Harrow green manure in early spring depending on temperature, preferably at beginning of March,
- Standard treatment to kill green manure if needed:
  chemically with Roundup,
  incorporation by ploughing or
  non-inversion tillage by mulching in late winter to facilitate decomposition and disking, harrowing or milling green manure just before spring growth is initiated.

Figure 24: An under sown green manure at the same time of maize planting (left); an under sown green manure after sowing (middle) and a sown green manure after harvest (right http://edepot.wur.nl/297103)

Advantages and application of the innovation

- Seeding maize and green manure in one field operation,
- No effect on yield of maize,
- Improved N-uptake compared to sowing after maize harvest,
- Reduced N-losses to groundwater,
- Improved organic matter production compared to sowing after harvest,
- A better ride-ability at the harvest of maize,
- No soil cultivation needed after harvest of maize,
- No time pressure on sowing green manure any more as in standard practice, green manure sowing after harvest is often delayed due to unfavorable weather conditions.

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertili-ty	Physical soil fertility	Other aspects
X	X		X	X	1)

1): reduced emissions of nitrogen to the groundwater

References:
http://edepot.wur.nl/5506
http://edepot.wur.nl/297103
http://www.barenbrug.nl/files/4/1/4/2/Onderzoek%20herbicidetolerantie%20Proterra%20mais.pdf
http://www.barenbrug.nl/veehouderij/vaknieuws/proterra-maize.htm

A.23 Underseeding under maize (Italian and/or perennial ryegrass) in combination with mechanical weed control and herbicide banding

Related to MP: MP 'not-coded' Undersowing of green manure within maize + MP41 Mechanical weeding

Related to FTZ: ENZ7_SL2_TXT3 – Arable / specialized
ENZ7_SL1_TXT1 - Dairy cattle / permanent grass

Key points

- Whole year round soil cover
- Soil quality improvement
- Reduced erosion risk

What is it?

- Sowing Italian and/or perennial ryegrass at a rate of 20 kg/ha at the maize 6-8 leaf stage.

How does it work / is it applied?

Underseeding:

- Broadcast seeding with a pneumatic spreader without a tillage operation (except for harrowing to cover the seeds);
- Emergence and vigor of ryegrass is not very successful in dry periods (competition with maize for the available water);
- The undersown grass can be seriously damaged by the machinery during the maize harvest.

Weed control:

- When Italian ryegrass is used for underseeding, the use of the herbicides dimethenamid-P en S-metolachloor should be avoided as they severely hinder the grass growth

Advantages and application of the innovation

The success of undersowing grass in maize will depend strongly on weather and soil conditions. If successful:

- Positive effect for soil organic matter;
- Good soil cover during winter (protection against soil erosion by wind and water);
- Better trafficability at maize harvest;
- Less dirt on the roads;
- Whole year soil cover;
- No negative effect on maize production;
- Prevents nutrient leaching.

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertili-ty	Physical soil fertility	Other aspects
	X		X	X	1)

1) Erosion control; Prevents nitrate leaching

Reference:

Latre, J., Stoop, T., Haesaert, G., Verheyen, J., Coomans, D., Rombouts, G. (2007). Mogelijkheden van grasinzaai in maïs of gras/rogge inzaai na maïs met het oog op bodembedekking, reductie herbicide input en reststikstof. Landbouwcentrum voor Voedergewassen vzw. 8p.
Handboek snijmaïs 2013. Wageningen UR Livestock Research, Praktijkonderzoek Plant en Omgeving (PPO), http://www.wageningenur.nl/nl/show/Handboek-Snijmais.htm
De Vliegher, A., Latré, J., Carlier, L. (2009). *Lolium multiflorum* as a catch crop in maize. Proceedings of the 15th European Grassland Federation Symposium, Brno (Czech Republic), 83-86.

Category:
B. GRASSLAND MANAGEMENT

B.1 Rational grazing planning combined with cultivated areas for feeding the livestock

Related to MP: MP11 Permanent grazing

Related to FTZ: ENZ11_SL5_TXT2; ENZ12_SL2+3+4_TXT2; ENZ13_SL2+3_TXT1; ENZ13_SL2+3+4+5_TXT2 - Sheep and goats/ Others (pigs); Beef and mixed cattle/Permanent grass

Key points

- The key is controlling livestock handling charges, species of animals and their age, and length of stay at the same place.
- Environmental factors must be estimated.
- The most important objective of the *dehesa* is extensive livestock rearing.

What is it?

Dehesas are made up of five major components: a tree layer, grass lands, crops, livestock, and wildlife. The annual grasslands in the dehesa system are used primarily for livestock grazing, although the land is also used for planting crops such as barley, oats, rye, and other types of cereals, which provide food for both animals and humans. The crops require a long fallow period (4 to 10 years), but very few agricultural inputs like fertilizer or pesticides are needed.

Figure 25: Sheep grazing on a typical Spanish dehesa (http://www.fao.org/fileadmin/templates/agphome/images/iclsd/documents/wk1_c5_radomski.pdf)

How does it work / is it applied?

- Know which are the available resources and order them in space and time.
- Sown of forage species, vetch-oats mainly, that can be preserved in time by hay or silage processes. But there are other possibilities, such as the introduction of fodder shrubs that can be used directly by livestock.
- In a pasture is harmful both overgrazing, which produces compaction and increases the nitrate level (incompatible with legumes) and undergrazing, which does not prevent the invasion by scrubs.
- It is important as well to control when the livestock is introduced to not harm the seeding (spring) or the early development of grass (autumn).
- Correction fertilization with phosphorus is recommended (60 - 80 kg P_2O_5 per hectare and a maintenance dose of about 40 kg every five years).

<u>Natural pastures:</u>

- As a consequence of the Mediterranean climate, natural pastures are usually annual grasslands. However, perennials play a fundamental role in valley bottoms and particularly in dense swards created and maintained by intense and continuous grazing.
- The management of natural pastures is aimed at increasing their quality (legumes: protein, minerals), since quantity is much less important due to high variability (up to 200 %, according to Olea et al., 1989). Therefore that management is based upon three fundamental topics: rational livestock grazing, legumes and phosphorus.
- However, seasonal periods of shortage of fresh fodder cannot be avoided, so browse, fruits (particularly acorns), crops and supplementary food also contribute to a suitable nutrition of livestock in hunger periods: summer and winter. The shrub layer is typically absent or sparse.

<u>Crops and sown pastures:</u>

- Crops and sown pastures often play a fundamental role in livestock feeding, as a complement to natural pastures, both in seasonal distribution (summer and late winter) and in quality (Joffre et al. 1988).
- In addition, cropping is usually carried out in cycles of seven years (3-6) years with the aim of keeping intolerant invading shrubs out of natural grasslands.

Advantages and application of the innovation

- Crops and sown pastures are a complement to natural pastures, both in seasonal distribution and in quality and therefore, it increases the yield and the productivity of the system.
- Control soil erosion enhancing soil conservation as it increases ground cover compared to fallow.

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
x				x	

Reference:

Granda, M.; Moreno, V.; Prieto, P.M. 1991. Mejora y utilización de pastos naturales de dehesa, MAPA, Madrid.
Joffre, R.; Rambal, S. 1988. Soil water improvement by ees in the rangelands of southern Spain, Oecologia Plantarum, 9, 405-422.
Moreno, V.; Bueno, C.; Santos, A. 1993. Respuesta a distintas dosis de superfosfato de cal en suelos pardos meridionales de la dehesa extremeña. SEEP (Ed.) Actas XXXIII Reunión Científica, Ciudad Real, pp. 234-243.
Moreno, V; González, F; Olea, L. 1994. Annual legumes improvement for pastures, Melhoramento, 33 (I), 230-240.
Olea, L.; Paredes, J.; Verdasco, P. 1989. Características productivas de los pastos de la dehesa del S.O. de la Península Ibérica. In: SEEP (ed): Actas II Reunión Ibérica de pastos, Badajoz, pp. 194-230.
Olea, L.; López-Bellido, R.J.; Poblaciones, M.J. 2005. Europe types of silvopastoral systems in the Mediterranean area: dehesa. In: Mosquera, M.R.; Rigueiro, A.; McAdam, J. (eds) Silvopastoralism and Sustainable Land Management, CABI Publishing.
http://www.fao.org/fileadmin/templates/agphome/images/iclsd/documents/wk1_c5_radomski.pdf
http://www.ecoagriculture.org/documents/files/doc_68.pdf
http://ws128.juntadeandalucia.es/agriculturaypesca/portal/export/sites/default/comun/galerias/galeriaDescargas/cap/servicio-estadisticas/Estudios-e-informes/ganaderia/dehesa/008_pastosdehesa.pdf

Category: C. TILLAGE

C.1 Use of specific machinery that allow non-inversion tillage (e.g. chisel or an eventual deep tillage pass)

Related to MP: MP17 Non-inversion tillage/reduced tillage + MP18 Non-inversion tillage/minimum tillage

Related to FTZ: ENZ13_SL1+2+3+4_TXT4 – Arable / Cereals

Key points

- Dense layers de-compaction
- Minimal soil disruption
- Improving of water infiltration and root penetration
- Crop residues management
- Weeds control

Figure 26: Chisel plow (http://www.deere.com/common/media/images/product/tillage/ primary_tillage/610_integral_chisel_plow/610_IntegralChiselPlow_0027064_642x462.png ; http:// www.farmequipmentfinder.com/view_item.php?id=2646)

What is it?

The **chisel plow** makes a primary tillage. It is equipped with curved shanks to penetrate and "stir" the soil without inverting a soil layer. It consists of a set of arms or fingers (resistant and flexible), which produce with its vibration an effect of spraying the soil surface and incorporating the stubble. In some cases rigid arms are used, so that their work characteristics are close to subsoiler. The arms are located preferentially in three lines and displaced sideways to facilitate the flow of the stubble avoiding the effect of raking. At the end of each arm there are narrow, double-ended shovels, or chisel points, effective to break the soil, or wider with flap shape for better control of the vegetation. Less frequently a ripper coulter warped is used to increase the effect of burying the stubble. The angle that forms the arm with the soil surface should be as acute as possible to avoid the effect of raking. In the back a roller can be used to cause soil sealing, which prevents moisture loss. Associated with circular knives or discs allows to make the preparation of the soil in a single pass.

Deep tillage-Subsoiler breaks up soil at depths below the level of a traditional plow without turning it over. It must work at least 10 cm below the layer that is trying to break. Implement with an odd number of arms or fingers robust and rigid to work in soil hardened, mounted on a frame capable of supporting these efforts. The distance between the arms determines the depth of work, in addition to the length of the bristles. At the end of each finger is a simple type of boot or with side wings. The bristles may be straight almost vertical, inclined forward and with parabolic profile. The situation of the bristles in the frame is usually done in V, with the closest in the center and on the outside the most distant, to prevent the wheels of the tractor affect the area of the broken ground. As auxiliary elements wheels are used for support or a rear roller that helps getting the soil leveled and sealed to reduce the moisture loss. In some cases systems that produce vibration are implemented to reduce the required traction effort to drag it.

How does it work / is it applied?

- Chisel plow is used to make a primary tillage by maintaining a large portion of the surface mulch (leaves 15% to 30% residue coverage on the soil), which makes it suitable for the conservation tillage with surface residue (see FS Deep non-inversion tillage).
- Subsoiler is used to breaks up compacted layers in the soil. The soil breaks as a V from the bottom of the furrow toward the surface. Cannot be used to control weeds.

It is recommended to use both implements with dry soil to facilitate its cracking. In the case of the chisel plow, it increases its effectiveness with dry soil for the effect of vibration of flexible arms or arms equipped with springs. If the working deep is excessive, the curved arms tend to lose their ability to vibration.

Chisel

- The work width should overcome the footfall of the tractor that drags it. This together to the necessary high speed forces to have potent tractors.
- The tractive effort required is approximately equal to half of what is needed to drag a moldboard plow of the same width working to the same depth. Even so, the needed power increases as a result of the recommended velocity of work (7.0 to 9.0 km/h) that is greater than the recommended for the moldboard.
- Power of 25-40 HP (18-29 kW) per meter of work width is recommended. The efficiency in plot is between 0.65 to 0.85.

Subsoiler

- The relationship between the working depth and separation of the bristles should be maintained between 1.0 and 1.5 for the simple boots and 1.5 to 2.0 in the boots with fins.
- Power demand by barb varies between 35-45 HP (28-33 kW) for up to 30 cm depth of work, up to 55-65 HP (45-48 kW) to 70 cm depth.
- Work speeds should be kept between 3.0 and 5.0 km/h, with a plot efficiency of 0.65 to 0.85.

Figure 27: Subsoiler (http://www.idae.es/uploads/documentos/documentos_10330_Sistemas_laboreo_agricola_06_ebaa2e1f.pdf)

Advantages and application of the innovation

- Minimal soil disruption and improving of water infiltration and root penetration

- Leaves more crop residues on the surface
- Produces a rough surface that helps to control hydric erosion
- Lower fuel consumption than with moldboard

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
				x	1)

1) Economical aspects

Reference:
http://www.magrama.gob.es/app/mecanizacion/fichaMaquinaria.aspx?lng=es&n1=3
http://www.fao.org/ag/ca/es/3e.html
http://www.idae.es/uploads/documentos/documentos_10330_Sistemas_laboreo_agricola_06_ebaa2e1f.pdf

C.2 Compact disc harrow for residues management

Related to MP: MP17 Non-inversion tillage/reduced tillage + MP18 Non-inversion tillage/minimum tillage

Related to FTZ: ENZ6_SL2_TXT3 - Arable / cereal

Key points

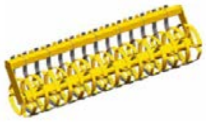
- perfect match to every tractors
- shallow cultivation
- high output
- all-rounder can also be used for seedbed preparation
- low drag resistance
- perfect ground penetration
- best crumbling and mixing effect


Figure 28: Compact disk harrow (http://www.poettinger.at/landtechnik/download/237.02.0113_Terradisc_en.pdf)

What is it?

- Discs – 24, set in two rows with disc diameter 580 mm, eight disc per meter of working width
- Working depth 0.03-0.12 m, hydraulically regulated by bilateral hydraulic rams
- Weight of 1370 - 2007 kg, depending on the applied roller
- Minimum power requirement of 70 – 78 kW (95 – 106 hp)
- Working width 3.0 m and 11 to 15 km/h recommended working speed
- Rear rollers for different soil types and moisture conditions

		Soil moisture			Soil characteristics		
Type	Description	dry	medium	damp	light	medium	heavy
Bar cage roller 	The ideal roller for working on dry, non-sticking soil. The roller is equipped with strong bars to provide the best packing effect.	X	X	-	X	X	-
Dual bar cage roller 	The dual bar cage rollers have different diameters. They are mounted with a free-dom of movement to deliver optimum ground tracking and crumbling effect.	X	X	-	X	X	-

Knife ring roller 	This 600 mm diameter roller is equipped with wedge-shaped rings for increased crumbling and compression. The knives between the rings break up clods and clean the spaces between the rollers. The corru-gated consolidation effect has the ad-vantage that water can be better absorbed. The right choice on dry and heavy soil.	X	X	X	X	X	X
Pack ring roller 	The packer rings are closed on either side and have a diameter of 550 mm with 8 rings per meter of working width (125 mm spacing). The roller leaves corrugated stripes, promoting water absorption and soil respiration. The ideal roller on stony, damp ground with large quantities of or-ganic matter.	X	X	X	X	X	X
Conical ring roller 	No rainwater is left standing on the surface thanks to the striped, conical packing ef-fect. Also works well in fields with harvest residues. The ideal roller for medium to heavy types of soil, since load-bearing is limited on very light soil.	X	X	X	X	X	X
Rubber packer roller 	This roller is ideal for widely varied ground conditions. Especially for use with trailed implements where the load-bearing capaci-ty of other rollers is near the limit. The diameter 590 mm and the special profile enable stripe-wise compaction.	X	X	X	X	X	X

How does it work / is it applied?

- The gear discs with a diameter of 580 mm are placed of 12 pieces on two beams and posi-tioned at an angle to the direction of a disc make it swell and shredding and mixing of crop residue with soil loosening.
- The rear roller packer is to knead the soil linearly to better water rise and at the same time accelerate the growth of weeds that were on the field after harvest. It also serves to regulate the working depth of disc harrow.
- The weight of the roller is transferred to the disc harrow during operation.
- Working depth is adjusted hydraulically quickly without risk to the operator.

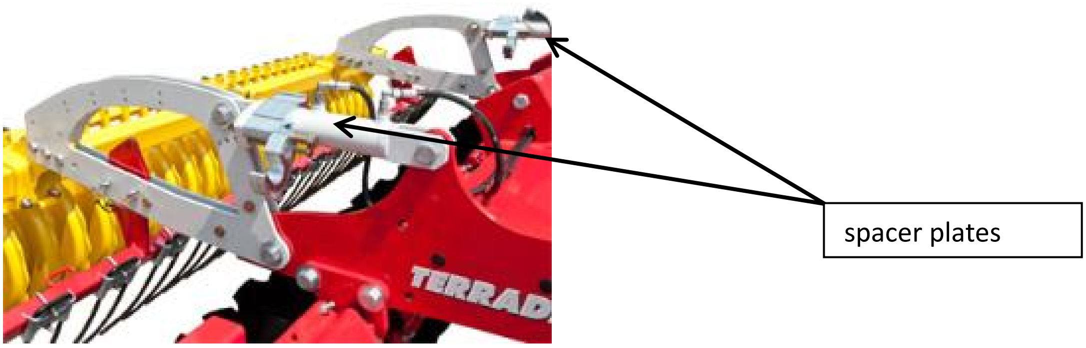


Figure 29: Depth adjustment of compact disc harrow (http://www.poettinger.at/land technik /download/237.02.0113_Terradisc_en.pdf)

- Folding 5 mm-thick spacer plates are used to fine-tune depth control. This ensures reliable penetration in dry and hard conditions.

- The trailed harrow tines are adjusted in unison with the roller mounting arms. No complicated manual intervention is required.

Advantages and application of the innovation

- Compact device with high strike capacity
- Stability due to 3-point mounting
- Easy compensation with stony soil conditions, only affected disc will be lifted
- 40 % reduction for fuel consumption (see table and figure for different soil types)
- 37.5 % reduced time requirement compared to plough

	Plough with packer	Compact disc harrow
Tillage depth	26 cm	8 cm
Fuel consumption	28-32 l/ha	10-14 l/ha
Time requirement	75-85 min/ha	25-35 min/ha

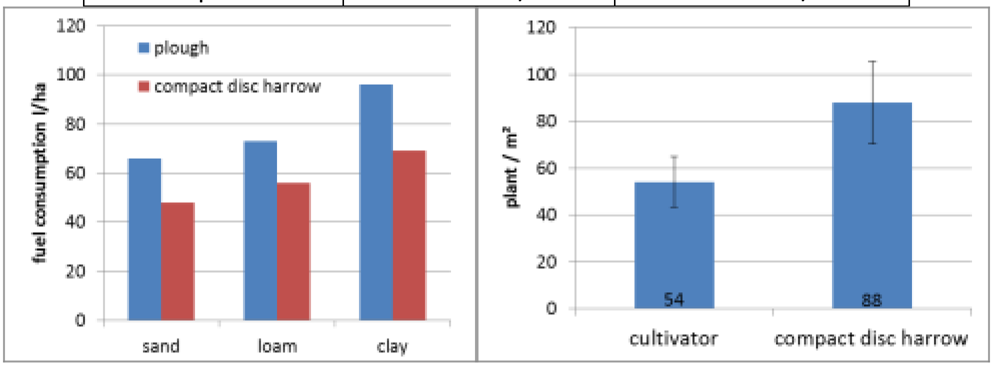


Figure 30: Fuel consumption for different soils between plough and compact disc harrow; volunteer cereals comparison between cultivator and compact disc harrow (AMAZONEN-Werke 2009)

- 16 % lower power requirement for a compact disc harrow application with packer roller
- Following the harvest, residues need to be worked in evenly so decomposition gets a head start (see FS Non-inversion spring tillage technique to incorporate green manures after maize)
- The mixture of straw and soil creates optimum conditions for soil life
- A uniform surface finish with the best mixing performance meets farmer's expectations in the field. That's why the compact disc harrow plays a major role in modern arable farming
- The cost of use a compact disk harrow is lower than different machines

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
x	x	x	x	x	1)

1): better distribution of crop residues and economical aspect

Reference:

http://www.poettinger.at/landtechnik/download/237.02.0113_Terradisc_en.pdf
AMAZONEN Werke (2009): Intelligenter Pflanzenbau. p.143
Hunger, R. (2014): Grubber oder Kurzscheibenegge. Schweizer Landtechnik, 3: p. 26-27.
fm (2012): Scheibenmischer. Agrartechnik 8: p. 54-55.

C.3 Stubble cultivator for shallow residues and seedbed management

Related to MP: MP17 Non-inversion tillage/reduced tillage + MP18 Non-inversion tillage/minimum tillage

Related to FTZ: ENZ6_SL2_TXT3 - Arable / cereal

Key points

- Passive cultivation tool
- Undercutting the top layer of the soil and mixing it with post-harvest residues
- Tubular roller pressing the soil on the surface
- Reduced tillage

What is it?

- 5 pieces of rigid cultivator tines with goose feet at the end, secured with springs
- 6 discs with tines with a diameter of 0.51 or 0.56 m, mounted on the bar
- Working width 2.2 m and working speed 7 to 9 km/h
- Gradual mechanical adjustment of the operation of discs to the maximum depth of 0.10 m
- Tubular roller which serves to set up the working depth of the cultivator by the gradual mechanical adjustment (see Figure 32)

Figure 31: Stubble cultivator (http://www.staltech.biz)

How does it work / is it applied?

- Rigid cultivator tines have goose feet at the end undercut the top layer of the soil and mix it with post-harvest residues
- Discs with tines with a diameter of 0.51 or 0.56 m set up in pairs in the number of 6 pieces on two bars at a certain angle to the movement direction of the cultivator mix post-harvest residues with the moved soil and level its surface. The rear tubular roller presses the soil on the surface to facilitate water permeating and accelerate the growth of weeds left on the field after combine harvesting. It also regulates the working depth of the cultivator by shifting its weight onto the roller.

- Gradual adjustment of the working depth is performed mechanically by safeguarding of the frame of the tubular roller with the bolt system on the adjustment ridge with drilled holes (Figure 32).
- Stubble cultivator with tines can cooperate with a tractor with a power of min. 75 kW (100 KM).
- Due to the spring safeguarding of the cultivator tines, the cultivator can also be user on the stoned soils.
- The dryer and heavier the soil the shallower tillage.

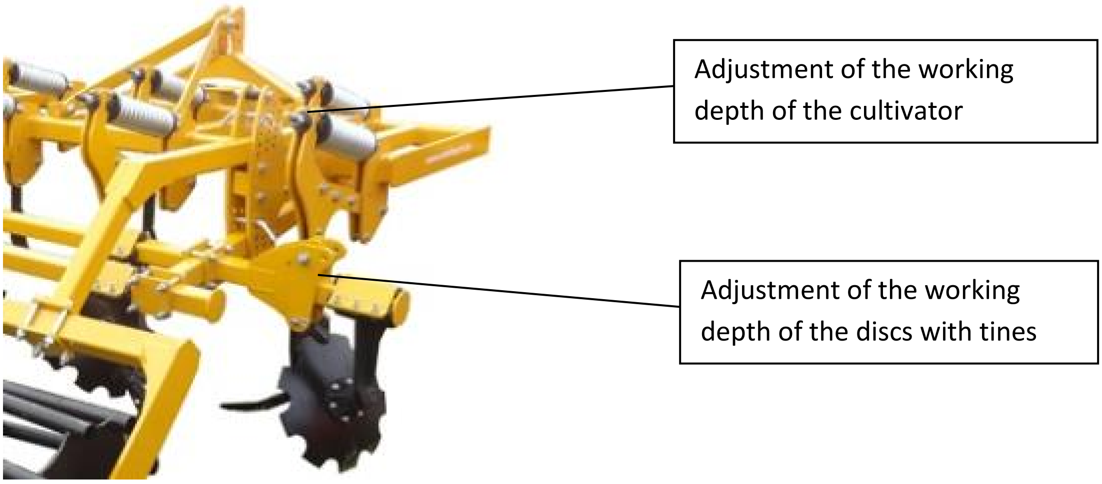
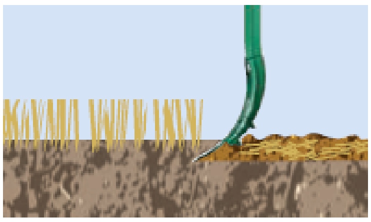
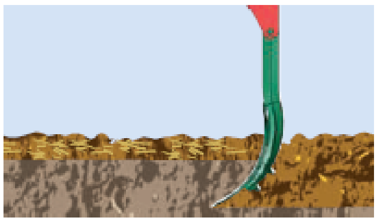
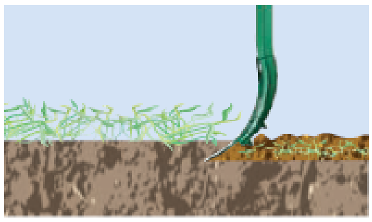


Figure 32: Adjustment of the working depth of the stubble cultivator (http://www.staltech.biz)

Table 6: Applicable for different tasks (http://www.vogel-noot.info (Cultivators – The perfect machine for every task)

		
Shallow stubble cultivation for rapid decomposition	Mid-depth stubble cultivation or depth loosening	Mulch seedbed cultivation in spring and autumn
- Initial shallow cultivation (to a depth of 3 to 8 cm) (see FS Non-inversion spring tillage technique to incorporate grass sod before maize) - Creation of ideal germination conditions for volunteer/spilt grain or weed seeds - Mix of crop remains and soil to begin a rapid straw decomposition process	- Speed up straw decomposition intensive, mid-depth mixing of straw remains after 2 to 3 weeks - 15 to 25 cm soil loosening for large quantities of straw, damp harvesting conditions or unstable soil structures	- Creation of best possible conditions for optimum seedbed cultivation (shallow seedbed preparation) (see FS Non-inversion tillage to reduce volunteer potatoes on clay soils) - Uniform mixing and precise leveling and consolidation of the cultivation horizon

Advantages and application of the innovation

- It is used for undercutting the top layer of the soil, covering mineral fertilizers, soil breaking and stubble cultivation by mixing post-harvest residues with the undercut soil.
- Stubble cultivator perfectly mixes the top layer of the soil with post-harvest residues which enhances their mineralization.
- Surface stubble cultivation by undercutting the soil inhibits intensive water evaporation and guarantees optimal conditions for germination of weeds and seeds left after the combine passage.
- It is mainly used for stubble cultivation instead of ploughing after the harvest of cereals and technologically similar plants.
- The final roller leaves behind soil strengthened on the surface, which determines water up-take and active air-flow.
- The cost of use stubble cultivator is lower than different machines.
- Cultivator avoid soil compaction (plough pan)
- Good mixing in of straw via wing share
- Adjustable angle of attack with wing share guarantees best possible penetration under even the hardest of conditions.
- Reduction of soil erosion due to crop residues incorporation
- Higher appearance of soil biology / fauna compared to plough application
- Cost comparison cultivator to plough: 50 % more favorable
- Cost comparison cultivator to compact disc harrow: > 50 % more favorable

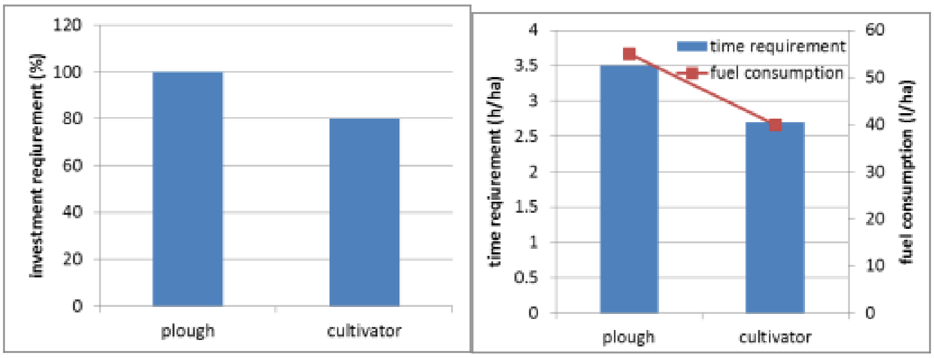


Figure 33: Relative investment requirement between plough and cultivator; time requirement and fuel consumption between plough and cultivator (Südzucker AG 2012)

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertili-ty	Physical soil fertility	Other aspects
x	x	x	x	x	1)

1): Better deterioration of post-harvest residues

Reference:

http://www.staltech.biz
http://www.vogel-noot.info (Cultivators – The perfect machine for every task)
Hunger, R. (2014): Grubber oder Pflug für die Grundbodenbearbeitung. Schweizer Landtechnik, 3: p. 24-25.
AMAZONEN Werke (2009): Intelligenter Pflanzenbau. p.143
Südzucker AG (2012): Innovative Bodenbearbeitung. Pflug – Locker – Mulch – Direktsaat.

C.4 Disc harrows with 2 rollers for small farms and fields

Related to MP: MP17 Non-inversion tillage/reduced tillage + MP18 Non-inversion tillage/minimum tillage

Related to FTZ: ENZ6_SL2_TXT3 - Arable / cereal

Key points

- passive tillage tool,
- cutting and mixing crop residues with the top layer of soil,
- reduced tillage

What is it?

- 18 pcs of discs with a diameter of 510 mm, installed in two sections (see Figure 34) the first including 9 tooth discs and the second including 9 full discs) in V system on a frame with a three-point linkage;
- each machine is equipped with handles which allow to couple it with a light string roller of 0.28 m, or heavy tubular roller of 0.50 m (see Figure 34);
- disc inclination angle adjustment depending on the variable conditions and the type of soils.
- working width 2.0 m (smaller specification possible)


Figure 34: Disc harrow with 2 rollers; tubular roller (http://www.bomet.pl)

How does it work / is it applied?

- The disc harrow is implemented for pre-seed tillage of heavy soil ploughed before winter season (beside stony fields) when the humidity ensures the proper working conditions.
- The disc harrow loosens the soil, cuts and mixes post-harvest residues with the moved soil.
- The rear string or tubular roller by crushing the soil enhances water permeating and growth of weeds, which were left on the field after combine harvesting.
- By pressing the soil, it also accelerates the deterioration of post-harvest residues. At the same time, the roller maintains a steady maximum working depth of the disc harrows by shifting its whole weight to the roller.
- The springs placed in the rear part of the machine's frame press the roller to the soil with an appropriate force.

- The disc angle adjustment in the range from 7° to 22° (Figure 34) allows to obtain an appropriate working quality, depending on the variable humidity conditions and type of soils.
- Due to the rigid mounting of discs to the frame, the unit should not be used on the strongly stoned soils due to the possible damages.
- The disc harrow can be used for the cutting and covering of manure and green manure (small and middle size) after its spreading.
- It is possible to apply the machine to mix fertilizers and lime with soil.

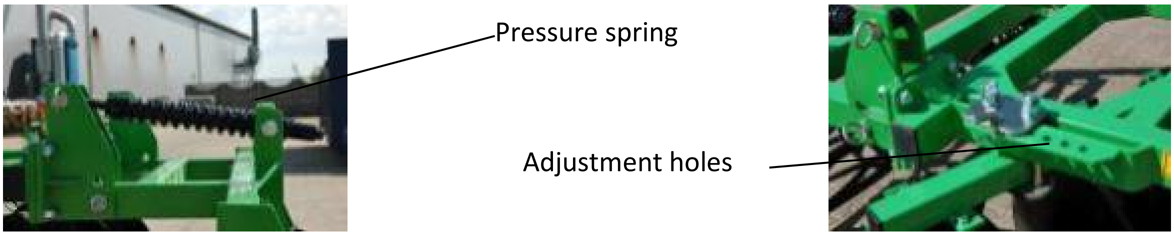


Figure 35: Adjustment of soil packer and disc inclination angle adjustments (http://www.bomet.pl)

Advantages and application of the innovation

- Stubble requires a flat soil tillage which guarantees optimal conditions left for the weeds and seeds' germination after the combine passage.
- Disc harrow perfectly mixes the upper layer of the soil with post-harvest residues.
- It is useful not only for stubble cultivation but also for soil cultivation under the seeding.
- The final roller leaves behind a soil strengthened on the surface, which determines water uptake and active air-flow in the soil, which in turn accelerates the deterioration of post-harvest residues.
- Disc harrows can cooperate with a tractor with the power of min. 40 kW (55 KM), which makes it useful in smaller farms.
- The cost of use a compact disk harrow is lower than different machines.

Table 7: Comparison of cultivator and disc harrow (+++=optimum; ++=very suitable; +=suitable)

	Cultivator	Disc harrow
Precision of working depth	++	+++
Incorporation of straw	+	+++
Aptitude of shallow cultivation (5 cm)	+	+++
Application	+++	++
Penetration capacity	+++	+++
Deep cultivation (15 cm)	+++	++
Price	+++	+

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
x	x	x	x	x	1)

1): better distribution of crop residues

Reference:
http://www.bomet.pl
Anken, T. (n.y.): Stoppelbearbeitung – Eigenschaften unterschiedlicher Stoppelbearbeitungssysteme. Agroscope, Eidgenössische Forschungsanstalt für Agrarwirtschaft und Landtechnik (http://www.fat.ch)

C.5 Strip till / Strip tillage

Related to MP: MP17 Non-inversion tillage/reduced tillage + MP18 Non-inversion tillage/minimum tillage

Related to FTZ: ENZ4_SL1_TXT1 - Arable and mixed farms
ENZ6_SL2+3_TXT3 - Arable farms

Key points

- Soil protection (erosion)
- improved water use and economic efficiency

What is it?

- Partial processing of the soil: Only a partial area of the entire surface is cultivated in strips – the space for further planting/seeding - whereas up to 80% of soil surface remain untreated.
- In Europa relative new technology of conservation soil tillage
- Combination of advantages from conventional soil tillage (yield security) and from direct seed (erosion protection)

Figure 36: Strip till after cereals (a), Strip till and white cabbage (b) (www.strip-till.de/verfahren. html), specific device for strip till (www.amazone.de)

How does it work / is it applied?

To generate a seedbed free from crop residues, the following tasks will be solved by special working tools: opening the row (cutting disk) - furrow cleaning – soil loosening – earthing up - re-compacting soil. Is an ideal technology for row cultures (maize, sugar beets, sun flowers, etc.). Depending on soil type, differences in the interaction between soil cultivation an crop rotation should be considered (Figure 37).

Preconditions:

- Setting the strips: Track discipline is advantageous; the use of Controlled Traffic Farming (FS: Controlled Traffic Farming) is beneficial for the future; if possible, only drive between the strips
- Before sowing: strips must be dried; examine vegetation containing weeds and grasses; if necessary, pesticides can be until the seeds germinate
- High power requirement to the tractor

Soil:

- In soil with > 10 % clay content, strip tilling should be used in autuum in order to utilize frost action.

- For all other soil types, strip tilling is possible in spring.

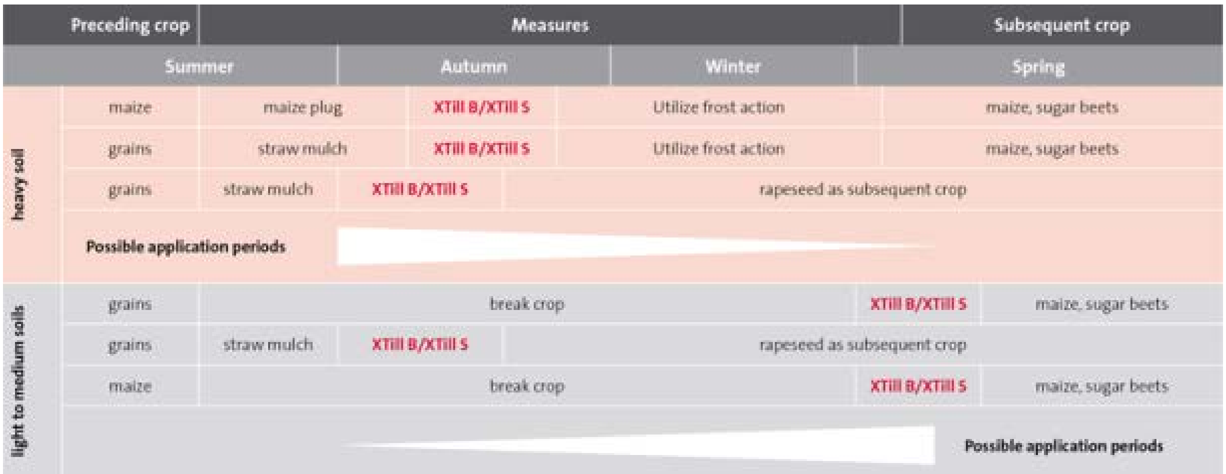


Figure 37: Soil cultivation and crop rotation (XTill B = strip till without and XTill S = strip till with slurry incorporation) (http://www.vogelsang.info/xtill/en/bodenbearbeitung.php)

Modifications:

- Strip till drill: combined strip till + direct drilling (FS: Strip till drill)
- Strip drill + root-level liquid manure fertilization (FS: Strip till drill)
- Vertical tillage: soil loosening in strips without horizontal moving of soil (FS: Vertical tillage)
- Smart till: whole surface soil loosening without horizontal moving of soil (FS: Smart till)

Advantages and application of the innovation

- Protection of soil against erosion and drying by the dead plant material (mulch) of the pre-crop, remaining on the soil surface
- Higher soil water content, better capillary water supply from subsoil and better water infiltration of precipitation water in the untreated part of soil -> essential before the background of climate change.
- Prevent track damage and harmful compactions especially in wet harvest conditions.
- Catch crops that freeze over the winter, such as mustard and oilseed radish, are suitable.
- Overwintering catch crops, such as winter seed types and grasses, can also be implemented and then used as whole-plant silage.
- Economic benefits (costs, fuel consumption)

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
x	x	x		x	

Reference:
http://www.gkb-ev.de/
http://www.strip-till.de/
http://www.gkb-ev.de/publikationen/2014-vortr%E4ge/2014-Hohenheim/kotthoff-Christiane-Neuester%20Stand%20der%20D%FCngetechnik1.pdf
http://www.smart-till.com/

C.6 Strip tillage

Related to MP: MP17 Non-inversion tillage/reduced tillage + MP18 Non-inversion tillage/minimum tillage

Related to FTZ: ENZ7_SL1_TXT1 - Dairy farming / permanent grassland
ENZ7_SL1_TXT2 - Mixed farms (pigs and horticulture)
ENZ7_SL2_TXT3 - Arable / specialized crops

Key points

- Non-inversion tillage
- Soil cover
- Reduced erosion risk

What is it?

- A less than full-width tillage of varying intensity that is conducted parallel to the crop row direction. Generally no more than 30% of the soil surface is disturbed by this practice, leaving most of the previous crop's residue intact.

How does it work / is it applied?

- The goal is to create a seedbed condition in the row that is equivalent to that achieved by full-width tillage systems, without disturbing the remaining soil;
- The seed is being drilled into the strips afterwards. This can be achieved with a single pass or in two passes. During the strip tillage, row fertilization can also be applied;
- Current strip tillage equipment is based on a tine and disc combination that ensures soil disturbance is limited to a narrow strip thus retaining surface crop residue between rows. A number of tine designs are available for strip tillage allowing for greater or lesser soil disturbance depending on the required effect and in relation to soil condition;
- Strip tillage creates narrow tilled strips which are typically 10–20 cm wide;
- Traditionally, strip tillage is conducted in the fall. Fall strip tillage dries and warms the soil ahead of spring planting, preparing a more uniform seedbed and improving seed-to-soil contact. Especially on heavy clay soils, fall tillage is recommended.
- Strip tillage in the fall has its limitations also as soils are sometimes too wet (e.g., after the harvest of sugar beet or grain maize late in the season). If soils are wet under the heavy residue, tillage tools used to prepare a strip for seed placement can lead to soil compaction. Consequently in those conditions, strip tillage is recommended in spring.
- Strip tillage can be used for many crops including wheat, maize, sugar beet, etc.

Advantages and application of the innovation

- Strip tillage is accomplished in a shorter time and with fewer energy inputs than full-width tillage;

- Removing crop residue from within row allows for early spring soil evaporation and warmer soil temperatures;
- The relatively large amount of crop residues which remains on the inter-row soil surface absorbs raindrop energy and enhances infiltration by maintaining worm channels and other macro pores at the surface. Consequently runoff and soil erosion are reduced;
- Strip tillage practitioners may have to invest in very accurate GPS systems to ensure that planted rows are placed on the previously strip tilled soil.

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
X	X	X		X	1)

1) Reduces soil erosion

Reference:

Wolowski, R., Cox, T., Leverich, J. 2009. Strip-tillage: A conservation option for Wisconsin Farmers. University of Wisconsin, Wisconsin, US. 6p.
Roisin, C., Olivier, C., Vandergeten, J.P., 2013. Strip-Till-techniek en haar implicaties voor de suikerbiet. De Bietplanter, 6, pp 6-7.
Proefresultaten suikerbieten en cichorei 2012-2013. Vzw PIBO Campus, Tongeren, Belgium. 101p.
Al-Kaisi, M. and Hanna, H. M., 2008. Resource Conservation Practices: Consider the Strip-Tilling Alternative. Agriculture and Environment Extension Publications. Book 159.

C.7 Strip till

Related to MP: MP17 Non-inversion tillage/reduced tillage + MP18 Non-inversion tillage/minimum tillage

Related to FTZ: ENZ7_SL2_TXT2 - Arable farms
ENZ12_SL3_TXT4 - Arable farms
ENZ7_SL2_TXT3 - Dairy cattle

Key points

- Precision farming
- The idea came from farmers who wanted to use simplified cultivation techniques but faced wet and cold soils. No tillage leads to compaction and hydromorphy, and the soils occurred to warm slower because of residues at the surface.

What is it?

- It is a partial processing of the soil: only strips are processed before seeding, usually at smaller depth than traditional plowing. The reminder of the field remains undisturbed.
- The technique is particularly appropriate for row cultures like corn, sunflower, sugar beets.

Figure 38: Fully adjustable strip tillage unit (http://www.slyfrance.com)

How does it work / is it applied?

- The basic idea is to help the soil warm quicker in the seeding row. Thus, the strip till machinery is often used two weeks before seeding.
- A specific machinery is needed: a disk opens the row, flushing debris pieces are used to clean the seed line and facilitate soil warming
- A narrow plow opens the row, coater discs and a reconsolidation wheel completes the dispositive

- It is not recommended to strip till and seed at the same time, for several reasons: 1) strips have to warm and dry before seeding; 2) speed of machineries are not compatible (between 8 and 12km/h for strip-till, and around 6km/h for most monograin seeders). Some constructors (Duro for instance) however advice to seed simultaneously.
- Can be combined with a local fertilizer spreader (to decrease the total amount of fertilizers because of precise spread over the row).

Figure 39: Strip till technique (www.duro-france.com/produits_agricoles.php?id=14)

Advantages and application of the innovation

- Pros : the technique is well adapted to plants that need large inter-rows (corn, sorghum, sunflower), preserves the advantages of direct seeding (less erosion, no crush) and avoid drawbacks (wetter and colder soils in spring); the row warms quicker.
- Cons: difficult technique that requests to intervene at the right moment (when the soil is dry enough, difficult to apply for clay soils), which is not always compatible with work agendas.
- New generation of machines
- Product on the market but yearly improvements from machine industry

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
x	x	x		x	1)

1): enables better soil warming in spring when correctly applied

Reference:
http://www.terre-net.fr/materiel-agricole/travail-sol-semis/article/plus-de-simplicite-d-utilisation-pour-l-outil-de-strip-till-de-sly-210-96392.html
http://www.terre-net.fr/strip-till/t426
http://www.slyfrance.com/produits/strip-till/semis-direct/

C.8 Strip till drill

Related to MP: MP17 Non inversion tillage/reduced tillage + MP18 Non inversion tillage/minimum tillage

Related to FTZ: ENZ4_SL1_TXT1 - Arable and mixed farms
ENZ6_SL1_TXT1 – Arable / cereals / mixed farms
ENZ6_SL2+3_TXT3 - Arable farms

Key points

- Combination of strip till and direct drilling (and underfoot fertilizer placement)
- Reduction of time demand
- Reduction of energy input
- Reduction of weed germination

What is it?

- Strip till drill is a one- or two-pass technique that creates a seed bed only where it is needed rather than across the entire field (either one-pass targeted seed-bed preparation and sowing or cultivation and slurry application ahead of a separate sowing operation).
- Direct drilling Into the stripe seed bed
- Fertilizer (also slurry or bioenergy digestate) can be placed underfoot

Figure 40: Strip till drills (http://www.fwi.co.uk/articles/19/06/2013/139561/cereals-2013-growing-options-for-strip-till-drills.htm)

How does it work / is it applied?

- The seed has drainage and roots have the channel to grow into unhindered by compaction to quickly find moisture and nutrients in the unmoved soil.
- To use on light soils and with special mechanisms also heavier soils and stone-laden soils.
- It is primarily applied for cereals or oilseed rape, sugar beet and maize.

Advantages and application of the innovation

- Soil structure will be improved by eliminating unnecessary cultivation.
- Reduction in soil movement can make significant savings in energy input
- The technique promotes fertilizer placement and targeted use of slurry and bioenergy digestate for arable crops.
- Earlier drilling dates and the efficiency of the systems gives a huge time window to establish the crops in the best conditions, using minimal tractors and machinery
- Reduced moisture loss and risk of wind erosion on light soils in a dry year, as well as environmental advantages of over-wintered stubbles

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
x		x	x	x	1)

1) Economical aspects

Reference:
http://www.fwi.co.uk/articles/19/06/2013/139561/cereals-2013-growing-options-for-strip-till-drills.htm
http://dlz.agrarheute.com/weniger-aufwand-wurzel
http://www.claydondrills.com/system

C.9 Bio strip till

Related to MP: MP17 Non-inversion tillage/reduced tillage + MP18 Non-inversion tillage/minimum tillage

Related to FTZ: ENZ4_SL1_TXT1 - Arable and mixed farms
ENZ6_SL2+3_TXT3 - Arable farms

Key points

- Improved areation, heating and structure of soil
- Concentration of low C/N material for rapid decomposition of straw

What is it?

- Combination of strip till and growing of special cover crops for improving soil structure

Figure 41: Bio strip till in cereals with pea and radish (www.ag .ndsu.edu/carringtonrec/cover-crops-forum/Bio Strip Till K. Cooper.pdf/at_ download/file)

Figure 42: Strip till in a catch crop canopy in fall (www.lksh.de /fileadmin/dokumente/Bauernb latt/PDF_Toepper_2014/BB_24_ 14.06/39-41_Tauchnitz_Bisch off.pdf)

How does it work / is it applied?

Bio strip till is a technology that combines catch crops and strip till. The main crop will be sown via strip till in a cover crop canopy. The selected catch crops are characterized by their positive effects regarding protection against erosion, weed supression, decomposition of old residues, etc.


Annual Ryegrass


Austrian Winter Peas


Barley


Cereal Rye


Crimson Clover


Oats


Oilseed Radish


Rape


Red Clover


Vetch

For light soils in Saxony-Anhalt, Germany, cover crops that have deep taproots and freeze in winter are preferred: Lupinus angustifolius, Pisum arvense, Ornithopus sativus, Avena strigosa, Fagopyrum esculentum, Phacelia tanacetifolia.

Advantages and application of the innovation

- Effective against erosion
- Improving soil health
- Preservation of nutrients
- Supression of weeds
- Improved areation, heating and structure of soil
- Open up channels for fast root proliferation
- Provide organic matter for symbiotic organisms to become established on increase population
- Separation of legumes and fertilizer
- Concentration of low C/N material for rapid decomposition of straw

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertili-ty	Physical soil fertility	Other aspects
x		x		x	

Reference:
http://www.ag.ndsu.edu/carringtonrec/cover-crops-forum/Bio_Strip_Till_K._Cooper.pdf/at_download/file
http://www.lksh.de/fileadmin/dokumente/Bauernblatt/PDF_Toepper_2014/BB_24_14.06/39-41_Tauchnitz_Bischoff.pdf
http://notillfarm.org/
http://www.advancecovercrops.com/bio-till-cover-crop-lineup/

C.10 Vertical tillage

Related to MP: MP17 Non inversion tillage/reduced tillage + MP18 Non inversion tillage/minimum tillage

Related to FTZ: ENZ4_SL1_TXT1 - Arable and mixed farms
ENZ6_SL1_TXT1 – Arable / cereals / mixed farms
ENZ6_SL2+3_TXT3 - Arable farms

Key points

- Tillage without horizontal moving of soil
- Soil loosening, residue management, consolidation, seedbed creation

What is it?

Application of soil cultivation tools to soil loosening in strips without horizontal moving of soil.

Soil loosening

Flat liner to shatter deeply embedded compaction layers (up to 550 mm down). Working width: 3.0 – 4.5 m.

In-line-subsoiler to eliminate compaction layers and soil density changes in one pass. Working width: 3.0 – 7.6 m.

Residue management, consolidation, seedbed creation

Combination to leave an excellent level finish; residue mixing and soil loosening down up to 300 mm. Working width: 2.8 – 8.0 m.

Unit for chopping, mixing and leveling. Working depth: up to 300 mm. Working width: 2.7 – 8.8 m.

Combination to create highest quality seed-beds. Working width: 4 – 6.7 m.

Unit with adjustable gang angle for ground leveling, weed removal and residue sizing. Working width: 3.7 – 12.2 m.

One-pass cultivator – restructures the soil and takes out compaction down to 250 mm. Working width: 2.5 – 4.0 m.

Figure 43: Examples of different vertical tillage equipment (http://www.greatplainsag.com/)

How does it work / is it applied?

Vertical tillage has been created for more than a decade. Implements in this category enter the soil vertically to clear a straight open path for roots to grow and create rows of even crop stands. It is applied to remove compaction layers, to maintain soil density and to manage residues.

1. Open up the soil profile to allow water to be absorbed instead of running off.
2. Size residue into planter-manageable pieces.
3. Not add horizontal layers.
4. Get the residue in contact with the soil for faster decomposition.
5. Lace and anchor residue to the ground.
6. Work soil to a consistent depth across the entire width of the tool.

Additionally, vertical tillage is performed to create the seedbed – with smooth, level surface on top and at seeding depth to ensure even emergence:

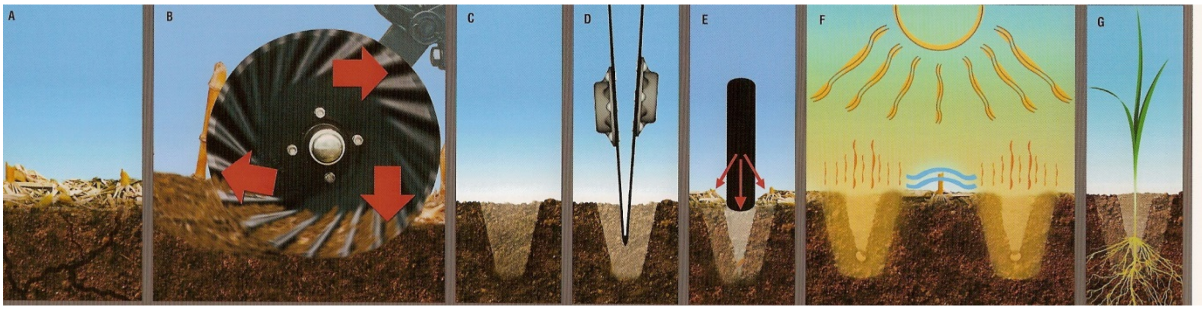


Figure 44: Principle of seedbed creation by vertical tillage equipment (http://ackerpower.com/)

Advantages and application of the innovation

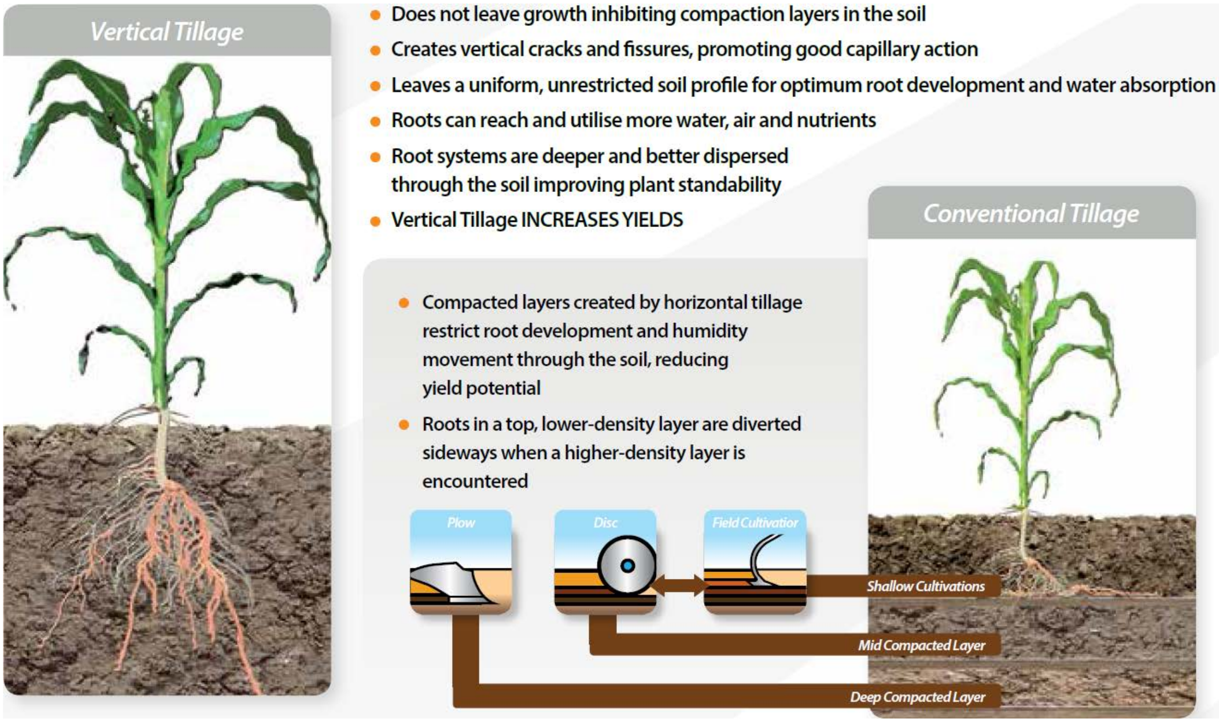


Figure 45: Advantages vertical tillage (http://www.greatplainsag.com/)

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertili-ty	Physical soil fertility	Other aspects
x		x	x	x	1)

1) Economical aspects

Reference:
http://www.greatplainsag.com/
http://ackerpower.com/
http://www.verticaltillage.com/

C.11 Smart till

Related to MP: MP17 Non inversion tillage/reduced tillage + MP18 Non inversion tillage/minimum tillage

Related to FTZ: ENZ4_SL1_TXT1 - Arable and mixed farms
ENZ6_SL1_TXT1 – Arable / cereals / mixed farms
ENZ6_SL2+3_TXT3 - Arable farms

Key points

- Whole surface soil loosening without horizontal moving of soil
- Soil loosening, residue management, reduces soil compaction, seedbed preparation
- Improves pasture/hay, soil and manure management

What is it?

Smart till is a vertical tillage tool to loosening whole surface without horizontal moving of soil. The machinery is characterized by a self-sharpening three-tine helical design; optional combination with rotary harrows.

How does it work / is it applied?

The special design of the tines (adjustable from 0 to 10 degrees depending on application) allows to fracture soil with little surface disturbance (Figure 46 , Figure 47 left). The tine shaft speed helps produce low torque and create a ”ripping” effect that breaks through soil to allow more rapid air and water exchange. The rotary harrows work on the whole soil surface (Figure 47 right).The operation depth is about 20 cm; the recommended operating speed is 13-16 km/h.

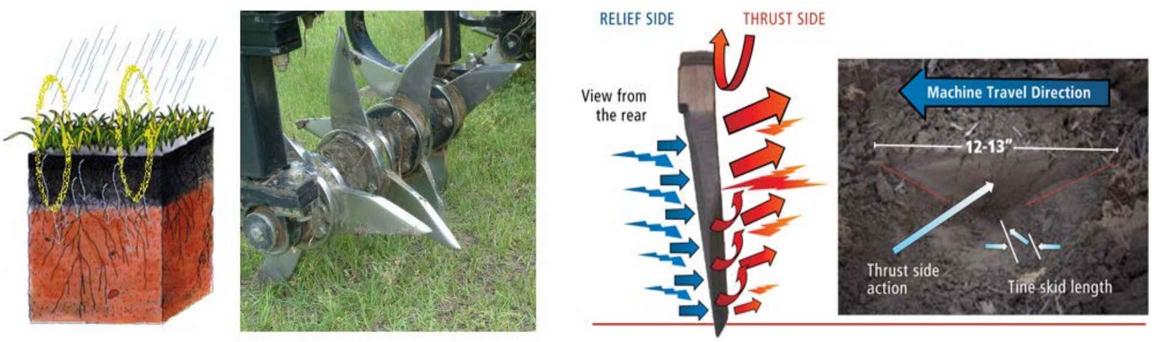


Figure 46: Operation principle of smart till (http://www.tristarfarms.com/smart-till.php)

Figure 47: Soil surface after smart till (left) and after additional rotary harrow (http://www.smart-till.com)

Following rotary harrow types were combined with smart till machinery (Figure 48):

Figure 48: Types of rotary harrows combined with smart till machinery (www.smart-till.com)

Advantages and application of the innovation

- Break up compaction with minimal surface disturbance
- Improve air and water exchange
- Manage residue
- Rapid incorporation of manure into soil
- Decrease risk of runoff

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertili-ty	Physical soil fertility	Other aspects
		x	x	x	1)

1) Economical aspects

Reference:
http://www.smart-till.com
http://www.tristarfarms.com/smart-till.php

C.12 Deep non-inversion tillage

Related to MP: MP17 Non-inversion tillage/reduced tillage + MP18 Non-inversion tillage/minimum tillage

Related to FTZ: ENZ7_SL1_TXT1 - Dairy farming / permanent grassland
ENZ7_SL1_TXT2 - Mixed farms (pigs and horticulture)
ENZ7_SL2_TXT3 - Arable / specialized crops

Key points

- Non-inversion tillage
- Reduced soil erosion

What is it?

- Non-inversion tillage at the same depth or deeper than ploughing depth

How does it work / is it applied?

- In Flanders a majority of the crops is harvested late in the season in often bad conditions (e.g., grain and silage maize, sugar beet, horticultural crops). As mostly heavy machinery is used, this results in considerable soil compaction in the arable layer;
- In general, non-inversion tillage is applied at a reduced depth compared to ploughing (i.e., 10-15 cm). This tillage depth will not suffice to remediate soil compaction in deeper soil layers. Therefore, a deep non-inversion tillage is required;
- Specific equipment is available for applying deep non-inversion tillage (e.g., chisel plow, see FS Use of specific machinery that allow non-inversion);
- When applying deep non-inversion tillage, a knife tine should be used instead of a winged tine in order to prevent soil smearing. Further, it is important that the equipment preserves the stratification of the arable layer (0-30cm);
- The tines lift and fracture the soil removing compaction in the top 0-30 cm soil layer. The cultivation can either be conducted in the autumn or spring depending on soil conditions and whether or not a cover crop is sown. In case of soil compaction by harvesting machinery, immediate remediation by deep non-inversion tillage is preferable.

Advantages and application of the innovation

- Improvements of soil physical properties;
- Remediating soil compaction;
- Higher ability of plant roots to grow and explore the soil for water and nutrients;
- Improved porosity of the entire arable layer (0-30cm) and consequently better infiltration and movement of air and water in the soil;
- Reduced soil erosion.

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
	x	x		x	1)

1) Reduced soil erosion

Reference:

Reubens, B., Ruysschaert, G., D'Hose, T., D'Haene, K. 2012. Eindrapport bodembreed Interreg: overzicht van resultaten, inzichten en aanbevelingen. Instituut voor Landbouw- en Visserijonderzoek (ILVO), Merelbeke, België. 147 p.

C.13 Non-inversion spring tillage technique to incorporate grass sod before maize sowing

Related to MP: MP17 Non-inversion tillage/reduced tillage + MP18 Non-inversion tillage/minimum tillage

Related to FTZ: ENZ4+7_SL1_TXT1 - Dairy cattle / permanent grass

Key points

- Improves soil fauna
- Soil protection (water, nutrients, erosion)
- Improves soil quality
- Increases soil organic matter content in top soil

What is it?

- No inverting soil tillage is needed to destroy the grass sod

How does it work / is it applied?

- If necessary, treat grass sod with cultivator in autumn (see FS Stubble cultivator for shallow residues and seedbed management)
- Before sowing one field operation with:
  fixed tine cultivator + harrow + incorporating disks
- Grass sod is often not completely destroyed but reduced
- An additional weed control after sowing maize might be necessary with 450 g glyphosate per liter

Figure 49 The incorporation of a grass-clover sod with a hooks cutter (www.wageningenur.nl)

Advantages and application of the innovation

- No soil inverting tillage is necessary,
- Less labor needed by faster working compared to ploughing,
- Keeps organic matter in top soil,
- Improves soil structure,
- Less fuel use compared to ploughing,
- Positive effect on organic matter balance due to reduced decomposition compared to ploughing,
- Yields might be reduced in first years of NIT (up to 25%), then comparable yields

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertili-ty	Physical soil fertility	Other aspects
	X	X		X	

Reference:
http://www.maisteeltinstroken.nl/sites/default/files/nieuws_bijlagen/samenvatting_proef_zand_mais_2012.pdf
http://www.vilt.be/application/public/upload/38/default/38331.pdf
http://www.wageningenur.nl/upload_mm/9/d/e/fdcfad65-920f-48c3-9a5e-335a882f6705_Flyer%20rapportage%20Bodemkwaliteit%20op%20zandgrond%202012.pdf

C.14 Non-inversion spring tillage technique to incorporate green manures after maize

Related to MP: MP17 Non-inversion tillage/reduced tillage + MP18 Non-inversion tillage/minimum tillage

Related to FTZ: ENZ4+7_SL1_TXT1 - Dairy cattle / permanent grass

Key points

- Improves soil fauna
- Soil protection (water, nutrients, erosion)
- Improves soil quality
- Increases soil organic matter content in top soil

What is it?

- No inverting soil tillage is needed to destroy the green manure after maize (green manure is mandatory in NL)

How does it work / is it applied?

- The mandatory green manure crop is destroyed by harrowing in early spring before it regenerates, and maize is sown into the unploughed soil,
- Green manure is mulched in late winter to facilitate decomposition,
- Disking, harrowing (see FS Compact disc harrow for residues management) or milling green manure just before spring growth is initiated,
- Green manure is damaged and harmed but not completely destroyed,
- Before planting, milling might be necessary for seed bed preparation,
- Sometimes an additional appropriate herbicide application is necessary.

Figure 50: A disc harrow cultivation (Lemken Rubin) in early spring destroys the green manure before regrowth has started (left, www.loonbedrijfgeelen.nl/pages/Schijveneg); the mechanically supported harrow Lemken Zirkon 8 loosens the grass-clover sod up till 5 cm deep and crumbles the sod effectively (middle, www.mechaman.nl/landbouwmechanisatie/2013/04/18/demonstratie-nkg-rotorkopeg-krijgt-grasklaver-er-onder); the Fusion Tillage Machine was developed to prepare a seedbed without ploughing after a green manure (right, www.agrifoto.nl)

Advantages and application of the innovation

- No soil turning treatment needed,
- Improves organic matter content in top soil,
- Improves soil structure,
- Less fuel use compared to ploughing,
- Positive effect on organic matter balance due to reduced decomposition compared to ploughing,
- Less labor needed by faster working,
- In first years of NIT reduced yields (up to 25%); gradually yields will recover in subsequent years.

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertili-ty	Physical soil fertility	Other aspects
	X	X		X	

Reference:
http://edepot.wur.nl/288706
http://www.louisbolk.org/downloads/2124.pdf

C.15 Non-inversion tillage to reduce volunteer potatoes on clay soils

Related to MP: MP17 Non-inversion tillage/reduced tillage + MP18 Non-inversion tillage/minimum tillage

Related to FTZ: ENZ4+7_SL1_TXT1 - Dairy cattle / permanent grass

Key points

- Reduces the need for pesticides (herbicides, fungicides)
- Better nematode control
- Volunteer potatoes freeze in winter as they remain in the top soil if the soil is not ploughed

What is it?

- In preparing the land before winter, a fixed tine cultivator (see FS Stubble cultivator for shallow residues and seedbed management) up to the depth of the plough layer is used instead of ploughing. This facilitates the freezing (in most winters) of volunteer potatoes that are left in the top soil after harvest

How does it work / is it applied?

- No soil inversion tillage is done after harvest of potatoes in the fall on clay soils,
- Soil preparation in the fall is done with a fixed tine cultivator to the depth of the plough layer (25 cm mostly) for the following crop,
- Soil preparation should result in a coarse structured top layer to facilitate freezing,
- Practiced before a sugar beet crop which is sown in the following spring,
- Seed bed preparation sugar beets in spring: standard practice

Figure 51: Due to non-inversion tillage volunteer potatoes freeze to death in most winters (left) where ploughing allows them to growth in the next season (right): example of sugar beets

Advantages and application of the innovation

- Reduced herbicide use for volunteer potato control,
- Less fuel use compared to ploughing,

- Reduced disease pressure due to adequate control of volunteer potatoes and thus reduced fungicide use in future potato crops or in potato crops on adjacent fields (Phytophthora),
- Better nematode control as no potato host plants are present,
- No virus infections from volunteer potatoes to potato crops on adjacent fields,
- Better control of potato specific diseases like Phoma exigua foveata and Rhizoctonia solani, of which soil infection contributes to the severity of the infection,
- No negative effects on sugar beet yield and quality

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertili-ty	Physical soil fertility	Other aspects
X	X	X		X	

Reference:
http://www.kennisakker.nl/kenniscentrum/handleidingen/teelthandleiding-consumptieaardappelen-ziekten-en-plagen
http://www.irs.nl/userfiles/ccmsupload/ccmsalg/Effect%20van%20niet%20kerende%20hoofdgrondbewerking.pdf

C.16 Tramlines

Related to MP: MP24 Controlled traffic farming

Related to FTZ: ENZ4_SL1_TXT1 - Arable and mixed farms

Key points

- Precision farming

What is it?

- Tramline is improved by adding electronic control and communication between the tractor and the associated sets of tools during soil management operations
- Controlled traffic farming is a farming system built on permanent wheel tracks where the crop zone and traffic lanes are permanently separated.

How does it work / is it applied?

Precondition:

- RTK GPS guidance is an essential technology for controlled traffic
- Identical width of tramlines and operations

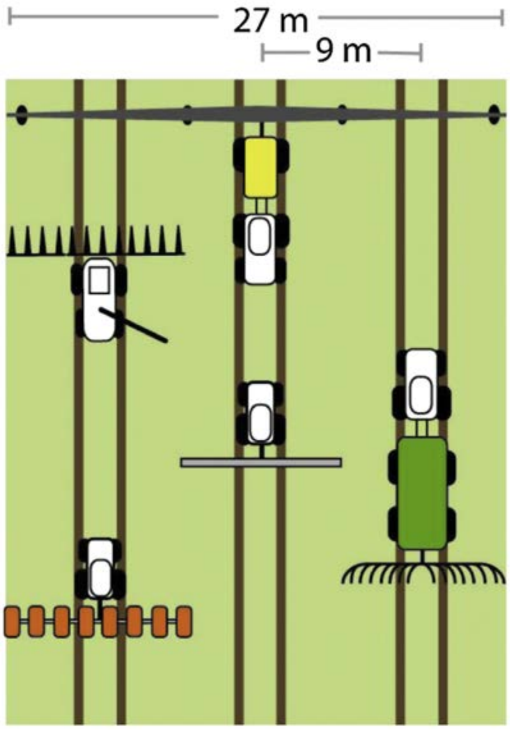


Figure 52: Tramlines established at a distance of 9 m and the machinery system that consists of machines operating in 9 m and 27 m (sprayer) (source: Bochtis et al. 2010)

Tramlines

- free of vegetation
- ~15 % of tracked area with machines with large track width and small tires) or above 30 % of tracked area with common tracks and tires
- ISOBUS (standardized communication protocol and one terminal) application for tramlines to simplify machine communication, to minimizes installation and interface problem for different machines and to document

Figure 53: ISOBUS Terminal to implement machines from different manufactures and to exchange data between PC and terminal (http://www.teejet .de/german/home/products/application-control-and-equipment/isobus-and-iso-11783-solutions/about-isobus.aspx)

Advantages and application of the innovation

- reduces manoeuver
- untracked areas of 58 to 67 %
- increases precision of seeding
- Improve soil structure – reduce overall compaction
- Increase of water infiltration and water availability
- Increase soil water storage Increase moisture use efficiencies
- Improve the productivity – no overlap and no untreated areas (sowing, fertilization, plant protection, harvest, tillage)
- Improve nutrient use efficiencies
- Reduce fuel consumption
- Improve trafficability of equipment
- New generation of machines
- Product on the market but yearly improvements from machine industry

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertili-ty	Physical soil fertility	Other aspects
x				x	

Reference:
http://www.terre-net.fr/materiel-agricole/travail-sol-semis/article/manoeuvrer-en-bout-de-champ-pour-le-jalonnage-un-mauvais-souvenir-210-100515.html
http://www.terre-net.fr/isobus/t290
http://www.ukagriculture.com/crops/tramlines.cfm
https://www.agric.wa.gov.au/grains-research-development/developing-controlled-traffic-tramline-farming-system
http://archive.agric.wa.gov.au/objtwr/imported_assets/content/lwe/land/cult/bulletin4607_part1.pdf
http://www.academia.edu/633235/Tramline_establishment_in_controlled_traffic_farming_based_on_operational_machinery_cost
http://www.controlledtrafficfarming.com/Home/Default.aspx
http://www.controlledtrafficfarming.org/index.php/about-ctf-alberta
Bochtis D.D., Sørensen C.G., Busato P., Hameed I.A., Rodias E., Green O., Papadakis G. (2010) Tramline establishment in controlled traffic farming based on operational machinery cost. Biosystems Engineering 107:221-231. DOI: http://dx.doi.org/10.1016/j.biosystemseng.2010.08.004.

C.17 The use of DGPS-RTK to drive over the field

Related to MP: MP24 Controlled traffic farming

Related to FTZ: ENZ4+7_SL1_TXT1 - Dairy cattle / permanent grass

Key points

- The DGPS-RTK system allows a tractor to always drive over the same lane/track at a precision of 1 cm
- Less soil compaction
- Improves yields
- Cultivation practices not depending on weather conditions any more

What is it?

- Tractors are equipped with a differential global positioning system (DGPS) and a real time kinematic (RTK) which allows them to drive on specified positions with an accuracy of 1 cm.

How does it work / is it applied?

- A receiver uses satellite data in combination with an identified location at the ground to improve estimates on the current position from several meters to approximately a 1 cm.
- This allows tractors or equipment on which the receiver is placed, to follow previously identified tracks in the field with great accuracy.
- This technique facilitates planting of crops in exact rows which then facilitates additional activities like mechanical weeding, spraying, row application of manure and harvesting.

Advantages and application of the innovation

- Field operations that require a high precision of planted crops can be carried out,
- Because soil is no longer compacted by heavy machinery, yields can increase significantly,
- Less soil on harvested root crops due to better soil structure,
- DGPS-RTK allows tractors or machines equipped with the system to drive on exactly the same track,
- DGPS-RTK allows field operations to be executed individually without damaging the crop,
- DGPS-RTK can be used to register where in the field the tractor has been to prevent overlap of fertilizer or pesticide applications,
- In general, it provides a good basis for precision farming operations such as:
  improved mechanical weeding,
  improved ridging of potatoes which reduces green potatoes,
  injection of slurry in rows close by planting rows shortly before planting to improve nutrient use efficiency (practiced in maize, potato, onion) (see FS DGPS-RTK to apply slurry in rows in maize),
  to monitor for instance energy consumption,

when combined with satellite imaging used to support decisions on pesticide use or nutrient use can be made in detail (very site/plot specific).

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertili-ty	Physical soil fertility	Other aspects
X	X			X	1)

1) Energy use; pesticide use; nutrient use

Reference:
http://library.wur.nl/way/bestanden/clc/1871703.pdf
http://www.kennisakker.nl/files/Kennisdocument/lm05_10_dlv_rendement.pdf
http://www.controlledtrafficfarming.com/Home/Default.aspx

C.18 Low tire pressure in controlled traffic systems

Related to MP: MP24 Controlled traffic farming

Related to FTZ: ENZ4+7_SL1_TXT1 - Dairy cattle / permanent grass

Key points

- Number of operational field days increases
- Reduced fuel use
- Improvement of soil quality
- Improvement of yield

What is it?

- When a wheel based vehicle enters the field the tire pressure is adjusted to the weight on the tire and to the specific field operation at hand

How does it work / is it applied?

- Tire pressure is balanced between minimal soil compaction and minimal wastage,
- Tire pressure is adjusted to actual weight on the tire by weighing and recommendations from the manufacturer belonging to the mounted tires,
- Optimization of tire pressure can increase tire surface up to 40% due to pressure reduction which reduces the rolling resistance significantly and thus saves fuel,
- An adapter is used to adjust the tire pressure to accommodate the operational task,
- The maximal pressure on soil should be 1 kg/cm² or 1 bar,
- An online database is developed that selects the appropriate tires for different uses.

Advantages and application of the innovation

- Increased number of operational field days,
- Reduced soil compaction,
- low tire pressure makes Controlled traffic (driving on the fixed lanes) with easier notably under wet conditions, when tires tend to slip from the compacted track,
- The optimal/low tire pressure reduces fuel use by 18-25%.

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
X	X	X		X	

Reference:

http://edepot.wur.nl/274539
http://www.kennisakker.nl/actueel/kennistekst/optimale-bandenspanning-maakt-groot-verschil
http://www.kennisakker.nl/advies/bandenkeuze

C.19 Precision ploughing

Related to MP: MP24 Controlled traffic farming

Related to FTZ: ENZ4+7_SL1_TXT1 - Dairy cattle / permanent grass

Key points

- Saving energy of following cultivation practices,
- Ploughing in exact rows to attain a flat seedbed

How does it work / is it applied?

- The DGPS system corrects the ploughing to plough in exact rows (see FS DGPS-RTK to drive over the field)

Advantages and application of the innovation

- Reduced overlap in soil disturbance,
- Saves energy of following cultivation practices,
- Makes ploughing fields with trapezoids shapes easier,
- Results in homogeneously ploughed land,
- Facilitates other cultivation practices such as crumbling the soil in the spring,
- Plough ridges can be synchronized with building ridges for potato cultivation, which then requires less energy.

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
X				X	1)

1): Energy saving of following cultivation practices

Reference:
http://www.groenkennisnet.nl/Pages/GPS_-_besturing_bij_ploegen.aspx

C.20 Improved fertilizer spreading techniques by variable rate technology at field borders or spreading jobs

Related to MP: MP24 Controlled traffic farming + MP26 Mineral N application

Related to FTZ: ENZ4+7_SL1_TXT1 - Dairy cattle / permanent grass

Key points

- Reduced fertilizer use (no overlap),
- Improved fertilizer application (no unfertilized area's),
- Reduced emissions of fertilizers to the environmental.

What is it?

- Using a DGPS based description map (see FS DGPS-RTK to drive over the field) to shut down fertilizer application pipes automatically when spreading on borders instead of the field and to prevent application overlap between passages.

How does it work / is it applied?

- Most fields have trapezoids shapes so field driving lane and field boarder taper,
- towards each other and the fertilizer spreader applies fertilizers at some point on the borders instead of the field,
- Field boundaries are determined with DGPS and loaded onto the tractor database,
- A description map is made using DGPS for controlled traffic in combination with the loaded field boundaries to automatically shut down fertilizer application pipes when spreading on border instead of the field,
- Between passages spreaders usually overlap to ensure complete cover with fertilizers,
- Registration of passages by DGPS minimizes overlap by shutting down spreaders.

Advantages and application of the innovation

- Improved fertilizer use efficiency,
- Reduced emissions of fertilizers to the environment
- Exempts driver from difficult task to manually shut down fertilizer application pipes on time,
- Prevents that part of the field is fertilized twice,
- Prevents that additional/second passage is needed to apply fertilizers on the last part of the field,
- This innovation can be used in all crops for fertilizer applications when driving lane and field boarder taper.

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
	X			X	1)

1): Major advantage: reduced emissions of fertilizers to the environment

Reference:

http://precisielandbouw.groenkennisnet.nl/GEOspread.ashx

C.21 Use of finger weeder: inter and intra row weed control combined with ridging and deridging

Related to MP: MP24 Controlled traffic farming + MP41 Mechanical weeding

Related to FTZ: ENZ4+7_SL1_TXT1 - Dairy cattle / permanent grass

Key points

- Reduced herbicide use,
- Reduced emissions of herbicides to the environment,
- Technique must start in time.

What is it?

- Planting maize in exact rows to facilitate mechanical weed control with finger weeders combined with ridging,
- Using DGPS (see FS DGPS-RTK to drive over the field) to sow maize in exact rows and apply mechanical weed control of finger weeders plus ridging to keep on moving the soil to destroy weeds

Figure 54: Finger weeder (Novelties of Guido Frijns te Reijmerstok)

How does it work / is it applied?

- In the in 4 to 5 leaves stage of maize use finger weeders combined with thrilling tine hoe to apply mechanical weed control,
- Adjust finger weeders widely at this stage to prevent damage of young plants
- Working speed approximately 8 to 10 km/hr,
- If necessary, finger weeders are used second time and finger weeders are adjusted shorter to the plants and disks are mounted to ridge,
- Finger weeders are used to de-ridging in next field operation,
- This practice (finger weeders + ridging / or de-ridging) can be used until maize is about 1.5 m high if necessary

- Working speed is now 15 km/hr. Only when maize is 1.5 m or higher, working speed is reduced.

Advantages and application of the innovation

- Reduced need for herbicides,
- Reduced emissions of herbicides to the environment,
- Planting in rows is needed to prevent damage by finger weeders,
- Yield neutrality

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
X		X			1)

1): Major advantage: reduced emissions of herbicides to the environment

Reference:
http://www.bioveem.nl/nieuws/NieuwbijBioveem/Persberichten/2004122301.pdf

Category:
D. NUTRIENT MANAGEMENT

D.1 Biochar application

Related to MP: MP Organic fertilizer

Related to FTZ: ENZ7_SL1_TXT1 - Dairy farming / permanent grassland
ENZ7_SL1_TXT2 - Mixed farms (pigs and horticulture)
ENZ7_SL2_TXT3 - Arable / specialized crops

Key points

- Carbon sequestration
- Improved soil functioning

What is it?

- Biochar is the carbon-rich product obtained when organic material is pyrolyzed, which implies thermal decomposition under limited supply of oxygen at relatively low temperatures (< 700°C);
- The application of biochar to the soil has the aim of improving soil functioning and increasing carbon sequestration.

How does it work / is it applied?

- In conventional field cropping systems, biochar should ideally be managed using traditional farm machinery and incorporated into routine field operations. Broadcasting can be done on large scales by using lime/solid manure spreaders.
- To avoid water erosion incorporation is the best way; it can be achieved by a rotary harrow, a rotary spading cultivator, etc.
- Ploughing is not recommended as it is unlikely to mix the biochar into the soil and it may result in deep biochar lenses;
- In most cases, moisture will have to be applied to the biochar during spreading to avoid wind losses and health risks;
- Mild rain conditions as right weather conditions helps during application (light rain will dampen biochar dust and hold it on the soil surface until it can be tilled in)
- No general recommendations exist yet on biochar application rates according to soil types and crops; however European field trials (with emphasis on the North Sea Region) with pure biochar applications pointed out that a positive effect on crop yields could be expected from an application rate of 10 ton/ha onward. High application rates (e.g., 300 t/ha) should be avoided as negative effects on crop yields have been reported;
- Frequence of application: due to its recalcitrance to decomposition in soil, single applications of biochar can provide beneficial effects over several growing seasons in the field. Biochar does not need to be applied with each crop.
- Form of application: pelleted biochar and it can also be mixed with other organic amendments such as manures and compost.

Advantages and application of the innovation

- Carbon sequestration;
- Most biochars are not substitutes for mineral fertilizers, so adding biochar without necessary amounts of nitrogen (N) and other nutrients cannot be expected to improve crop yields in the short term;
- Beneficial effects of applying biochar on soil quality and crop yield are believed to improve with time. In temperate regions little significant effects on soil quality and crop productivity have been noticed in the short term;
- Mostly, biochar itself cannot be considered as a source of nutrients. Therefore there is a growing interest in blending it with other materials such as compost and manures to enhance its value as a soil amendment. Furthermore, biochar has been shown to retain nutrients against leaching, potentially improving the efficiency of nutrients applied alongside the biochar;
- Legal constraints applying to biochar need to be taken into account. It is unclear whether biochar will receive the status of ‘waste’, ‘byproduct’ or ‘end of waste’.

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
	X				

Reference:
Lehman, J., Joseph, S., 2009. Biochar for Environmental Management: An introduction. In: Lehman, J., Joseph, S. (Eds.), Biochar for Environmental Management. Earthscan, London, pp. 1-12.
Nelissen, V., 2013. Effects of biochar on soil processes, soil functions and crop growth. PhD thesis, Ghent University, Ghent, Belgium, 222p.
Major, J., 2010. Guidelines on Practical Aspects of Biochar Application to Field Soil in Various Soil Management Systems. International Biochar Initiative, 23p.
Ruysschaert et al., in preparation. European field applications of pure biochar with emphasis on the North Sea Region. In Shackley et al., (eds) Biochar in European Soils and Agriculture: Science and Practice

D.2 CULTAN fertilization

Related to MP: MP26 Mineral N application

Related to FTZ: ENZ4_SL1_TXT1 - Arable and mixed farms

Key points

- Ammonium deposit fertilization placed a point-like-deposits in the plant root area as injection

What is it?

- CULTAN = "Controlled Uptake Long Term Ammonium Nutrition"
- Plant N-supply from the so called well compatible NO_3 to the so-called high phytotoxic NH_4
- NH_4 is placed in the soil in wide-tracked line- or point-like-deposits in the plant root area as an absolutely stable N-source
- CULTAN bases on physiological regularities, i.e plant growth and metabolism is controlled by phytohormones (cytokinin = root dominant, auxin + gibberellin = shoot dominant)
- High phytotoxicity in deposits, ammonium by the plants is taken up controlled and assimilated according to the intensity of growth

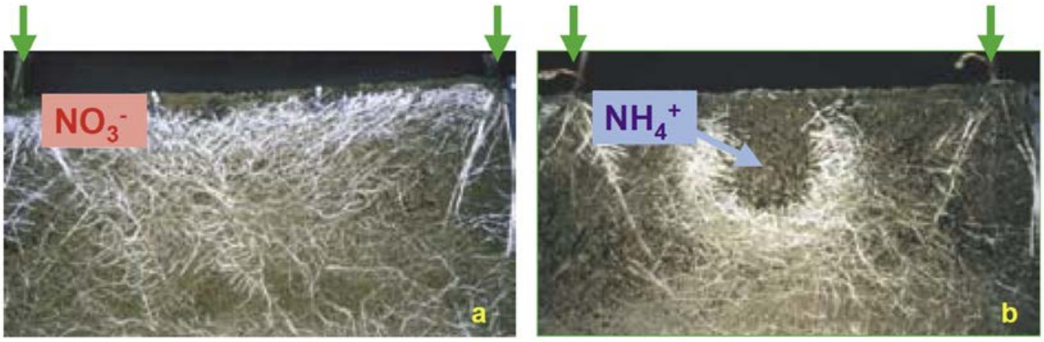


Figure 55: Root images of two maize plants (green arrows) with nitrate fertilization (a) and with CULTAN NH_4 deposit fertilization (b) (soruce: Spiess & Meier2008)

Figure 56: Device (sprocket wheel) for point injection (source: Weimar); set of srocket wheels (http://www.cultan.de/inhalt/c_technik/c_technik_gal.html)

How does it work / is it applied?

- Point injection (see Figure 56,)
- Date of application
    - Summer cereals:
        - If possible only one application at sowing, at least before leaf development (development stage BBCH 10), i.e. during phase of root dominant growth (high content of Cytokinin compared to Auxin and Gibberellin)
        - Inter-row application (wheels distance from 25 to 30 cm; 5 to 10 cm application depth)
    - Winter cereals with less soil N supply:
        - 1. Root side-dress fertilization as start fertilization
        - 2. a latent N-deficiency of the plants (N content < 2.5 % at the stage 29 to 30 end of tillering) before the CULTAN fertilization
        - Inter-row application (wheels distance from 25 to 30 cm; 5 to 10 cm application depth)
    - Winter cereals (with intensive growth):
        - CULTAN at the beginning of shooting (stage 31)
        - cutting the plants above the primordia of the ears, resulting in a change of the shoot-/root-relation by favoring of the roots
        - Inter-row application (wheels distance from 25 to 30 cm; 5 to 10 cm application depth)
    - Maize:
        - 1. a DAP-side root dressing at sowing
        - 2. CULTAN fertilization at the beginning of growth of the third leaf
        - application between every second row (10 to 15 cm application depth)
    - Potato:
        - CULTAN is applied at planting time as depending on the kind of soil
        - 10 to 15 cm underneath the planted potatoes
    - Sugar beet:
        - 1. spraying a fertilizer band (10 cm wide with 40 kg N/ha as NH_4 x NO_3 x urea - solution) at sowing time
        - 2. CULTAN fertilization at the development of the five leaf
        - application between every second row (10 to 15 cm application depth)
    - Meadows and pastures:
        - CULTAN after every period of grazing or after every cutting of the grass
        - Inter-row point injection with wheels (distance from 25 to 30 cm; 5 to 10 cm depth)

Table 8: Fluid fertilizers for CULTAN application (point injection)

Fertilizer	Content of nutrient (%)				
	N	NO3-H	NH4-H	Amid-N	S
Ammonia water	20	-	20	-	-
Ammonium nitrate urea solution	28	7	7	14	-
Ammonium nitrate urea solution + Ammonium sulphate	24	5	8	11	3
Ammonium thiosulphate	28	6.4	8.8	12.8	5
Ammonium sulphate urea solution	20	-	6	14	6
NP solution 11+37	11	-	11	-	-
NP solution 22+6 (+2)	22	-	22	-	2
NP solution 27 (+3)	27	6.2	8.5	12.3	3
NPKS solution 19+3+5 (+2)	19	2.4	4.2	12.4	2

Table 9: Technique, application and related crops for CULTAN

Technique	Application	Crops
Liquid deposits	Injection	Cereals, rapeseed, maize, potato, sugar beet, grass, vegetables
Granulate deposits	Surface	Pasture, clover, grass
Granulate deposits	Soil	Cereals, rapeseed, maize, potato, sugar beet
Pellet deposits	Single plant	Vegetables
Cup deposits	Single plant	Greenhouse : tomato, cucumber, pepper, etc.
Cup deposits	Two plants	Greenhouse : tomato, cucumber, pepper, etc.

Advantages and application of the innovation

- very high N use efficiency
- without any losses of nitrogen by leaching or denitrification
- improvement of nitrogen balance
- improvement of yield

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
x	x				

Reference:

Schumacher, H.-J. (2009): Ertrags- und Qualitätsvorteile für Braugerste, Sommergetreide mit CULTAN-Düngung erfolgreich anbauen. Landwirtschaft ohne Pflug, 1: 26-28 p.
Sommer, K. & Scherer, H. W. (2007): Source / Sink – Relationships in Plants as Depending on Ammonium as „CULTAN“, Nitrate or Urea as Available Nitrogen Fertilizers. International Symposium “Sink-Source Relationships in Plants”, Kaliningrad, Russia.
Sommer, K. (2008): Bestandesführung bei Getreide nach dem “CULTAN”-Verfahren. Getreide Magazin, 2: 2-4 p.
Spiess, E. & Meier, U. (2008): Cultan-Düngetechnik praxisreif. Schweizer Landtechnik, 3: 14-17 p.
Weimar, S.(n.d.): CULTAN-Verfahren im Ackerbau – Ausbringungsverfahren, Dienstleistungszentrum Ländlicher Raum Rheinhessen-Nahe-Hunsrück.

D.3 Use of app to determine optimal nitrogen fertilization for winter rape-seed in spring

Related to MP: MP26 Mineral N application

Related to FTZ: ENZ4_SL1_TXT1 - Arable and mixed farms
ENZ6_SL2+3_TXT3 - Arable farms
ENZ6_SL1_TXT1 - Arable / cereal and mixed farms

Key points

- Non-invasive method by using pictures and a flexible mobile application
Optimal N fertilization recommendation for winter rape

What is it?

- An app with image analysis to determine N fertilization for winter rape

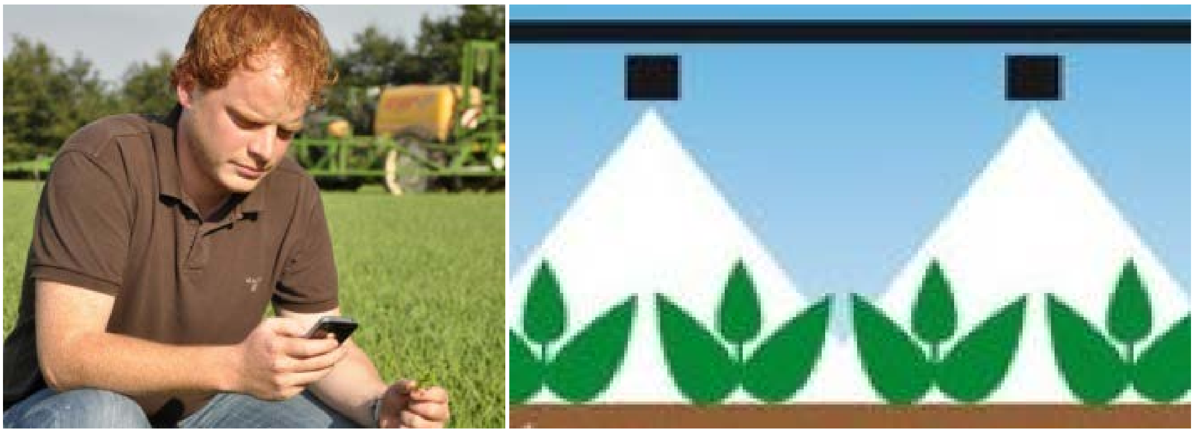


Figure 57: App and position to take pictures (http://www.topagrar.com/news/Acker-Wetter-Ackernews-Neuheit-Top-Unkraut-App-2014-1336368.html)

How does it work / is it applied?

- Take several pictures in the stand of winter rapeseed (representative) with your smartphone or tablet
    - Take 10 to 20 pictures (minimum 4) vertical with a distance of 1.5 to 2 m to the soil surface
    - Effect picture detail size 50 x 50 to 70 x 70 cm
    - Soil coverage should not be more than 80 %
    - Pictures should contain only plants and soil (no shoes, hands, etc.)
    - No weeds, algae, moss or snow on the pictures
    - Also avoid rime and dew
    - If rows are available, take pictures at the least of 2 to 3 rows
    - Avoid direct sun light, covered sky is better
- App will send pictures to server which will analyze them

  - o With the soil coverage from the pictures it calculates fresh biomass and also the resulting nitrogen uptake
- With the help of agronomical calibration the nitrogen fertilizer requirement will be prepared
- User / farmer will receive the nitrogen fertilizer recommendation (kg / ha) with your smartphone or tablet immediately

Advantages and application of the innovation

- High varying nitrogen fertilization requirement of rape (depending on development) could be considered with determination of biomass
- Non-invasive and fast method
- Efficient fertilization to avoid and reduce common nitrogen balance surplus for rape
- Comparable with invasive biomass balance method

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
x	x				1)

1): economic and environmental aspects

Reference:
http://www.yara.de/media/apps/imageit/index.aspx
http://landundforst.agrarheute.com/yara
http://www.effizientduengen.de/download/Duengebedarf_Raps_ImageIT_NL_9_2013.pdf

D.4 Fertigation with mineral fertilizer

Related to MP: MP26 Mineral N application + MP27 Mineral P application + MP28 Mineral K application

Related to FTZ: ENZ13_SL1+2+3+4_TXT4 - Arable/Cereals
ENZ13_SL2+3+4_TXT3 - Permanent crops

Key points

- Low quality water can be used.
- Controlled deficit Irrigation strategies.
- Higher efficiency in the use of water and fertilizers.

What is it?

Fertigation is a technique that allows the application of water and fertilizers simultaneously through the irrigation system to apply the necessary nutrients to plants.

How does it work / is it applied?

Steps:
1. Test the soil
2. Calculate planted acre, taking into account field surface and bed spacing
3. Select the correct fertilizer, attention to mixing and compatibility (see Table 12)
4. Calculate the correct amount of fertilizer needed
5. Determine how much fertilizer is needed per planted acre
6. Determine how much water is needed to solubilize the fertilizer
7. Determine the time needed to inject fertilizer through an irrigation system

Fertigation Approaches:

The most common fertigation approaches are the quantitative approach and the proportional approach.

- The quantitative approach is commonly used in open fields. The grower first decides how much fertilizer has to be applied per area (e.g. kg/ha, lbs/acre). This quantity of fertilizer is then delivered through the irrigation water.
- The proportional approach is mostly used in soil-less media and sandy soils. Here, a defined quantity of fertilizer stock solution is injected into each unit of water flowing through the irrigation system (e.g. l/m^3, lbs/gal).
- Nutrient levels are determined by their concentration in the irrigation water. Most growers who use proportional approach, use units of ppm (parts per million) or mmol/l (see Table 11).

Equipment (Drip and sprinkler irrigation - see FS Combined Centre Pivot with mobile drip tubes; FS Centre Pivot / Linear irrigation system; FS Combined Centre Pivot-Linear irrigation system; FS Precision Irrigation - Variable Rate Irrigation): a basic unit of fertigation should have an injector of fertilizer and a fertilizer mixture tank, preferably of plastic material (iron or steel undergoes very rapid corrosion), for supplying liquid manure or, if necessary, prepare the solution with soluble fertilizers. An agitator, a control valve and a filter is also required. Depending on the fertigation system, may require additional equipment such as valves, pressure regulators, pumps mixers. Fully extended in the case of drip irrigation.

Requirements of the fertilizers:

- **Solubility:** high solubility, considering the compatibility with other fertilizers and the irrigation water itself (see Table 10 and Table 12, also jar test).

Table 10: Solubility of fertilizers

	Solubility g/l					
Fertilizer / Temperature (°C)	5	10	20	25	30	40
Potassium nitrate	133	170	209	316	370	458
Ammonium nitrate	1183	1510	1920	.	.	.
Ammonium sulfate	710	730	750	.	.	.
Calcium nitrate	1020	1130	1290	.	.	.
Magnesium Nitrate	680	690	710	720	.	.
Mono Ammonium Phosphate	250	295	374	410	464	567
Mono Potassium Phosphate	110	180	230	250	300	340
Potassium chloride	229	238	255	264	275	.
Potassium sulfate	80	90	111	120	.	.
Urea	780	850	1060	1200	.	.

- **Purity:** products as pure as possible, because sometimes salts containing inert materials can cause unpredictable reactions, and even cause blockages in irrigation systems.

- **Salinity and toxicity:** the dose should not exceed the allowable salinity values. The same happens regarding the toxicity of certain ions.
- **Mixing:** Jar test - The fertilizers should be mixed exactly in the same concentration as intended to be used in the stock tanks. If a precipitate forms or if the solution has a "milky" appearance, the test should be repeated with lower concentrations of the fertilizers.

- pH adjustment in fertigation
  - For optimal uptake of nutrients, especially micronutrients
  - To keep the irrigation system free from clogging
  - In soilless culture and in sandy soils it is very important to keep the pH of nutrient solution at an optimal range for nutrient availability (normally for most crops pH 5.5 to 6.5)
  - decrease of water pH with common acids for agricultural use - Sulfuric, Phosphoric and Nitric acid with essential plant nutrients (S, P and N that should be considered)
    - Water amount applied will affect the amount of nutrient applied with the acid
    - Concentration X Volume = Amount

Advantages and application of the innovation

- Water and nutrients are perfectly located in the root absorption zone.

- Different fertilization plans can be set in parallel with the growth stage of the crop or based on the absorption curves of nutrients.
- Quick correction of nutritional deficiencies of the crop.
- It allows the use of low agricultural quality water (electrical conductivity greater than 3 dS/m).
- Growth rate can be increased or decreased as interest (controlled deficit irrigation).
- More efficiency in the use of water and fertilizers, save up of fertilizers
- Good effects on crop yield.
- Protection of the environment.
- It can be used in soilless and hydroponic crops.

Table 11: Nutrient Recommendations for various vegetables (proportional approach), concentration in mg/l (ppm)

Crop	N	P	K	Ca	Mg
Tomato	190	40	310	150	45
Cucumber	200	40	280	140	40
Pepper	190	45	285	130	40
Strawberry	50	25	150	65	20
Melon	200	45	285	115	30
Roses	170	45	285	120	40

Table 12: Compatibility of Fertilizers (✔ = Compatible, X = Incompatible, R = Reduced Solubility)

	Urea	NH4 Nitrate	NH4 Sulphate	Calcium Nitrate	Potassium Nitrate	Potassium Chloride	Potassium Sulphate	NH4 Phosphate	Fe, Zn, Cu, Mn Sulphate	Fe, Zn, Cu, Mn Celate	Magesium Sulphate	Phosphoric Acid	Sulphuric Acid	Nitric Acid
Urea	✔													
NH4 Nitrate	✔	✔												
NH4 Sulphate	✔	✔	✔											
Calcium Nitrate	✔	✔	X	✔										
Potassium Nitrate	✔	✔	✔	✔	✔									
Potassium Chloride	✔	✔	✔	✔	✔	✔								
Potassium Sulphate	✔	✔	R	X	✔	R	✔							
NH4 Phosphate	✔	✔	✔	X	✔	✔	✔	✔						
Fe, Zn, Cu, Mn Sulphate	✔	✔	✔	X	✔	✔	R	X	✔					
Fe, Zn, Cu, Mn Celate	✔	✔	✔	R	✔	✔	✔	R	✔	✔				
Magesium Sulphate	✔	✔	✔	X	✔	✔	R	X	✔	✔	✔			
Phosphoric Acid	✔	✔	✔	X	✔	✔	✔	✔	✔	R	✔	✔		
Sulphuric Acid	✔	✔	✔	X	✔	✔	✔	✔	✔	X	✔	✔	✔	
Nitric Acid	✔	✔	✔	✔	✔	✔	✔	✔	✔	X	✔	✔	✔	✔

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other as-pects
X	x		X	X	X

1): Economic aspects

References:

http://www.fertirrigacion.com/
http://www.etceter.com/c-agricultura/p-tipos-de-riego-en-la-agricultura/
http://crea.uclm.es/siar/publicaciones/pdf/HOJA11.pdf
http://www.smart-fertilizer.com/
http://edis.ifas.ufl.edu/hs1206

D.5 Use of compost to improve soil fertility

Related to MP: MP29 Plant compost application

Related to FTZ: ENZ4+7_SL1_TXT1 - Dairy cattle / permanent grass

Key points

- Compost can be applied at any time,
- only half of the P content in compost is accounted for (up to specified maximum); this allows farmers to enhance soil organic matter without being too much restricted by P application standards (NL legislation),
- The low P content per unit organic matter allows for high organic matter applications.

What is it?

- In NL, there is a maximum annual application limit of 55 kg of phosphate per ha (2014) on arable land with high P-status (80 kg/ha for low P status).
- Compost has a threshold value for phosphate applications of 3.5 g per kg dry mass.
- All P above this threshold is fully (100%) accounted for under the application standards.
- Composts are professionally made of organic waste materials in open hall systems, closed hall systems or outdoor systems (no cover).
- Compost available on the market, professionally composted:
  from vegetable, fruit and garden waste;
  from organic waste from municipalities (grass clippings and shrubs mainly);
  Nature compost, mostly from roadside cutting and clippings.
- Products can be certified by KIWA, an international quality authority.


Figure 58: Organic waste from municipalities is collected (left, www.wdde.org/12167-wilmington-compost-center) and composted outdoors to a valuable organic matter source for agriculture (right, www.maschinenring.at/default.asp?medium=MR_NOE_11&tt=MR_NOE _11_R2)

How does it work / is it applied?

- Compost can be spread with a manure spreader over the field,
- Compost (of plant origin) is allowed to be applied all year round, no restrictions in time,
- Application dose is limited by statutory values; these values also depend on the soil P status (see FS On-farm composting; FS Compost application as soil amendment and fertilizer)

- The humification coefficient (fraction of organic matter remaining one year after application) of plant compost is high (75%) compared to those of for farm yard manure (50%), slurries (60%) and green manures (25%),
- The phosphate content per kg effective organic matter (part of organic matter that still remains one year after application) of compost is ±3.5%, which is low compared to solid cow manure (3.7%) or pig slurry (15.3%). So contribution to maintain soil organic matter within maximum allowed P input is high,
- Legal N-fertilizer value of compost is low, 10%
- Agricultural N-fertilizer value is 10% for crops with a short growing seasons and 20% for crops with a long growing season,
- Due to low legal N-fertilizer value, compost applications displace only small part of allowed N input quota (the crop specific statutory N application standard that confines effective N input in NL)


Figure 59: Compost is loaded on a manure spreader (left) and applied on a sandy soils in winter time (right, http://www.landwirt.com/Produktion-und-Einsatz-von-Kompost-in-der-Landwirtschaft-und-im-Gemuesebau,,354,,Bericht.html)

Advantages and application of the innovation

- Compost provides valuable organic matter to the soil,
- Compost is used as a soil improver rather than a fertilizer,
- Decomposition of compost is very slow,
- Positive effect on organic matter balance,
- Can be applied during winter time,
- Attention to quality of the product is needed: no visual contamination,
- Attention to quality of the product is needed: should be sufficiently mature to prevent N-immobilization,
- Easy to handle and positive long term effect on soil fertility.

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
X	X	X	X	X	

Reference:
http://www.akkerwijzer.nl/nieuws/342/goede-compost-is-als-een-bruine-boterham
http://edepot.wur.nl/255461
http://edepot.wur.nl/257872

D.6 On-farm composting

Related to MP: MP29 Plant compost application + MP30 Bio-waste compost application + MP31 Sludge compost application

Related to FTZ: ENZ7_SL1_TXT2 - Mixed farms (pigs and horticulture)
ENZ7_SL2_TXT3 - Arable / specialized crops

Key points

- Carbon sequestration
- Improved soil quality
- Yield stability

What is it?

- Farm compost is made of feedstock which can be found on the farm: wood chips and bark, manure, straw, grass clippings, crop residues, etc.

How does it work / is it applied?

- Composting can be defined as a managed biological oxidation process that converts heterogeneous organic matter into a more homogenous humus-like material;
- Composting begins as soon as appropriate materials are piled together;
- The raw materials which are commonly available to the farmer are manure, crop residues, spoiled hay, straw, wood chips and bark, grass clippings, animal beddings, etc.;
- At farm level, there is mostly a primary raw material, which is a troublesome waste needing treatment (e.g., crop residues, manure), and other materials are added;
- 'Green' (low C:N ratio; e.g., manure) and 'brown' (high C:N ratio; e.g., wood chips) materials should be mixed in a such a way that a C:N ratio of 25:1 to 40:1 is reached;
- In order to get an active composting, the moisture content of the raw material mix should reach the recommended range of 40-65 %;
- The most common composting method is windrow composting: placing the mixture or raw materials in a long narrow pile or windrow which is turned on a regular basis. In this system, the windrows aerate primarily by natural or passive air movement;
- Turning is crucial and the frequency depends on the rate of decomposition, the moisture content, porosity of the materials and the desired composting time.
- Windrow temperatures or odors indicate when turning is needed. Low temperatures and/or odors signal the need for more oxygen and turning while turning is also required for cooling when the windrow gets too warm.
- Turning mixes the materials, rebuilds the porosity of the windrow and releases trapped heat, water vapor and gases.
- The frequency of the turning will decrease as the windrow ages.
- At the process start easily degradable or high-nitrogen mixes may require daily turnings.
- As the process continues, the turning frequency can be reduced to a single turning per week

- Depending on the scale of the on-farm composting, turning can be accomplished by using a bucket loader on a tractor in combination with a manure spreader, a tractor powered rotary drum with flails or a self-powered rotary drum. During the turning operation, moisture can be applied to the windrow also;
- When active composting is finally completed, it can be stored or applied to the field;
- In conventional field cropping systems, compost should ideally be managed using traditional farm machinery and incorporated into routine field operations. Broadcasting can be done on large scales by using compost/solid manure spreaders. Incorporation can be achieved by a rotary harrow, a rotary spading cultivator, etc.;
- Due to the large variability in compost composition the application rate of the compost will depend on the nutrient legislation, the final plant-available nutrient content of the compost and the nutrient requirement of the specific crop (see FS Compost to improve soil fertility; FS Compost application as soil amendment and fertilizer).

Advantages and application of the innovation

- On-farm composting can be an efficient recycling method for (troublesome) waste streams (e.g., crop residues, manure) at the farm;
- Carbon sequestration;
- Soil improvement (increased chemical, physical and biological soil quality);
- A more stable form of nitrogen that is less likely to leach into water supplies;
- When used as a fertilizer, compost provides a slow release of nutrients;
- When determining compost application rates based on crop needs, farmers should remember that only a portion of the nitrogen in the compost is available for plant growth during the first year. So, in crops that require large amounts of nutrients, supplemental application of mineral fertilizers may be necessary;
- Yield stability;
- Availability, nutrient legislation and costs are the major bottlenecks for the moment for a wide application of farm compost
    - ‘Brown’ materials (e.g., wood chips) are not always available at the farm;
    - In areas with elevated phosphate levels (e.g., Flanders), land application of compost may be limited based on phosphorus content. Also the amount of plant-available nitrogen can pose problems as farmers prefer animal manures (which are abundantly available) over compost as an organic fertilizer to satisfy the crop’s nitrogen needs;
    - To start a farm composting, the initial investment can be very high (e.g., windrow turner). Also the purchase of wood chips and bark can be quite costly.

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
x	x	x	x	x	

Reference:
Baldwin, K., R., Greenfield, J., T., 2009. Composting on organic farms. Organic Production. Centre for Environmental Farming Systems, North Carolina (US), 21p.

Rynk, R. 1992. On Farm Composting Handbook. National Resource, Agriculture and Engineering Service, New York (US), 186p.
Dougherty, M., 1999. Field guide to on-farm composting. National Resource, Agriculture and Engineering Service, New York (US), 118p.
Willekens, K., Jamart, A., Vandevannet, N., 2003. Boerderijcompost nieuws, jaargang 1, nr 1. Technologische Adviseerdients (TAD): FarmCOMPOST.
Willekens, K., Jamart, A., Vandevannet, N., 2004. Boerderijcompost nieuws, jaargang 1, nr 2. Technologische Adviseerdients (TAD): FarmCOMPOST.

D.7 Compost application as soil amendment and fertilizer

Related to MP: P30 Bio-waste compost application

Related to FTZ: ENZ12_SL1_TXT1+2+3 - Arable/ cereal
ENZ12_SL3_TXT2, ENZ12_SL4_TXT2+3 - Arable/ cereal

Key points

- addition of organic matter to the soil
- addition of readily available nutrients to the soil

What is it?

Distribution of organic matter from a mixed composting of urban organic wastes (fresh or after anaerobic digestion for biogas production), together with ornamental trees pruning and parks and garden mowed grass.

Figure 60: Compost application on field (http://www.provincia.torino.gov.it/agrimont/ eventi_iniziative/2008/compost_incontro17Ott08)

How does it work / is it applied?

Bio-waste compost (see FS Compost to improve soil fertility; FS On-farm composting) can be a valuable fertilizer with readily available N (high NH_3/total N). Compost is distributed using a special machine. A rapid incorporation is needed to reduce NH_3 volatilization.

As for all manures, summer crops take more advantage of released nutrients than winter cereals. Although there is a risk of a yield reduction in the first 1-2 years of supply (on wheat, maize, tomato and lettuce), if N fertilization is not increased, a progressive increase in nutrient availability across years is expected.

The amount of compost to be distributed should be calculated based on the N content of compost. Then, an extra-amount of N as mineral fertilizer (e.g. 25% of the total) can be supplied to the crop to reduce the problem of N immobilized, especially in the first 2 years.

The use of certified quality compost is highly recommended, to reduce the risk of supplying toxic substances, heavy metals or undesired inert materials to the soil.

How much compost should be applied?

A normal amount for field crops is 25-30 t/ha of compost before sowing, incorporated into the soil with tillage.

In order to maintain the OM content of a soil across years, the following amounts (t/ha) should be distributed every year:

Table 13: Compost amount (t/ha) every year

	Compost has an organic matter content (%) of:			
	35-40	**40-45**	**45-50**	**50-55**
Soil organic matter (%)				
<1.5	24-31	21-27	19-24	17-22
1.5-2.0	32-41	28-36	25-32	23-29
>2.0	42-51	37-45	33-40	30-36

Advantages and application of the innovation

- low-cost and low-energy consuming organic fertilizer
- recycling an organic waste (fresh or after biogas production)
- nutrient supply, relevant amendment effect on soil physical properties
- reduction of mineral fertilizer use in the medium and long term
- immobilization can occur, depending on the C:N ratio of compost and on soil aeration. Nutrient recovery is expected to increase after some years of application
- positive effect on soil life

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
x	x	x	x	x	

Reference:
Efficacia del compost da Forsu: bene su mais, meno su frumento. - L'Informatore Agrario num. 22, pag. 42 del 05/06/2014
Il ruolo del compost nei piani di fertilizzazione. - L'Informatore Agrario num. 40, pag. 57 del 18/10/2002
http://www.compost.it/temi-dinteresse/utilizzo-del-compost.html
http://www.ambienteterritorio.coldiretti.it/Documents/COMPOSTAGGIO%20E%20AGRICOLTURA_2008.pdf

D.8 Top dressing of maize with bovine slurry

Related to MP: MP33 Cattle slurry application

Related to FTZ: ENZ12_SL1_TXT1+2+3 - Dairy cattle / temporary grass

Key points

- Late distribution of slurry in maize, a high-demanding N crop which is the key diet component in intensive dairy and pig farms
- high N use efficiency due to synchronization with crop needs

What is it?

Bovine or pig slurry distributes to maize when the crop is well established and actively growing (top-dressing).


Figure 61: Top dressing of maize using hose trails and injection (Bassanino et al. 2008)

How does it work / is it applied?

Slurry is applied to maize at a 3-7 leaves stage, using low compaction special machinery. Slurry is distributed either using hose trails or injectors, to reduce NH_3 volatilization and odour emission. Sub-contracting is a good solution for distribution.

The amount of distributed slurry should be calculated on the basis of a recent chemical analysis and accounting for the crop requirements (nutrient management plan). Mechanical weeding can be performed at the same time of slurry distribution and incorporation, thus optimizing the number of mechanical operations.

The N use efficiency of top-dressed N fertilizers is usually high. Consequently, the use of farm slurry as a top-dress fertilizer increases the overall farm utilization efficiency if compared to a unique distribution before sowing. The use of highly-efficient slurry instead of mineral fertilizer will reduce farm costs and increase farm profitability and environmental sustainability of agriculture. Moreover, the distribution period for slurry is enlarged, therefore the capacity of farm tanks to store slurry is reduced.

Advantages and application of the innovation

- enlargement of the distribution period of slurry for dairy or pig farms
- reduction of farm storage capacity for slurry
- reduction of synthetic N use because of a better use of farm manure
- increase in N efficiency because of late distribution period

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
x	x	x	x		

Reference:
Bassanino, M., Remogna, E., Viglione, P., Sanino, N., Grignani, C. (2008): Risultati positivi sul mais con l’utilizzo di reflui zootecnici”. Informatore Agrario, 13/2008
Tecniche e attrezzature per lo spargimento dei liquami. L'Informatore Agrario num. 45, pag. 71 del 14/11/2003

D.9 Fertigation of maize with bovine slurry using a ranger irrigation system

Related to MP: MP33 Cattle slurry application + MP54 Sprinkler irrigation

Related to FTZ: ENZ12_SL1_TXT1+2+3 - Dairy cattle / temporary grass

Key points

- small and portable ranger irrigation system suitable for maize
- high N use efficiency due to synchronization with crop needs
- wider distribution timing for slurry in intensive pig or dairy farms

Figure 62: Fertigation system for maize (Bassanino et al. 2008)

What is it?

Irrigation of maize using slurry mixed with water, in some of the irrigation events before the flowering stage.

How does it work / is it applied?

Low pressure sprinkler systems (sprinklers, pivot, and rangers - see FS Combined Centre Pivot with mobile drip tubes; FS Centre Pivot / Linear irrigation system; FS Combined Centre Pivot-Linear irrigation system; FS Precision Irrigation - Variable Rate Irrigation) ensure a high efficiency of fertigation. Mobile or fixed irrigation systems can be adapted to mixing pig or bovine slurry to irrigation water. Separated liquid fraction of slurry is suitable for this purpose, however also diluted unseparated slurry can be used. For example, a 4% dilution is needed for a pig slurry having 4-5% of dry matter content.

Figure 63: Membrane pump and injection system (Bassanino et al. 2008)

Mixing the slurry with irrigation water reduces ammonia emission and enhances infiltration, which increases crop utilization of applied N if compared to surface application of fresh slurry or mineral fertilizers.

Additional costs are required to modify the irrigation system, with the inclusion of a membrane pump and injection system to the sprinkler pipeline. However, these costs are compensated by the reduction in purchased mineral fertilizers.

Later in the season, the same irrigation system can be used to supply irrigation water below the canopy, to reduce leaf water interception and direct evaporation if compared with surface irrigation or sprinkler irrigation systems.

A high efficiency can be achieved through a ranger irrigation system, equipped with long soft tubes to supply irrigation water below the canopy, to reduce leaf interception and direct evaporation

Advantages and application of the innovation

- high N use efficiency because of late supply
- high water use efficiency if compared with traditional surface irrigation
- investments are needed to modify farm irrigation system
- slight yield decrease because of machinery trail passage

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
x	x	x	x		

Reference:
http://www.youtube.com/watch?v=uSsGmdrMR2o
http://www.crpa.it/media/documents/crpa_www/Settori/Ambiente/Download/Archivio_2013/IA_2013_21_p32.pdf
Bassanino, M., Remogna, E., Viglione, P., Sanino, N., Grignani, C. (2008): Risultati positivi sul mais con l’utilizzo di reflui zootecnici”. Informatore Agrario, 13/2008
Liquami e digestati: come usarli in fertirrigazione. L'Informatore Agrario num. 21, pag. 32 del 30/05/2013

D.10 Manure processing (solid-liquid separation)

Related to MP: MP33 Cattle slurry application + MP34 Poultry manure application + MP35 Pig slurry application

Related to FTZ: ENZ7_SL1_TXT1 - Dairy farming / permanent grassland ENZ7_SL1_TXT2 - Mixed farms (pigs and horticulture)

Key points

- Reducing the surplus of manure minerals
- Improved nutrient efficiency
- Use of separated manure fractions in line with the nutrient requirements of crops

What is it?

- Manure separation into a solid and a liquid fraction after which both fractions can be applied to land separately or further processed.

How does it work / is it applied?

Several methods can be used to separate solids from liquids.

- Sedimentation: the manure is placed in a settling basin after which the solids in the manure settle to the bottom of the basin over time, resulting in a solids layer at the bottom with a liquid layer on the top (most basic and least effective method);
- Filtration: the manure is passed through natural (e.g., crop residues) or man-made (e.g., porous membrane) filter media. The solid particles in the manure become trapped by the filters while the liquid fraction passes through;
- Mechanical separation: gravity + mechanical means to separate the solids and the liquids
    - Centrifugal separators: centrifugal forces are used to force the heavier solids to move to the outside wall of the cylinder where they are removed. Can be used in mobile manure separators;
    - Screen separators: the liquid fraction passes down through a metal screen while the solids are held. Screen separators can be stationary, brushed, vibrating or rotating;
    - Presses: the liquid is squeezed out and the solids remain on a screen or perforated belt. In a screw press, a screw-type conveyor forces the manure through a tube and past a cylindrical screen.

The effectiveness of most separators improves as the solid content increases and the process is more effective with fresh rather than with stored manure.

The process creates a nutrient rich solid faction which has the potential to be applied to land as a fertilizer, to be composted, sold or used as bedding in barns. The remaining liquid fraction still contains nutrients and can be applied to fields as a nutrient source or as irrigation water. Alternatively, the liquid fraction can be treated, recycled and reused within the operation as wash or flush water.

Advantages and application of the innovation

- Phosphorus reduction in the liquid fraction. About 96% of the P in manure is contained within the solid fraction;
- In case of a nutrient surplus at the farm, the nutrient-rich, low-moisture solid fraction can easily be transported, allowing for the movement of nutrients farther from the yard, and reducing the risk of nutrient accumulation in nearby soils;
- Liquid from the separation process can be applied to nearby fields as a 'mineral' fertilizer as it contains a high amount of N which becomes directly available. It has also an increased N:P ratio which results in a more balanced fertilizer for crops;
- The removal of solids from the liquid fraction makes handling, pumping and application of the liquid easier and it decreases transportation costs;
- Composting of the solid fraction of manure has the potential to stabilize the organic N fraction;
- Manure processing results in a reduction of greenhouse gas emissions, due to a reduction in storage period;
- Disadvantage: increased management requirements and costs.

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
X	X		X		

Reference:
Zwart, K., Postma, R., Schils, R.L.M., 2013. Sustainability of products from manure. International conference on manure management and valorization 2013, Bruges, Belgium. Final program and abstract book, p 72-74.
ManuREsource - International conference on manure management and valorization 2013, Bruges, Belgium. Final program and abstract book, 223p.
Schoumans, O.F., Chardon, W.J., Bechmann, M.E., Gascuel-Odoux, C., Hofman, G., Kronvang, B., Rubaek, G.H., Ulén, B., J.-M. Dorioz, 2014. Mitigation options to reduce phosphorus losses from the agricultural sector and improve surface water quality: A review. Science of the Total Environment 468-469, 1255-1266.
Troy, S.M. 2012. Treatment options for the separated solid fraction of pig manure. PhD thesis, National University of Ireland Galway, Galway. 225p.
Beneficial Management Practices: Environmental Manual for Livestock Producers in Alberta, 2010. Alberta Agriculture and Rural Development, Alberta, Canada. 96p.

D.11 Application of slurry in winter wheat on clay soils in the spring

Related to MP: MP33 Cattle slurry application + MP34 Poultry manure application + MP35 Pig slurry application

Related to FTZ: ENZ4+7_SL1_TXT1 - Dairy cattle / permanent grass

Key points

- Reduced N-losses compared to fall application (not allowed in NL anymore),
- Cheap replacement of the standard applied mineral N-fertilizer in the spring,
- Contribution to soil organic matter content.

What is it?

- Slurry is injected into the clay soil in winter wheat between 1 February and the end of April

Figure 64: Slurry is injected in winter wheat on clay soils (source: Huijsmans, November 2011)

How does it work / is it applied?

In general:

- On a dry day slurry is injected up to an amount of 20 to 25 tons/ha in winter wheat between 1 February and before the end of April (in NL, allowed application rate depends on phosphate content of slurry),
- Injected (mandatory to reduce NH_4 emissions) done by making a small furrow into the soil where manure is put into, see picture,
- Application best done before or at the beginning of tillering.

Using a tank with a slurry injector or a slot coulter:

- A number of slurry release pipes of injector are blocked at location of crop row,
- Soil pressure must stay below 100 kPa (1 bar), if higher yield loss up to 1.5% may occur

Using drag hose supply with a slurry injector or a slot coulter:

- To avoid damage to soil and crop by the heavy manure tank, a system with a drag hose supply is developed (Figure 65, compare right with left). Supply tank situated at field border,
- Care must be taken not to drive over the supply hose.

Figure 65: Tractor with tank and slurry injector (top left), detail of slurry injector (top right) and drag hose supply with slot coulter (bottom left) and detail of slot coulter (bottom left) (source: Huijsmans et al. 2012; http://edepot.wur.nl/203220)

Advantages and application of the innovation

- Fall application of slurry contributes to high N-losses in winter time and is therefore not allowed any more on all soil types in the Netherlands,
- Spring application in established crops such as winter wheat was thought to cause damage to soil structure and roots, leading to yield losses,
- Yields of winter wheat comparable to those of crops that receive mineral fertilizer,

- Soil damage + subsequent yield loss by heavy machinery prevented by use of drag hose supply,
- Cutting of soil by slot coulter causes no yield loss when done before stem elongation / shoot development (Feekes stage 4 / BBCH 30); 3% yield loss when done at stem elongation with one knots visible (Feekes stage 6 / BBCH 31) and 5% when done at stem elongation two knots visible (Feekes stage 7 / BBCH 32),
- Positive effect on organic matter balance,
- In addition to N and P, K and micronutrients are applied at low cost,
- Must be done on dry days to prevent soil damage when heavy machinery is used,
- Must be injected into the coulter furrow to minimize ammonium losses (mandatory),
- N fertilizer value of slurry application increases from 20% of fall application to 50- 55% of spring application.

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
X	X		X		

Reference:
www.kennisakker.nl/files/Kennisdocument/Mesttoeding_in_voorjaar.pdf
http://edepot.wur.nl/203220
http://www.kennisakker.nl/kenniscentrum/document/naar-andere-aanwending-van-mest-op-kleigrond

D.12 Components in direct seeders for residue management

Related to MP: MP36 Return of crop residues

Related to FTZ: ENZ13_SL1+2+3+4_TXT4 - Arable / Cereals

Key points

Residue Management is referred to:

- the process of assessing field conditions (during and after harvest) and considering seed and fertilizer placement, in order to make informed decisions about machine selection and field methods to manage crop residue.
- the use of machinery and methods to prevent crop residue from interfering with successful crop production.

In direct seeding systems, residue management begins at harvest.

What is it?

Direct seeding, is a cropping system which aims to improve soil and soil moisture conservation. Direct seeding is more flexible than no-till; it allows some tillage to solve immediate weed problems and to deal with high moisture and heavy clay soil conditions.

How does it work / is it applied?

In direct seeding, soil is not tilled in the spring before planting. This is to conserve soil moisture in the seedbed. Any fall tillage must leave the soil surface compact and level to preserve soil moisture. Most of the crop residue remains on the surface with at least half the stubble remaining upright and anchored to trap as much snow as possible. Typical operations are fall fertilizer banding with knives, and redistributing crop residue and incorporating herbicides with heavy or rotary harrows.

Figure 66: Mature beds with standing residues (source: Guzman 2011)

Some components of the direct seeders are the following ones:

<u>Row cleaner</u>

Under some circumstances, direct seeders have a row cleaner just before or combined with the cutting disc. Row cleaners make the seeding more efficient under the following conditions:

- Heavy or difficult mulch.
- Delicate seeds.

- In cold climates to warm up the soil.

Cutting disc

A cutting disc is usually necessary to make a clean cut through residue cover and avoid residue collection around the planter elements or the pressing of residues into the seed row. They are particularly important with heavy residue covers and with chisel type furrow openers. The efficiency of the disc that cuts the (cover) crop residues depends on various factors:

- Soil conditions: texture, resistance to penetration, humidity and porosity.
- Straw and residue conditions: resistance to cutting, humidity, quantity and management.
- Seeder: weight and dynamics.
- Disc: size, shape and profile.

For good results it is recommended:

- To work during the warmest hours of the day (after 10 in the morning).
- Work when the straw is either green or completely dried, never when it is only wilted.
- Operate when soil moisture is at the point of soils being friable.
- When using animal traction, never try to seed when more than 5 tons of dry matter per hectare is left on the surface.

Furrow opener

A furrow can either be opened by a chisel tine (= long, straight piece of metal with a flat end) or hoe, single disc at an angle to the furrow, double discs or by punch type injection. Usually the furrow opener is placed just before or on the tip of the tubes that drop the fertilizer and the seeds. The performance of the furrow opener depends on its geometric characteristics, the speed, the texture and density of the soil, the quantity of residues and the pressure placed on it by the seeder. It can take the form of:

- A chisel tine or hoe: commonly used in soils that have a higher resistance to penetration, but these will result in more problems with clogging the implement with residues, and cannot be used in areas with stones, trunks or a lot of roots.
- Single discs at an angle to the furrow.
- Double discs, either the same diameter or not and placed in an angle forming a "V" to each other. The additional effect is that residues not completely cut by the cutting disc, are cut by these discs resulting in less obstruction of the implement.
- Other types of openers, like inverted T and cross slot.

The rolling punch

The rolling punch injection is another form of furrow opener. The seed is placed between the fingers of two star-wheels which are at an angle comparable to a double disc, punched into the soil and released. It handles residues quite well, but tends to clog when used in sticky soils.

It is recommended for annual crops that fertilizer should be placed about 5 cm besides and beneath the seeds. In a direct seeder this would mean that the furrow opener for fertilizer is offset to one side of the line of work of the seeder. However, in many planters the fertilizer is placed under the seed, but in the same line.

Advantages and application of the innovation

- low disturbance reduces soil moisture loss.
- weed seeds are less likely to germinate and grow on the undisturbed soil surface.
- low disturbance systems use less fuel for field operations.
- crop residue cover protects soil from wind and water erosion.
- standing stubble traps snow.

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertili-ty	Physical soil fertility	Other aspects
	x	x	x	x	1)

1): Environmental aspects

Reference:

http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex3483
http://teca.fao.org/es/read/7417
Guzman, G. (2011): Development of sediment tracers to study soil redistribution and sediment dynamic due to water erosion. Dissertation – University of Cordoba.

D.13 Maintain organic matter content of the soil by the incorporation of straw

Related to MP: MP36 Return of crop residues

Related to FTZ: ENZ4+6+7_SL1_TXT0+1 – Arable / specialized

Key points

- Incorporation of straw improves soil organic matter content,
- Supports soil fauna,
- Temporarily immobilizes mineral nitrogen,
- No damage to soil structure due to straw removal by heavy machines.

What is it?

- After harvest straw residues are chopped and incorporated into the soil

How does it work / is it applied?

- Straw residues are chopped after or during harvest,
- After chopping, residues are incorporated into the soil (see FS Compact disc harrow for residues management; FS Stubble cultivator for shallow residues and seedbed management; FS Disc harrows with 2 rollers for small farms and fields).

Advantages and application of the innovation

- Improves organic matter balance,
- Improves soil fauna,
- Due to its high C:N ratio, the incorporated straw will temporarily immobilize mineral nitrogen,
- No damage to soil structure by heavy machines with high tire pressure to remove straw,
- Incorporation reduces disease pressure by fungi from straw residues as compared to leaving the stubbles on the field.

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
X	X	X	X	X	

Reference:
http://www.kennisakker.nl/kenniscentrum/document/30-vragen-en-antwoorden-over-bodemvruchtbaarheid

D.14 Manganese sensor

Related to MP: MP 'not-coded' Soil analysis (Development and adoption of fertilization plans)

Related to FTZ: ENZ5_SL5_TXT2 - Dairy cattle / permanent grass
ENZ8_SL3+1_TXT2 - Arable / cereal, permanent crops
ENZ6_SL3_TXT3 - Mixed farms

Figure 67: Manganese sensor (Copyright: LAND-DATA Eurosoft GmbH & Co. KG)

Key points

- Evaluation of the manganese supply of the youngest developed leaf
- Adapted leaf fertilization of the plants
- Easy handling of the technical device

What is it?

- Technical device to evaluate the manganese supply of the youngest developed leaf and the missing amount of manganese fertilizer/surface unit

How does it work / is it applied?

- The evaluation of the manganese supply based on a higher fluorescence of the photo system with manganese deficiency compared to a sufficient manganese supply.
- This very specific response is measured with a technical device (manganese sensor).
- The measured values and their classification are presented immediately on the display.
- The device uses six classes for the classification: from "good manganese supply" to "extreme manganese deficiency".
- The data of the measurement is stored by the sensor and could be read and edited on a computer.

Advantages and application of the innovation

- Can be used for all the crops in all stages of development in the vegetation season
- Fast adaption of the crop fertilization during the vegetation season
- Evaluation of the manganese supply of the youngest developed leaf, therefore no influence by recent leaf manganese fertilizations
- Direct measurement on the field or later on after sampling
- Reduced work load and costs

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
x					

Reference:

Kuchenbuch, R. (2013): Spurenelemente im Getreidebau düngen? Welche Entscheidungshilfen stehen zur Verfügung? Getreide Magazin 06, 44-47.
http://www.eurosoft.de/produkte/mangan-tester.html
Borchert, A. (2014): Dem Mangan auf der Spur. Top agrar 4: p. 64-65.
Olf, H.-W. & Pralle, H. (2010): Erst testen, dann düngen. Dlz agarmagazin Pflanzenbau: p. 34-37.

#1) young leaf has to fix at a clip; clip with an open slider
#2) clip with closed slider; 20 min to darken the leaf
#3)30 clips belongs to the diagnose set
#4) after darken the clip will connected to quick test and will get light impulse
#5) photo cell, (here without a leaf) measures fluorescence depending on the manganese supply
#6) the result will be displayed as PEU value and asterisk (the more asterisk the less Mn deficit)

Figure 68: Application of manganese sensor (Olf & Pralle 2010)

D.15 Soil nutrient sensor

Related to MP: MP ‘not-coded’ Soil analysis (Development and adoption of fertilization plans)

Related to FTZ: ENZ5_SL5_TXT2 - Dairy cattle / permanent grass
ENZ8_SL3+1_TXT2 - Arable / cereal, permanent crops
ENZ6_SL3_TXT3 - Mixed farms

Key points

- On farm analysis by a soil nutrient sensor
- Evaluation of different nutrient contents e.g. NO3, NH4, K and PO4
- Adaption of fertilization

What is it?

- The soil sensor evaluates different nutrient contents e.g. nitrogen to adapt the fertilization to the crop needs and to reduce nutrient losses by leaching or emissions.

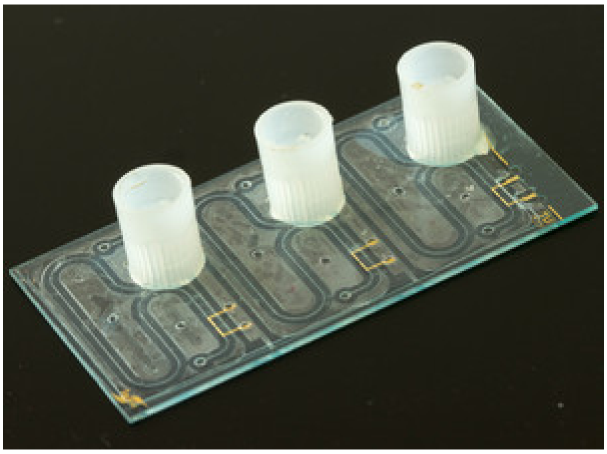


Figure 69: A unit of three chips for the measurement of NO3, NH4, K and PO4 (chip size 16 mm x 26 mm) (Copyright: TU Wien)

How does it work / is it applied?

After soil sampling the sample is homogenized and a defined amount (15 g) of soil is weighed on a scale. Afterwards the soil is sieved and diluted with an extraction liquid. The solution is filtered and stored till the sample has to be analyzed by the soil nutrient sensor.

First the prepared soil sample is injected into a capillary and a high electrical voltage is applied. Many of the dissolved chemical constituents are electrically charged and start to move in the electric field. Depending on the molecular size and charge (defined per nutrient) each molecule moves with its individual speed through the buffer liquid. So the different nutrient compounds of the solution can be easily separated by the suggested method. They move through the capillary and pass the detection unit (chip) where they are recorded. The nutrients are determined depending of their passing time finally.

Advantages and application of the innovation

- On farm analysis by a soil nutrient sensor
- Evaluation of different nutrient contents e.g. NO3, NH4, K and PO4
- Fast and easy handling of the technical device
- Reduction of the nutrient losses by leaching or emissions

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertili-ty	Physical soil fertility	Other aspects
x	x		x		

Reference:
Smolka, M. (2014): Lab on Chip Soil Nutrient Sensor – iMetos NPK. AgriFuture Days 2014, Villach. http://www.optifert.eu/

D.16 The use of digestate and its solid / liquid separation products

Related to MP: MP ‘not-coded’ Application of digestate (from biogas plants)

Related to FTZ: ENZ4+7_SL1_TXT1 - Dairy cattle / permanent grass

Key points

- Digestate application as fertilizer or soil improver

What is it?

- Digestate is the waste product from biogas production which is used to replace fertilizers or used as soil improver. It can be applied untreated, or separated into solid and liquid, enabling export or application of the separate products.

How does it work / is it applied?

Theory

- Organic products are used for biogas production and the waste is called digestate
- Origin is from animals (manure) or plants (crop residues e.g. sugar beet heads)
- Digestate originating from animal manure is subject to (in NL) the manure law in application guidelines (limited to 80 kg P_2O_5 /ha or 170 kg N-total/ha)
- Digestate originating from crop residues is subject to the “additional organic fertilizer“ application guidelines (limited to 80 kg P_2O_5 /ha or N mineralized (N-total * relative N fertilizer value) < crop specific application rate)
- Waste product can be separated into a solid or liquid fraction (6:1), or used untreated

Figure 70: Manure is digested in on farm facilities into gas and digestate (http://edepot.wur.nl/28917)

Practice: Use of liquid fraction (from manure and plant origin) (see FS Use of liquid fraction of digestate as fertilizer)

- Liquid fraction contains relatively more NH_4 and less P_2O_5 than solid fraction,
- Liquid fraction is applied as slurry to fertilize crops,

- Liquid fraction can be used as side dressing (potatoes, maize, onions),
- Application rate depends on “crop specific application rate”,
- Application preferably in crops with high N-demand and short uptake period (avoid leaching losses),
- If manure origin: incorporation compulsory to minimize ammonium losses,
- Compensate N-fertilizer application to expected N-mineralization ,
- In potato and beets recommended application rate not more than 2/3 of total N-application,
- If manure origin: application allowed between 1 February and 1 August, or till 1 September when green manure or winter rape seed is sown before 1 September; or on land where flower bulbs are to be planted,
- Plant origin: hardly available yet.

Practice: Use of solid fraction (manure and plant origin)

- Solid fraction contains relatively more P_2O_5 and less N than liquid fraction,
- Applied with solid manure spreader as soil improver,
- If manure origin: application allowed between 1 February -1 September (NL),
- If plant origin: application allowed year round (NL).

Practice: Use of untreated fraction (manure and plant origin)

- Untreated fraction is easy to handle and more homogeneous than slurry
- Mostly used as nitrogen fertilizer source
- Nitrogen fertilizer replacement value higher than of undigested product
- If manure origin: subject to above statutory regulations / constraints
- If plant origin: subject to above statutory regulations /constrains

Advantages and application of the innovation

- Substantial part of N in unseparated digestate is mineral when applied,
- Liquid fraction can replace fertilizer use during the growing season,
- Application includes application of micro nutrients,
- Digestate is thin and homogeneous, so easy to handle (pumping),
- Digestate is practically free of weed seeds or diseases due to the digestion process
- Digestate usually smells (much) less than manures and slurries,
- N-release of liquid and untreated fraction is faster than of undigested product and comes within the same year of application,
- N-replacement value (‘fertilizer equivalency’) of liquid and untreated fraction higher than of undigested product.

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertili-ty	Physical soil fertility	Other aspects
X	X		X	X	1)

1): due to digestion process digestate free of diseases and weed seeds, which will decrease pesticide use com-pared to the use of slurry

Reference:

http://edepot.wur.nl/28917
https://mijn.rvo.nl/home

D.17 Use of liquid fraction of digestate as fertilizer

Related to MP: MP 'not-coded' Application of digestate (from biogas plants)

Related to FTZ: ENZ12_SL1_TXT1+2+3 - Arable/ cereal
ENZ12_SL3_TXT2, ENZ12_SL4_TXT2+3 - Arable/ cereal

Key points

- addition of organic matter to the soil
- addition of readily available nutrients to the soil

What is it?

Liquid digestate distributes as an organic fertilizer. Digestate is the product obtained from anaerobic digestion of various organic materials: manure crops, organic wastes from agrifood industry. The liquid fraction is obtained after mechanical separation of digestate. It can be used as a fertilizer.

Figure 71: Trailing shoe distribution system or slurry injection device (source: Riva et al. 2013)

How does it work / is it applied?

The liquid fraction of digestate (see FS The use of digestate and its solid / liquid separation products) can be a valuable fertilizer because of its high content in readily available N (high NH_3/total N). The anaerobic digestion process determines a reduction of labile organic matter, but it does not reduce the total amounts of nitrogen and phosphorus; a large portion of organic N is converted to ammonia.

The amount to be distributed should be calculated on the basis of a recent chemical analysis of liquid digestate, and accounting for the crop requirements (nutrient management plan).

A rapid incorporation is needed to reduce NH_3 volatilization, but digestate normally infiltrates into the soil more rapidly than slurry. As for all manures, summer crops take more advantage of released nutrients than winter cereals, therefore spring pre-sowing and late spring top dressing applications are recommended.

Liquid digestate can be distributed using normal farm machinery for slurry. A trailing shoe distribution system or slurry injection is recommended to reduce volatilization of ammonia and odour emission. Alternatively, plough the soil immediately after slurry application.

A progressive increase in nutrient availability across years is expected, as for all organic fertilizers.

Advantages and application of the innovation

- low-cost and low-energy production organic fertilizer
- recycling an organic waste after biogas production
- reduction of mineral fertilizer use
- relevant nutrient supply, moderate effect on soil physical properties
- positive effect on soil life

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
x	x	x	X	x	1)

1) Reduction of mineral fertilizer use

Reference:

Riva, C., Orzi, V., Adan,i F., Carozz, M., Acutis, M., Sommariva, F., Boccasile, G. (2013): L' uso del digestato in campo sostituisce i concimi chimici. L'Informatore Agrario num. 09, pag. 50 del 07/03/2013
Come fertilizzare con il digestato. L'Informatore Agrario num. 29 Supplemento Stalle da latte, pag. 34 del 17/07/2009
http://www.biogas-info.co.uk/
http://www.iea-biogas.net/files/daten-redaktion/download/publi-task37/digestate_quality_web_new.pdf
http://www.biofertiliser.org.uk/pdf/Anaerobic-Digestion-Quality-Protocol.pdf

D.18 The use of DGPS-RTK to apply slurry in rows in maize

Related to MP: MP ‘not-coded’ Row application of fertilizer + MP24 Controlled traffic farming

Related to FTZ: ENZ4_SL1_TXT2+3 – Arable / specialized + cereals

Key points

- The DGPS-RTK system eliminates the need to combine various operations simultaneously,
- Field operations can be executed successively, allowing to optimize use of available machinery and labor,
- Slurry can be injected shortly (some days) before maize is planted in proximity of the injected manure row,
- Improves nutrient use efficiency from slurry applications,

What is it?

- A tractor equipped with differential global positioning system (DGPS) and a real time kinematic (RTK) (see FS DGPS-RTK to drive over the field) injects manure in the first field operation and sows maize seeds in a second field operation shortly after manure injection

Figure 72: The manure injectors are positioned at each side of the to be planted maize row (left); two manure rows at 12 cm deep are placed and registered with DGPS. In a day, the maize seed is planted exactly in between the manure rows (right; http://edepot.wur.nl/206790)

How does it work / is it applied?

- A receiver uses satellite data in combination with an identified location at the ground to improve estimates on the current position from several meters to approximately a 1 cm
- This allows tractors or equipment on which the receiver is placed to register the exact track when injecting the slurry 12 cm deep at 9 cm at each side of the expected maize seed rows which are spaced at 75 cm,
- The second field operation follows exactly the same track, seeding maize seeds at 5 cm deep in between or close to the slits with injected slurry (no damage due to ammonium will occur)

- In cold springs a higher phosphate concentration by row application of manure close to the roots improves yield

Advantages and application of the innovation

- This technique facilitates planting of crops close to but not too close to the rows of previously applied manure,
- Space between slurry at 12 cm deep and maize seeds at 5 cm deep is enough to avoid crop damage due to ammonium concentrations of slurry,
- The nutrient use efficiency of the slurry application is improved by 20% relative to the standard practice (slurry injecting before ploughing and seed bed preparation) as nutrients are positioned close to the roots
- The soil treatment operation after manure application to evenly distribute the manure in the plough layer to guarantee availability to the roots, is not necessary any more
- This technique finally enables row application of slurry as it resolves the bottlenecks in field operations logistics.

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
X	X			X	1)

1): improves nutrient use efficiency

Reference:
http://edepot.wur.nl/249908
http://edepot.wur.nl/206790

D.19 Soil scanner

Related to MP: MP 'not-coded' Use of smart N indicators to yearly adapt N fertilization or precision farming

Related to FTZ: ENZ4_SL1_TXT1 - Arable and mixed farms
ENZ6_SL2+3_TXT3 - Arable farms
ENZ6_SL1_TXT1 - Arable / cereal and mixed farms

Key points

- non-invasive method to measure soil heterogeneity
- high resolution soil property maps
- precision farming

What is it?

Measurement systems that allow non-invasive to get high-resolved information of soil heterogeneity.

EM 38 (http://www.agricon.de/produkte-leistungen/kartierung-agronomie/ bodenscanner)

Veris 3100 (http://www.veristech.com/the-sensors/v3100)

ARP (http://www.geocarta.net)

Geophilus (http://www.geophilus.de)

Figure 73: Soil scanner for commercial soil mapping

How it works / is applied?

The measurement systems showed above measure the electrical conductivity or its reverse expression – the electrical resistivity of soils. Two principal measurement principles are applied for these measurements. The EM28 works contactless based on the electromagnetic induction principle. ARP, Veris 3100 and Geophilus work with galvanic coupling rolling electrodes. For technical details and pros and cons see Adamchuk et al. (2004).

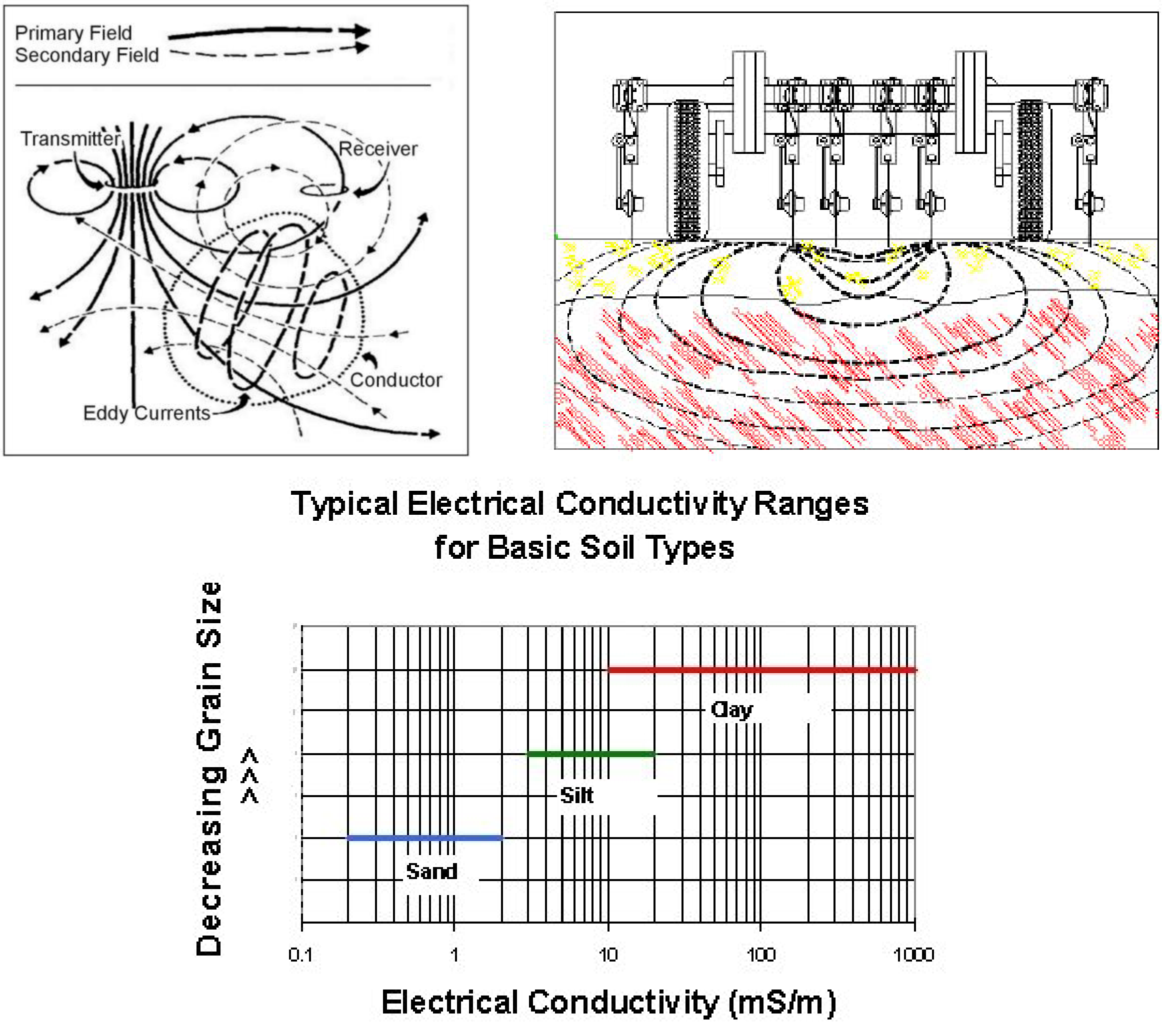


Figure 74: Measurement principles of EM38 (left, www.epa.gov) and ARP, Veris 3100 and Geophilus (right, www.fvmmi.hu/) and typical electrical conductivity ranges of basic soil types (bottom, www.geoprobe.com/sites/default/files/images/di/ec/figure-3.jpg)

Advantages and application of the innovation

- Dividing the field in management zones (assumption: zones with similar sensor values = zones with similar physical soil properties)
- Management zones can be applied for:
  - Soil sampling (pH, P, K, Mg,…) (see FS Soil nutrient sensor) and corresponding fertilization/manure application
  - Differentiating sowing density (e.g. less seeds in areas with lower soil water holding capacity)
  - Differentiating depth of tillage
  - Differentiating irrigation amount
  - Creating yield potential maps -> differentiating N fertilization

Figure 75: Resulting map by the soil scanner (http://www.agricon.de/produkte-leistungen/kartierung-agronomie/bodenscanner)

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertili-ty	Physical soil fertility	Other aspects
x	x		x	x	1)

1): Reduction of nutrient losses to the environment

Reference:

Adamchuk, V.I.; Hummel, J. W.; Morgan, M. T.; and Upadhyaya, S. K., (2004). On-the-go soil sensors for precision agriculture. *Biological Systems Engineering: Papers and Publications.* Paper 1. (http://digitalcommons.unl.edu/bio-sysengfacpub/1)
http://www.agricon.de/produkte-leistungen/kartierung-agronomie/bodenscanner
http://www.geocarta.net
http://www.geophilus.de
http://geoprobe.com/sites/default/files/images/di/ec/figure-3.jpg
http://www.epa.gov
http://www.fvmmi.hu/
http://www.veristech.com/the-sensors/v3100

Category:
E. CROP PROTECTION

E.1 Désherbinage

Related to MP: MP41 Mechanical weeding + MP24 Controlled traffic farming

Related to FTZ: ENZ7_SL2_TXT2 - Arable farms
ENZ12_SL3_TXT4 - Arable farms
ENZ7_SL2_TXT3 - Dairy cattle

Key points

- Combination of spraying herbicide on the row and hoeing in between rows
- Decrease of herbicide use (lowers production costs)

What is it?

- Combination of a sprayer on a hoeing machine that enables targeting the row, while inter-row is hoed.

How does it work / is it applied?

- Hoeing and drilling equipment needs the same numbers of rows, otherwise maize plants will cut
- Technique often requires two steps
    - First step:
        - Row application of herbicide at the 3 or 4 leave stage of maize with maximum speed of 8 km/h
        - At the same time hoeing inter-row
        - Discs are lowered to protect rows against soil which could fly into the row
        - Technique application with sufficient relative humidity and dry weather conditions in the next 2 to 3 days
    - Second step:
        - 8 to 10 leave stage
        - In the most cases without herbicide application, only hoeing with maximum speed of 12 km/h
        - Protection discs are lifted to get slight dams
        - This step could be used drill underseeding crops (see FS Underseeding under maize with herbicide I; FS Underseeding under maize with herbicide II; FS Undersowing of a green manure under maize after maize sowing; FS Undersowing of a green manure within maize at the same time as maize sowing; FS Underseeding under maize combined with mechanical weed control and herbicide banding)
- Depends on the herbicide strategy:
    - If herbicide is to be sprayed at pre-germination of the weeds, a sprayer has to be adapted on the sewer (spraying kit). A nozzle per sewer rank spreads at 20 cm width on each of the sewing rank, during sewing operation.

  - o Post-germination weed control requests spreading at the right moment (usually 20 days after the sewing date). Efficiency will strongly depend on the growth of the weeds and that strategy is not often recommended by technical advisors.
- Hoeing is realized with a specific material. There are several on the market, simple (mechanic), guided by camera, guided by GPS (see FS DGPS-RTK to drive over the field).

Advantages and application of the innovation

- Pros: reduces herbicide costs, favors water circulation in the soil (hoeing)
- Cons: can increase erosion if the row are seeded along a sloppy field
- Addon to a family of techniques
- Marketed product (machinery), longlife learning courses available in all regions

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
x		x		x	1)

1): cost reduction

References:

http://www.reussir-grandes-cultures.com/actualites/tournesol-adopter-le-desherbinage-pour-reduire-ses-intrants:20240.html
http://www.dordogne.chambagri.fr/fileadmin/documents_ca24/Internet/AgronomieFourrages/201105_ArtTech_Desherbinage.pdf
http://www.bretagne.synagri.com/ca1/PJ.nsf/TECHPJPARCLEF/17418/$File/0031_333.pdf?OpenElement
http://www.terre-net.fr/observatoire-technique-culturale/strategie-technique-culturale/article/gratter-l-inter-rang-et-pulveriser-le-rang-un-must-217-100422.html
http://www.lafranceagricole.fr/dossiers/cultures/desherbage-du-mais-les-programmes-de-traitement/le-desherbinage-reduit-les-phytos-sur-mais-6703.html

E.2 Autonomous platforms

Related to MP: MP41 Mechanical weeding + MP24 Controlled traffic farming

Related to FTZ: ENZ7_SL2_TXT2 - Arable farms
ENZ12_SL3_TXT4 - Arable farms
ENZ7_SL2_TXT3 - Dairy cattle

Key points

- Precision farming
- Enables automated and semi-automated tasks like mechanical weed control or precision seeding

Figure 76: New automated agricultural platform (www.kongskilde.com); Multi-functional field robot for agricultural applications (www.amazone.de)

What is it?

- It’s an electrically driven tracked module.
- The track module does not use fuel (cost saving) and is light (avoids compaction). It also saves time (autonomous).
- The module can so far be combined with a seeder or discs for hoeing (see Figure 76).

How does it work / is it applied?

- Batteries can be refilled when back at farm.
- The module uses GPS to find the appropriate field (more efficient for fields located close around the farm because it does not handle road traffic control).
- Once on the field, it uses cameras and sensor to guide operations on the row.

Advantages and application of the innovation

- The autonomous machine performs
  - hoeing
  - precision direct seeding
  - phenotyping

  - independent and objective penetrometer measurements
  - camera based plant precise herbicide application
- Decreases fuel use
- No compaction
- Reduces labour costs
- New generation of machines
- Product on the market but yearly improvements from machine industry

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertili-ty	Physical soil fertility	Other aspects
x				x	1)

1): reduces compaction

Reference:

http://www.kongskilde.com/ro/en/News/Year%202013/09-09-2013%20-%20New%20automated%20agricultural%20platform%20-%20Kongskilde%20Vibro%20Crop%20Robotti
http://www.amazone.de/1857.asp
BoniRob - Multifunktionaler Feldroboter für landwirtschaftliche Anwendungen. AMAZONEN-Werke

E.3 Vegetated buffer strips using double seeded density crop

Related to MP: MP44 Patches or stripes of natural vegetation

Related to FTZ: ENZ12_SL1_TXT1+2+3 - Dairy cattle / temporary grass
ENZ12_SL1_TXT1+2+3 – Arable / cereal
ENZ12_SL3_TXT2, ENZ12_SL4_TXT2+3 - Arable/ cereal

Key points

- the crop itself is used as a buffer strip just increasing the seeding density and changing the sowing direction

What is it?

The downhill portion of the field, next to the water course, can stop most of soil, nutrients and pesticides transported by runoff water. Normally, buffer strips are recommended, but they reduce the field size. The use of double seeding of the crop itself reduces the volume of runoff water and soil loss, thus avoiding additional buffer strips.

Figure 77: Buffer strips (http://www.topps.unito.it/ruscellamento/misure-di-mitigazione/pratiche-colturali.html)

How does it work / is it applied?

It is realized by passing twice the seed drill in the downhill field strip and in field areas which are prone to runoff, so as to alternate areas in which the crop density is higher than that in the rest of the field. Double seeding is applied in strips perpendicular to the direction of the slope or in the twaleg areas, which are prone to higher runoff and erosion.

The same method can be used for vegetated buffer strips also within the field, to reduce the size of large fields. In this case, strip double cropping is made along contour lines.

The crop is sown across the main slope direction, in order to slow runoff water speed and promote the deposition of sediments. No pesticide and fertilizer is applied in buffer strips next to the water course.

The reduction of nutrients and pesticide load to the water course can be 90-99%, depending on its width (3-20 m).

Advantages and application of the innovation

- environmental impact reduction
- runoff and erosion control
- slight reduction of yield in the vegetated strip

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertili-ty	Physical soil fertility	Other aspects
				x	1)

1): environmental impact reduction, runoff and erosion control

Reference:
http://www.topps.unito.it/ruscellamento/misure-di-mitigazione/pratiche-colturali.html
http://www.minambiente.it/sites/default/files/archivio/allegati/vari/Prodotti_fitosanitari_-_Misure_di_mitigazione.PDF

E.4 Integrated pest management (IPM)

Related to MP: MP 'not-coded' Integrated weed management (only post-emergence)

Related to FTZ: ENZ13_SL1+2+3+4_TXT4 - Arable/Cereals
ENZ13_SL2+3+4_TXT3 - Permanent crops

Key points

- Possible crop protection techniques including monitoring, crop sanitation, cultural and mechanical control, and the introduction of beneficial insects and mites
- Chemical control is considered just only as a corrective measurement

What is it?

- Process of the balanced use of cultural, biological, chemical procedures that are environmentally compatible and economically feasible to reduce pest populations to tolerable levels

How does it work / is it applied?

Cultural control

- Increased resistance of the crop can be achieved by taking good care of growing.
- Sub-optimal growing factor(s) plants express symptoms of plant stress.
- Use resistant or tolerant varieties when and where appropriate.
- Grow susceptible varieties preferably in a period when the level of infestation is low.
- Avoid high planting densities. Use plant material from tissue culture as much as possible.
- Use plant material from nurseries where IPM is practiced as much as possible.
- Prevent plants from being under- or overloaded with fruits or flowers. Use crop rotation.

Crop sanitation

- Plant material must be free from pests and diseases.
- Remove old foliage and weed promptly and carefully.
- Check the crop regularly for the presence of pests and diseases during the complete crop cycle.
- Avoid plant damage as entry for secondary infestations.
- Organize crop work so that workers move from the clean towards the infested areas of the crop.
- Prevent transmission of harmful organisms by people, machines or tools and water.
- Remove refuges for harmful organisms.
- The ground or the substrate for the crop should not contain any diseases or pests.

Mechanical control

- Keep insects away from the plants by netting.
- Trap insects (sticky traps, insect-o-cutors, trap plants, pheromone traps).
- Use temperature treatment (hot water, hot air, solarisation, steaming) or flooding as a technique to kill harmful organisms.

- Remove infested plant materials.
- The ground or the substrate for the crop should not contain any diseases or pests.

Biological control

- Introduce beneficial organisms at the right time (the earlier applied the lower the number, the better the effect).
- Pay attention to the quality of the material.
- Obtain the material from a recognized supplier.
- Keep in mind the indicated storage temperature and the use-by-date.
- Become acquainted with the biology of the beneficial.
- Encourage spontaneously occurring natural enemies to enter the crop.
- Use attractive plants or banker plants (*Daruta* L., *Ricinus communis* L.)
- Ensure that operations in the farm do not substantially reduce the population of beneficial.
- Ensure that other natural enemies are not harmed by the application of natural products.

Chemical control

- Use selective application pesticides and techniques.
- Use pesticides with a short persistence.
- Ensure that the plant propagator does not use pesticides with a long persistence.
- Avoid the use of pesticides with a long persistence prior to beginning biological control.
- Avoid dusting any products, as dusting inhibits the development of beneficial.
- Be aware that pesticides or their vapor may drift from the area of application into an area with biological control.

Advantages and application of the innovation

- Method to develop better decision making in crop protection.
- Integration of natural resources and regulating mechanisms in farming activities to minimize the contributions of inputs from outside the farm.
- Ensures sustainable food production and other high quality products by the preferential use of technologies that respect the environment.
- Eliminate or reduce the sources of pollution currently caused by agriculture.
- Maintains the multiple functions of agriculture.

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
X	x	x	x	x	1)

1): Economical aspects

Reference:
http://entomologia.rediris.es/aracnet/6/entapl/
http://www.koppert.com/
http://www.plantprotection.org/PlantProtection/Introduction.aspx
http://www.agromatica.es/

E.5 Cultural weed control

Related to MP: MP 'not-coded' Integrated weed management (only post-emergence)

Related to FTZ: ENZ13_SL1+2+3+4_TXT4 – Arable / Cereals

Key points

- Cultural methods, alone cannot control weeds, but help in reducing weed population. They should, therefore, be used in combination with other methods.
- In cultural methods, tillage, fertilizer application and irrigation are important.
- In addition, aspects like selection of variety, time of sowing, cropping system, cleanliness of the farm etc., are also useful in controlling weeds.

What is it?

- long-term weed management strategy based on the practical application of the ecological concept of 'maximum diversification of disturbance' (diversifying crops and cultural practices in a given agro-ecosystem)
- a continuous disruption of weed ecological niches (Liebman and Davis, 2000) to minimize risk of weed flora evolution (presence of a limited number of highly competitive species)

How does it work / is it applied?

• In practice, weed management strategies should integrate indirect (preventive) methods with direct (cultural and curative) methods. The first category includes any method used before a crop is sown, while the second includes any methods applied during a crop growing cycle.

• Methods in both categories can influence either weed density and/or weed development. However, while indirect methods aim mainly to reduce the numbers of plants emerging in a crop, direct methods also aim to increase crop competitive ability against weeds.

Classification of cultural practices potentially applicable in an integrated weed management system, based on their prevailing effect.

Cultural practice	Category	Prevailing effect	Example
Crop rotation	Preventive method	Reduction of weed emergence	Alternation between winter and spring-summer crops
Cover crops (used as green manures or dead mulches)	Preventive method	Reduction of weed emergence	Cover crop grown in-between two cash crops (see A below tables)
Primary tillage	Preventive method	Reduction of weed emergence	Deep ploughing, alternation between ploughing and reduced tillage
Seed bed preparation	Preventive method	Reduction of weed emergence	False (stale)-seed bed technique
Soil solarization	Preventive method	Reduction of weed emergence	Use of black or transparent films (in glasshouse or field)
Irrigation and drainage system	Preventive method	Reduction of weed emergence	Irrigation placement (micro/trickle-irrigation), clearance of vegetation growing along ditches

Crop residue management	Preventive method	Reduction of weed emergence	Stubble cultivation (see B below tables)
Cultural practice	**Category**	**Prevailing effect**	**Example**
Sowing/planting time and crop spatial arrangement	Cultural method	Improvement of crop competitive ability	Use of transplants, higher seeding rate, lower inter-row distance, anticipation or delay of sowing/transplant date
Crop genotype choice	Cultural method	Improvement of crop competitive ability	Use of varieties characterized by quick emergence, high growth and soil cover rates in early stages
Cover crops (used as living mulches)	Cultural method	Improvement of crop (canopy) competitive ability	Legume cover crop sown in the inter-row of a row crop
Intercropping	Cultural method	Reduction of weed emergence, improvement of crop competitive ability	Intercropped catch crops
Fertilization	Cultural method	Reduction of weed emergence, improvement of crop competitive ability	Use of slow nutrient-releasing organic fertilizers and amendments, fertilizer placement, anticipation or delay of pre-sowing or top-dressing N fertilization
Cultivation	Curative method	Killing of existing vegetation, reduction of weed emergence	Post-emergence harrowing or hoeing, ridging (see FS Use of finger weeder)
Herbicide application	Curative method	Killing of existing vegetation, reduction of weed emergence	Pre- or post-emergence spraying
Thermal weed control	Curative method	Killing of existing vegetation, reduction of weed emergence	Pre-emergence or localized post-emergence flame-weeding
Biological weed control	Curative method	Killing of existing vegetation, reduction of weed emergence	Use of (weed) species-specific pathogens or pests

A: see additional fact sheets (FS Intercropping / green manure / catch crops; FS Fast growing cover crops (as green manures); FS Cover crops (as green manures) for maize; FS Cover crops (as green manures) for potato rotations; FS Nematodes reducing cover crops (as green manures); FS Soil structure improving cover crops (as green manures); FS Cover crops (as green manures) for sugar beet rotations; FS Cover crops (as green manures) for water protection areas; FS Catch crops as green manures; FS Green manure to reduce beet cyst nematodes; FS Green manure online decision support system; FS Use of green manure to limit potato cyst nematodes)
B: see additional fact sheets (FS Compact disc harrow for residues management; FS Stubble cultivator for shallow residues and seedbed management; FS Disc harrows with 2 rollers for small farms and fields)

Advantages and application of the innovation

- A highly diversified cropping system reduces risk of the development of herbicide-resistant weed populations.
- Cultural methods are easy to adopt and no residual problems.
- Technical skill is not involved.
- Effective weed control, no damage to crops.
- Crop-weed ecosystem is maintained.
- Vigorous and fast growing crop varieties are better competitors with weeds.

- Proper placement of fertilizers ensures greater availability of nutrients to crop plants, thus keeping the weeds at a disadvantage.
- Better irrigation practices to have a good head start over the weeds
- Higher plant population per unit area results in smothering effect on weed growth

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
x		x	x		1)

1): Economical aspects

Reference:
http://www.fao.org/docrep/006/y5031e/y5031e0e.htm
http://www.magrama.gob.es/ministerio/pags/biblioteca/hojas/hd_2006_2119-2120.pdf

E.6 Weed detection using UAV to adapt herbicide application

Related to MP: MP ‘not-coded’ Integrated weed management (only post-emergence)

Related to FTZ: ENZ4_SL1_TXT1 - Arable and mixed farms
ENZ6_SL1_TXT1 - Arable / cereal and mixed farms

Key points

- UAV application
- Image analysis
- precise and site-specific weed control

What is it?

- small unmanned aircraft vehicle (microcopter) with a modified RGB camera (see figure 1)
- spatial mapping of weeds from low altitudes

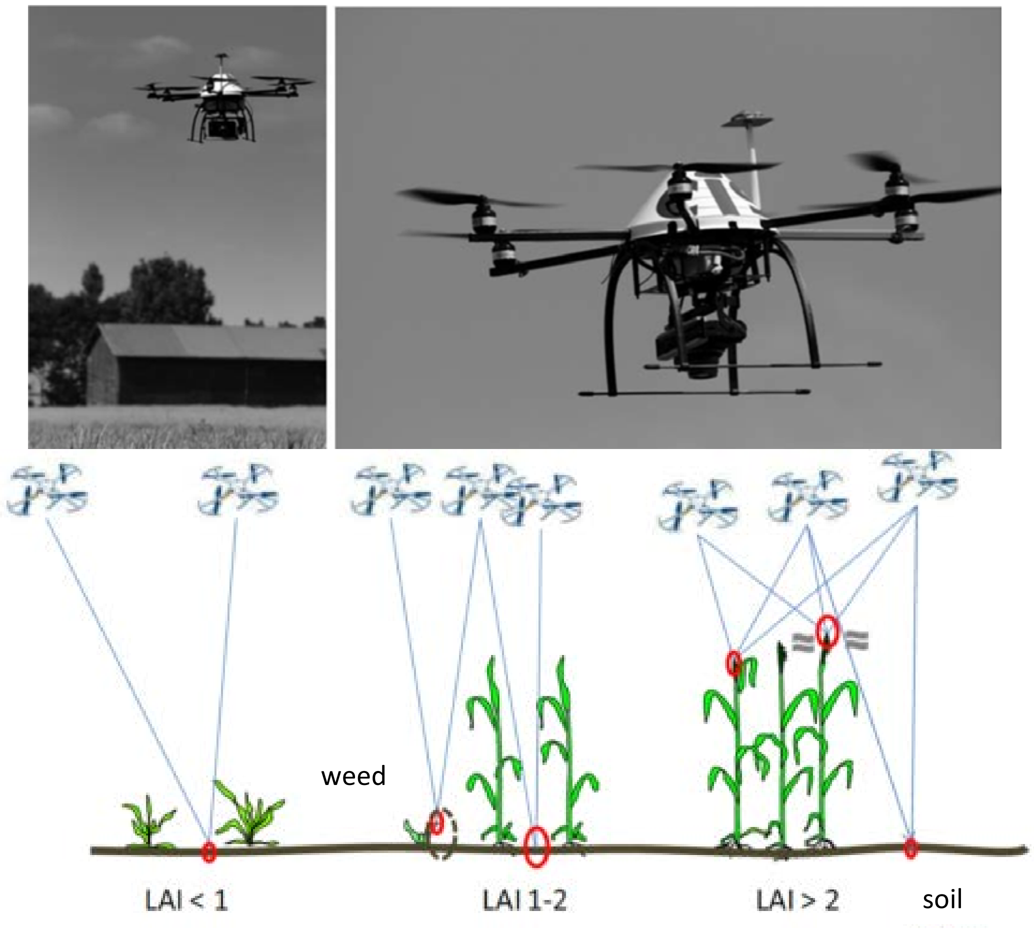


Figure 78: Flying UAV and detect of weed, plants and soil (Pflanz et al. 2014)

How does it work / is it applied?

- UAV application for image taking from agricultural fields
  - with modified RGB compact camera
  - Lens with focal distance of 16 mm
  - Low fly altitudes (10 m)
  - Picture every 4 seconds
- Image preparation
  - Mosaicing of the images
- Image analysis with web application (http://imaging-crops.dk)
  - Identification of thistle nests in a wheat field
  - Calculation of the potential application areas (see figure 2)
- Site-specific herbicide application

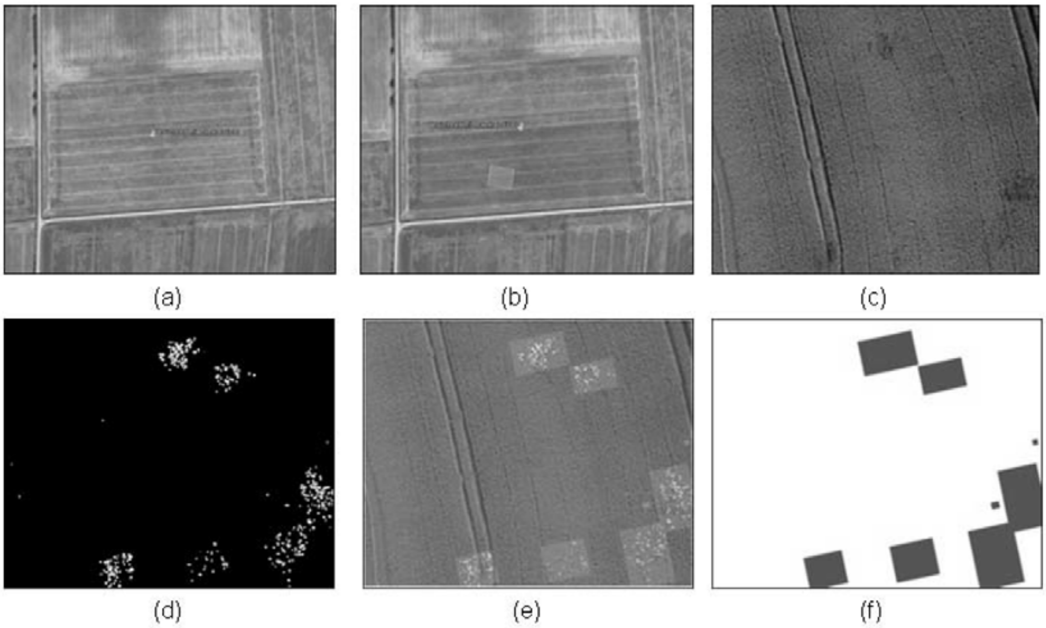


Figure 79: (a) and (b) images of total sample area and reference surface; (c) Georeferenced images of thistle clusters in maturing wheat; (d) Results of color segmentation; (e) and (f) manually labeled area of potentially site-specific herbicide application

Advantages and application of the innovation

- Flexible and continuous UAV flights for documentation
- High spatial resolution of images, real-time processing, lower costs
- Adapted herbicide application
- Reduction of herbicide

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertili-ty	Physical soil fertility	Other aspects
x					1)

1) Reduction of herbicides and economic aspects

Reference:

Pflanz, M., Feistkorn, D. & Nordmeyer, H. (2014): Unkrauterkennung mit Hilfe unbemannter Luftfahrzeuge. 26. Deutsche Arbeitsbesprechung über Fragen der Unkrautbiologie und -bekämpfung, 11.-13. März 2014 in Braunschweig, Julius-Kühn-Archiv, 443: p. 396 – 403.
Grenzdörffler, G. (2014) UAS zur hochgenauen und flächenhaften Bestimmung der Bestandeshöhe bzw. Biomasse. 19. Workshop Computer-Bildanalyse in der Landwirtschaft und 2. Workshop Unbemannte autonom fliegende Systeme in der Landwirtschaft: p. 14 – 23.
Dobers, E. (2012): Das Wissen kommt von oben: Drohnen und Fernerkundung für die Landwirtschaft. DLG Pressedienst.

E.7 Weed detection using weed app to recommend herbicides

Related to MP: MP 'not-coded' Integrated weed management (only post-emergence)

Related to FTZ: ENZ4_SL1_TXT1 - Arable and mixed farms
ENZ6_SL2+3_TXT3 - Arable farms
ENZ6_SL1_TXT1 - Arable / cereal and mixed farms

Key points

- Flexible mobile application
- Herbicide recommendations

What is it?

- An app with new developed independent, detailed herbicide recommendations for important crops and grassland

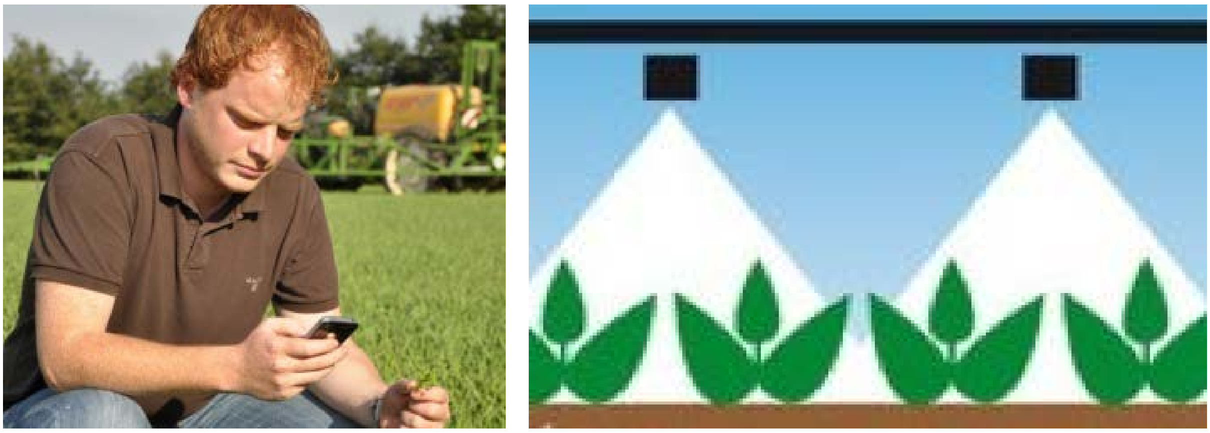


Figure 80: App and position to take pictures (http://www.topagrar.com/news/Acker-Wetter-Ackernews-Neuheit-Top-Unkraut-App-2014-1336368.html)

How does it work / is it applied?

- Weed identification based on three pictures, which show weeds in different development stages
- Choice of 1 to 3 main weeds in the stand to get specific adapted recommendation for herbicides / herbicides sequence
- Recommendation contains information about date of application, application amount, price per hectare, requirement of moisture, active ingredient, class of resistance, etc.
- Additional information – optimal and limiting application conditions, possible mixing, clean-ing of nozzles etc.
- Cross compliance relevant information about water bodies and margin structures according to recommended herbicides

Advantages and application of the innovation

- Extensive, detailed information about the herbicides
- Adapted herbicide application

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertili-ty	Physical soil fertility	Other aspects
x					1)

1) Economic and environmental aspects

Reference:
http://www.topagrar.com/news/Acker-Wetter-Ackernews-Neuheit-Top-Unkraut-App-2014-1336368.html

E.8 Underseeding under maize (Italian and/or perennial ryegrass) in combination with mechanical weed control and herbicide banding

Related to MP: MP41 Mechanical weeding + MP 'not-coded' Undersowing of green manure within maize

Related to FTZ: ENZ7_SL1_TXT1 - Dairy farming / permanent grassland
ENZ7_SL2_TXT3 - Arable / specialized crops

Key points

- Whole year round soil cover
- Soil quality improvement
- Reduced erosion risk

What is it?

- Sowing Italian and/or perennial ryegrass at a rate of 20 kg/ha at the maize 6-8 leaf stage.

How does it work / is it applied?

Underseeding:

- Broadcast seeding with a pneumatic spreader without a tillage operation (except for harrowing to cover the seeds);
- Emergence and vigor of ryegrass is not very successful in dry periods (competition with maize for the available water);
- The undersown grass can be seriously damaged by the machinery during the maize harvest.

Weed control

- When Italian ryegrass is used for underseeding, the use of the herbicides dimethenamid-P en S-metolachloor should be avoided as they severely hinder the grass growth

Advantages and application of the innovation

The success of undersowing grass in maize will depend strongly on weather and soil conditions. If successful:

- Positive effect for soil organic matter;
- Good soil cover during winter (protection against soil erosion by wind and water);
- Better trafficability at maize harvest;
- Less dirt on the roads;
- Whole year soil cover;
- No negative effect on maize production;
- Prevents nutrient leaching.

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertili-ty	Physical soil fertility	Other aspects
	X		X	X	1)

1) Erosion control; Prevents nitrate leaching

Reference:

Latre, J., Stoop, T., Haesaert, G., Verheyen, J., Coomans, D., Rombouts, G. (2007). Mogelijkheden van grasinzaai in maïs of gras/rogge inzaai na maïs met het oog op bodembedekking, reductie herbicide input en reststikstof. Landbouwcentrum voor Voedergewassen vzw. 8p.
De Vliegher, A., Latré, J., Carlier, L. (2009). Lolium multiflorum as a catch crop in maize. Proceedings of the 15th European Grassland Federation Symposium, Brno (Czech Republic), 83-86.

Category:
F. WATER MANAGEMENT

F.1 Centre pivot irrigation with mobile drip tubes to conserve water

Related to MP: MP53 Drip irrigation

Related to FTZ: ENZ6_SL1_TXT1 - Arable / cereal and mixed farms

Key points

- Combined irrigation system
- Water conservation

What is it?

- Centre pivot irrigation combined with mobile drip tubes
- Length of drip tubes is 5 to 7 m (is depends on the position in the centre pivot, i.e. the more outside the longer)
- a distance of 75 cm between drip tubes
- every 15 cm dropper are integrated into the drip tube
- the end of tubes is closed by plugs


Figure 81: Mobile drip irrigation (drip tubes) with center pivot irrigation machines for potatoes (source: Lüttger); mobile drip irrigation (drip tubes) with center pivot irrigation machine (source: Sourell et al. 2014)

How does it work / is it applied?

- Mobile drip tubes are pulled from the centre pivot system (see FS Centre Pivot / Linear irrigation system)

Advantages and application of the innovation

- Water reduction of 10 – 15 % by minimizing of evaporation compared to nozzle
- Increase of efficiency
- Energy conservation due to pressure reduction (nozzle 1.5 bar to drip tube 0.5 bar)

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertili-ty	Physical soil fertility	Other aspects
x					1)

1): economic aspects

Reference:

Sourell, H., Eberhard, J., Thörmann, H.-H. (2014): Bewässerung und Beregnung. In: Frerichs, Ludger (Hrsg.): Jahrbuch Agrartechnik 2013. Braunschweig: Institut für mobile Maschinen und Nutzfahrzeuge, S. 1-9.
Lüttger, A.: Mobile Tropfbewässerung – Bewässerung durch gezogene Tropfrohre an einer Kreisberegnungsanlage – Infoblatt
Sourell, H. (2009): Bewässerungstechnik: Wasserverteilung mit Blick in die Zukunft, Freilandberegnung. – In: Dirksmeyer, W. & Sourell, H. (eds.): Wasser im Gartenbau. Tagung zum Statusseminar.
LVLF (2005): Zusammenfassung der Versuchsberichte 1999-2004 – Pilotprojekt Beregnung des Landes Brandenburg: 35 p.
Lüttger, A. (2012): Ergebnisse des Pilotvorhabens Beregnung und Vergleich alternativer Erschließungsmöglichkeiten eines neuen Standortes für die Beregnung. 3. Brandenburger Beregnungstag Güterfelde – Kurzfassung der Vorträge

F.2 Use of centre pivot or linear irrigation system to optimize irrigation

Related to MP: MP54 Sprinkler irrigation

Related to FTZ: ENZ6_SL1_TXT1 - Arable / cereal and mixed farms

Key points

- Improved irrigation systems (water pressure, efficient water distribution, automatic)

What is it?

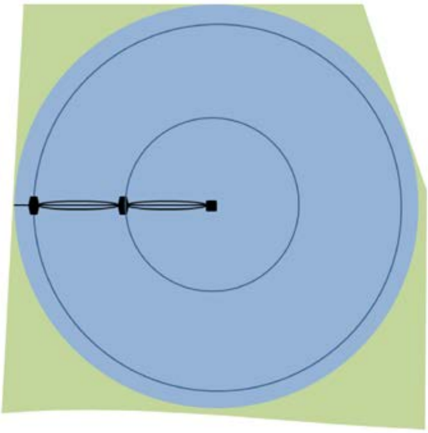


Figure 82: Schemata of a centre pivot irrigation system (blue = irrigated, green = unirrigated); picture of a centre pivot system with swing arm at the end (source: Mersch & von Haaren)

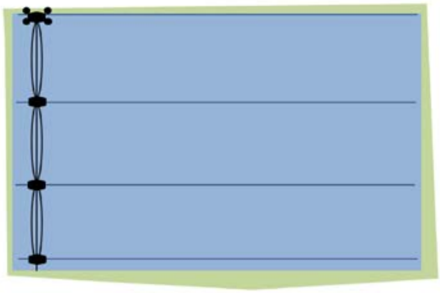


Figure 83: Schemata of a linear irrigation system (blue = irrigated, green = unirrigated); picture of a linear system (source: Mersch & von Haaren)

How does it work / is it applied?

- Centre pivot system:
  - Applied for square areas
  - Fixed position for stationary pivot tower
  - describing a circle
  - Maximal 80 % of the area
  - Extensions (e.g. swing arm) could enlarge irrigated area

Figure 84: Centre pivot irrigation system with swing arm (www.bauer-at.com)

  - Water supply with pipeline or well in the center of the system
  - Control by smart phone or PC
  - Applicable for terrain with slopes
- Linear system:
  - Applied optimal for rectangular areas
  - Tracking for mobile drive towers with tubes for water supply
  - Up to 100 % of the area
  - Control by smart phone or PC
  - Only applicable for 2 % slope (in direction of tubes) to 10 % slope (in driving direction)

Advantages and application of the innovation

Table 14: Comparison of reel and centre pivot system

	Reel system	Centre pivot
Operating hours (h/a)	1000	1000
Power (kW)	26.3	5.3
Energy (kW*h/a)	26300	5300
CO_2 emission (t/a)	23.7	4.8
Energy price (€/kW*h)	0.20	0.30
Costs of energy (€/a)	5260	1590

- 50 to 80 % reduction of energy for pivot and linear systems compared to reel systems
- centre pivot has 85 to 88 % accuracy of water distribution compared to around 60 % reel system
- reduced water pressure
- irrigation close to the soil and plant
- reduction of interception and evaporation
- homogenous water distribution
- small drop size and less wind drift

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
x					1)

1): economic aspects

Reference:

http://www.bauer-at.com/de/produkte/beregnung/pivot-linear-systeme
Claas, P. (2014): Energetische Optimierungsmöglichkeiten bei Beregnungsanlagen. Kartoffelbau 4: p. 32-35.
LZ Rheinland (2014): Effizientes Beregnungs-System, p. 67.
Mersch, I. & von Haaren, M. (2014): Zukunftsfähige Kulturlandschaften, Landwirtschaft im Klimawandel: Wege zur Anpassung – Forschungsergebnisse zu Anpassungsstrategien der Landwirtschaft in der Metropolregion Hamburg an den Klimawandel, Teil 5, Landwirtschaftskammer Niedersachsen, Bezirksstelle Uelzen.
Claas, P. (2013): Kreisregner liefern gute Arbeit ab – Systemvergleich, LAND & Forst 24: p. 30 – 32.
Claas, P. (2014): Langsam mit wenig Druck – Bauernzeitung 12: p. 36 – 37.

F.3 Combined centre pivot & linear irrigation system

Related to MP: MP54 Sprinkler irrigation

Related to FTZ: ENZ6_SL1_TXT1 - Arable / cereal and mixed farms

Key points

- Improved combined irrigation systems (water pressure, efficient water distribution, automatic, irregular field areas)

What is it?

Figure 85: Schemata of a combined irrigation system (blue = irrigated, green = unirrigated); picture of a combined system (source: Mersch & von Haaren)

Figure 86: Adaptation of irrigation schemata (www.bauer-at.com)

How does it work / is it applied?

- Combines all advantages of centre pivot and linear systems (see FS Centre Pivot / Linear irrigation system)
- Fully automatic device for optimal adaptation to irrigated area (100 %)
- Applied especially for L-shaped, curved or irregular area
- Control by smart phone or PC (see FS Leaf clamp to improve and to optimize irrigation scheduling and amount)

Advantages and application of the innovation

- reduced water pressure
- irrigation close to the soil and plant
- reduction of interception and evaporation

- homogenous water distribution
- small drop size and less wind drift

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertili-ty	Physical soil fertility	Other aspects
x					1)

1): economic aspects

Reference:

Mersch, I. & von Haaren, M. (2014): Zukunftsfähige Kulturlandschaften, Landwirtschaft im Klimawandel: Wege zur Anpassung – Forschungsergebnisse zu Anpassungsstrategien der Landwirtschaft in der Metropolregion Hamburg an den Klimawandel, Teil 5, Landwirtschaftskammer Niedersachsen, Bezirksstelle Uelzen
Claas, P. (2013): Kreisregner liefern gute Arbeit ab – Systemvergleich, LAND & Forst 24: p. 30 – 32.
http://www.bauer-at.com/de/produkte/beregnung/pivot-linear-systeme
AGRITECHNICA (2013): Precision Farming: GPS Corner for Irrigation accurate-to-the centimeter. p.3

F.4 Precision Irrigation - Variable Rate Irrigation System

Related to MP: MP54 Sprinkler irrigation

Related to FTZ: ENZ4_SL1_TXT1 - Arable and mixed farms

Key points

- Site-specific irrigation

What is it?

- advanced centre pivot irrigation system for variable rates
- Individual control of each nozzle

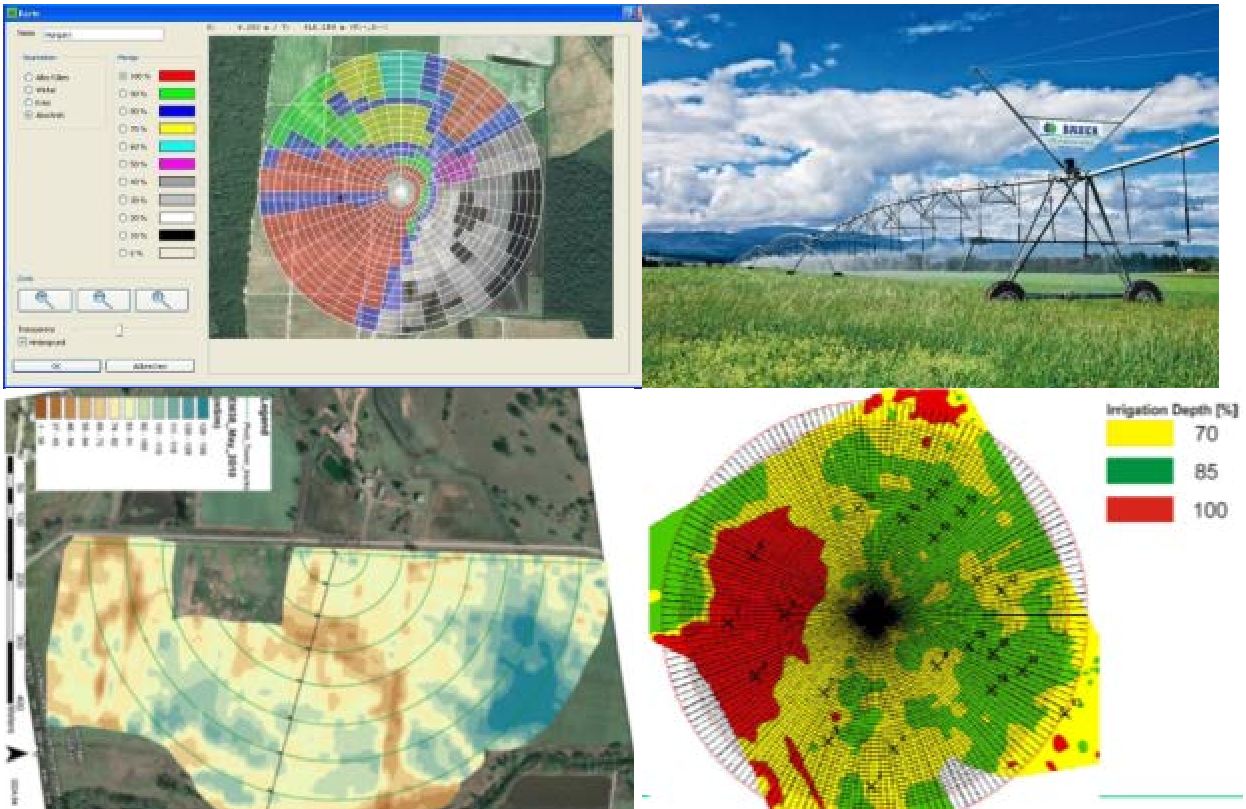


Figure 87: Software for VRI and centre pivot irrgation system (www.bauer-at.com); Centre pivot irrigation system and field map of the electrical conductivity as a basis for an application map for the water distribution (Hezarjaribi 2008); Derived irrigation zones (Derbala 2003)

How it works/applied?

- software needs field map of soil structure, obstacles, slopes
- field map of the electrical conductivity as a basis for an application map for the water distri-bution
- the operator determinates the water level

- the software automatically adapts and controls the right water amount to each nozzle or nozzle group

Advantages and application of the innovation

- Taking into consideration the need of crops (see FS Leaf clamp to improve and to optimize irrigation scheduling and amount), the soil types, the degree of humidity and the absorption capacity of the soil
- Water conservation
- Energy reduction
- Increase of efficiency

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
x					1)

1): economic aspects

Reference:
http://www.bauer-at.com/de/produkte/beregnung/pivot-linear-systeme
http://www.bauer-at.com/de/unternehmen/news/die-individuellste-form-der-beregnung-bauer-lanciert-variable
Sourell, H. (2011): Innovative Beregnungstechniken für Niedersachsen und deren Kosten und Nutzen
Sourell, H., Eberhard, J., Thörmann, H.-H. (2013): Bewässerung und Beregnung. In: Frerichs, Ludger (Hrsg.): Jahrbuch Agrartechnik 2013. Braunschweig: Institut für mobile Maschinen und Nutzfahrzeuge, 2014. S. 1-9
Hezarjaribi, A. (2008): Site-specific irrigation: Improvement of application map and a dynamic steering of modified centre pivot irrigation system. Dissertation – Justus Liebig University, p. 166.
Derbala, A. (2003): Development and Evaluation of mobile drip irrigation with center pivot irrigation machines. Dissertation – Justus Liebig University Giessen, p. 129.
Sourell, H. (2009): Bewässerungstechnik: Wasserverteilung mit Blick in die Zukunft, Freilandberegnung. – In: Dirksmeyer, W. & Sourell, H. (eds.): Wasser im Gartenbau. Tagung zum Statusseminar.

F.5 Water management systems with treatment of low quality waters

Related to MP: MP53 Drip irrigation + MP54 Sprinkler irrigation

Related to FTZ: ENZ13_SL1+2+3+4_TXT4 - Arable/Cereals
ENZ13_SL2+3+4_TXT3 - Permanent crops

Key points

- source of irrigation water is treated wastewater
- municipal wastewater and treated effluents are rich of nutrients and supplemental fertilizers are sometimes not necessary
- environmental and health requirements must be taken into account when treated wastewater is the source of irrigation water

What is it?

- Irrigation with treated wastewater for crop production with adopting appropriate on-farm management strategy

How does it work / is it applied?

Many different **methods** are used by farmers **to irrigate crops**. They range from watering individual plants from a can of water to highly automated irrigation by a centre pivot system. However, from the point of wetting the soil, these methods can be grouped in flood, furrow, sprinkler, sub- and localized irrigation (see FS Combined Centre Pivot with mobile drip tubes; FS Centre Pivot / Linear irrigation system; FS Combined Centre Pivot-Linear irrigation system; FS Precision Irrigation - Variable Rate Irrigation).

Success in **using treated wastewater** will largely depend on adopting appropriate strategies for a given set of conditions. Prior information on effluent supply and its quality ensure the formulation and adoption of an appropriate on-farm management strategy.

Table 15: Information on effluent supply and strategies for irrigation

Information	Decision on irrigation management
Effluent supply	
The total amount of effluent that would be made available during the crop growing season.	Total area that could be irrigated.
Effluent available throughout the year.	Storage facility during non crop growing period either at the farm or near wastewater treatment plant, and possible use for aquaculture.
The rate of delivery of effluent either as m3 per day or litres per second.	Area that could be irrigated at any given time, layout of fields and facilities and system of irrigation.
Type of delivery: continuous or intermittent, or on demand.	Layout of fields and facilities, irrigation system, and irrigation scheduling.
Mode of supply: supply at farm gate or effluent available in a storage reservoir to be pumped by the farmer.	The need to install pumps and pipes to transport effluent and irrigation system.

Effluent quality	
Total salt concentration and/or electrical conductivity of the effluent.	Selection of crops, irrigation method, leaching and other management practices.
Concentrations of cations, such as Ca++, Mg++ and Na+.	To assess sodium hazard and undertake appropriate measures.
Concentration of toxic ions, such as heavy metals, Boron and Cl-.	To assess toxicities that are likely to be caused by these elements and take appropriate measures.
Concentration of trace elements (particularly those which are suspected of being phytotoxic).	To assess trace toxicities and take appropriate measures.
Concentration of nutrients, particularly nitrate-N.	To adjust fertilizer levels, avoid over-fertilization and select crop.
Level of suspended sediments.	To select appropriate irrigation system and measures to prevent clogging problems.
Levels of intestinal nematodes and faecal coliforms.	To select appropriate crops and irrigation systems.

Two options allow using the effluent and the conventional source of water - blending conventional water with treated effluent and using the two sources in rotation.

Under normal conditions, the **type of irrigation method selected** will depend on water supply conditions, climate, soil, crops to be grown, cost of irrigation method and the ability of the farmer to manage the system. However, when using wastewater as the source of irrigation other factors, such as contamination of plants and harvested product, farm workers, and the environment, and salinity and toxicity hazards, will need to be considered. There is considerable scope for reducing the undesirable effects of wastewater use in irrigation through selection of appropriate irrigation methods. The choice of irrigation method in using wastewater is governed by the following factors:

- the choice of crops,
- the wetting of foliage, fruits and aerial parts,
- the distribution of water, salts and contaminants in the soil,
- the ease with which high soil water potential could be maintained,
- the efficiency of application, and
- the potential to contaminate farm workers and the environment.

Table 16: Analysis of factors in relation to four widely practiced irrigation methods

Parameters of evaluation	Furrow irrigation	Border irrigation	Sprinkler irrigation	Drip irrigation
1 Foliar wetting and consequent leaf damage resulting in poor yield	No foliar injury as the crop is planted on the ridge	Some bottom leaves may be affected but the damage is not so serious as to reduce yield	Severe leaf damage can occur resulting in significant yield loss	No foliar injury occurs under this method of irrigation
2 Salt accumulation in the root zone with repeated applica-	Salts tend to accumulate in the ridge which could harm the	Salts move vertically downwards and are not likely to accumulate in the	Salt movement is downwards and root zone is not likely to accumu-	Salt movement is radial along the direction of water movement. A

tions	crop	root zone	late salts	salt wedge is formed between drip points
3 Ability to maintain high soil water potential	Plants may be subject to stress between irrigations	Plants may be subject . to water stress between irrigations	Not possible to maintain high soil water potential throughout the growing season	Possible to maintain high soil water potential throughout the growing season and minimize the effect of salinity
4 Suitability to handle brackish wastewater without significant yield loss	Fair to medium. With good management and drainage acceptable yields are possible	Fair to medium. Good irrigation and drainage practices can produce acceptable levels of yield	Poor to fair. Most crops suffer from leaf damage and yield is low	Excellent to good. Almost all crops can be grown with very little reduction in yield

Advantages and application of the innovation

Agricultural benefits: reliable and possibly less costly irrigation water supply; increased crop yields, often due to the wastewater's nutrient content; higher urban agricultural production; income and employment generation in urban areas.
Water resources management benefits: additional drought-proof water supply, often with lower cost than expanding supplies through storage, transfers, or desalinization; more local sourcing of water.
Environmental benefits: avoidance of surface water pollution, dissolved oxygen depletion, eutrophication, foaming, and fish kills; conservation or more rational use of freshwater resources, especially in arid and semi-arid areas; reduced requirements for artificial fertilizers.

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
x		x	x	x	1)

1): Economic aspects

Reference:
http://www.fao.org/docrep/t0551e/t0551e00.htm
http://energy.gov/eere/femp/best-management-practice-water-efficient-irrigationn
Scheierling, S. M., Bartone, C., Mara, D. D., & Drechsel, P. (2010). Improving wastewater use in agriculture - An emerging priority.

F.6 Leaf clamp to improve and to optimize irrigation scheduling and amount

Related to MP: MP53 Drip irrigation + MP54 Sprinkler irrigation

Related to FTZ: ENZ6_SL1_TXT1 - Arable / cereal and mixed farms

Key points

- direct plant method to control irrigation

What is it?

- Magnetic non-invasive patch clamp pressure probe to measure very small leaf turgor changes in real time

How does it work / is it applied?

- The turgor in the leaf patch is opposed to the magnetic pressure
- The ZIM-probe measures the difference (P_p) between magnetic pressure and turgor
- Irrigation stop (red arrow) results ongoing drought and it induces a continuous increase of the output pressure signal at noon (and partly during night)
- Monitoring of water status via internet to adapt irrigation events and amounts

Figure 88: Leaf clamp (http://yara.zim-plant-technology.com/de/?Produkte)

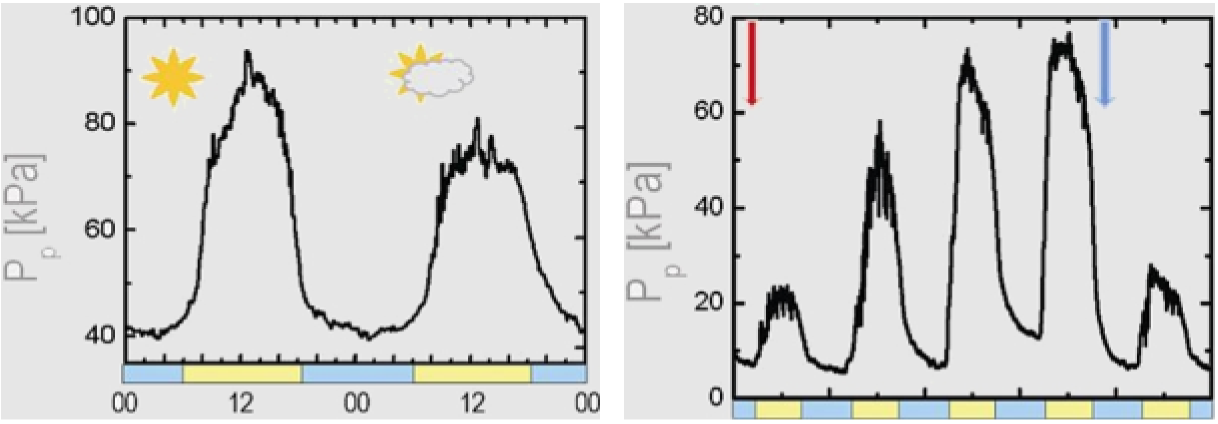


Figure 89: Typical measurements on a sunny and a partially cloudy day (day = yellow; night = blue); Measurements with influence of irrigation (http://yara.zim-plant-technology.com/de/?News)

Advantages and application of the innovation

- Applicable for agricultural crops and leafy trees
- Direct plant method compared to soil measurement (indirect)

- Adapted water management and irrigation systems (see FS Combined Centre Pivot with mobile drip tubes; FS Centre Pivot / Linear irrigation system; FS Combined Centre Pivot-Linear irrigation system; FS Precision Irrigation - Variable Rate Irrigation; FS Water management systems with treatment of low quality waters)
- Yield increase
- Quality assurance
- Sustainability

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
X					1)

1): economic aspects

Reference:

http://yara.zim-plant-technology.com/de/?News
http://bmwi.de/DE/Themen/Technologie/Innovationsfoerderung-Mittelstand/hightechlights,did=572678.html
http://www.berlin-sciences.com/standort-berlin/erfolgsbeispiele/erfolgsbeispiele/zim-plant-technology-gmbh/
http://tunesien.ahk.de/index.php?id=58245
Bramley, H., Ehrenberger, W., Zimmermann, U., Palta, J. A., Rüger, S., Siddique, K. H. M. (2013): Non-invasive pressure probes magnetically clamped to leaves to monitor the water status of wheat. Plant and Soil 369: 257-268. doi: 10.1007/s11104-012-1568-x

Category:
G. OTHER PRACTICES

G1. Soil Bioengineering

Related to MP: MP 'not-coded' Soil conservation practices

Related to FTZ: ENZ13_SL1+2+3+4_TXT4 - Arable/Cereals
ENZ13_SL2+3+4_TXT3 - Permanent crops
ENZ11_SL5_TXT2 + ENZ12_SL2+3+4_TXT2 +
ENZ13_SL2+3_TXT1 + ENZ13_SL2+3+4+5_TXT2 - Sheep and goats/Others (pigs) + Beef and mixed cattle/Permanent grass

Key points

- Use of engineering design principles with biological and ecological concepts with various construction material to control erosion and flooding
- Biotechnical engineering complements and improves other technical engineering methods

Figure 90: Example of soil bioengineering technique

What is it?

Constructions:

1. combine engineering design principles with biological and ecological concepts
2. assure the survival of living plant communities in their natural settings (horticultural principles)
3. control erosion and flooding

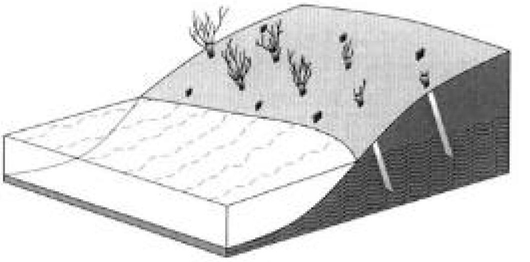
How does it work / is it applied?

Soil bioengineering techniques can be used to address the erosion resulting from dam operation. Grading or terracing a problem stream bank or eroding area and using interwoven vegetation mats, installed alone or in combination with structural measures, will facilitate infiltration stability. Many erosion control techniques are also intended to expedite re-vegetation.

Table 17: Erosion control methods and material and purpose

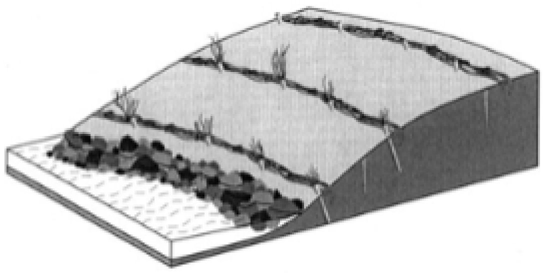
Methods	Material / purpose
Surface protection methods/ covering methods	- primarily to provide quick surface protection for soil conservation (securing of deeper soil layers is only secondary) - large number of plants such as grasses and herbs per unit area to protect soil surface against erosion
Structures of live materials only	- improve slope stability and prevent erosion
Structures of mixed materials	- under less favorable conditions, support structures of non-living material may be required to augment constructions made of living materials
Supplementary methods	- specific and effective methods to facilitate emergence of the climax vegetation (e.g. plantings of single trees or

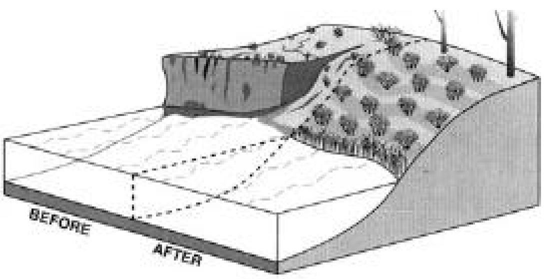
	soil improvement techniques / costly and restricted in use)
Support constructions	- constructions of non-living materials such as concrete, rocks and dead branches under extreme conditions (unfavorable soil, extreme weather, short growing season), or if a site requires stabilization before live plants can be used



Live stakes: woody cuttings that are capable of rooting with relative ease. Material are tamped into the soil and then grow into mature shrubs stabilize the soil surface. It secures stream banks or slope erosion prevention materials and it provides quick, inexpensive and easily installed permanent cover on simple areas.

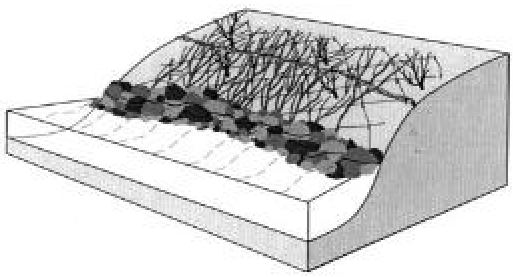
Live fascine: sausage-like bundles of live cut branches of wetland/streamside materials (willow (*Cornus* L.), dogwood (*Salix* L.). These bundles are placed into trenches along the stream bank and grow out perpendicular to the bank providing protective vegetative cover and a root structure to stabilize banks. It slows the surface flows by breaking up slopes and allowing vegetation to establish, which allows enhanced filtration.

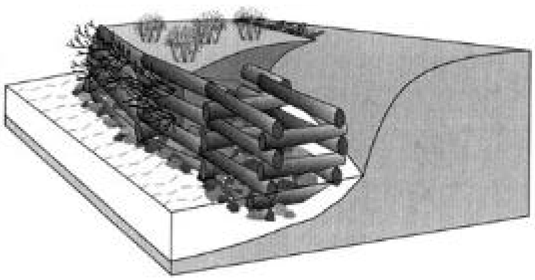




A brush layer is a layer of plant material that is laid between successive lifts of a fill slope and brush packing, staking down layers of material join in the rills or gullies to repair a fill slope. They are most commonly used for upland slope conditions. Both systems require live branches lay horizontally within the slope and provide quick wildlife habitat. It supports the establishment of permanent vegetative cover.

A brush mattress combine live stakes, live fascines and branch cutting to form a protective vegetated mattress over a stream bank or other slope. It supports the establishment of permanent vegetative cover and provides immediate flood protection.





A live crib wall is a rectangular framework of untreated logs or timbers, rock and woody cuttings that protect eroding stream banks and provide overhead cover for the fish. Design of these systems requires an in-depth assessment and understanding of stream flows and stream behavior.

Advantages and application of the innovation

- Technical advantages and application of the innovation protection against surface erosion; an increase of slope stability by root reinforcement and draining of the soil; protection against rock fall and wind
- Ecological advantages and application of the innovation regulation of temperature and humidity close to the surface, thus promoting growth; improvement of the soil water regime via interception, evapotranspiration and storage; soil improvement and top soil formation; improvement of and provision for habitat
- Economic advantages and application of the innovation reduction of construction and maintenance costs; creation of areas for agricultural and recreational use
- Aesthetic advantages and application of the innovation structures fit into the landscape; landscape is more appealing

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
	x	x	x	x	1)

1): Economical, landscaping and aesthetic aspects

Reference:
http://www.fs.fed.us/publications/soil-bio-guide/guide/chapter5.pdf
http://water.epa.gov/polwaste/nps/czara/ch6-3a.cfm
http://www.env.gov.bc.ca/wld/documents/wrp/wrpr_2.pdf
http://www.portlandoregon.gov/bds/article/101713
http://www.controlerosion.es/english/
http://www.acrcd.org/
http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/water/manage/restoration/?cid=nrcs143_026887 (all schemata)

G.2 Low pressure tires/caterpillars

Related to MP: MP 'not-coded' Reducing soil compaction (by use of low pressure tires)

Related to FTZ: ENZ7_SL2_TXT2 - Arable farms
ENZ12_SL3_TXT4 - Arable farms
ENZ7_SL2_TXT3 - Dairy cattle

Key points

- Decreases pressure on the topsoil and thus compaction over the soil profile. The idea is to enable the tractor and machinery to operate at lower pressure on the fields and travel at reasonable speed on roads between the farm buildings and the fields.

What is it?

- Specific tires or caterpillars added to wheels. They have been developed following the consideration that 1) soils need low pressure to avoid compaction (between 0.8 to 1 bar); 2) the higher the machinery the higher pressure a tire will request; 3) the higher the speed on road the higher pressure a tire needs. Larger low pressure tires are able to bear higher loads and quicker speeds without requesting much pressure increase for that.
- There are three main families:
    - Low pressure tires, second generation (see FS Low tire pressure in controlled traffic systems)
    - Low pressure tires with remote control of pressure
    - Caterpillars

Figure 91: Tractor with caterpillars (www.frendt.fr)

How does it work / is it applied?

- New generation radial large tires can bear higher loads and greater speed with lower pressure. With pressure well adapted to each task or operation (and regularly checked), constructors claim that fuel consumption is reduced, soil compaction can be avoided (unless used in very wet conditions).
- There is a need to adapt the pressure to loads and expected speed, which means using pressure tables proposed by tires constructors. In addition it is possible to adapt a manometer and a compressor on the tractor, with remote commands, to add some pressure in roads and lower it on fields (again, using the appropriate abacus to enable convenient grip, not to damage the tires, and reduce pressure on soil).
- Sold by Canadian enterprises, caterpillars have the reputation to lower pressure on soils. But more and more analysis stress that, compared with second generation tires, caterpillars don't add any additional benefit.

Figure 92: Low pressure tires with remote control of pressure (www.michelin-pneu-agricole.fr)

Advantages and application of the innovation

- Reduction of fuel costs
- Improves traction power
- Reduces pressure on soil
- New generation technology from the tires point of view, add-on to a family from the tractor constructors point of view

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertility	Physical soil fertility	Other aspects
				x	1)

1): reduces soil pressure and fuel consumption

References:

Caterpillars: http://www.terre-net.fr/materiel-agricole/tracteur-quad/article/soucy-international-pense-aux-grosses-pointures-207-89608.html
Ultraflex tires: http://www.michelin-pneu-agricole.fr/S-informer/Evenements/2013/Plus-de-traction-et-moins-de-carburant-avec-la-Technologie-MICHELIN-ULTRAFLEX2
Tire Pressure Control Systems: http://www.fendt.fr/cotpresse_informationpresse_3198.asp ; http://www.terre-net.fr/materiel-agricole/tracteur-quad/article/comment-ca-marche-207-98587.html

G.3 Management to reduce and minimize soil compaction

Related to MP: MP ‘not-coded’ Reducing soil compaction (by use of low pressure tires)

Related to FTZ: ENZ7_SL1_TXT1 - Dairy farming / permanent grassland
ENZ7_SL1_TXT2 - Mixed farms (pigs and horticulture)
ENZ7_SL2_TXT3 - Arable / specialized crops

Key points

- Avoiding soil compaction
- Improved soil structure

What is it?

- A number of strategies to avoid both sub- and topsoil compaction.

How does it work / is it applied?

Compaction can be avoided by paying attention to several aspects:

- Avoiding heavy axle loads as much as possible;
- Increasing the number of axles for the heaviest pieces of equipment on the farm (e.g. manure spreader, grain carts);
- Reducing tire pressure to minimal allowable pressures (see FS Low pressure tires / caterpillars, see FS Low tire pressure in controlled traffic systems);
- Using a pressure control system;
- Using flotation tires;
- Using tracks or dual tires to replace singles;
- Using three-wheeled vehicles (trikes) (e.g. slurry injector);
- Using special equipment (e.g. overloading wagons, on-land plough, self-propelled sugar beet harvester with dog-legged left and right hand side positioning of the wheels);
- Reducing the number of passes over the field and the total area per hectare actually travelled;
- Controlled traffic farming (concentrating repeated traffic in travel lanes) (see FS DGPS-RTK to drive over the field, FS Tramlines) ;
- Avoiding traffic on very wet soils (especially with high loads and tire pressures).

Advantages and application of the innovation

- Improved soil structure;
- Better infiltration and movement of air and water in the soil;
- Improved root growth and consequently higher crop yields;
- Time management and costs are probably the major bottlenecks for the wide implementation of soil compaction management:

- o Factors such as optimum planting or harvest time often dictate that a farmer will be in the field at suboptimum soil moisture conditions for traffic;
- o The investment in specific tires, a pressure control system, special equipment, etc. can be quite high.

Contribution to CATCH-C major goals:

Productivity	C sequestration/ GHG reduction	(Biological) soil health	Chemical soil fertili-ty	Physical soil fertility	Other aspects
x				x	1)

1) Reducing soil compaction

Reference:

Duiker, S., 2004. Avoiding soil compaction. The Pennsylvania State University, Pennsylvania, US. 8p.
Elsen, F., Beckers, V., Diels, J., Van Orshoven, J., Wauters, S., Huybrechts, M. 2014. Praktijkonderzoek naar de toepassing van preventieve en remediërende maatregelen tegen bodemaantasting door bodemverdichting. Tussentijds rapport

References

Asenso-Okyere, K. & Davis, K. (2009): Knowledge and innovation for agricultural development.

Daane, J. (2010): Enhancing performance of agricultural innovation systems.

Gildemacher, P. & Wongtschowski, M. (2013): Catalysing Innovation: from theory to action. Royal Tropical Institute.

Ornan, H., Khobe, D. & Ornan, B. (2010): Adoption of agricultural innovations by rice farmers in Yola – South local Government Adamawa State, Nigeria.

Glossary

Agri-environmental zone – the applied zonation is based on three variables: climate (environmental zone), soil texture, and slope. An agri-environmental zone is homogeneous in each of these three aspects.

Best management practices (BMP) – a management practice that contributes to (aspects of) soil quality. This is a working definition used in this report. Examples are reduced tillage, application of external organic inputs (manures, composts), crop rotation, and the incorporation of crop residues.

Categories of soil management – crop rotation, grassland management, tillage, nutrient management, crop protection, and water management

Current management practice (CMP) – management practice commonly applied in the respective farming systems covered by the project. See also WP2, Deliverable D2.242.

Description of work (DoW) – detailed description of the Catch-C work plan

Farm type – the applied farm typology is based on information about farm specialization and land use over Europe, as derived from FADN. Farm types were defined in WP2, Deliverable D2.242.

Farm type * agri-environmental zone combination (FTZ) – intersection of a farm type with an agri-environmental zone. An FTZ unit is homogeneous with respect to farm type, climate zone, soil texture and slope. See also Deliverable D2.242.

Innovation – an assembly - of e.g. ideas, instruments, germplasm, instructions and procedures, software, tips and tricks, etc. - that enables the adoption of better soil management practices.

Major goals of sustainable soil management – to improve the productivity of re-sources (land, labor, water, nutrients, etc.); to mitigate climate change; and to im-prove soil quality (biological, chemical, physical).

Management Practice (MP) – an activity or choice that is implemented on-farm and that affects the properties of soil or its immediate environment. MPs were defined in WP3 of the project, and are listed in Appendix 1 of this report.

Soil quality – the ability of a soil to sustain high productivity of resources (i.e. crop production per ha of land area, per kg of fertilizer or water, per hour of labor, ...). In this project, we address three aspects of soil quality: (a) biological soil health and disease suppressiveness, (b) chemical soil fertility and (c) physical structure and integrity of the soil.

Appendices

Appendix 1

Classification of management practices (MPs) as defined in Work Package 3

MP1	Monoculture	The growing of a single arable crop species on a field year after year, for at least 9 to 10 years.
MP2	Rotation with cereals	The growing of different species of crops in a crop rotation with >50% coverage with cereals.
MP3	Rotation with legume crops	The growing of different species of crops in a crop rotation with >25% coverage with legume crops.
MP4	Rotation with tuber or root crops	The growing of different species of crops in a crop rotation with >25% coverage with tuber or root crops.
MP5	Rotation with fallow land	The growing of different species of crops in a crop rotation with >25% fallow.
MP6	Rotation with grassland	The growing of different species of crops in a crop rotation with >50% grassland.
MP7	Intercropping	The growing of two or more different arable crops simultaneously in different rows in the same field.
MP8	Rotation with cover/catch crops	The growing of different species of crops in a crop rotation with >25% coverage with cover/catch crops. Double cropping (two different crops grown on the same area in one growing season) is here included. Cover/catch crops are harvested.
MP9	Rotation with green manures	The growing of different species of crops in a crop rotation with >25% coverage with green manure crops. Green manure crops are incorporated into the soil.
MP11	Permanent graz-ing	Continuous feeding on standing vegetation by livestock.
MP12	Rotational graz-ing	Rotational feeding (i.e. changing the grazed parcels) on standing vegetation by livestock.
MP13	Zero grazing	No grazing but only mowing to harvest grass.
MP15	Conventional tillage	The conventional tillage consists of ploughing the soil (e.g. Â± 30 cm), which causes turning, loosening, crumbling and aeration of the topsoil. This should result in a clean field surface.
MP16	No / Zero tillage	No tillage. Sod-seeding or Direct drilling are included
MP17	Non inversion tillage/reduced tillage	Tillage without inversion, at a reduced depth (e.g. 5-15 cm), with specific equipment (e.g. grubber/cultivator) more than once a year. About 30% of soil cover after seeding or the incorporation of organic matter >1120 kg/ha.
MP18	Non inversion tillage/minimum tillage	Tillage without inversion, at a reduced depth (e.g. 5-10 cm), with specific equipment (e.g. rotovator) only once a year. About 30% of soil cover after seeding or the incorporation of organic matter >1120 kg/ha.
MP19	Non inversion tillage.	Tillage at a reduced depth (about 30% crop residues remaining on the field surface), often with specific machines (e.g. rotovator).
MP20	Deep ploughing	The deep ploughing describes the use of the plough, where the soil is ploughed > 35 cm. It causes a turn, loosening, crumbling and aeration of the topsoil and parts of the subsoil. Furthermore, deep ploughing is used as a measure for agricultural land imp

MP22	Contour ploughing	Parallel ploughing to the contours of hill slopes.
MP23	Terrace farming	The term describes the use of graded terrace steps of sloped land, used to farm on hills and mountainous area.
MP24	Controlled traffic farming	Controlled traffic farming means using similar traffic lanes for different application within one year and the same traffic lanes between years , often applying a navigation system.
MP26	Mineral N application	Applications of nitrogen in inorganic fertilisers.
MP27	Mineral P application	Applications of phosphorus in inorganic fertilisers.
MP28	Mineral K application	Applications of potassium in inorganic fertilisers.
MP29	Plant compost application	Application of plant compost which results from biodecomposition of plant material in the presence of air.
MP30	Bio-waste compost application	Application of bio-waste which results from biodecomposition of organic material, such as animal wastes, plant residues, etc. in the presence of air.
MP31	Sludge compost application	Application of sludge which consists of suspended particles settling out of the water and sediment on the bottom in the presence of air including mechanical mixing and aerating. The term "compost" describes the additional mixinng of sludge with structura
MP32	Farm yard manure (FYM) application	Application of manure from livestock which is a mixture of excrements (faeces and urine) of animals with a binding medium such as usually straw.
MP33	Cattle slurry application	(Cattle slurry application) Application of slurry from livestock which is mainly a mixture of faeces and urine.
MP34	Poultry manure application	(Poultry manure application) Application of manure from livestock which is mainly a mixture of faeces and urine.
MP35	Pig slurry application	(Pig slurry application) Application of slurry from livestock which is mainly a mixture of faeces and urine.
MP36	Return of crop residues	Crop residues (e.g. stubble and roots) that remain after harvesting and are ploughed in.
MP37	Burning of crop residues	Straws are left on the soil and set to fire after harvesting
MP38	Harvesting of crop residues	Crop residues are harvested and removed for different purposes (e.g. biogas, livestock feeding, ...)
MP41	Mechanical weeding	The mechanical weeding uses technical tools to bury, cut or uproot the existing weeds. For this mechanical method, straight-row planting is essential.
MP42	Herbicide application	The application of herbicides to combat weeds and protecting crops.
MP43	Push-pull strategies	Push-pull technology is a method of biological pest control. Within cultures, crops are cultivated with repellent effects and outside the cultures crops are grown with attractive effects. This makes it possible to pull or to push the insects from the crop
MP44	Patches or stripes of natural vegetation	Patches or stripes of natural vegetation are included in the field. They serve as a refuge for beneficial insects for biological pest control, for promotion of soil-field weeds, and to avoid erosion and prevent leaching of nutrients.
MP45	Pheromones application	The application of pheromones to influence plant growth.

MP46	Insecticide application	The application of insecticides to protect crops.
MP47	Fungicide application	The application of fungicides to protect crops.
MP48	Nematode application	The application of nematodes to protect crops.
MP49	Soil fumigation	After covering the soil the application of gaseous pesticides by specialized devices are used to control pests inside the soil.
MP50	Soil solarization	Covering the soil to trap solar energy and heat the soil to control pests.
MP50	Fertilization plan	Different methods and procedures to determine biological, physical and chemical soil parameters, e.g. supply with nutrients. Development and adoption of fertilisation plans (for mineral and organic fertilisers).
MP52	Surface irrigation	Application of water to the field by surface irrigation.
MP53	Drip irrigation	Application of water under low pressure through a piped network in a pre-determined pattern, applied as a small discharge to each plant or adjacent to it and adjustable by irrigation nozzles.
MP54	Sprinkler irrigation	Application of water to the field by sprinkler irrigation.
MP55	Subsurface drainage	Artificial systems of furrows, ditches, pipes, etc. to improve drainage of excess water from the sub-soil.

Appendix 2

Table A2. 1: Environmental zonation for Europe

ENZ	Environmental Zone
ENZ1	Alpine North
ENZ2	Boreal
ENZ3	Nemoral
ENZ4	Atlantic North
ENZ5	Alpine South
ENZ6	Continental
ENZ7	Atlantic Central
ENZ8	Panonnian
ENZ9	Lusitanian
ENZ10	Anatolian
ENZ11	Mediterranean Mountains
ENZ12	Mediterranean North
ENZ13	Mediterranean South

Table A2. 2: Slope classification

slope	in degrees	in percentage
SL1	0°	0%
SL2	1°	2%
SL3	2 – 3°	3-6%
SL4	4 – 7°	7-14%
SL5	> 8°	>14%

Table A2. 3: Soil texture classification

texture	description	range
TXT1	coarse (sand)	Clay <18% and sand > 65%
TXT2	medium	18% < clay < 35% and sand >15% sand, or clay <18% and 15% < sand < 65%
TXT3	medium fine	clay < 35% and sand < 15%
TXT4	fine	35% < clay < 60%
TXT5	very fine (clay)	clay > 60 %

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