**Interim Report**
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**Annex 25-LS**

# Action recommendations for priority cost-effective planning of measures [Deliverable 4.2]

LIFE05 ENV/D/000182

Water Resources Management in Cooperation with Agriculture (WAgriCo)

LIFE05 ENV/D000182

# Action recommendations for priority cost-effective planning of measures

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# 1 Introduction

The major problem for reaching the objectives of the Water Framework Directive (WFD) in Lower Saxony is high nitrate concentrations in the groundwater. Therefore, the planning of measures targets to reduce N losses under agricultural land use. Other aspects like reduction of reduction of surface runoff or phosphorus immissions are positive environmental side-effects of the selected measures and evaluated in a qualitative way within the project approach for Lower Saxony.

The cost-effective planning is carried out in two steps within the WAgriCo-project. First, the priority areas are selected and characterised as the measures shall be concentrated in those areas. For the methodology see deliverable D 6.1_LS (Eisele, 2007, in German). The next step is the selection of the most appropriate measures. This deliverable describes the measures and methodology for this step. Cost aspects are discussed more intensively in task 7. In this paper cost, estimates are based on public transfer payments to farmers for the selected voluntary measures. These costs as well as assumptions on environmental effects are used for the calculation of cost-effectiveness.

This deliverable presents in chapter 2 a toolbox of 13 action-oriented measures and one result-oriented measure offered for a practical test within the WAgriCo project in the years 2006/2007 and 2007/2008. The selection of the 14 measures is the result of a cooperative approach. The deliverable D 4.1 (Schmidt et al., 2007, in German) contains extended descriptions of 22 potentially suitable water protection measures and the general framework for the implementation of water protection measures.

A ranking of the 14 selected measures by cost-effectiveness to reduce N losses to the groundwater and by additional positive ecological effects as well as by the applicability to farm types is shown in chapter 3. The estimation of the ecologic impacts is based on a literature review and expert knowledge.

In addition to the single specifications, the combination of WAgriCo-measures and their cumulative ecological and economic effects (chapter 4) will be used as an element for modelling, together with the methods for cost predictions and scenario analysis described in deliverables 7.1 (Osterburg and Runge, 2007) and 7.2 (Osterburg et al., 2007). Hence, final conclusions on ´action recommendations for priority cost-effective planning of measures´ are limited to the comparison of single measures and to combinations at farm scale as a basis of further planning (chapter 5). A suggestion for the state-wide implementation, considering the project results, will be a subject of deliverable 9.2 (due in April 2008).

# 2 Profiles of WagriCo measures in Lower Saxony

This part of the report contains sheets of all 14 measures that are selected for a practical test within the WAgriCo-project. The evaluation of the ecologic effects of the measures is based on a prior work at FAL (Osterburg et al., 2007), reviewed by the WAgriCo experts with regard to N reduction potentials of the offered measures. Project results regarding effects of measures on N surplus reduction are not available yet. Once additional data analysis has been performed, the estimated effects will be re-assessed if appropriate. Table 1 contains an overview over the tested measures with a short characterisation followed by the measure sheets, one for each measure.

**Table 1:** List of WAgriCo-measures in Lower Saxony

| No | Description | Reference unit | Category of measures | Main scope |
|---|---|---|---|---|
| H 1 | catch cropping after harvest, winter hardy, late ploughing | ha | greening | reduction of N leaching |
| H 2 | catch cropping after harvest, standard | ha | greening | reduction of N leaching |
| H 3 | three-year fallow with active greening | ha | greening | reduction of N leaching and N surplus |
| H 4 | volunteer rye or triticale before summer crops | ha | greening, reduced tillage | reduction of N leaching and mineralization |
| H 5 | No soil tillage/ploughing in autumn after maize/sugar-beet | ha | reduced tillage | reduction of N leaching and mineralization |
| H 6 | Restrictions for farm manure application in autumn | farm | manure management | reduction of N leaching and N surplus |
| H 7 | Improved slurry application techniques | ha | manure management | reduction of N leaching and N surplus |
| H 8 | Reduced row spacing for maize | ha | cultivation technique | reduction of N leaching and N surplus |
| H 9 | Use of ammonium based liquid fertilisers using injection technique in cereals | ha | manure management | reduction of N leaching and N surplus |
| H 10 | Application of stabilised mineral fertilizer in spring on winter cereals and potatoes | ha | manure management | reduction of N leaching and N surplus |
| H 11 | Undersown catch crops in maize | ha | greening | reduction of N leaching |
| H 12 | Turnip (brassica rapa sylvestris) as catch crop before winter cereals | ha | greening | reduction of N leaching |
| H 13 | volunteer rape seedlings before winter cereals respectively summer crops | ha | greening, reduced tillage | reduction of N leaching and mineralization |
| E | Result-oriented measure to improve N use efficiency | farm | manure management | reduction of N surplus |

The profiles of all measures are described in detail, using a standardised form. The design of the form and some information about the measures were taken from Osterburg et al., 2007).

First the entire name of the measure and its internal WAgriCo number is mentioned on the measure sheet followed by a short description of the intended environmental target and the target area. The main target for all of the selected measures is the reduction of diffuse N pollution towards groundwater. The target area is the farmed parcel, except for H 6 (restrictions for farm manure application) and the result-oriented measure, which have to be implemented and managed at farm scale. The measure sheet is further divided into three sections: The first part contains the management conditions that have to be followed by the farmers and additional remarks. The detailed management prescriptions as well as the characterization of the reference situation are determining the following ecologic appraisal. All changes in the management conditions and the reference situation affect the environmental impact of the measure. The next section contains a qualitative assessment of the suitability of the measure concerning site conditions, farm type and land use. In the process of finding applicable measures it is of central importance to consider this appraisal.

The third section of the form is the proper evaluation of the measure itself and contains quantitative information. It consists of three parts: The payment in € per hectare, the potential impacts of the measure to reduce N losses estimated using the indicators ´N balance´ and ´soil mineral N´, and figures on cost-effectiveness. For N reduction potentials a range between minimum and maximum effect and the expected average effect are presented. The cost-effectiveness [€/kg N] is calculated on basis of payments [€/ha] divided by the N reduction [kg N/ha].

There is often quite a large variation of ecological effects, even if all management conditions are correctly realised. The result depends on the one side on weather conditions that can not be influenced by the farmers, on the other side the crop / cultivation technology and fertiliser management can have a high influence. Sometimes there is no N reduction at all, and in these cases the cost-effectiveness is infinitely high. Additional information about implementation conditions and environmental impacts on other natural resources helps to select appropriate measures considering beneficial side-effects. A more detailed description of the other environmental effects can be found in deliverable 4.1. Further, the environmental interrelationships of the measures are presented in Annex 1 on the basis of impact charts. Finally, some comments complete the evaluation with additional information for a successful implementation of the measures.

## 2.1 catch cropping after harvest, winter hardy, late ploughing (H 1)

**Environmental target:** reduction of N-leaching over winter, accumulation of N in biomass over a long period

**Target area:** parcel scale

| Management conditions | Explanations and recommendations |
|---|---|
| sow legume-free, winter-hardy ground cover (at least 30% of growing crop has to be winter hardy) by 5th of September | to avoid biological N-fixation leguminous plants are excluded, winter-hardy plants conserve N over winter, to achieve a positive environmental impact it is essential to have a good growth of the catch crop |
| N fertiliser: max. 40 kg creditable N for green manure, max. 80 kg creditable N for use as fodder (with removal) | a renouncement of N-fertilisation in autumn is recommended for water protection reasons, especially if catch crops are not harvested |
| after rape, maize and potatoes no N-fertilisation for catch crop | after these crops enough N remains in the soil, so that no N fertilisation is necessary to assure a good growth of catch crops |
| no grazing | to prevent hot-spots of N losses due to animal excrements |
| ploughing not before 15th of March | minimizing the period of time without plants on the ground for a secure conservation of the N captured in the biomass of the catch crop until the following crop |
| | For a positive effect on N-surplus it is necessary to include N-fertilisation of the catch crop into the fertilising plan for crop rotation, unless the catch crop is harvested |
| **Reference situation without measure** (for impact assessment) | |
| uncultivated field before summer crops (ploughed in autumn or non-returning tillage of the stubble field) | |

**Assessment of suitability:** +++ = very good, ++ = good, + = modest, 0 = unapt

| Site condition (soil/climate) | | Farm type / organic N-input | | Land use | |
|---|---|---|---|---|---|
| sandy soil, < 600 mm | ++ | arable (< 40 kg N/ha) | ++ | arable | +++ |
| sandy soil, >= 600 mm | +++ | pigs/poultry (40-120 kg N/ha) | +++ | grassland | 0 |
| loamy soil, < 600 mm | ++ | pigs/poultry (> 120 kg N/ha) | +++ | permanent crops | 0 |
| loamy soil, >= 600 mm | ++ | dairy (40-120 kg/ha) | +++ | vegetables | +++ |
| peatland, organic soil | +++ | dairy (>120 kg N/ha) | +++ | | |
| **Specification of land suitablity:** on arable land before summer crops; prior crop harvested before end of August | | | | | |

| Payment [€/ha] | Indicators | Reduction [kg N/ha] | | | Cost-effectiveness [€/kg N] | | |
|---|---|---|---|---|---|---|---|
| | | min. | ∅ | max. | min. | ∅ | max. |
| 120 (2006: 100) | N balance | 0 | 20 | 40 | 3 | 6 | ∞ |
| | soil mineral N autumn | 30 | 40 | 60 | 2 | 3 | 4 |

| implementation conditions | | other environmental impacts | |
|---|---|---|---|
| acceptance | ++ | climate protection | + |
| possibility to control | ++ | landscape and nature conservation | ++ |
| possibility to administrate | +++ | soil protection, erosion control | +++ |

**Comments:** If the catch crops are well established, the measure has an assured positive effect on soil mineral N in autumn, especially on sandy soils and not too heavy soils in regions with enough water availability in autumn. Catch crop growing reduces the quantity of the leachate. This measure is difficult to be established in dry areas without irrigation. The suitability is influenced by the length of the vegetation period, among others dependent on altitude. An increase of the N surplus can not be excluded, because it is difficult to control whether the N conserved by the catch crops is taken into account in the fertilising plan for the following crop.

## 2.2 Catch cropping after harvest, standard (H 2)

**Environmental target:** reduction of N-leaching over winter, accumulation of N in biomass

**Target area:** parcel scale

| Management conditions | Explanations and recommendations |
|---|---|
| sow legume-free ground cover by 5th of September | to avoid biological N-fixation leguminous plants are excluded, winter-hardy plants conserve N over winter, to achieve a positive environmental impact it is essential to have a good growth of the catch crop |
| N fertiliser: max. 40 kg creditable N for green manure, max. 80 kg creditable N for use as fodder (with removal) | a renouncement of N-fertilisation in autumn is recommended for water protection reasons, especially if catch crops are not harvested |
| after rape, maize and potatoes no N-fertilisation for catch crop | after these crops enough N remains in the soil, so that no N fertilisation is necessary to assure a good growth of catch crops |
| no grazing | to prevent hot-spots of N losses due to animal excrements |
| ploughing not before 1st of February | avoidance of the release of the N captured in the biomass from catch crop before winter<br>recommendation: ploughing not earlier than three weeks before sowing of the following crop |
| existing fallow with legume-free ground cover without ploughing before spring also counts as catch crop | For a positive effect on N-surplus it is necessary to include N-fertilisation of the catch crop into the fertilising plan for crop rotation, unless the catch crop is harvested |
| **Reference situation without measure** (for impact assessment) | |
| uncultivated field before summer crops (ploughed in autumn or non-returning tillage of the stubble field) | |

**Assessment of suitability:** +++ = very good, ++ = good, + = modest, 0 = unapt

| Site condition (soil/climate) | | Farm type / organic N-input | | Land use | |
|---|---|---|---|---|---|
| sandy soil, < 600 mm | + | arable (< 40 kg N/ha) | ++ | arable | ++ |
| sandy soil, >= 600 mm | ++ | pigs/poultry (40-120 kg N/ha) | ++ | grassland | 0 |
| loamy soil, < 600 mm | + | pigs/poultry (> 120 kg N/ha) | ++ | permanent crops | 0 |
| loamy soil, >= 600 mm | ++ | dairy (40-120 kg/ha) | ++ | vegetables | ++ |
| peatland, organic soil | + | dairy (>120 kg N/ha) | ++ | | |
| **Specification of land suitablity:** on arable land before summer crops; prior crop harvested before end of August | | | | | |

| Payment [€/ha] | Indicators | Reduction [kg N/ha] | | | Cost-effectiveness [€/kg N] | | |
|---|---|---|---|---|---|---|---|
| | | min. | Ø | max. | min. | Ø | max. |
| 80 | N balance | 0 | 20 | 40 | 2 | 4 | 99999 |
| | soil mineral N autumn | 20 | 40 | 60 | 1.3 | 2 | 4 |

| implementation conditions | | other environmental impacts | |
|---|---|---|---|
| acceptance | +++ | climate protection | + |
| possibility to control | ++ | landscape and nature conservation | ++ |
| possibility to administrate | +++ | soil protection, erosion control | +++ |

**Comments:** If the catch crops are well established, the measure has an assured positive effect on soil mineral N in autumn, especially on sandy soils and not too heavy soils in regions with enough water availability in autumn. Catch crop growing reduces the quantity of the leachate. The suitability is influenced by the length of the vegetation period, among others dependent on altitude. An increase of the N surplus can not be excluded, because it is difficult to control whether the N conserved by the catch crops is taken into account in the fertilising plan for the following crop.

## 2.3 Three-year fallow with active greening (H 3)

**Environmental target:** reduction of N leaching through renouncement of tillage and accumulation of N in biomass over a long period

**Target area:** parcel scale

| Management conditions | Explanations and recommendations |
|---|---|
| sow winter-hardy grasses as pure stand or as variety-mixtures by 5 Sept. 2006 | to achieve a positive environmental impact it is essential to have a good growth and a permanent ground cover |
| only land cropped in 2006 is accepted for establishment of the three-year fellow | limitation to land cropped in the year before starting with fallow to avoid tillage and grass sowing on already established fallow/set-aside and to avoid windfall profits, because of already existing voluntary set-aside |
| ploughing not before 1st of February 2009 | avoidance of the release of the N captured in the biomass and in the root zone before winter |
| | recommendation: ploughing not earlier than three weeks before sowing of the following crop |
| no N-fertilisation | impoverishment of soil fertility of the arable land |
| no grazing | to prevent hot-spots of N losses due to animal excrements |
| **Reference situation without measure** (for impact assessment) | |
| arable land use with low productivity | |

**Assessment of suitability:** +++ = very good, ++ = good, + = modest, 0 = unapt

| Site condition (soil/climate) | | Farm type / organic N-input | | Land use | |
|---|---|---|---|---|---|
| sandy soil, < 600 mm | +++ | arable (< 40 kg N/ha) | +++ | arable | +++ |
| sandy soil, >= 600 mm | +++ | pigs/poultry (40-120 kg N/ha) | +++ | grassland | 0 |
| loamy soil, < 600 mm | +++ | pigs/poultry (> 120 kg N/ha) | +++ | permanent crops | 0 |
| loamy soil, >= 600 mm | +++ | dairy (40-120 kg/ha) | +++ | vegetables | +++ |
| peatland, organic soil | +++ | dairy (>120 kg N/ha) | +++ | | |
| **Specification of land suitablity:** on arable land before summer crops; prior crop harvested before end of August | | | | | |

| Payment [€/ha] | Indicators | Reduction [kg N/ha] | | | Cost-effectiveness [€/kg N] | | |
|---|---|---|---|---|---|---|---|
| | | min. | ∅ | max. | min. | ∅ | max. |
| 120 | N balance | 40 | 60 | 80 | 0.7 | 2 | 3 |
| | soil mineral N autumn | 30 | 50 | 70 | 1.7 | 2.4 | 4 |

| implementation conditions | | other environmental impacts | |
|---|---|---|---|
| acceptance | + | climate protection | ++ |
| possibility to control | +++ | landscape and nature conservation | +++ |
| possibility to administrate | +++ | soil protection, erosion control | +++ |

**Comments:** Measure with a high ecologic efficiency compared to arable land use (especially with increasing proportion of crops for renewable energy use), because of high effectiveness and reliability of the measure with relatively low cost. Additional fallow land is dependent from payment level, productivity of the land and the competitiveness of other crops (partly dependent from framework conditions like commodity prices and subsidies for biomass crops). In dry regions the sufficient growth of grass could be a problem.

## 2.4 Volunteer rye or triticale before summer crops (H 4)

**Environmental target:** inhibition of N mineralization through renouncement of tillage (or shallow tillage), accumulation of N in biomass

**Target area:** parcel scale

| Management conditions | Explanations and recommendations |
|---|---|
| single shallow tillage only immediately after harvesting | to allow a good establishment of the volunteer seedlings a shallow cultivation is permitted, but not obligatory |
| no N-fertiliser | enough N remains in the soil, so that no N fertilisation is necessary to assure a good growth of volunteer rye or triticale |
| no grazing | to prevent hot-spots of N losses due to animal excrements |
| ploughing not before 1st of February | avoidance of the release of the N captured in the biomass and in the root zone before winter<br>recommendation: ploughing not earlier than three weeks before sowing of the following crop |
| | impoverishment of soil fertility of the arable land |
| | to prevent hot-spots of N losses due to animal excrements |
| | to have a positive effect on the N balance the N content of volunteer cereals has to be included in the crop rotation fertiliser plan |
| **Reference situation without measure** (for impact assessment) | |
| ploughing of the stubble field | |

**Assessment of suitability:** +++ = very good, ++ = good, + = modest, 0 = unapt

| Site condition (soil/climate) | | Farm type / organic N-input | | Land use | |
|---|---|---|---|---|---|
| sandy soil, < 600 mm | +++ | arable (< 40 kg N/ha) | +++ | arable | +++ |
| sandy soil, >= 600 mm | +++ | pigs/poultry (40-120 kg N/ha) | +++ | grassland | 0 |
| loamy soil, < 600 mm | +++ | pigs/poultry (> 120 kg N/ha) | +++ | permanent crops | 0 |
| loamy soil, >= 600 mm | +++ | dairy (40-120 kg/ha) | +++ | vegetables | +++ |
| peatland, organic soil | +++ | dairy (>120 kg N/ha) | +++ | | |
| **Specification of land suitablity:** on arable land before summer crops; prior crop harvested before end of August | | | | | |

| Payment [€/ha] | Indicators | Reduction [kg N/ha] | | | Cost-effectiveness [€/kg N] | | |
|---|---|---|---|---|---|---|---|
| | | min. | ∅ | max. | min. | ∅ | max. |
| 30 | N balance | 0 | 10 | 30 | 1 | 1.5 | ∞ |
| | soil mineral N autumn | 20 | 30 | 40 | 0.8 | 1 | 1.5 |

| implementation conditions | | other environmental impacts | |
|---|---|---|---|
| acceptance | ++ | climate protection | ++ |
| possibility to control | +++ | landscape and nature conservation | +++ |
| possibility to administrate | +++ | soil protection, erosion control | +++ |

**Comments:** This measure directly compete with catch crop growing that has a better ecologic effect on the reduction of the soil mineral N in autumn. But especially in regions with little rainfall it is an alternative to the usual intensive tillage of stubble fields.

## 2.5 No soil tillage/ploughing in autumn after maize/sugar-beet (H 5)

**Environmental target:** reduction of N losses over wintertime through renouncement of tillage before spring

**Target area:** parcel scale

| Management conditions | Explanations and recommendations |
|---|---|
| no soil management after harvesting of maize/ sugar-beet before 1st of March | reduction and retardation of the mineralization by prolongation of time the soil remains untilled until spring, but problems with the European corn borer or fusarium could occur |
| use of herbicides in spring is permitted | avoids intensive tillage with high mineralization potential and improves the acceptance of the measure |
| **Reference situation without measure** (for impact assessment) | |
| tillage after maize, ploughing before winter | |

**Assessment of suitability:** +++ = very good, ++ = good, + = modest, 0 = unapt

| Site condition (soil/climate) | | Farm type / organic N-input | | Land use | |
|---|---|---|---|---|---|
| sandy soil, < 600 mm | ++ | arable (< 40 kg N/ha) | ++ | arable | +++ |
| sandy soil, >= 600 mm | ++ | pigs/poultry (40-120 kg N/ha) | ++ | grassland | 0 |
| loamy soil, < 600 mm | + | pigs/poultry (> 120 kg N/ha) | +++ | permanent crops | 0 |
| loamy soil, >= 600 mm | ++ | dairy (40-120 kg/ha) | ++ | vegetables | 0 |
| peatland, organic soil | + | dairy (>120 kg N/ha) | +++ | | |
| **Specification of land suitablity:** in regions with low rainfalls in the late summer | | | | | |

| Payment [€/ha] | Indicators | Reduction [kg N/ha] | | | Cost-effectiveness [€/kg N] | | |
|---|---|---|---|---|---|---|---|
| | | min. | Ø | max. | min. | Ø | max. |
| 25 | N balance | 0 | 5 | 10 | 2.5 | 5 | ∞ |
| | soil mineral N autumn | 0 | 10 | 20 | 0.8 | 2.5 | ∞ |

| implementation conditions | | other environmental impacts | |
|---|---|---|---|
| acceptance | ++ | climate protection | ++ |
| possibility to control | +++ | landscape and nature conservation | +++ |
| possibility to administrate | +++ | soil protection, erosion control | +++ |

**Comments:** In some regions it is common to renounce to soil tillage after maize harvest, thus windfall profits could be quite important.

## 2.6 **Restrictions for farm manure application in autumn (H 6)**

**Environmental target:** improvement of N use efficiency by substitution of mineral fertilisers and reduction of N losses over winter time

**Target area:** farm scale

| **Management conditions** | **Explanations and recommendations** |
|---|---|
| application of slurry, liquid manure, poultry droppings, fermentation substrates and other organic secondary raw material fertilisers after harvesting on all cropped land only to catch crop or winter rape until 15th of September | only when the applied organic fertiliser N can be taken up into biomass before winter high soil mineral N values can be avoided; the limitation of the application until 15th of September instead of the 1st of November (arable) or the 15th of November (grassland) assures a good uptake and thus avoids excess supply in autumn; the earliest application in spring is the 1st of February following the restrictions of the fertilising ordinance |
| above mentioned organic fertiliser on grassland until 31st of September | the vegetation period of grassland is longer and the risk of N losses is lower, therefore the period fixed for manure application on grassland is 2 weeks longer in autumn than for arable land |
| measure restricted to farms using more than 100 kg N of the specified farm internal organic fertilisers per hectare of agricultural land, where as contracts to supply organic fertiliser from third parties count as "farm-internal" | the measure targets farms with a high amount of organic fertilisers , because especially they usually apply manure on stubble fields and have high values for soil mineral N in autumn; import of organic fertiliser is treated like the own manure to take into account transfers between farms (e.g. exchange of pig slurry against dairy slurry and vice versa) |
| **Reference situation without measure** (for impact assessment) | |
| spreading of organic fertilisers following the guidelines of the good agricultural practice (e.g. up to 80 kg N /ha on stubble fields and less restricted time period | |

**Assessment of suitability:** +++ = very good, ++ = good, + = modest, 0 = unapt

| **Site condition (soil/climate)** | | **Farm type / organic N-input** | | **Land use** | |
|---|---|---|---|---|---|
| sandy soil, < 600 mm | +++ | arable (< 40 kg N/ha) | 0 | arable | +++ |
| sandy soil, >= 600 mm | +++ | pigs/poultry (40-120 kg N/ha) | ++ | grassland | ++ |
| loamy soil, < 600 mm | + | pigs/poultry (> 120 kg N/ha) | +++ | permanent crops | + |
| loamy soil, >= 600 mm | ++ | dairy (40-120 kg/ha) | ++ | vegetables | 0 |
| peatland, organic soils | +++ | dairy (>120 kg N/ha) | +++ | | |
| **Specification of land suitablity:** in regions with a high portion of organic fertilisers | | | | | |

| **Payment [€/ha]** | **Indicators** | **Reduction [kg N/ha]** | | | **Cost-effectiveness [€/kg N]** | | |
|---|---|---|---|---|---|---|---|
| | | **min.** | **Ø** | **max.** | **min.** | **Ø** | **max.** |
| 15 | N balance | 10 | 15 | 40 | 0.6 | 1.7 | 2.5 |
| | soil mineral N autumn | 10 | 15 | 20 | 0.8 | 1 | 1.5 |

| **implementation conditions** | | **other environmental impacts** | |
|---|---|---|---|
| acceptance | ++ | climate protection | ++ |
| possibility to control | ++ | landscape and nature conservation | 0 |
| possibility to administrate | + | soil protection, erosion control | + |

**Comments:** The measure aims to improve the on-farm organic fertiliser management. Fallow land (non fertilised) is excluded from the payment. The above mentioned N reduction is an average over all arable and grassland uses. There is a possibility of double support in combination with catch crop growing. The export of manure to other farms in the neighbourhood is not excluded. This can abolish the effect at regional level. An extension of the minimum storage capacities for slurry (by the year 2009 6 months) has a similar effect like this measure. The measure rewards the renouncement of manure application on stubble fields with no rape or catch crop follwing in autumn, and of late application on grassland.

## 2.7 Improved slurry application techniques (H 7)

**Environmental target:** improvement of N use efficiency by substitution of mineral fertilisers

**Target area:** parcel scale

| Management conditions | Explanations and recommendations |
|---|---|
| application of slurry and fermentation substrates in spring/summer (from 1st of February to 15th of July) with drag hoses, trailing shoes or injection technique in growing winter cereals, winter rape and on grassland/ ley farming<br>for application with contractors the evidence has to be present; for self-application a record about slurry quantities and surface has to exist | Targets a replacement/ reduction of mineral fertiliser in winter cereals and winter rape in spring as well as an improved organic fertilisation of grassland (avoids gaseous losses, surface run-off and by the way a better use of the slurry N) |
| **Reference situation without measure** (for impact assessment) | |
| spreading of slurry with usual technology (broadcast) | |

**Assessment of suitability:** +++ = very good, ++ = good, + = modest, 0 = unapt

| Site condition (soil/climate) | | Farm type / organic N-input | | | Land use | |
|---|---|---|---|---|---|---|
| sandy soil, < 600 mm | +++ | arable | (< 40 kg N/ha) | 0 | arable | +++ |
| sandy soil, >= 600 mm | +++ | pigs/poultry | (40-120 kg N/ha) | ++ | grassland | ++ |
| loamy soil, < 600 mm | + | pigs/poultry | (> 120 kg N/ha) | +++ | permanent crops | + |
| loamy soil, >= 600 mm | ++ | dairy | (40-120 kg/ha) | ++ | vegetables | 0 |
| peatland, organic soils | ++ | dairy | (>120 kg N/ha) | +++ | | |
| **Specification of land suitablity:** growing cereals and growing rape (drag hoses, injection), grassland and ley farming (trailing shoes) | | | | | | |

| Payment [€/ha] | Indicators | Reduction [kg N/ha] | | | Cost-effectiveness [€/kg N] | | |
|---|---|---|---|---|---|---|---|
| | | min. | ∅ | max. | min. | ∅ | max. |
| 25-35* | N balance | 10 | 15 | 40 | 0.6-0.9 | 1.7-2.3 | 2.5-3.5 |
| | soil mineral N autumn | 0 | 10 | 20 | 1.3-1.8 | 2.5-3.5 | ∞ |

| implementation conditions | | other environmental impacts | |
|---|---|---|---|
| acceptance | +++ | climate protection | +++ |
| possibility to control | +++ | landscape and nature conservation | + |
| possibility to administrate | ++ | soil protection, erosion control | 0 |

* 25 €/ha for drag hoses, 35 €/ha for trailing shoes or injection

**Comments:** The slurry application can be done to a greater surface in spring with improved application technique. Today the technique is dominated by drag hoses on arable land and trailing shoes on grassland. Injection technique is up to now used on a very small share. Only if mineral fertiliser is replaced by improved slurry application (especially for fertilisation in spring) a positive effect on the N balance can be achieved. On grassland it is important to have a dry matter fraction under 8 % to avoid application problems.

## 2.8 **Reduced row spacing for maize (H 8)**

**Environmental target:** improvement of N uptake by the maize plants, increase of N use efficiency

**Target area:** parcel scale

| **Management conditions** | **Explanations and recommendations** |
|---|---|
| sowing of maize with reduced distance between maize rows (maximum width 45 cm) | the plants are more evenly distributed and cover the soil earlier, this allows a better uptake of N; especially suitable for silage maize (and for biomass production) |
| no N-fertilisation after maize harvesting until 1st of March | enough N remains in the soil, so that no N fertilisation is necessary for a good decomposition of the maize stubble; no N fertilisation is necessary even if a late winter crop is following |
| obligation for each farmer to saw maize with usual space (approx. 75 cm) in one part of a field with a maximum size of 2 ha); | this management condition is due to the WAgriCo project approach and allows to get data for a with-without comparison of soil mineral N content in autumn |
| | recommendation to limit the N-fertilisation to max. 140 kg/ha |
| **Reference situation without measure** (for impact assessment) | |
| Silage maize with usual row spacing (75 cm) | |

**Assessment of suitability:** +++ = very good, ++ = good, + = modest, 0 = unapt

| **Site condition (soil/climate)** | | **Farm type / organic N-input** | | **Land use** | |
|---|---|---|---|---|---|
| sandy soil, < 600 mm | ++ | arable (< 40 kg N/ha) | ++ | arable | +++ |
| sandy soil, >= 600 mm | ++ | pigs/poultry (40-120 kg N/ha) | ++ | grassland | 0 |
| loamy soil, < 600 mm | + | pigs/poultry (> 120 kg N/ha) | ++ | permanent crops | 0 |
| loamy soil, >= 600 mm | ++ | dairy (40-120 kg/ha) | +++ | vegetables | 0 |
| peatland, organic soils | + | dairy (>120 kg N/ha) | +++ | | |
| **Specification of land suitablity:** also suitable to reduce erosion on sloped plots | | | | | |

| **Payment [€/ha]** | **Indicators** | **Reduction [kg N/ha]** | | | **Cost-effectiveness [€/kg N]** | | |
|---|---|---|---|---|---|---|---|
| | | **min.** | **Ø** | **max.** | **min.** | **Ø** | **max.** |
| 40 | N balance | 0 | 10 | 20 | 2 | 4 | ∞ |
| | soil mineral N autumn | 0 | 10 | 15 | 2.7 | 4 | ∞ |

| **implementation conditions** | | **other environmental impacts** | |
|---|---|---|---|
| acceptance | + | climate protection | 0 |
| possibility to control | ++ | landscape and nature conservation | 0 |
| possibility to administrate | +++ | soil protection, erosion control | ++ |

**Comments:** The impact assessment for this measure is ambiguous so far, but the effectiveness increases for low / suboptimal N fertilisation. Therefore it is suitable to combine the reduced row spacing of maize with a limited N fertilisation and reduced tillage after harvest (to reduce mineralization).

## 2.9 Use of ammonium based liquid fertilisers using injection technique in cereals (H 9)

**Environmental target:** reduction of N losses and increase of N use efficiency by creation of ammonium depots

**Target area:** parcel scale

| Management conditions | Explanations and recommendations |
|---|---|
| application of the injection technique for liquid mineral nitrogen fertilisation before stem elongation of the cereals (once or twice) | avoidance of N losses in spring, increase of the N use efficiency; it is allowed to use other N fertilisers for the corn filling period (for high-protein wheat) |
| solely use of injection technique until 15th of May; P and K fertilisation can be done in the conventional way | change to an ammonium based N uptake of the plants is only possible if no other N fertilisers are applied |
| no organic fertilisation from sowing until harvest, then only in autumn; | field trials showed that the ammonium uptake is much better from soils without organic N fertilisation |
| an evidence for use of injection technique has to be provided | |
| **Reference situation without measure** (for impact assessment) | |
| Application of mineral fertiliser with the usual technique | |

**Assessment of suitability:** +++ = very good, ++ = good, + = modest, 0 = unapt

| Site condition (soil/climate) | | Farm type / organic N-input | | Land use | |
|---|---|---|---|---|---|
| sandy soil, < 600 mm | ++ | arable (< 40 kg N/ha) | +++ | arable | +++ |
| sandy soil, >= 600 mm | ++ | pigs/poultry (40-120 kg N/ha) | +++ | grassland | 0 |
| loamy soil, < 600 mm | + | pigs/poultry (> 120 kg N/ha) | + | permanent crops | 0 |
| loamy soil, >= 600 mm | + | dairy (40-120 kg/ha) | ++ | vegetables | +++ |
| peatland, organic soils | 0 | dairy (>120 kg N/ha) | + | | |
| **Specification of land suitablity:** especially suitable for nutrient-poor, sandy soils with application of the injection technique once or twice at the beginning of the vegetation period | | | | | |

| Payment [€/ha] | Indicators | Reduction [kg N/ha] | | | Cost-effectiveness [€/kg N] | | |
|---|---|---|---|---|---|---|---|
| | | min. | ∅ | max. | min. | ∅ | max. |
| 35 | N balance | 0 | 10 | 20 | 1.8 | 3.5 | ∞ |
| | soil mineral N autumn | 0 | 10 | 20 | 1.8 | 3.5 | ∞ |

| implementation conditions | | other environmental impacts | |
|---|---|---|---|
| acceptance | ++ | climate protection | + |
| possibility to control | +++ | landscape and nature conservation | 0 |
| possibility to administrate | ++ | soil protection, erosion control | 0 |

**Comments:** The application in spring helps to reduce N losses in the early vegetation period and leads to a reduction of the N surplus by a better N use efficiency. Field trials have shown a reduction of the N use efficiency compared to the conventional N fertilisation, if bad growing conditions occur after a sole N application with the N injection technique as well as in situations where the available N is not fully used by the plants. The measure aims to stabilise the yield. In vegetables better qualities with lower nitrate values are produced using ammonium based injection technique.

## 2.10 Application of stabilised mineral fertilizer in spring on winter cereals and potatoes (H 10)

**Environmental target:** increase of N use efficiency by adaptation of the N supply to the needs

**Target area:** parcel scale

| Management conditions | Explanations and recommendations |
|---|---|
| use of stabilised mineral nitrogen fertiliser, for potatoes in the formula of ammonium | avoidance of N losses in spring, increase of the N use efficiency, the risk of a high supply of N in times when the plants have only a little need is lower when stabilised mineral fertiliser are used |
| solely use of stabilised fertiliser in spring until 15th of May | the N use efficiency is influenced negatively if other N fertilisers are used in addition to the stabilised one |
| if use of organic fertilisers, then only in autumn | |
| purchase (expense) voucher as evidence | |
| **Reference situation without measure** (for impact assessment) | |
| Application of mineral fertiliser with the usual technique | |

**Assessment of suitability:** +++ = very good, ++ = good, + = modest, 0 = unapt

| Site condition (soil/climate) | | Farm type / organic N-input | | Land use | |
|---|---|---|---|---|---|
| sandy soil, < 600 mm | ++ | arable (< 40 kg N/ha) | ++ | arable | +++ |
| sandy soil, >= 600 mm | ++ | pigs/poultry (40-120 kg N/ha) | ++ | grassland | 0 |
| loamy soil, < 600 mm | + | pigs/poultry (> 120 kg N/ha) | + | permanent crops | 0 |
| loamy soil, >= 600 mm | + | dairy (40-120 kg/ha) | ++ | vegetables | + |
| peatland, organic soils | 0 | dairy (>120 kg N/ha) | + | | |
| **Specification of land suitablity:** especially suitable for nutrient-poor, sandy soils with application once at the beginning of the vegetation period | | | | | |

| Payment [€/ha] | Indicators | Reduction [kg N/ha] | | | Cost-effectiveness [€/kg N] | | |
|---|---|---|---|---|---|---|---|
| | | min. | Ø | max. | min. | Ø | max. |
| 25 | N balance | 0 | 10 | 20 | 1.2 | 2.5 | ∞ |
| | soil mineral N autumn | 0 | 10 | 20 | 1.2 | 2.5 | ∞ |

| implementation conditions | | other environmental impacts | |
|---|---|---|---|
| acceptance | ++ | climate protection | + |
| possibility to control | ++ | landscape and nature conservation | 0 |
| possibility to administrate | ++ | soil protection, erosion control | 0 |

**Comments:** The application in spring aims at reduction of N losses in spring and thus the reduction of the N surplus. The measure shall also stabilise the yield. It is quite difficult to manage a well adapted N supply to reach the optimal yields. The environmental effects are much better if the use of stabilised N fertilisers is combined with a reduced N fertilisation.

## 2.11 **Undersown catch crops in maize (H 11)**

**Environmental target:** reduction of N-leaching over winter, long storage of N in biomass

**Target area:** parcel scale

| **Management conditions** | **Explanations and recommendations** |
|---|---|
| Sow grasses as pure stand or as variety-mixtures (legume-free) as undersown crops in silage maize | to avoid biological N-fixation leguminous plants are excluded |
| no N-fertilisation after maize harvesting until 1st of February | the sowing technique is essential for a good growth of the grass and thus for a positive the environmental effect |
| earliest ploughing in the following year from 1st of February | avoidance of the release of the N stored in the biomass of catch crop before winter |
| no grazing | to prevent hot-spots of N losses due to animal excrements |
| **Reference situation without measure** (for impact assessment) | |
| ploughing in autumn before summer crop | |

**Assessment of suitability:** +++ = very good, ++ = good, + = modest, 0 = unapt

| **Site condition (soil/climate)** | | **Farm type / organic N-input** | | **Land use** | |
|---|---|---|---|---|---|
| sandy soil, < 600 mm | 0 | arable (< 40 kg N/ha) | + | arable | ++ |
| sandy soil, >= 600 mm | ++ | pigs/poultry (40-120 kg N/ha) | ++ | grassland | 0 |
| loamy soil, < 600 mm | 0 | pigs/poultry (> 120 kg N/ha) | +++ | permanent crops | 0 |
| loamy soil, >= 600 mm | ++ | dairy (40-120 kg/ha) | ++ | vegetables | 0 |
| peatland, organic soils | ++ | dairy (>120 kg N/ha) | +++ | | |
| **Specification of land suitablity:** needs enough rainfall, especially in late summer | | | | | |

| **Payment [€/ha]** | **Indicators** | **Reduction [kg N/ha]** | | | **Cost-effectiveness [€/kg N]** | | |
|---|---|---|---|---|---|---|---|
| | | **min.** | **Ø** | **max.** | **min.** | **Ø** | **max.** |
| 125 | N balance | 0 | 10 | 20 | 6.3 | | ∞ |
| | soil mineral N autumn | 10 | 20 | 40 | 3.1 | 6.3 | 12.5 |

| **implementation conditions** | | **other environmental impacts** | |
|---|---|---|---|
| acceptance | + | climate protection | + |
| possibility to control | ++ | landscape and nature conservation | ++ |
| possibility to administrate | +++ | soil protection, erosion control | +++ |

**Comments:** For this measure a good timing and a well adapted technique for sowing the grass is essential. A better acceptance is possible if contractors are responsible for the sowing of the grass into the maize. If the maize is harvested late, especially in combination with dry climate conditions in late summer, a total loss of the undersown crops is possible. On the other side, if the undersown crops grow to well there is the risk of maize yield losses, because of water and nutrient competition. Those difficulties explain the until now low acceptance rate of this measure in practice. If well practiced the environmental effects are similar to those of winter-hardy catch crops. Another problem to cope with is the risk of injuries and the need to adapt the use of herbicides. An increase of the N surplus could not be excluded, because it is difficult to control if the preserved N is taken into account for the following crop if the grass is not harvested.

## 2.12 Turnip (brassica rapa sylvestris) as catch crop before winter cereals (H 12)

**Environmental target:** reduction/avoidance of N leaching over winter, storage of N in biomass and in the root zone

**Target area:** parcel scale

| Management conditions | Explanations and recommendations |
|---|---|
| sow catch crop by 15th of August | to accumulate N in the root zone of the turnip and to achieve a high N uptake it is essential that the growing period is long enough, therefore it is necessary that the catch crop is sown as quick as possible after harvest of the previous crop |
| use 10-12 kg of sowings | to reach a quick and good coverage of the soil a high number of plants is necessary |
| no N fertilisers to the turnip and the following winter cereals in autumn | enough N remains in the soil (previous crop in general cereals or rape), so that no N fertilisation is necessary to assure a good growth of turnip and following winter cereals |
| ploughing not before 10th of October | the shorter the time period between ploughing of the catch crop and sowing of the following cereal the lower the N losses in autumn |
| **Reference situation without measure** (for impact assessment) | |
| tillage of stubble field with winter cereals following | |

**Assessment of suitability:** +++ = very good, ++ = good, + = modest, 0 = unapt

| Site condition (soil/climate) | | Farm type / organic N-input | | Land use | |
|---|---|---|---|---|---|
| sandy soil, < 600 mm | ++ | arable (< 40 kg N/ha) | ++ | arable | ++ |
| sandy soil, >= 600 mm | ++ | pigs/poultry (40-120 kg N/ha) | ++ | grassland | 0 |
| loamy soil, < 600 mm | + | pigs/poultry (> 120 kg N/ha) | ++ | permanent crops | 0 |
| loamy soil, >= 600 mm | ++ | dairy (40-120 kg/ha) | ++ | vegetables | ++ |
| peatland, organic soils | + | dairy (>120 kg N/ha) | ++ | | |
| **Specification of land suitablity:** on arable land before winter crops; harvest of previous crop until end of July | | | | | |

| Payment [€/ha] | Indicators | Reduction [kg N/ha] | | | Cost-effectiveness [€/kg N] | | |
|---|---|---|---|---|---|---|---|
| | | min. | Ø | max. | min. | Ø | max. |
| 60 | N balance | 0 | 10 | 20 | 3 | | ∞ |
| | soil mineral N autumn | 20 | 30 | 40 | 1.5 | 2 | 3 |

| implementation conditions | | other environmental impacts | |
|---|---|---|---|
| acceptance | ++ | climate protection | + |
| possibility to control | ++ | landscape and nature conservation | ++ |
| possibility to administrate | +++ | soil protection, erosion control | +++ |

**Comments:** There is only little experience with that measure, but monitoring of soil mineral N in autumn shows a good environmental effect. N storage in the turnip roots means slower mineralization compared to catch crops storing N mainly in the leaves and stalks which are more quickly decomposed after tillage. If well managed and if the temperature is not high after sowing the winter cereals the N mineralization in autumn is quite low, while high temperature in winter is negative. Turnip needs enough water in late summer/early autumn and reduces the leachate. The suitability is influenced by the length of vegetation time dependent from the altitude.

## 2.13 Reduced tillage of volunteer rape seedlings before winter cereals respectively summer crops (H 13)

**Environmental target:** reduction of N losses and reduction of N mineralization

**Target area:** parcel scale

| Management conditions | Explanations and recommendations |
|---|---|
| after harvesting no tillage or immediately after harvest single shallow cultivation | to allow a good establishment of the volunteer seedlings a shallow cultivation is permitted, but not obligatory |
| no N-fertiliser | enough N remains in the soil, so that no N fertilisation is necessary to assure a good growth of volunteer rape seedlings |
| no grazing | to prevent hot-spots of N losses due to animal excrements |
| if summer crops are following ploughing not before 15th of March; for winter cereals no ploughing before 1st of October | minimizing the period of time without plants on the ground for a secure uptake of the N captured in the biomass of the volunteer rape until the following crop |
| before winter cereals use of herbicides from 10th of September allowed | the use of herbicides avoids an intensive tillage of the soil that may cause high N mineralization and makes it possible to use direct seeding technique |
| | recommendation: N content of volunteer rape has to be included in the fertilising plan for follwing crops |
| **Reference situation without measure** (for impact assessment) | |
| tillage of stubble field after rape and ploughing before following crop (winter cereals) | |

**Assessment of suitability:** +++ = very good, ++ = good, + = modest, 0 = unapt

| Site condition (soil/climate) | | Farm type / organic N-input | | Land use | |
|---|---|---|---|---|---|
| sandy soil, < 600 mm | + | arable (< 40 kg N/ha) | ++ | arable | +++ |
| sandy soil, >= 600 mm | ++ | pigs/poultry (40-120 kg N/ha) | ++ | grassland | 0 |
| loamy soil, < 600 mm | + | pigs/poultry (> 120 kg N/ha) | +++ | permanent crops | 0 |
| loamy soil, >= 600 mm | ++ | dairy (40-120 kg/ha) | ++ | vegetables | 0 |
| peatland, organic soils | + | dairy (>120 kg N/ha) | +++ | | |
| **Specification of land suitablity:** suitable for crop rotations with rape and winter cereals | | | | | |

| Payment [€/ha] | Indicators | Reduction [kg N/ha] | | | Cost-effectiveness [€/kg N] | | |
|---|---|---|---|---|---|---|---|
| | | min. | ∅ | max. | min. | ∅ | max. |
| 40 | N balance | 0 | 15-20* | 30-40* | 1.3-1 | 2.7-2 | ∞ |
| | soil mineral N autumn | 0 | 10 | 40 | 1 | 4 | ∞ |

| implementation conditions | | other environmental impacts | |
|---|---|---|---|
| acceptance | + | climate protection | + |
| possibility to control | +++ | landscape and nature conservation | + |
| possibility to administrate | ++ | soil protection, erosion control | ++ |

* 15 kg N/ha (average) or 30 kg N/ha (maximum) for winter crops following the measure and 20 kg N/ha (average) or 40 kg N/ha (maximum) for summer crops

**Comments:** Especially in regions with little or insecure rainfall it is an alternative to catch crop growing.

## 2.14 **Result-oriented measure to improve N use efficiency (E)**

**Environmental target:** improved N fertiliser management at farm scale

**Target area:** farm scale

| **Management conditions** | **Explanations and recommendations** |
|---|---|
| no specific management conditions besides to consistently provide data of nitrogen input and output at farm level in order to allow a documentation of the N balances | farm specific N management adaptations instead of detailed prescriptions<br>recommendations:<br>elaborate a fertiliser plan (using EDV technique) on parcel level to have an overview over the on farm N management and to detect possibilities to reduce fertiliser input<br>analysis of soil mineral N in spring to take N reserves into account, for maize, sugar beet and vegetables in the late spring<br>analysis of the slurry before spreading to know the N content |
| **Reference situation without measure** (for impact assessment) | |
| three-year average of the N balances in the years before participation / *planned:* reference levels for N use efficiency (calculated separately for organic and mineral fertilisers) | |

**Assessment of suitability:** +++ = very good, ++ = good, + = modest, 0 = unapt

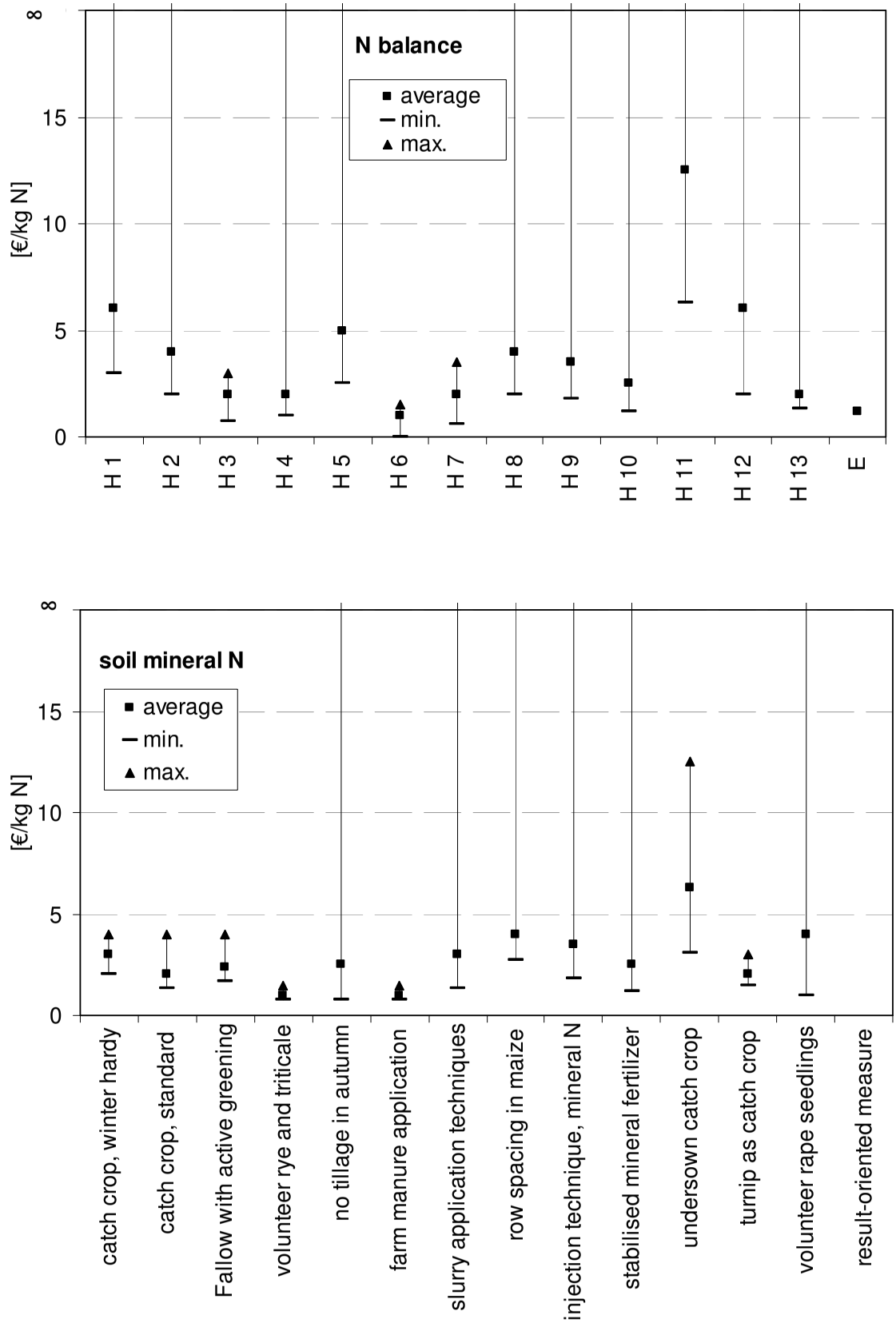
| **Site condition (soil/climate)** | | **Farm type / organic N-input** | | **Land use** | |
|---|---|---|---|---|---|
| sandy soil, < 600 mm | +++ | arable (< 40 kg N/ha) | +++ | arable | +++ |
| sandy soil, >= 600 mm | +++ | pigs/poultry (40-120 kg N/ha) | +++ | grassland | +++ |
| loamy soil, < 600 mm | +++ | pigs/poultry (> 120 kg N/ha) | +++ | permanent crops | +++ |
| loamy soil, >= 600 mm | +++ | dairy (40-120 kg/ha) | +++ | vegetables | +++ |
| peatlands, organic soils | +++ | dairy (>120 kg N/ha) | +++ | | |
| **Specification of land suitablity:** all farms are suited for a participation, thus actually focus lays on arable and grassland use | | | | | |

| **Payment [€/ha]** | **Indicators** | **Reduction [kg N/ha]** | | | **Cost-effectiveness [€/kg N]** |
|---|---|---|---|---|---|
| | | **min.** | **Ø** | **max.** | |
| 0 - 40 | Reduced N surplus (through increased N use efficiency) | 0 | | 33.3* | 1.2 |
| **implementation conditions** | | | **other environmental impacts** | | |
| acceptance | ++ | | climate protection | | +++ |
| possibility to control | + | | landscape and nature conservation | | ++ |
| possibility to administrate | ++ | | soil protection, erosion control | | 0 |

* Payment limited to a maximum of 40 € / ha, so that only a reduction of up to 33.3 kg N/ha is rewarded, although the real reduction could be higher.

**Comments:** Until now only little experience with the result-oriented approach exists. In the WAgriCo project the measure is tested as top-up payment to the 13 action-oriented measures. All project farmers agreed to participate. A reliable and consistent nutrient accounting system is a must. To improve the acceptance this measure has to be supported by technical advice, at least in the beginning. As there exists no benchmarking, in the WAgriCo project it was agrred to reward the improvement of N use efficiency (calculated separately for organic and mineral fertilisers). In future it is planned to reward only N use efficiencies above a fixed reference level. A realistic setting of this reference level shall be derived from project data and discussed during the ongoing project.

**Figure 1:** Cost-effectiveness of the single measures tested within WAgriCo



The figure 1 shows that there is a high uncertainty about cost-effectiveness of the selected measures. Nevertheless, there are some measures with a quite secure result to reduce soil mineral N, like catch crop growing. By the same time, for this group of measures the effect on N surplus depends mainly on fertiliser management in the following year, which again implies uncertainties about effects in follwing years.

Table 2 contains a summary of the payments and the expected values of average N reduction that could be obtained. It has to be considered that the N reduction potentials are indicated for good conditions concerning the selection of site, farm type and land use, and for 'good practice' implementation of the measures. On basis of this information the average cost-effectiveness of the 13 measures was calculated. For the result-oriented measure the cost-effectiveness is directly represented by the reward per kg N, while the possible N reduction varies within the range defined for remuneration (5-33 kg N/ha). The result-oriented measure (E) may also have a positive effect on soil mineral N in autumn, but this effect is not quantified here, as it depends on the specific situation of the farm and the management adaptations selected.

**Table 2:** Average N-reduction and cost-efficiency of single WAgriCo-measures

| No | Name | Payment [€/ha*a] | Average N reduction [kg N/ha*a] | | Average cost-efficiency [€/kg N] | |
|---|---|---|---|---|---|---|
| | | | N balance | Soil mineral N | N balance | Soil mineral N |
| H 1 | catch crop, winter hardy | 120 | 20 | 40 | 6 | 3 |
| H 2 | catch crop, standard | 80 | 20 | 40 | 4 | 2 |
| H 3 | Fallow with active greening | 120 | 60 | 50 | 2 | 2.4 |
| H 4 | volunteer rye and triticale | 30 | 15 | 30 | 2 | 1 |
| H 5 | no tillage in autumn | 25 | 5 | 10 | 5 | 2.5 |
| H 6 | farm manure application | 15 | 15 | 15 | 1 | 1 |
| H 7 | slurry application techniques | 30 | 15 | 10 | 2 | 3 |
| H 8 | row spacing in maize | 40 | 10 | 10 | 4 | 4 |
| H 9 | injection technique, mineral N | 35 | 10 | 10 | 3.5 | 3.5 |
| H 10 | stabilised mineral fertilizer | 25 | 10 | 10 | 2.5 | 2.5 |
| H 11 | undersown catch crop | 125 | 10 | 20 | 12.5 | 6.25 |
| H 12 | turnip as catch crop | 60 | 10 | 30 | 6 | 2 |
| H 13 | volunteer rape seedlings | 40 | 20 | 10 | 2 | 4 |
| E | result-oriented measure | 6 - 40 | 5 – 33 | - | 1.2 | - |

# 3 Ranking of WAgriCo measures offered in Lower Saxony

There is not one single solution for a cost-effective planning of measures as in practice for the measure selection more than one criterion has to be considered and the aspects could vary from one catchment or river basin to another. Therefore different rankings of the fourteen water protection measures are presented.

The easiest one is the ranking where only one aspect is considered: the cost-efficiency of the reduction of soil mineral N or of N surplus reduction. The necessary information can be found on the measure sheets. In the ranking example is ranked equal to a median effect of all 13 measures (see table 3). This simple ranking allows to exclude measures that are unsuitable and to make a short list of measures that have to be considered in detail. It can be used as a starting point for further selection.

Another ranking approach presented shows how to proceed if besides the cost-effectiveness of the reduction of nitrogen surplus as the most important selection indicator (and the only environmental effect considered in the hydro-geological modelling approach) the add-on effects like nature and landscape protection, soil and climate protection as well as erosion and surface runoff control are taken into account in the ranking as they are important assets in certain groundwater catchments, too. In this case the methodology used for the ranking is a multi-criteria analysis where different environmental impacts are taken into account simultaneously. In the multi-criteria analysis to each criteria considered a score is given (in our case +, ++ or +++).

A differentiation taking into account their importance is possible by giving weighting factors to each criteria. In the last step the scores are aggregated, in this example by addition of the estimates of all ranking criteria. Whereas the more or less positive ecological effects (+, ++, +++) of measures can be taken directly from the measure sheets, the N reduction is taken from the ranking (ranking number 1 to 7 = +++, 8 to 11 = ++, 12 to 14 = +). A weighting is needed to emphasise the importance of N surplus mitigation. The selection of the appropriate criteria, the definition of weighting factors as well as the aggregation process could be set by groups of stakeholders, in order to increase acceptance for multi-criteria analysis with its subjective elements. In this way, the definition of the ranking procedures makes the selection of measures more comprehensible and reproducible. As the N reduction is the dominating target, lower weighting factors have been used for the other environmental impacts in our example presented in table 3.

In table 4 a third approach is presented. In a first step the measures are grouped considering their suitability per farm type and not their cost-effectiveness. In our case the decisive factor is the farm type. This is based on the fact, that there is in

general a quite good local knowledge about the dominating farm types and their contribution to N pollution. Instead of using an additive aggregation, the criteria cost-efficiency of the reduction of the N balance and the suitable farm types, the aggregation of the ranking factors is done by multiplication. This allows to consider the degree of suitability and area potential of the measures. Using this ranking methodology the measures that fit best for the particular farm type have a higher ranking than those with a less positive assessment of suitability even if their cost-effectiveness of N reduction is better.

In general, additive aggregation of ranking factors is appropriate if there are several, separate aspects evaluated, e. g. impacts on different environmental goods. Multiplicative aggregation is recommended for factors like farm type suitability, acceptance, and administrability.

**Table 3:** Ranking of WAgriCo measures using an additive aggregation

<table>
<tr><th>Ranking</th><th>Cost-efficiency of N balance</th><th>Cost-efficiency of soil mineral N</th><th>Climate protection</th><th>nature and landscape conservation</th><th>soil protection , erosion control</th><th>Cost-efficiency of N mitigation and other ecological impacts</th></tr>
<tr><td>1</td><td>H 6</td><td rowspan="2">H 4, H 6</td><td rowspan="2">H 7, E</td><td rowspan="3">H 3, H 4, H 5, E</td><td rowspan="5">H 1, H 2, H 3, H 4, H 5, H 11, H 12</td><td rowspan="2">H 3, H4</td></tr>
<tr><td>2</td><td>E</td></tr>
<tr><td>3</td><td rowspan="4">H 3, H 4, H 7, H 13</td><td rowspan="2">H 2, H 12</td><td rowspan="3">H 3, H 4, H 5, H 6</td><td>H 5</td></tr>
<tr><td>4</td><td>E</td></tr>
<tr><td>5</td><td>H 3</td><td rowspan="3">H 1, H 2, H 11, H 12</td><td>H 6</td></tr>
<tr><td>6</td><td rowspan="2">H 5, H10</td><td rowspan="6">H 1, H 2, H 9, H 10, H 11, H 12, H 13</td><td rowspan="3">H 2, H 7, H 12</td></tr>
<tr><td>7</td><td>H 10</td><td rowspan="2">H 8, H 13</td></tr>
<tr><td>8</td><td>H 9</td><td rowspan="2">H 1, H 7</td><td rowspan="2">H 7, H 13</td></tr>
<tr><td>9</td><td rowspan="2">H 2, H 8</td><td>H 10</td></tr>
<tr><td>10</td><td rowspan="2">H 9, E</td><td>H 6</td><td rowspan="2">H 1, H 13</td></tr>
<tr><td>11</td><td>H 5</td><td rowspan="3">H 6, H 8, H 9, H 10</td><td rowspan="3">H 7, H 9, H 10, E</td></tr>
<tr><td>12</td><td rowspan="2">H 1, H 12</td><td rowspan="2">H 8, H 13</td><td>H 11</td></tr>
<tr><td>13</td><td>H 9</td></tr>
<tr><td>14</td><td>H 11</td><td>H 11</td><td>H 8</td><td>H 8</td></tr>
<tr><td colspan="7"></td></tr>
<tr><td>Weight</td><td>2</td><td>2</td><td>1</td><td>1</td><td>1</td><td>∑</td></tr>
<tr><td colspan="7">Example:</td></tr>
<tr><td>H 7</td><td>+++ * 2</td><td>++ * 2</td><td>+++ * 1</td><td>+ * 1</td><td>0 * 1</td><td>14</td></tr>
<tr><td>H 13</td><td>+++ * 2</td><td>+ * 2</td><td>+ * 1</td><td>+ * 1</td><td>++ * 1</td><td>12</td></tr>
</table>

**Table 4:** Ranking of WAgriCo measures using a grouped aggregation

<table>
<tr><th rowspan="2">Ranking</th><th rowspan="2">Cost-efficiency of N balance</th><th rowspan="2">Arable farms</th><th rowspan="2">Dairy farms</th><th rowspan="2">Pigs/ poultry farms</th><th colspan="3">Cost-efficiency of N balance<br>IN COMBINATION WITH</th></tr>
<tr><th>Arable farms</th><th>Dairy farms</th><th>Pig/poultry farms</th></tr>
<tr><td>1</td><td rowspan="6">H 6, E, H 3, H 4, H 7, H 13 H 10</td><td rowspan="3">H 3, H 4, H 9, E</td><td rowspan="3">H 1, H 3, H 4, H 8, E</td><td rowspan="3">H 1, H 3, H 4, E</td><td rowspan="2">H 3, H 4, E</td><td rowspan="2">H 3, H 4, E</td><td rowspan="2">H 3, H 4, E</td></tr>
<tr><td>2</td></tr>
<tr><td>3</td></tr>
<tr><td>4</td><td rowspan="5">H 1, H 2, H 5, H 8, H 10, H 12, H 13</td><td rowspan="4">H 5, H 6, H 7, H 11, H 13</td><td rowspan="2">H 9, H 10, H 13</td><td rowspan="3">H 6, H 7, H 8, H 13</td><td rowspan="2">H 6, H 7, H 13</td></tr>
<tr><td>5</td></tr>
<tr><td>6</td><td rowspan="2">H 2, H 8</td><td rowspan="2">H 1</td></tr>
<tr><td>7</td><td rowspan="3">H 9, H 2, H 8</td></tr>
<tr><td>8</td><td rowspan="3">H 2, H 12,</td><td rowspan="3">H 2, H 8, H 9, H 12</td><td rowspan="2">H 1, H 5, H 12</td><td rowspan="2">H 2, H 5, H 11</td><td rowspan="3">H 2, H 5, H 8, H 9, H 11</td></tr>
<tr><td>9</td></tr>
<tr><td>10</td></tr>
<tr><td>11</td><td rowspan="4">H 5, H 1, H 12, H 11</td><td rowspan="2">H 11</td><td rowspan="2">H 11</td><td rowspan="2">H 12</td></tr>
<tr><td>12</td></tr>
<tr><td>13</td><td rowspan="2">unapt: H 6, H 7</td><td rowspan="2">unapt: H 9, H 10</td><td rowspan="2">unapt: H 10</td><td rowspan="2">H 6, H 7</td><td rowspan="2">H 9, H 10</td><td>H 12</td></tr>
<tr><td>14</td><td>H 10</td></tr>
<tr><td colspan="8">Example:</td></tr>
<tr><td>H 9</td><td>++</td><td>+++</td><td>0</td><td>+</td><td>6</td><td>0</td><td>2</td></tr>
<tr><td>H 7</td><td>+++</td><td>0</td><td>++</td><td>++</td><td>0</td><td>6</td><td>6</td></tr>
</table>

In practice there is a need of individual decisions in order to select the most appropriate measures for the given situation, which depends on site conditions (soil, rainfall), additional environmental impacts, farm type, land use and crop rotation. Other decisive criteria for the administrative body when they look for useful water protection measures are the possibility to control and to administrate the measures, and last but not least acceptance of farmers to perform water protection measures.

# 4 Combinations of WAgriCo measures and estimated cumulative effects in Lower Saxony

One farm can conduct several measures by the same time, either on different parcels or in the same year on the same land. In the case of different parcels, the single technical-organisational measures have effects independent from other measures. However, the optimal protective effect can often be achieved by specific combinations on the same parcel with higher reliability. In addition, the question of measure combinations is politically relevant, e.g., with regard to the question whether the measure payments are added or whether a cumulation should be excluded. There are several combinations possible between the selected fourteen measures that are both technically feasible and usual practice. A matrix of single parcel combinations of the action-oriented measures is shown in Annex 2. How far

these combinations are realised, depends on the specific situation of the single farm (location, farm type etc.). In principle the measure combinations, which allow an easy integration into the present management and the existing crop rotation are more accepted by the farmers. Nevertheless, for measure combinations often higher management skills are necessary than for the implementation of one single action-oriented measure at parcel level. In order to extrapolate the measure implementation at state level and to estimate the N reduction potential as well as the resulting financial cost, an estimation of the cumulative effects of the WAgriCo measures has to be conducted. As it is not possible to estimate the cost-effectiveness of measure combinations simultaneously it is necessary to proceed in three steps. First the costs for selected measure combinations are estimated:

*Costs = target area x potential measure area x acceptance x cumulative payments.*

The environmental effectiveness of the measure combination is calculated using the quantitative information out of the measure sheet and taking into account possible combinations on plot-level (see Annex 2):

*Environmental effectiveness = target area x potential measure area x cumulated effectiveness of the measure combination*

Finally, to quantify the cumulative cost-effectiveness it is necessary to calculate the cost divided by the environmental effectiveness for the selected measure-combinations.

Information necessary for the estimation of the cost-effectiveness of measure combinations is the suitability of the measures in accordance with farm type and site conditions, the potential surface of each measure, and the level of expected acceptance. Table 5 contains the selected measures and distinguishes two categories: implementation possible and probable shown by “x” and implementation technically feasible, but not probable (e.g. because of water restrictions under dry conditions) shown by “(x)”. The latter are not further considered. The classification is done for four farm types and five different site conditions. Selected (applicable) measures are possible to be combined within one farm unit, but for some measures not on the same parcel. A distinction is made between low and high rainfall with 600 mm precipitation per year as borderline. The second site condition considered is the soil, with sandy or loamy soils differing in sand content by more or less than 50 %. The potential surface for measure implementation has to be estimated using information about the surface of appropriate crops and crop rotations. For the parcel-related measures the surface is limited to agricultural land within the target areas. With the help of the assembled information it is possible to make a rough estimation about the possible N reduction and the cost and the resulting cost-effectiveness.

**Table 5:** Applicable measures depending from farm type, measure-combinations on farm level

| Number of measure | H1 | H2 | H3 | H4 | H5 | H6 | H7 | H8 | H9 | H10 | H11 | H12 | H13 | E | Site condition |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Land use<br>farm type | arable land | arable land | arable land | arable land | arable land | arable-/ grass-land | arable-/ grass-land | arable land | arable land | arable land | arable land | arable land | arable land | arable-/ grass-land | |
| arable farm 1 | (x) | x | x | x | x | | | | x | x | | x | x | x | sandy, low rainfall |
| arable farm 2 | x | x | x | x | x | | | | x | x | | x | x | x | sandy, high rainfall |
| arable farm 3 | (x) | x | x | x | x | | | | x | x | | x | x | x | loamy, low rainfall |
| arable farm 4 | x | x | x | x | x | | | | x | x | | x | x | x | loamy, high rainfall |
| arable farm 5 | x | x | x | x | x | | | | x | x | | x | x | x | peatlands, org. soils |
| dairy farm 1 | x | x | x | x | x | x | x | x | (x) | x | (x) | x | x | x | sandy, low rainfall |
| dairy farm 2 | x | x | x | x | x | x | x | x | (x) | x | x | x | x | x | sandy, high rainfall |
| dairy farm 3 | x | x | x | x | x | x | x | x | (x) | x | (x) | x | x | x | loamy, low rainfall |
| dairy farm 4 | x | x | x | x | x | x | x | x | (x) | x | x | x | x | x | loamy, high rainfall |
| dairy farm 5 | x | x | x | x | x | x | x | x | (x) | x | x | x | x | x | peatlands, org. soils |
| pigs, poultry farm 1 | x | x | x | x | x | x | x | x | (x) | x | (x) | x | x | x | sandy, low rainf. |
| pigs, poultry farm 2 | x | x | x | x | x | x | x | x | (x) | x | x | x | x | x | sandy, high rainfall |
| pigs, poultry farm 3 | x | x | x | x | x | x | x | x | (x) | x | (x) | x | x | x | loamy, low rainf. |
| pigs, poultry farm 4 | x | x | x | x | x | x | x | x | (x) | x | x | x | x | x | loamy, high rainfall |
| pigs, poultry farm 5 | x | x | x | x | x | x | x | x | (x) | x | x | x | x | x | peatlands, org. soils |
| others 1* | (x) | (x) | x | | | | | | (x) | x | | (x) | | x | sandy, low rainfall |
| others 2* | (x) | (x) | x | | | | | | (x) | x | | (x) | | x | sandy, high rainfall |
| others 3* | (x) | (x) | x | | | | | | (x) | x | | (x) | | x | loamy, low rainfall |
| others 4* | (x) | (x) | x | | | | | | (x) | x | | (x) | | x | loamy, high rainfall |
| others * | (x) | (x) | x | | | | | | (x) | x | | (x) | | x | peatlands, org. soils |

* others include permanent crop and vegetables growing

x – implementation possible and probable

(x) –implementation technically feasible, but not probable (e.g. competitive water) and therefore not considered for the cost-calculation

# 5 Action recommendations for priority cost-effective planning of measures

Water protection measures can be implemented through EU co-financed schemes within the Rural Development Plans, as well as independently from the EU with regional or local funding. For co-financed agri-environmental measures, the EU sets the general objectives and provides rules for administrative procedures for design and implementation. Design of measures is restricted in terms of maximum payments, calculation of payments, controllability and the duration of at least five years. For EU co-financed agri-environmental measures, the incorporation into the Integrated Administration and Control System (IACS), which was created for direct payments of the so-called first pillar of the CAP, is mandatory. This includes precision in determining the size of eligible area, and a minimum number of on-the-spot controls per measure at a rate of 5 % of beneficiaries. While the payments to the farmers are EU co-funded, administrative costs for agri-environmental programmes have to be borne entirely at the member-state level. For member states and regions with limited administrative personnel, measures with low costs for administration and control thus might be more attractive.

Besides co-funding of action-oriented measures it is possible to get financial support from the EU for agricultural advisory services. In the WAgriCo project is has to be futher discussed to which degree the implementation of water protection measures should be flanked by technical advice in order to reach a sufficient acceptance and good practive of measure placement and implementation. With regard to the result-oriented measure, advice and possibly auditing to verify effects on N efficiency are important elements. At least at the outset, farmers should be supported to become entrepreneurs for water protection-oriented agriculture and to develop appropriate measures tailored to their proper farm situation.

According to the rankings of WAgriCo-measures, it will be executed a cost-effective planning for the pilot areas and at country scale. The result-oriented measure is paid ´on the top´ within the project practical testing. That means that the payment is independent of the payments for action-oriented measures, even if they have an effect on the N-efficiency and thus on the N surplus. Within an agri-environmental programmes, additive effects of combinations of measures should be considered, as they have impacts on cost-effectiveness and the justification of payments. Action-oriented measures that target directly the N-efficiency are thus not fully compatible with the result-oriented approach. For the result-oriented measure, the combination with action-oriented measures focussing on N-leaching in autumn, and with volunteer advisory service and an audit of mineral bookkeeping shall be further explored.

## References


Eisele, M. (2007): Target areas for water conservation (Deliverable 3.1, unpublished)

Osterburg, B. and Runge, T. (2007): Procedures for cost predictions at the level of the individual farm, region, river basin area and Federal State (Deliverable 7.1, unpublished)

Osterburg, B., Rühling, I., Runge, T., Schmidt, T.G., Seidel, K., Antony, F., Gödecke, B. and Witt-Altfelder, P. (2007): Kosteneffiziente Maßnahmenkombinationen nach Wasserrahmenrichtlinie zur Nitratreduktion in der Landwirtschaft. In: Osterburg, B. and Runge, T. [eds.]: Maßnahmen zur Reduzierung von Stickstoffeinträgen in Gewässer - eine wasserschutzorientierte Landwirtschaft zur Umsetzung der Wasserrahmenrichtlinie. Landbauforschung Völkerode, Sonderheft 307, pp. 3-156.

Osterburg, B., Runge, T., Schmidt, T.G. (2007): Report on impact scenarios: Definition of scenarios for the economic analysis (Deliverable 7.2) - 05/2007 (unpublished)

Reiter, K., Roggendorf, W., Runge, T., Schnaut, G., Horlitz, T. and Leiner, C. (2005): Aktualisierung der Halbzeitbewertung von PROLAND NIEDERSACHSEN Programm zur Entwicklung der Landwirtschaft und des ländlichen Raums, Kapitel 6, Agrarumweltmaßnahmen - Kapitel VI der VO (EG) Nr. 1257/1999. In: Bundesforschungsanstalt für Landwirtschaft (FAL), Institut für Ländliche Räume [eds.]: Aktualisierung der Halbzeitbewertung von PROLAND NIEDERSACHSEN Programm zur Entwicklung der Landwirtschaft und des ländlichen Raumes gem. Verordnung (EG) Nr. 1257/1999. pp. 1-155. Braunschweig, Hamburg, Hannover.

Schmidt, T. G., Osterburg, B. and Laggner, A. (2007): Datenauswertung zur Quantifizierung diffuser Stickstoffemissionen aus der Landwirtschaft im Rahmen des Projekts „Integriertes Monitoring des chemischen Zustandes des Grundwassers" in Niedersachsen. Top-Down-Ansatz mit Daten der Agrarstrukturerhebungen 1999 und 2003 und Analyse des Landnutzungswandels. Arbeitsberichte des Bereichs Agrarökonomie 02/2007 der FAL. Braunschweig.

# Annexes

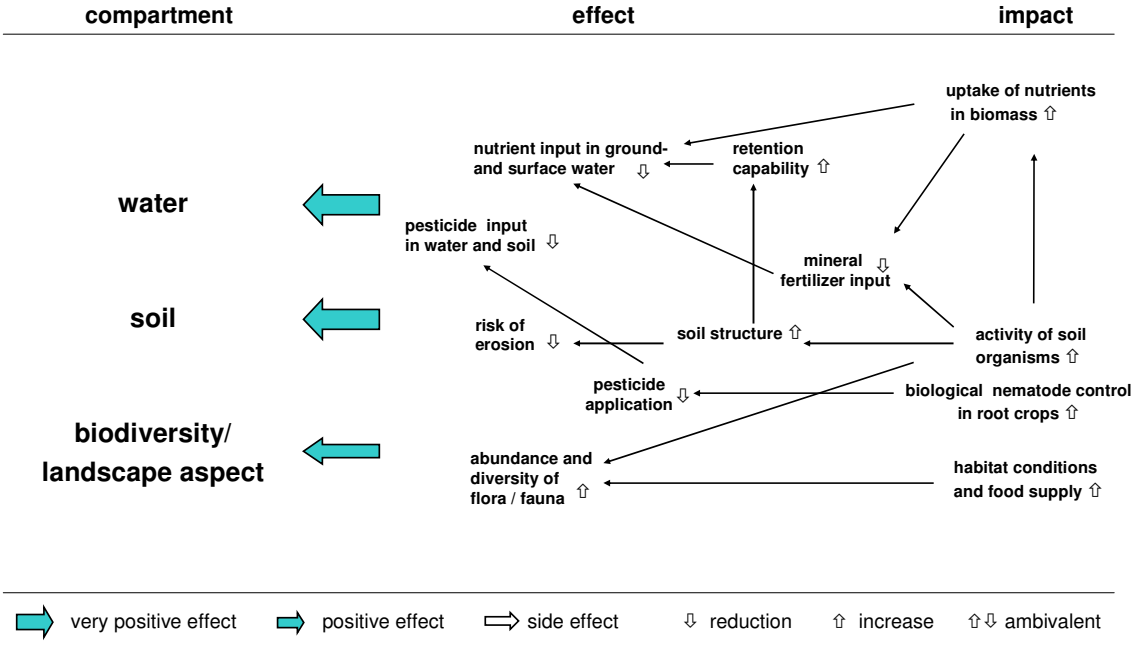
**Annex 1:** Impact charts of the ecological impacts of WAgriCo-measures

| No. | Impact chart | WAgriCo-measure |
|---|---|---|
| **1** | Catch crops and undersown crops | H 1, H 2, H 4, H 11, H 12 |
| **2** | Timing of tillage, conservation tillage in autumn | H 5, H 13 |
| **3** | Timing of manure spreading, timing of mineral fertilisation | H 6 |
| **4** | Improved techniques for manure spreading | H 7, H 9 |
| **5** | N-reduced fertilisation and use of N-stabilised fertiliser | H 10 |
| **6** | Pasture management | H 3 |

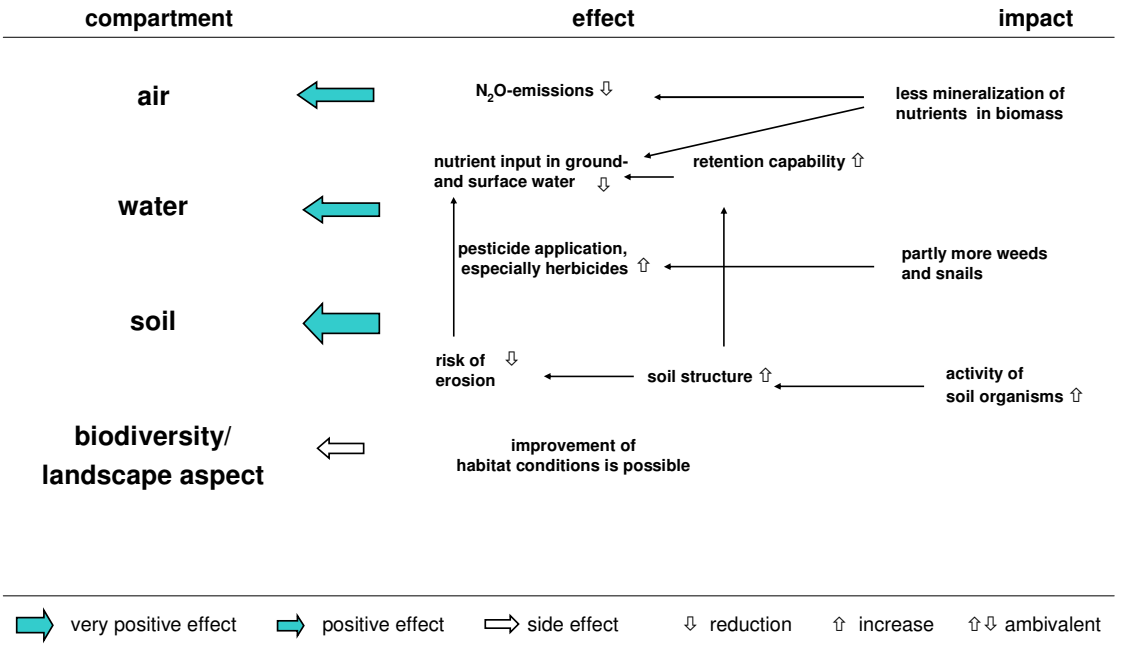
WAgriCo-measure H 8 is not assigned. It corresponds with impact chart No. 1 only in terms of an improved uptake of nutrients in biomass.

Design and contents of the charts were taken from Osterburg and Runge, 2007, and Reiter et al., 2005.

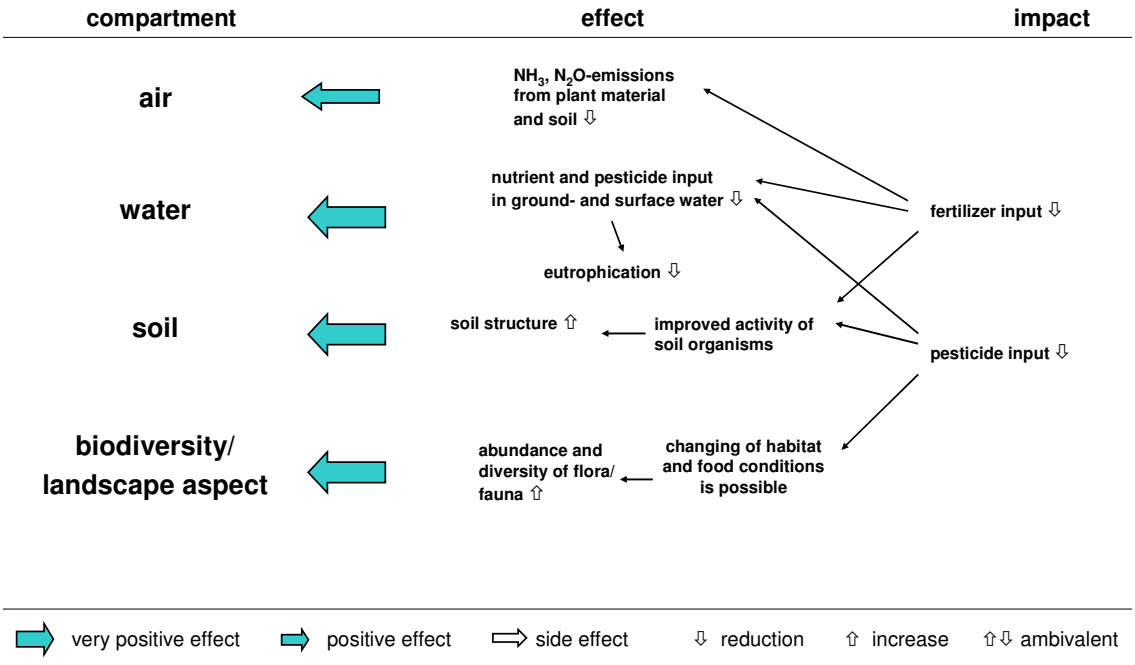
## Catch crops and undersown crops



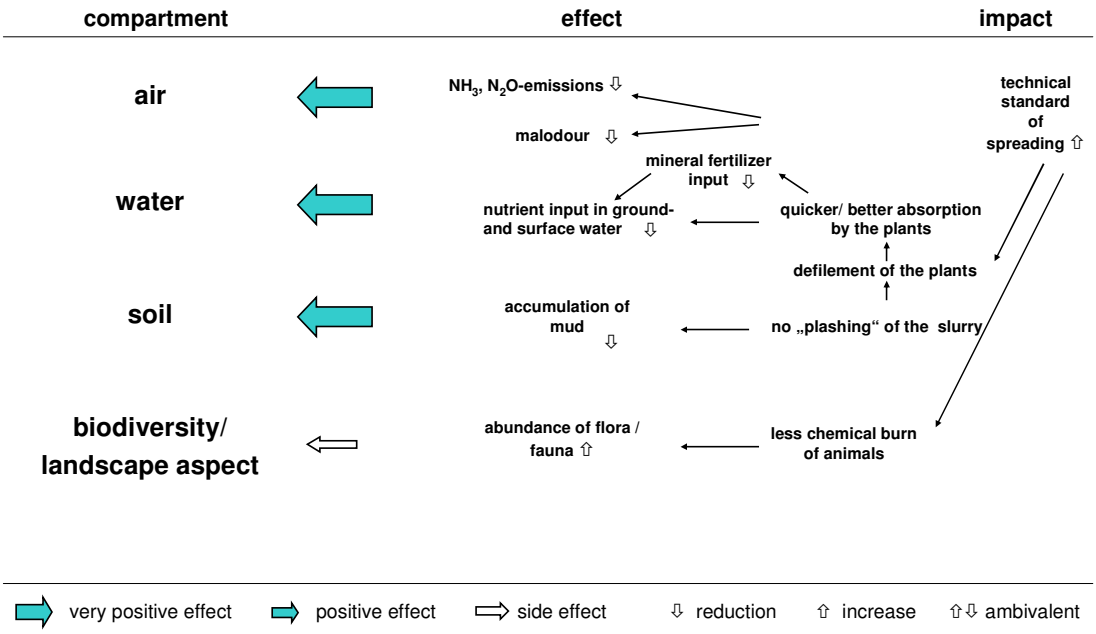

## Timing of tillage, conservation tillage in autumn



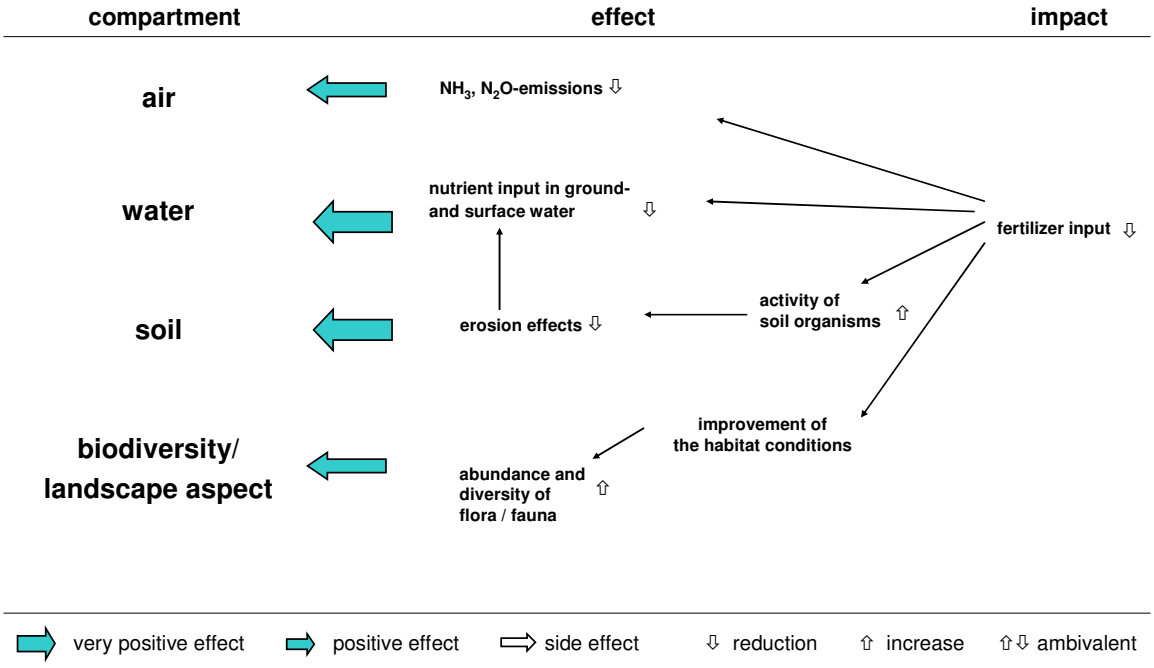
## Timing of manure spreading, timing of mineral fertilisation



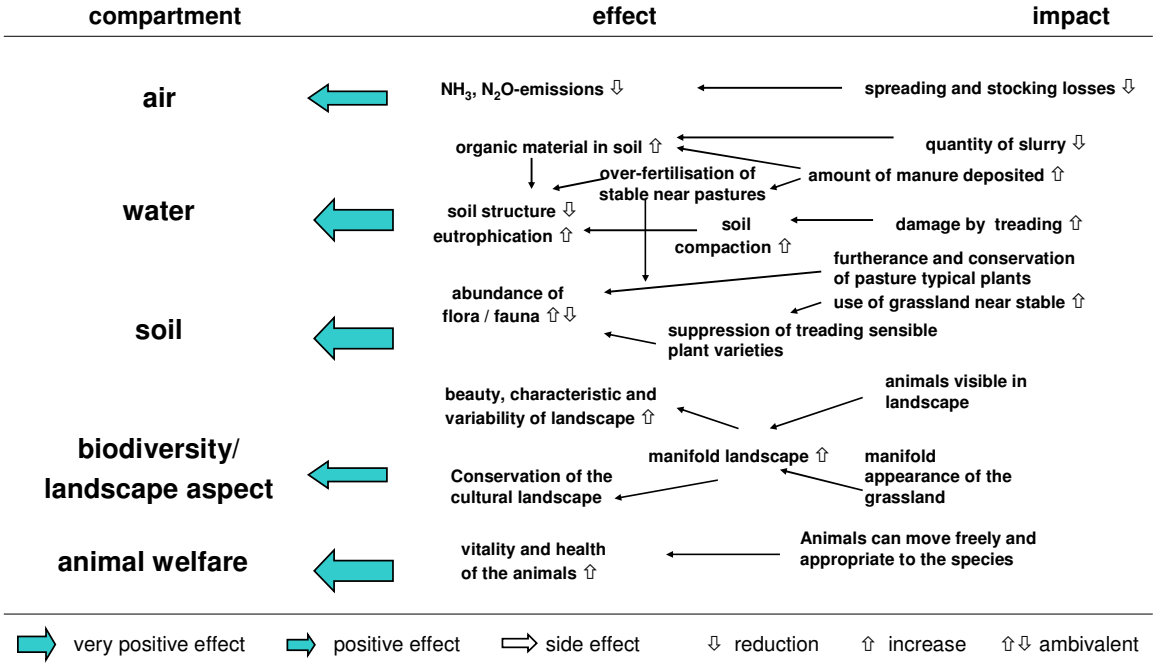

## Improved techniques for manure spreading



## N-reduced fertilisation and use of N-stabilised fertiliser




## Pasture management



**Annex 2:** Single parcel combinations of the measures

| | | N-surplus reduction [kg N/ha*a] | | | H1 | H2 | H3 | H4 | H5 | H6 | H7 | H8 | H9 | H10 | H11 | H12 | H13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | min | avg | max | | | | | | | | | | | | | |
| **H1** | Catch cropping after harvest (winter-hardy, late ploughing) | 0 | 20 | 40 | | - | - | - | - | (+) | - | + | + summer cereals | + H1 first, potatoes succeed | + H1 first | - | - |
| **H2** | Catch cropping after harvest (standard) | 0 | 20 | 40 | - | | - | - | - | (+) | - | + | + summer cereals | + H2 first, potatoes succeed | + H2 first | - | - |
| **H3** | Three-year fallow with active greening | 40 | 60 | 80 | - | - | | - | - | - | - | - | - | - | - | - | - |
| **H4** | Volunteer rye or Triticale before summer crops | 0 | 10 | 30 | - | - | - | | - | - | - | + | + summer cereals | + H4 first, potatoes succeed | + H4 first | - | - |
| **H5** | No soil tillage/ploughing in autumn after maize/sugar-beet | 0 | 5 | 10 | - | - | - | - | | - | - | + | + summer cereals | + H5 first, potatoes succeed | + | - | - |
| **H6** | Restrictions for farm manure application in autumn | 10 | 15 | 40 | (+) | (+) | - | - | - | | + | + | + | + | + | (+) | + |
| **H7** | Improved slurry application techniques | 10 | 15 | 40 | - | - | - | - | - | + | | - | - | - | - | + winter cereals | - |
| **H8** | Reduced row spacing for maize | 0 | 10 | 20 | + | + | - | + | + | + | - | | - | - | - in practice | - | - |

| | | N-surplus reduction [kg N/ha*a] | | | H1 | H2 | H3 | H4 | H5 | H6 | H7 | H8 | H9 | H10 | H11 | H12 | H13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | min | avg | max | | | | | | | | | | | | | |
| **H9** | Use of ammonium based liquid fertilisers using injection technique in cereals | 0 | 10 | 20 | + summer cereals | + summer cereals | - | + summer cereals | + summer cereals | + | - | - | | - | - | + | + |
| **H 10** | Application of stabilised mineral fertilizer in spring on winter cereals and potatoes | 0 | 10 | 20 | + H1 first, potatoes succeed | + H2 first, potatoes succeed | - | + H4 first, potatoes succeed | + H5 first, potatoes succeed. | + | - | - | - | | - | + winter cereals | + |
| **H11** | Undersown catch crops in maize | 0 | 10 | 20 | + H1 first | + H2 first | - | + H4 first | + after catch c. | + | - | - in practice | - | - in practice | | - | - |
| **H12** | Turnip (brassica rapa sylvestris) as catch crop before winter cereals | 0 | 10 | 20 | - | - | - | - | - | (+) | + winter cereals | - | + | + winter cereals | - | | - |
| **H13** | Reduced tillage of volunteer rape seedlings before winter cereals (respectively summer crops) | 0 | 15 (20) | 30 (40) | - | - | - | - | - | + | - | - | + | + | - | - | |

+ Combination possible, payments for both measures and a cumulative effect
(+) combination possible and payments for both measures, but only positive environmental effect from catch crop growing
- combination at parcel level not possible

**Annex 3:** Estimated N-surplus reduction and payment level for the WAgriCo action-oriented measures

| Number and name of the measures | | payment [€/ha*a] | N-surplus reduction* [kg N/ha*a] | | | cost-effectiveness [€/kg N] | | |
|---|---|---|---|---|---|---|---|---|
| | | | min | avg | max | min | avg | max |
| **H1** | Catch cropping after harvest (winter-hardy, late ploughing) | 120 | 0 | 20 | 40 | 3 | 6 | ∞ |
| **H2** | Catch cropping after harvest (standard) | 80 | 0 | 20 | 40 | 2 | 4 | ∞ |
| **H3** | Three-year fallow with active greening (only offered in 2006) | 120 | 40 | 60 | 80 | 0.7 | 2 | 3 |
| **H4** | Volunteer rye or Triticale before summer crops (in 2006 also volunteer rape seedling) | 30 | 0 | 15 | 30 | 1 | 1.5 | ∞ |
| **H5** | No soil tillage/ploughing in autumn after maize/sugar-beet | 25 | 0 | 5 | 10 | 2.5 | 5 | ∞ |
| **H6** | Restrictions for farm manure application in autumn (application only to catch crop, rape, grassland with time restrictions) | 15* | 10 | 20 | 30 | 0.5 | 0.75 | 1.5 |
| **H7** | Improved slurry application techniques (to winter cereals, winter rape, grassland) | 25(35)** | 10 | 20 | 40 | 0.6 (0.9) | 1.7 (2.3) | 2.5 (3.5) |
| **H8** | Reduced row spacing for maize | 40 | 0 | 10 | 20 | 2 | 4 | ∞ |
| **H9** | Use of ammonium based liquid fertilisers using injection technique in cereals | 35 | 0 | 10 | 20 | 1.8 | 3.5 | ∞ |
| **H10** | Application of stabilised mineral fertilizer in spring on winter cereals and potatoes | 25 | 0 | 10 | 20 | 1.2 | 2.5 | ∞ |
| **H11** | Undersown catch crops in maize | 125 | 0 | | 20 | 6.25 | | ∞ |
| **H12** | Turnip (brassica rapa sylvestris) as catch crop before winter cereals (only offered in 2007) | 60 | 0 | | 20 | 2 | | ∞ |
| **H13** | Reduced tillage of volunteer rape seedlings before winter cereals respectively summer crops (only offered in 2007) | 40 | 0 | 15 (20) | 30 (40)*** | 1.3 (1) | 2.7 (2) | ∞ |

* In 2006/2007 payment for arable land with cereal production: 30 €/ha; in 2007/2008 only fellow excluded from payment.

** 25 € / ha for drag hoses, 35 € / ha for trailing shoes or injection

*** 30 for winter crops and 40 for summer crops