Final Report
December 2008

Annex 48-LS

Report to the EU Commission by vTI on expected costs of adequate programmes of measures to be implemented state-wide in Lower Saxony

[Deliverable 9.2]

LIFE05 ENV/D/000182

Deliverable 9.2: Report to the EU Commission by vTI on expected costs of adequate programmes of measures to be implemented state-wide in Lower Saxony

Bernhard Osterburg, Thomas Schmidt and Tania Runge

vTI, Dezember 2008

1 Introduction **3**

2 Description of water protection measures **3**

2.1 Action- versus result-oriented measures 4

2.2 Fact sheets for the description of water protection measures 5

2.3 Features of the result-oriented measure and first experiences 6

3 Results of scenario analysis **8**

4 Proposal for programmes of measures **10**

5 Sources **12**

Annex: Fact sheets of water protection measures **2**

1 Introduction

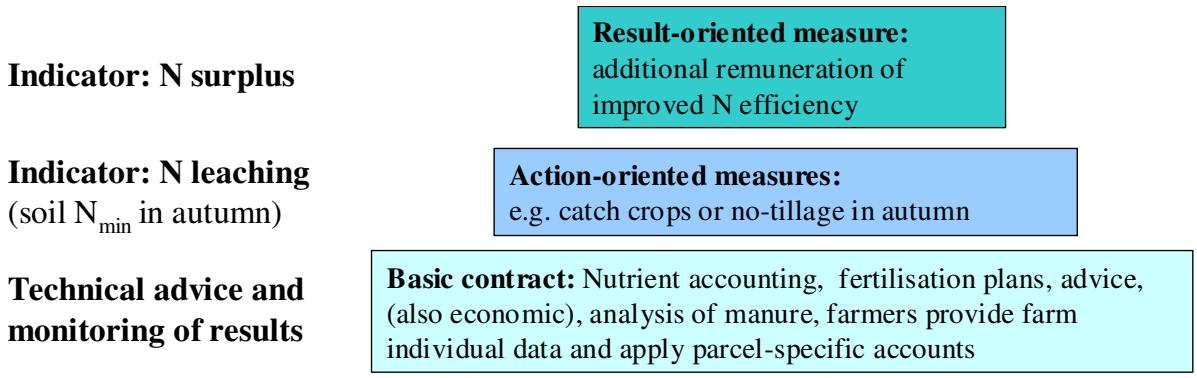
In this deliverable, the outcomes of the WAgriCo project activities co-ordinated by the Johann Heinrich von Thünen-Institute (vTI, former FAL) are presented in a brief overview. Especially, the content of deliverables 7.2, 7.3 and 9.1, which are published in German, is summarised in English. The vTI had the main responsibility for task 4 (Measure planning and compilation of programmes of measures) and task 7 (Agro-economic analysis), and co-operated with other WAgriCo partners in tasks 8 (Checking the results of the programmes of measures) and 9 (Establishment of programmes of measures under the WFD in state agro-environmental programmes).

In this report, selected water protection measures are described and ranked, based on deliverable 9.1. The possible cost and impact of selected measures has been assessed in a scenario analysis developed in deliverable 7.2. Finally, the project conclusions regarding programmes of measures for addressing the ground water related targets of the Water Framework Directive (WFD) in agriculture are described.

2 Description of water protection measures

As the basis of co-operation with pilot farms, basic contracts were established to provide for data exchange and advice related activities. On top of this support, action-oriented measures are offered. The measures designed and tested in the project were primarily derived from experiences in designated areas for drinking water protection of Lower Saxony, where co-operative approaches are applied for more than 15 years. These measures are mainly action-oriented, that means they are based on fixed management prescriptions to be implemented by the farmers. Catch crops serving for uptake of mineral nitrogen in the soil in autumn are an example for such measures. These measures are easy to understand and should have a secure and quantifiable positive effect on water quality. Further, controllability and acceptance matter. These measures serve primarily to control undesired leaching of N from the soil pool, especially during winter time. In order to complement a measure addressing N surplus, a result-oriented remuneration has been developed and discussed during the project. Options for the design of measures and the new category of result-oriented measures are briefly described in thefollwing sub-chapters. The proposed combination of instruments and measures is illustrated in figure 1.

Figure 1: Elements of measures in the WAgriCo project



2.1 Action- versus result-oriented measures

In addition to the control of the N stock in agricultural soils and of leaching during winter, another central WFD objective analysed in the project is the reduction of unproductive N surplus resulting from yearly fertilisation of crops, especially with regard to the often low efficiency of N from animal excretions. N efficiency is defined as the relation of N input to harvested plant N uptake, also named "N utilisation". Although some of the action-oriented measures have an potential effect on the N surplus, there are few measures with a clear-cut impact. This is due to the role of farm management decisions in the area of fertilisation and plant production. There is no mechanistic link between simple management prescriptions and the overall result on the N balance. Therefore, a result-oriented measures has been developed on the basis of farm nutrient accounting, reflecting the fact that an improved N efficiency means less N surplus and undesired emissions. However, during the project the development of such a new category of measures has not been finalised.

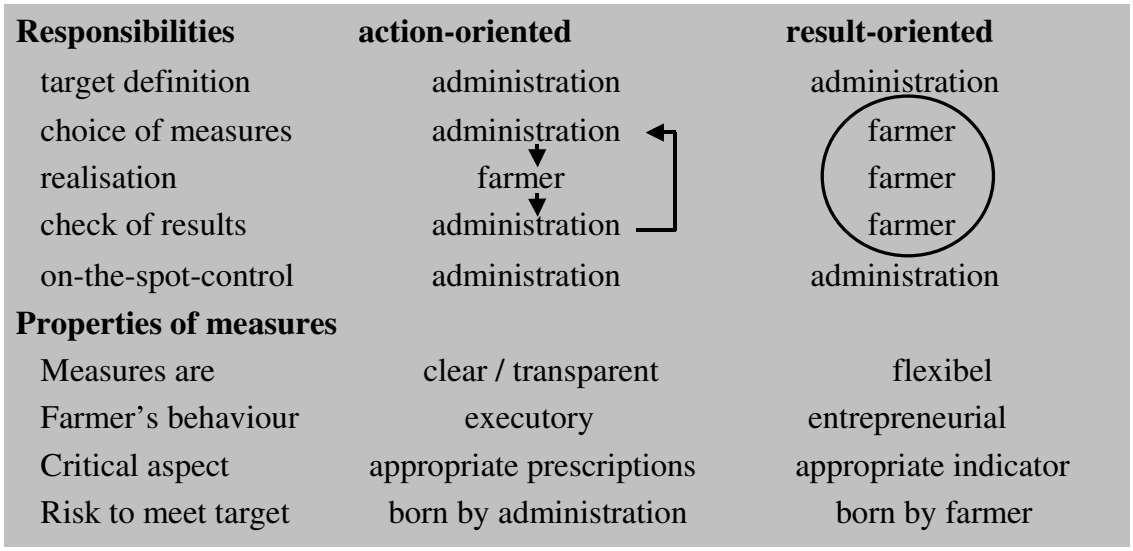
While action-oriented agri-environmental measures demand farmers to adopt well-defined management practices, farmers acting under a result-oriented approach have a free hand in their adjustments to fertilisation and crop management. Thus they are actively involved as entrepreneurs pursuing water protection objectives. The calculation of improvements to be rewarded is based on a farm-gate balance, with additional information about on-farm use of feed and organic fertiliser. Coefficients for N-efficiency are calculated separately for mineral and organic N to allow for a documentation of efficiency improvements independent from structural changes, e. g. a reduction of livestock which would lead almost automatically to lower N surplus. In the result-oriented approach the outcome indicator "N-efficiency improvement" is directly rewarded.

Support conditions of action-oriented measures are fixed packages of restrictions going beyond 'good farming practice', the legal baseline for farming. Crucial for action-oriented measures are appropriate management prescriptions which result in desired improvements

of environmental conditions. Also, prescriptions must be simple and thus understandable, and acceptable for farmers. In action-oriented measures farmers show executing behaviour and have free hand only in the realisation itself (see figure 2). However, not all possible options to reduce N emissions from agriculture can be formulated and programmed as action-oriented measures. Farmers adopting action-oriented measures are responsible to comply with restrictions, but not to maximise desired effects of the measure. The choice of the measures offered and the check of the results as well as measure adaptations are the responsibility of the administration. In case of insufficient effects, the measured offered to farmers have to be adjusted. This regulation cycle may take much time and leaves the final responsibility for programme success to the administration.

For the result-oriented approach selection of the appropriate indicator is decisive (see figure 2) as the indicator should reflect the management activities of the farmers to a large extent, should be verifiable and easy to obtain, and suitable for self-assessment. In the result-oriented approach the farmer is responsible for the selection of suitable measures, their realisation and the check whether results have been reached. That gives farmers much more entrepreneurial flexibility, but at the same time participation is more risky: Farmers are only rewarded if the desired environmental effect is achieved.

Figure 2: Action-oriented versus result-oriented measures: Role of farmers and administration



2.2 Fact sheets for the description of water protection measures

All 14 measures that were selected for practical testing during the WAgriCo project are described in the annex. There have been filled fact sheets for describing water protection measures in terms of prescriptions, suitability and effects, including cost-effectiveness. Cost-effectiveness is calculated using direct public cost of measures due to payments to farmers, but excluding so far cost of public administration and advice. The fact sheets

have been developed in a parallel project for the Bund-Länder-Arbeitsgemeinschaft Wasser (LAWA) in the year 2007 (Osterburg et al., 2007). In the annex, also recommendations regarding inclusion in programmes of measures are included in the first table A1. More information is presented in deliverable 9.1 (in German).

2.3 Features of the result-oriented measure and first experiences

Reducing N mineralisation and leaching over winter through action-oriented measures is a practical approach, as reduction of soil N_{min} in autumn can be reached regularly e. g. through catch cropping. Monitoring the soil N_{min} in autumn is costly and results vary according to climatic conditions in autumn, so that a result-oriented approach is not easily applicable. In contrast, addressing the farm N surplus requires an appropriate nutrient accounting and evaluation of N surplus. Measures for N input reduction have been abolishe in Germany after unfavourable evaluation of such measures by the European Court of Auditors. Therefore, there are only few action-measures left addressing N surplus.

Nutrient accounting is an obligatory part of good farming practice according the Fertilisation Ordinance (implementing the EU Nitrates Directive in Germany), offering the chance to built a result-oriented approach on this data without additional bureaucratic effort. N from animal excretion is a key problem of low N efficiency in Lower Saxony, while mineral N fertiliser is utilised normally to a much higher degree. Any change in livestock density e. g. due to changing market conditions, would thus lead to changing performance when using the overall N efficiency or the N surplus as result indicator. To avoid the remuneration of casual effects of structural changes, a separate evaluation of mineral and organic N efficiency has been proposed (described in more detail in deliverable 9.1 (in German)).

Farmers who improved N efficiency compared to 3 years before the WagriCo project were offered an additional remuneration. The result indicator was calculated on the basis of yearly N input and a 3 year average for N plant uptake. Several key challenges could not be completely resolved during the project. The insights gained indicate the path for further steps towards a feasible result-oriented measure:

– The offer to remunerate positive farm performance measured on the basis of nutrient accounting raised considerably the interest in the content and truthfulness of N balances, and to understand differences in N efficiency.
– Providing reliable data for nutrient accounting without too big additional administrative effort is a key issue and requires inclusion of farm data, e. g. available data from administrative applications (IACS – Integrated Administration and Control System) and from economic bookkeeping systems, both on a voluntary basis.

- Inconsistencies between surface N balance and farm gate balance, and between stable and field balance indicate the data are often not in line with simple balance requirements, especially N amounts regarding livestock feeding and excretion, and N uptake through feed produced on-farm.
- Ideally, the different balance approaches shall provide different views on the same N flows and should therefore be fully compatible. However, surface balances show on average higher N uptake compared to farm gate balances (and lower N surplus), thus requiring more effort for verification and complementation through data on livestock and feeding. The extent of differences between these N balances is relevant for emission related targets of the WFD.
- While it was assumed that N input varies to a lesser extent compared to N uptake by plant which depends on climatic variations, farm data showed that even mineral N input may vary from year to year to a considerable degree. Thus, 3 year averages should be used as basis for evaluation the performance of N efficiency. Thus, a result-oriented approach addressing N surplus is not suitable for providing short-term effects, but can support a long-term process of benchmarking and management improvements.
- Minimum N efficiency coefficients were discussed during the project but could not be determined even in discussions with several experts and farmers. This indicates that a benchmarking process for determining which minimum N efficiency could used as reference level under different conditions would be a useful tool.

The high effort to verify N accounts, the degrees of freedom to alter balance-related results, and the unpredictable effect on remuneration in the first WagriCo test year 2007 raised a critically discussion whether the approach could be implemented in one or another form. The following three questions have to be answered:

1. Which system of nutrient balancing can provide sufficiently reliable data at an justifiable effort.
2. How to determine reference levels for minimum N efficiency under conditions of good farming practice, or how to alternatively evaluate N balances.
3. Is an incentive for improved N efficiency required, and in which form (yearly area payments, awards, services free of charge, acknowledgement by administration or public appreciation).

At the end of the WagriCo project, representatives of the farmers, advisory services, scientists and the water administration all stated interest to continue in developing result-oriented approaches addressing the reduction of N emissions.

3 Results of scenario analysis

For scenario analysis expected uptake and effects of the action-oriented measures presented in the annex have been calculated. The acceptance has been derived from experiences in water protection co-operations in Lower Saxony. Public costs for payments to farms are based on the payment levels developed in the project. Additional costs for public administration of the programmes are estimated at about 10 % of total programme cost, and cost for technical advice free of charge amounts to about 40 % of the budget for measures plus advice (i. e. direct cost of measures 60 %, cost of advice 40 %, plus administrative cost for handling of applications, and control). The costs of advice have to be considered in relation to the acceptance, which depends to a high degree on advisory activities. Both effects on soil N_{min} and on N suplus have been regarded as possible effects of the measures.

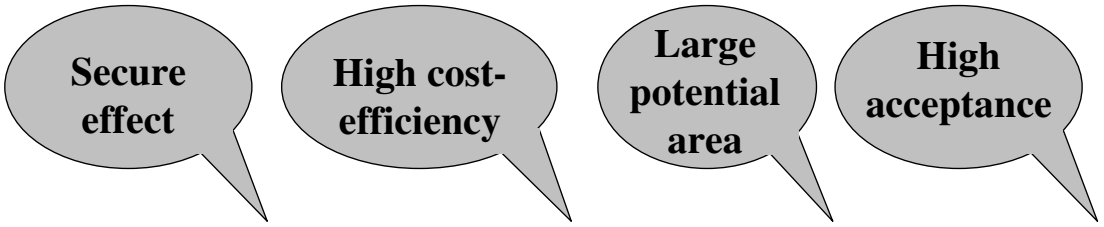
It was assumed that future changes of framework conditions, e.g. agricultural policy and markets, will only partly contribute to targets of WFD, and are highly insecure. Therefore, targeted agri-environmental policy instruments have to be implemented in order to reach WFD target or at least to change emission trends. The basic measure for the agricultural sector is the Fertilisation Ordinance, which requires that farms reach a fairly low N surplus by the year 2011. However, effects are still unclear, and within the project this mandatory regulation has not been analysed in detail. The focus was on additional, voluntary measures with payments.

The scenario analysis is based on geo-referenced IACS data of the years 2005 and 2006, in order to reflect real farming conditions for the assessment of acceptance within the tentative target areas of WFD. The target areas comprise almost 30 % of total utilised agricultural land in Lower Saxony. Two targets for reduction of N emission have been considered, one without de-nitrification in the groundwater body, and another with inclusion of a limited de-nitrification. Overall N surplus in the target areas has to be reduced by 26,500 or about 19,000 t of nitrogen, respectively, until 2015 in order to reach WFD groundwater quality target. In terms of reduction of N emission per hectare this means on average a reduction of 25 to 35 kg N per hectare agricultural used land within the WFD target areas. Need for reductions reaches values of up to 60 kg N per hectare in some areas.

Due to both limited potential area and acceptance, effects of action-oriented alone will contribute only partly to the WFD target, leaving need for further efforts. Figure 3 illustrates important properties of efficient action-oriented measures. In a scenario with realistic acceptance, substantial effects were reached at a budget of almost 30 Mio. € p. a. for all target areas in Lower Saxony for direct measure costs. Total programme cost including advice and administration would amount up to 55 Mio. € per year. Support intensity is above the budgets provided for designated areas for water protection (75 €/ha agricultural area in WFD target areas compared to about 50 €/ha). Overall cost-effectiveness of pro-

grammes focussed on action-oriented measures varies around 4-5 € per kg reduced N emission, although the selection of most cost-effective measures in the scenario calculation. The required budget exceeds by far the actually available funds for agri-environment measures in Lower Saxony. These also comprise other objectives such as management of Natura 2000 areas, so that additional funds are necessary. On the background of scarce additional funds, optimising the effectiveness of programmes is a key priority.

Figure 3: Cost, effects and acceptance of action-oriented measures – example catch crops



Effect	Payment	Efficiency	Potential area	Acceptance
[kg N/ha]	[€/ha]	[€/kg N]	[ha]	[%]
30	120	4	Summer crops with early harvest in previous year	40

Including optimistic effects, the WFD targets could be approached to a much higher degree, which shows that selection of participating farms with high potential for improvements, optimising implementation of measures, and targeting of most sensitive areas are crucial. In combination with advice, a measure oriented towards fertilisation planning and potentially the result-oriented measure could provide additional N emission reduction.

Another important insight is that in regions with high livestock densities the WFD targets would require considerable, but not unrealistic improvements of N efficiency. For this, ammonia emissions play an important role as avoided gaseous emissions represent certain scope for increased N efficiency. With given farm structures, the reduction of N surplus is limited through the possibilities to further improve N efficiency. When increasing N efficiency far beyond the levels observed today in existing farms, marginal mitigation cost will probably increase considerably. However, the variance of N efficiency between similar farms of similar structures indicates that there might be still scope for larger improvements.

4 Proposal for programmes of measures

In the WAgriCo project in Lower Saxony, the focus was on the reduction of N emissions in WFD target areas for ground water protection. These comprise about one third of agricultural land in Lower Saxony, where on average N emission have to be reduced by 25 to 35 kg per hectare agricultural land, in some regions up to 60 kg per hectare. The selection of two target indicators for depicting agricultural N emissions are the soil N_{min} in autumn, and the farm N surplus. The first is addressing the need to reduce undesired mineralization of N from the soil pool, and subsequent leaching in winter. The second regards the need to reduce the overall N surplus which increases the threat of emissions into the water. Both indicators should be addressed through measures, however they are not directly representing the immission into ground or surface water but should be seen as indirect indicators or proxies.

Regarding analysis of N balances and the target to reduce N surplus, the following key insights can be formulated as a guide for further activities:

1. N efficiency is a key indicator, because unused N represents potential emissions,
2. the analysis of farm balances suggests that N efficiency can still be raised,
3. however, a N efficiency of 100 % will be never be reached because agricultural production systems are not closed cycles like industrial processes, but subject to varying and often unpredictable climatic, soil and biological conditions.
4. Therefore, a participatory benchmarking and incentive driven process to increase N efficiency is needed to better understand which degree of N efficiency can be reached, and how this can be realised.

The discussion in the WAgriCo working group on measures showed that a policy mix of different instruments and an integrated package of measures addressing whole farms are needed for WFD programmes. The following aspects summarise important conclusions of these discussions:

- **Information and education:** Should be integrated into current activities at federal state level, regarding the preparation of material possibly a project based budget is needed.

- **Advice:** Establishment of a multi-level advisory system offered free of charge within WFD target areas, with significantly more farms per advisor compared to the co-operation in designated water protection areas in Lower Saxony (that means far beyond 100 farms per advisor). Field days, information events and advice for groups of farmers are the entrance level. Farmers interested in implementing measures should also give access to farm nutrient accounting data to the advisors. On this basis, it can be decided to apply further steps: Individual advice for starting in action-oriented measures (level 2: advice on package of water protection

measures), and/or targeted advice on fertilisation planning (level 3: level 2 plus fertilisation plans, and result-oriented audit). Level 3 activities should be focussed on farms with larger potentials for improvement.

- **´Package of water protection measures´:** A framework contract (basic contract) should be offered over at least 5 years. Elements are nutrient accounting, fertilisation plans, and a ´water protection audit´ combined with an initial, intensive technical advice. Responsibilities for accounting and fertilisation planning should be passed to the farmers, and audits should be carried out not each year but e. g. two times during the contract time. Evaluation of nutrient balances (as the basis for incentives for good performance, if appropriate) is an element of the contract. Regarding participation in specific action-oriented measures with regular, yearly effects, farms should be free to decide on the degree of realisation each year within this framework contract. Co-financing of action-oriented measures from the national and EU budget should be used as far as possible, possibly resulting in certain minimum requirements (e. g. catch crops o at least 5 % of arable land).

- **Parcel-specific targeting versus whole farm approach:** Instead of addressing single parcels within WFD target areas, whole farms with at least 25 % of their agricultural land within this area should be supported with an integrated package of measures implemented both at the level of the whole farm (nutrient accounting, fertilisation plans, measures related to manure management) and parcel level (catch crops, etc.). However, farmers should be allowed to participate with their whole farm area in such programmes also including support for parcel-specific measures outside the WFD area, in order to increase acceptance. According to IACS data analysis, the spill-over towards areas outside the target area would be small, and also measure effects outside these areas improve the overall objective to reduce diffuse N emissions.

- **Nutrient accounting, fertilisation planning, and ´water protection audit´:** Experiences of WAgriCo task 5 (see deliverable 8.2) show the need for reliable nutrient balances, which is the basis for all following steps of fertilisation plans, evaluation of N efficiency, and a result-oriented measure.

- **A result-oriented measure** remunerating improved N efficiency (utilisation) should be further developed as an element of the ´package of water protection measures´. For this, nutrient accounting methods, evaluation of balances, audits and calculation of possible remuneration (also: kind and usefulness incentives) have to be defined. For valuating the N balances and a result-oriented remuneration, reference values for N efficiency achievable under practical conditions have to be fixed.

- **Action-oriented measures:** Focus should be on reduction of soil N_{min} in autumn. Measures with significant impacts on N balances (manure measures H 6: Restrictions for farm manure application in autumn, and H 7: Improved slurry application techniques) should be re-assessed in case of implementing the result-oriented measure in order to avoid double-support.

- **Investment measures:** ´Small investment measures´ currently are not offered due to priority for yearly support via agri-environment measures (e.g. H6).

- **Basic measure ´Fertilisation Ordinance´:** The advisory service within WFD target areas shall help to reach compliance with mandatory requirements of the Fertilisation Ordinance. Farms with problems to reach N surplus targets should be supported in their efforts to improve fertilisation planning and N efficiency. This reduction of N surplus is supposed to cause very low mitigation cost, and are thus in the interest of both water administrations and the farming community.

WAgriCo prosal regarding 5-year contracts of EU co-financed measures

A framework contract for advice and fertilisation planning shall be established for at least 5 years, with initially more intensive advice activities, e. g. for the establishment of a reliable nutrient accounting system. Participation in action-oriented measures should be more flexible, with varying yearly contract areas. A binding requirement to realise measures which have a regular, yearly effect on WFD objectives, could be replaced by this more flexible, co-operative approach of a basic contract plus fertilisation plans plus flexible, action-oriented measures.

5 Sources

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

Annex: Fact sheets of water protection measures

Annex 1 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 vTI (former 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.

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. Finally, some comments complete the evaluation with additional information for a successful implementation of the measures.

Table A1: List of WAgriCo measures

No	Description	Reference unit	Category of measures	Main scope	Acceptance[1]	WAgriCo Recommen-dation	WAgriCo Statement
H 1	catch cropping after harvest, winter hardy, late ploughing	ha	greening	reduction of N leaching	10-20	yes	as described
H 2	catch cropping after harvest, standard	ha	greening	reduction of N leaching	30-60	yes	as described
H 3	three-year fallow with active greening	ha	greening	reduction of N leaching and N surplus	70	yes	Variant 1: 1.5 yrs, ploughing in spring, Variant 2: 3.5 yrs (higher payment)
H 4	volunteer rye or triticale before summer crops	ha	greening, re-duced tillage	reduction of N leaching and mineralization	10-20	no	more pest control, com-petitive to cover crop and uncertain eco-logical effect
H 5	No soil tillage/ploughing in autumn after maize/sugar-beet	ha	reduced tillage	reduction of N leaching and mineralization	10-30	yes	not after sugar beet, only after mais
H 6	Restrictions for farm manure application in au-tumn	farm	manure mana-gement	reduction of N leaching and N surplus	20	yes	as described
H 7	Improved slurry application techniques	ha	manure mana-gement	reduction of N leaching and N surplus	30-50	yes	only own ma-nure, anually anylysis obligatory

[1] [% of potential area, see *reference situation without measure* in the fact sheet*s*] after 3 years of information and advice offered in the respective region.

No	Description	Reference unit	Category of measures	Main scope	Acceptance[1]	WAgriCo Recommendation	WAgriCo Statement
H 8	Reduced row spacing for maize	ha	cultivation technique	reduction of N leaching and N surplus	10-30	with reservations	needs more research
H 9	Use of ammonium based liquid fertilisers using injection technique in cereals	ha	manure management	reduction of N leaching and N surplus	5-10	with reservations	needs more research
H 10	Application of stabilised mineral fertilizer in spring on winter cereals and potatoes	ha	manure management	reduction of N leaching and N surplus	5-10	with reservations	needs more research
H 11	Undersown catch crops in maize	ha	greening	reduction of N leaching	5	no	low acceptance, can cause water-availability problems
H 12	Turnip (brassica rapa sylvestris) as catch crop before winter cereals	ha	greening	reduction of N leaching	5-15	yes	prior to winter cereals or summer crops
H 13	volunteer rape seedlings before winter cereals respectively summer crops	ha	greening, reduced tillage	reduction of N leaching and mineralization	10-20	yes	.
E	Result-oriented measure to improve N use efficiency	farm	manure management	reduction of N surplus	.	with reservations	.

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.

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 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.

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.

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 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.

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 15th 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
no manure application after harvesting and before 1st of March	
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.	∅	max.	min.	∅	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.

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 30st 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)
	manure input from other farms managed like own manure
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.	∅	max.	min.	∅	max.
15	N balance	10	15	40	0.6	1	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.

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 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.

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.	∅	max.	min.	∅	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).

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.

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.

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.

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.

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.	Ø	max.	min.	Ø	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.

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 for nitrogen accounting on input and output at farm level in order to allow a documentation of the N balance surplus and to calculate N efficiency (utilisation)	farm specific N management adaptations instead of detailed prescriptions recommendations: 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 analysis of soil mineral N in spring to take N reserves into account, for maize, sugar beet and vegetables in the late spring 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] min.	Ø	max.	Cost-effectiveness [€/kg N]
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 agreed 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 should be derived from project data and discussed, however, this step could not be realised during the project.