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A feasibility study on the potential use of buffer plantings as pollutant traps of emissions from livestock farming

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Note 33

WAGENINGEN UR

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Table of contents

Abbreviations used in the text

CAP	Common Agricultural Policy
CLM	Centrum voor Landbouw en Milieu (Dutch Centre for Agriculture and Environment)
EAP	Environmental Action Programme
EEC	European Economic Community
EHS	Ecologische Hoofdstructuur
EU	European Union
GV	German: Großvieheinheit (500 kg live weight), livestock unit
GVE	Dutch: Groot vee eenheid (500 kg live weight), livestock unit
LAI	Leaf area index (m^2 leaf area m^{-2} surface area)
LNV	Ministerie van landbouw, natuurbeheer en visserij (Dutch MAFF)
MAK	Maximale conc. toelaatbaar aan werkplaats (Maximum allowable workplace concentration)
NOx	Oxidized nitrogen, mainly from transport and energy sector
NHy	Reduced nitrogen, mainly from livestock farming
PM_{10}	Air Quality Standard on particulate matter with diameter below 10 μm
RGR	Relative growth rate ($g\ g^{-1}\ d^{-1}$)
SLA	Specific leaf area ($m^2\ kg^{1}$)
TNO	Netherlands Institute of Applied Geoscience TNO
UN-ECE	United Nations Economic Commission for Europe
USDA	US Department of Agriculture
VDI	Verein Deutscher Ingenieure (Board of German Engineers)
VOC	Volatile organic compounds
VROM	Ministerie van volkshuisvestiging, ruimtelijke ordening en milieubeheer (Dutch DoE)

Keywords: buffer plantings, shelter belts, hedgerows, windbreaks, farm woodlands, biofilters, pollutant traps, re-naturalisation, extensification, landscape fragmentation, habitat corridors, biodiversity, livestock farming.

Prologue

...trees *'absorb at once the malarious emanations and gases of decomposition, and abstract their poisonous properties for their own consumption; they withdraw from the air the carbonic acid thrown off from the animal system as a poison and decomposing it appropriate the element dangerous to man, and give back to the atmosphere the element essential to his health and even life...'*

(The New York Commissioner of Health, Smith in 1899, cited from Smith & Staskawicz, 1977)

1. Introduction

1.1 Foreword

It is evident by the turn of the century that the EU Common Agricultural Policy (CAP) will be obliged to reach a reasonable compromise between economy and ecology. For the sake of an overall sustainable agricultural development a political, social and ecological framework needs to be created, which may negatively affect the individual farmer, but from which the society as a whole will profit. In the Netherlands, the re-structuring of the pig farming sector will soon become operative by a quite restrictive legal framework (see chapter 2.3).

Besides the Common European Market putting further pressure upon the farmers, regional and national restoration programmes will have to be supported by the Community to encourage an increasing number of farmers to play an active role in landscape and nature conservation. Nationally or EU funded initiatives like the field border strip programmes have already enabled many farmers in the past to get monetary compensation for a reduced income. Financial support may be the primary reason for farmers willing to join these programmes, but the active participation of farmers in improving the local agro-ecology may also stimulate their self-esteem. Furthermore, it is of great use to assist in creating a positive image of modern farming in the public opinion.

Meanwhile, far-reaching initiatives to reward farmers for their willingness to share responsibility for environmental improvement in the agricultural landscape have fully come into operation in the EU (Agro-environment Programmes under the regulation EEC, no. 2078/92, see Appendix 1). However, these programmes have not been recognised to the same extent in the 15 member states and especially the Dutch farmers do not yet participate much in it. The regeneration and maintaining of farm woodlands and the planting of hedgerows may be an attractive alternative in the future especially for those (smaller) farmers who suffer most from the restructuring of the livestock-farming sector.

Comparable efforts are also being made in the heavily industrialised agriculture of the United States. In 1997 the Dept. of Agriculture (USDA) and the Natural Resources Conservation Service (NRCS) have jointly launched the *National Conservation Buffer Initiative*. Liaisons have been made with conservationist groups, the agrochemical industry and farmer organisations like the National Pork Producers Council to perform projects and to promote the acceptance of conservation buffers as a means of aiding livestock manure management efforts. The goal of the ambitious programme is to build 2 million miles of conservation buffers by the year of 2002. While the programme has the primary aim to somewhat relieve the saturated N-American agricultural market, the programme description states that farmers and other landowners who install buffers:

- help to improve soil, air and water quality
- enhance wildlife habitats
- restore biodiversity; and
- create scenic landscapes.

In this report we approach the question whether in the Netherlands (and the EU) landscape elements can effectively be used in the coming years to reduce and compensate emissions from livestock farming. After addressing issues relating to livestock emissions, their dispersal, their adverse effects and some legal aspects we present scientific information on the issue of plants as pollutant traps and collate information on tree species to be used as *green barriers* or buffer plantings. In a final chapter a summary is given of a 'round table' discussion organised by Plant Research International. The report thus makes an important contribution in developing further concepts and formulates the research need relating to a sustainable management of agro-ecosystems with a high livestock density.

1.2 Perception of the problem

When performing feasibility studies for new products or innovative technologies, the chances for their introduction to a market must also be addressed. The (re)introduction of landscape elements may not be regarded as 'innovative' in the first place. It is however quite obvious that the acceptability of buffer plantings (farm woodlands, hedgerows and tree lines) must be addressed as well, respecting *agro-sociological* and *behavioural* aspects.

A **perception analysis** performed within the different 'conflicting parties' (e.g. using questionnaires) may be useful in order to find possible solutions to associated dilemmas more easily. Table 1 sums up relevant objections of conflicting parties as well as the reasons speaking for the planting of green barriers. It can be seen from this evaluation that (re-)introducing landscape elements conflicts only with agricultural production. Conventional farmers still want to increase primary crop production, which in their view can best be achieved on large fields. Criticising these modern large-scale practices, conservationists and environmentalists tend to use oversimplified terms *(monoculture, agrosteppe)*, that do not help solving the underlying conflicts.

However, 'non-conventional' farming practices may not be primarily yield oriented and reaching high product quality standards may not *per se* be contradicted by designing and introducing more landscape elements. The positive image and high environmental standards of a diversified agroregion possessing a *multifunctional* structure instead of a monotonous character may strongly raise demand for products from these regions on the growing *eco-minded* markets. Information on how to quantify this in monetary terms is however lacking.

1.3 Aims and use of this study

Both, natural and man-made landscape elements, like forests, tree lines and hedgerows are believed to scavenge part of the ammonia that is laterally transported via emissions from agricultural emissions sources. Their acting as *biofilters* may be quite limited, but turbulence is significantly increased by green or man-made barriers, including fences and walls. Calculations (but field measurements have not been performed) have shown that in un-structured grassland 10% of the emitted ammonia will be deposited within 200 m, while this will be increased to 50%, if surface roughness is increased by the presence of windbreaks or wooden fences (van der Eerden, pers. communication). Generally speaking, emissions will not be dispersed far from the source and high concentrations will be reached in the vicinity of the farms if landscape elements are built or planted near the livestock buildings.

At the start-off, the central question of this feasibility study was, whether an indication could be found that emissions from livestock farming are indeed effectively reduced by landscape elements. Much attention had therefore to be paid to the directed planting of hedgerows and tree lines (i.e. shelter-belts or windbreaks) in order to reduce regional nitrogen loads and to increase deposition locally. Using an extensive literature survey in combination with going through the various aspects relating to usefulness and applicability of landscape elements, finally lead to an attempt to recommend plant species, which may be suited in buffer plantings acting as biofilters.

Table 1. Perception of introduction of landscape elements after 'conflicting parties' indicates both, drawbacks and benefits. The judgement on these and the existence of scientific evidence are indicated by numbers in brackets, where 100 indicates that the perception is a fact, 50 indicates that scientific assessment is unclear and 10 indicates that the perception grounds on a 'myth'.

Conflicting parties	Drawbacks		Benefits	
Agriculture				
Conventional	Loss of agricultural production area	(100)		
	Shadow effects	(100)		
	Competition for resources (water and nutrients)	(70)		
	Breeding ground of germs and disease (dangerous to crops and animals)	(10-50)		
			Structure elements to separate properties	(100)
			Windbreaks against erosion in sandy and lössy areas	(80)
Non-conventional	Principally, less dangers perceived than conventional farmers		Positive image	(80)
			Meliorate microclimate of orchards	(80)
			Breeding ground of germs and disease (which work as *biologicals*)	(10-50)
Nature conservation	None		Increased nature wealth and higher biodiversity	(100)
			More habitat corridors, exchange of metapopulations, less fragmentation	(100)
The environment	None		Scavenging of emissions from agriculture	(80)
			Keep emissions close to source	(80)
			Active biofiltering of agricultural emissions	(50)
Recreation and culture	Less accessibility if landscape elements have high nature value		Landscape gets more attractive, more visitors, more income	(100)
	Traditionally open landscapes may not be attractive, but need to be kept open if culture demands it.		Landscape elements may reflect the history of a regional culture (e.g. *coulissen* in Eastern NL, *Knicks* in NW-D, *bocages* in F and hedgerows in GB)	(100)

Moreover, another important aspect of this study was to address questions relating to the perception and willingness of farmers, nature conservationists, environmentalists and politics to accept, promote, finance, control and guide the active use of landscape elements. Specially, we wanted to also address the issue if managing the restructuring in intensive livestock farming areas in the Netherlands may be supported by re-introducing landscape elements. Therefore, we organised a *round table meeting*, in which different aspects and opinions relating to the item should be openly discussed. We invited participants from farmer organisations, politics, ministries, environmental unions, nature conservation groups and research institutes to take place in that discussion. Unfortunately, there was hardly a response to the announcement of the meeting (see Appendix 2 for the original folder, the programme and the participation). As a consequence, we addressed possible reasons for the 'lack of interest' and/or the 'explosivity' of the item, which may somewhat, assist in the future to better approach the topic. The study thus gives an overview of agrosocial and scientific problems related to landscape elements and outlines the contribution applied plant science may have in the future in reducing and compensating air quality problems in agroindustrial regions.

2. Characterisation, effects and control of emissions from livestock farming

2.1 Emissions from livestock farming

2.1.1 Gaseous emissions from stables

The most important gaseous compound emitted from livestock farming is ammonia, NH_3. In the coming years ammonia will become the dominant source of N-emissions in Europe, because of the reductions in NOx exhausts from cars due to rapidly ongoing technical improvements. With 36 kg NHy-N a^{-1} a dairy cow releases 13-23 times as much N as the average passenger car of 2005 (Isermann & Isermann, 1999). While cows have the highest NH_3- output, a horse emits 12-18, a pig 4.8-6.3, a sheep 3.6 and a chicken 0.3 kg a^{-1} on the average (Asman & Van Jaarsveld, 1990). Calculations on underspending the tolerable N-inputs into forest ecosystems defined as the UN-ECE critical load of 10 kg N ha^{-1} a^{-1} have shown that Dutch livestock numbers would have to be reduced by 74% (Isermann & Isermann, 1999).

Mechanistic models describing the release of ammonia from liquid manure have recently been summarised by Jiquin Ni (1999). The author addressed the theoretical basis for ammonia transfer from the manure surface to a free air stream and included modifying variables like differences in pH and releases of carbon dioxide from the top layer of the slurry. Generally, livestock farming produces emissions via three routes:

- emissions from manure storage facilities
- emissions during and after slurry application to the soil
- emissions from animal houses

Emissions from storage facilities are believed to play only a minor role because the drying of the upper layer of the slurry reduces evaporation of ammonia and other gases. Only the stirring of the slurry before it is applied to the field will lead to the release of a significant amount of gases. While exceptionally high concentrations of NH_3 will occur during and some days after the slurry application to the field, emissions from animal houses will pose an environmental and hygienically problem throughout the whole year.

Apart from ammonia there are other gaseous emissions from livestock farming, which may have adverse health and environmental effects. Typical nighttime concentrations of trace gases in stable air have been determined by Hartung *et al.* (1998) (Table 1). Even when animals sleep, maximum workplace concentrations (MAK-values) of several gases are exceeded, so that negative effects on the lung's functioning can be expected in farmers as well as in animals.

Although hydrogen sulphide is normally not present in high concentrations, it can eventually reach very high concentrations when slurry is mixed or pumped off the storage facilities. In accidents (wrong handling of slurry) concentrations of 1200 ml m^{-3} may be reached, which will directly kill the farmer and/or his animals.

Along with gaseous emissions, substantial amounts of particulates are emitted via the ventilation of animal houses. It is important to note that there are significant differences in loads and the composition of emissions from different animals and housing types.

Table 2. Concentration of gases in stables when animals sleep (Hartung, 1998).

Compound	Concentration In stables (ml m-3)	German MAK Allow. conc. (ml m-3)	Exceedance Of MAK (+yes,-no)
Carbon dioxide	5700	5000	+
Carbon monoxide	500	30	+
Ammonia	67	20	+
Dimethylamine	10.7	2	+
Fatty Acids	0.46	10	-
Acetone	0.14	500	-
Phenols and Indols	0.03	5	-
Hydrogen sulphide (H_2S)	0.004	10	-

2.1.2 Particulate emissions from stables

The average dust concentration in animal houses was investigated in four EU countries (after Takai *et al.* cited in Hartung, 1998). Fig. 1 represents the results of maximum 24h-values of dust measurements. Dust concentrations in pig stables are substantially lower than the loads in chicken stables. However, there are large differences in stables for fattening pigs and young piglets.

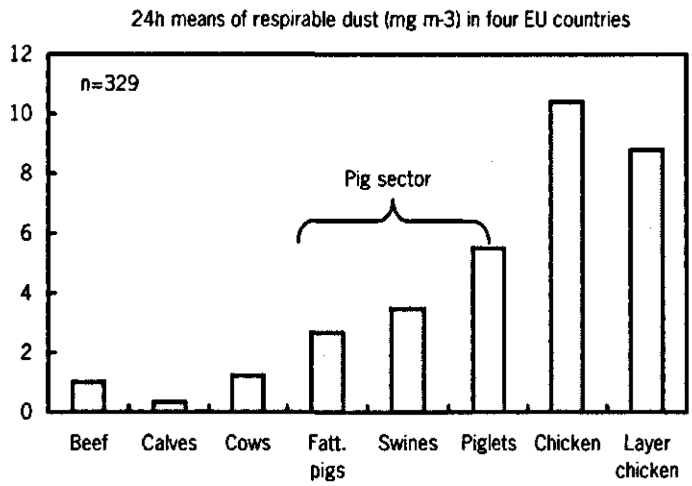

Figure 1. Maximum 24 h dust concentrations in EU animal stables after numbers cited in Hartung (1998).

Dust is transported out of the stables via the ventilation system of the units. 90% of the particles emitted from animal houses are composed from organic material. 24% of the dust from pig stables is made up from protein (Hartung, 1998).

Generally, dust emitted from pig stables contains a variety of substances, including animal food, animal skin and hair, insect parts and particles of faeces and straw. Sorbed onto small particles (PM10, particle diameter < 10 μm) microorganisms and endotoxins may be transported over large areas, where they might pose epidemiological risks to humans and animals. Information on measurements of endotoxins close to animal houses is not available but it can be assumed that highest concentrations occur in emissions from chicken stables, as these are also comparatively high inside the stables (Figure 2).

In order to reduce dust concentrations (and associated health effects) inside the pig stables, different methods have been applied, which are summed up by Pedersen (1998). These source-oriented technical approaches are certainly best suited to also reduce the quantities of emissions leaving the stable. Reductions of up to 50% can be achieved when animal food has higher fat contents, when mixtures of water/rape oil are sprayed regularly, when straw is used and/or when air filtration and re-circulation is performed.

The aspects addressed so far primarily dealt with the concentrations of gases and dusts inside the pig stables. These emissions are directly related to the *production* process and the economic and health risk of the farmer.

Upon leaving the stable, emissions from the livestock production are dispersed into air and immissions may result in a so-called 'tragedy of the commons', i.e. the externalisation of a problem in economic and ecological terms. Adverse effects of emissions from large livestock farms can be manifold,

- possibly posing health risks to neighbours (relevant to humans)
- odours being a nuisance to the neighbours (relevant to humans)
- emissions (NH_3, CH_4, H_2S and dust relevant to environment)
- spreading of germs (e.g. swine fever, relevant to farming)

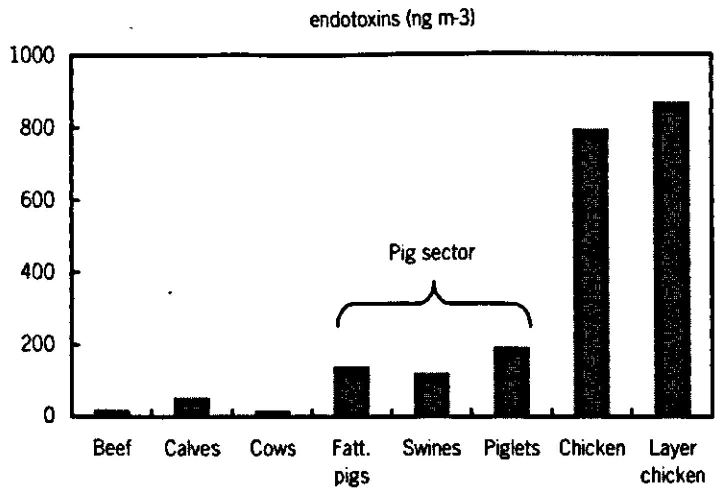

Figure 2. Mean daytime concentrations of endotoxins in animal stables (after data cited in Hartung, 1998).

2.2 Effects of emissions on human, animal and ecosystem health

2.2.1 Health effects

Although difficult to causally attribute health effects to gaseous or particulate compounds in and outside pig stables, it is generally accepted that intensive pig farming causes health problems in mammals, which can be related to lung functioning. General implications of different livestock housing systems used in Europe, the 'animal requirements' as well as animal health aspects are presented and discussed in Wathes & Charles (1994). Elbers (1991) was able to prove air pollution effects on pig health. The author found that 50% of the pigs brought to Dutch slaughterhouses showed lung deformations, which in consequence lead to the rejection of these organs from meat production. But lung diseases prove also to be relevant to farmers for the occupational respiratory medicine has identified higher risks of bronchitis and *organic dust syndrome* in pig farmers of several European countries (Nowak, 1998). Especially the above-named endotoxins, i.e. degrading cell-walls of bacteria (lipopolysaccharides) are thought to be of special importance in creating lung diseases in humans, because they have very small diameters (< 5µm), long residence times and long persistence (Hartung, 1998).

Upon leaving the stables, emissions from intensive animal farming may have adverse effects on the health of neighbours living in the vicinity of farms. The MORBUS sentinel practice network in Southern Oldenburg (Lower Saxony, Germany) indicated more children with asthma in this highly agricultural region compared to city regions. However, the larger frequency of pulmonary diseases could not be directly attributed to emissions from the livestock industry (Schlaudt *et al.*, 1998). To be able to derive clear conclusions the quality and quantity of pig stables would have to be mapped thoroughly in a future ecological study.

Spreading of germs like the swine fever virus is another hygienic problem, which has often been related to the emissions of farms. However, the transport of germs via the wind from one farm to the other plays only a minor role compared to the primary outbreaks due to contact with wild boars or the feeding of kitchen waste containing wild boar meat. And secondary outbreaks arise mainly from transport of infected piglets or the transmission by rodents rather than transfer of germs via the air (Ahl, 1994).

2.2.2 Ecological effects

Acute foliar injury on plants will not occur under ambient concentrations of NH_3. According to Adaros & Dämmgen (1994) short-term phytotoxic concentrations leading to acute foliar injury are believed to be in the range of 1 ppm (ca. 1440 µg m^{-3}). Chronic effects of emissions from livestock farming on environmental health can primarily be attributed to the input of excess nitrogen (in the form of gaseous NH_3) into closeby or remote semi-natural ecosystems. These depositions will eventually lead to eutrophication of nutrient poor habitats and secondary acidification of unbuffered ecosystems. Adverse responses to raised concentrations of ammonia may be long-term changes in the composition of the vegetation. These effects are difficult to prove but scientists attribute a great part of the recent ruderalisation of semi-natural vegetation in the Netherlands and large parts of NW-Europe to the introduction of nitrophile, competitive grasses into heaths, forests and other semi-natural vegetation (Aerts & Berendse, 1988, Bolte & Beck, 1997, Bobbink & Lamers, 1999).

On a European scale the concept of *critical loads* of nitrogen (NOx and NHy) inputs has been developed in order to address and evaluate adverse effects on semi-natural vegetation (Bobbink, 1996) and to identify regions with high deposition values (Werner & Spranger, 1996, Nagel & Gregor, 1999). For actual differences of NH_3-emissions within the EU refer to Appendix 4. The UN-ECE concept is of great use in mesoscale and regional models, but on the 'small scale or when the purpose is to quantify input for the assessment of effects, it may be necessary to consider inhomogenities in the nature' (Grennfelt & Hasselrot, 1987). A good example for this is the higher scavenging rate of air pollutants found at margins of forests. These edge effects may be indicated by higher pollutant concentrations in plants from forest margins. An example for this are the N-contents in Douglas needles collected in a forest highly exposed to emissions from livestock farms in the Netherlands (van der Eerden *et al.*, 1999). N contents were lower in the samples collected inside the forest and also NH_3-concentrations were significantly lower inside the forest compared to the open terrain (Figure 3). Artificially creating edge effects and enhancing inhomogenities in the landscape significantly increases deposition (see chapter 4), which may be a primary aim of landscape planning in the future.

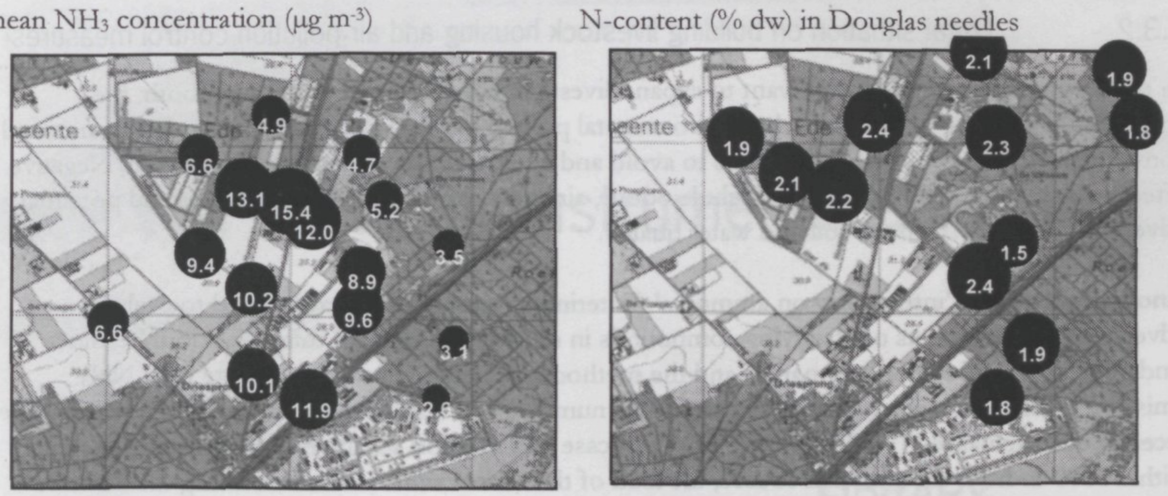

Figure 3. *Edge effects in receptors of emissions from livestock farming indicated by different concentrations of* NH_3 *in open terrain and forest (left) and nitrogen contents (% dm) in Douglas needles (right) collected in the summer 1999 at Driesprong (Ede, Prov. Of Gelderland, The Netherlands). Data on* NH_3 *was obtained from TNO-MEP, Apeldoorn, The Netherlands. The investigation was performed within the Dutch STOP-project (Stikstofonderzoeksprogramma, Erisman & van der Eerden, 1999).*

2.3 Legal aspects related to emissions from livestock farming in the Netherlands

2.3.1 The restructuring of livestock farming in the Netherlands

Due to the problems related to animal pests and eutrophication, the laws with regard to intensive livestock farming are currently heavily discussed in the Netherlands. Especially the pig farming sector has come under pressure by the proposed legal provisions and regulations on 'restructuring the pig farming' ('Herstructurering varkenshouderij') and 're-construction of the concentration areas' ('Reconstructie concentratiegebieden'). Aim of these enactments is to achieve a production of meat which satisfies environmental standards (reduction of slurry production and emissions of ammonia), human health and animal well being (less pests and more space in livestock compartments).

The introduction of these laws will ultimately lead to the limitation of numbers of pigs a farmer may keep. Every farm will have disposal over so-called 'pig claims' and when ascribing these claims a fixed percentage will be taken from that number to realise the cutback of the slurry overflow. At the same time the so-called 'pig-levy' ('varkensheffing') will be introduced by which the administrative bodies can compensate for the costs arising from infectious animal diseases.
The law on reconstruction has also the background of pest management and aims at the reduction of the 'veterinary vulnerability' by introducing 'pig free zones'. This practically means that farms will have to be relocated to other regions, considering also the reduction of impacts of ammonia emission in regions, which are sensitive to acidification. Moving farms to regions where ammonia deposition does not yet play a role may offer these farms economic improvement. Discussion and administration of justice is still on the way and definitive enactment is not yet in operation. However, numbers of pig farms are believed to significantly decrease in the coming years.

2.3.2 Legal situation on building livestock housing and air pollution control measures

In the Netherlands, farmers who want to expand livestock farming facilities must get both, the approval for building a stable and the environmental permission from local authorities. Environmental consequences of the expansion and ways to avoid and counteract these need to be lined out. Negative effects that may need to be assessed include odour, air and noise pollution from stables and potential adverse ecological effects on soil and water quality.

Another decree, the 'interim law on ammonia' ('interimwet ammoniak') may be used to evaluate adverse ecological effects of acidifying compounds in sensitive regions. In this regulation, 'sensitive' landscape types and regions are names and the methods are outlined how to calculate total NH_3 emission loads from stables with regard to animal numbers and stable types. The emission factors have recently been actualised (VROM, LNV, 1999). In case of a location sensitive to acidification present within 3000 m from the emission source, the load of the source will be calculated using the 'table of distances' presented in the decree. Permissions to expand livestock farming will not be given in case the maximum allowable deposition is exceeded or if the expansion is not conform to regional plans to reduce emissions.

Normally, crops are cultivated in the direct neighbourhood of livestock farms, which may be negatively affected by emissions of ammonia. The interimlaw does not mention this danger, but a useful regulation would be desirable. Principally, three crop categories include relatively sensitive species: fruity culture, glasshouse crops and arboriculture. Severe crop damage in the neighbourhood of NH_3 sources does not occur frequently, but eventual claims of damage prove that it must not be neglected. Therefore, planning local authorities request an estimate of risk for crop damage in order to use this in their allowance policy.
Plant Research International developed a method to assess the risk of NH_3 damage to crops as related to the distance to the source on a local scale (Van der Eerden *et al.*, 1998). A safe distance for sensitive crops can be calculated taking local and regional background levels of NH_3 into account (Figure 4). Furthermore, estimation can be made on the effect of adapting emission, increasing distance to the sensitive object or introducing landscape elements like farm woodland and hedgerows.

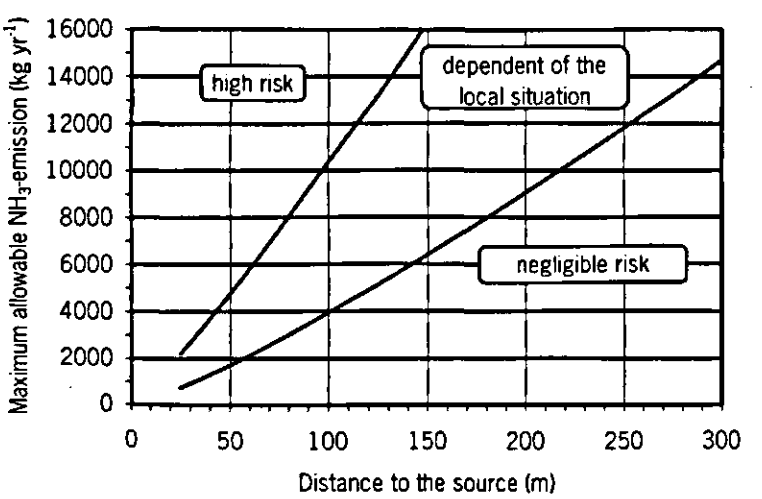

Figure 4. Relationship between the maximum NH_3-emission with no exceedance of the no-observed effect level (NOEL) and the distance between source and sensitive object. An NH_3 source above the curve has too high emission or is in too short distance of the sensitive object. The lower curve indicates situations in which the prevailing wind direction (in NL: SW) is from the source to the sensitive object, the background concentration is high etc., and the upper curve shows the opposite situation (object SW of the source, low background concentration, many vertical landscape elements around the source etc.).

2.4 Emission control and livestock management in Germany

Emission control from livestock farms in Germany aims at reducing odours, while the legal framework in the Netherlands opts for avoiding the adverse ecological effects of eutrophication and acidification. In Germany, legal restrictions on expanding livestock farms have been reglemented in the laws on housing construction and air quality control (e.g. in D: BauO, Bauordnung and BImSchG, Bundesimmissionsschutzgesetz). In case a maximum number of animals are exceeded, farmers have to get a license to build another stable. No information was available, whether complete environmental impact assessment studies (EIA) have to be performed within these legal frameworks. It is interesting to note that the still ongoing intensification in European livestock farming resulted in higher animal threshold numbers in the re-edition of the German law on emission control in 1997 (Table 2), while the receptor-oriented laws are certainly more restrictive in the Netherlands.

Table 2. Maximum numbers of animals for which permission on building a stable is required in Germany.

Type of animals	In Germany (after BImSchG before February 1997)	In Germany (after BImSchG from February 1997)
Layer chicken	7000	20000
Young chicken	14000	40000
Meat chicken	14000	40000
Turkeys	7000	20000
Fattening pigs	700	2000
Swines	250	750
Piglets	-	6000

In Germany, the **VDI 3471** technical guideline on emission control, livestock management - pigs and chicken of 1986 (VDI, 1986, German Board of Engineers, Verein Deutscher Ingenieure) assists in defining acceptable emissions from pig and chicken stables close to human housing. A scoring system (0-100 points, where 0 equals 'intensive' and 100 'low-emissive' livestock farming) is introduced therein, which assists in the calculation of **critical distances**, taking into account the number and sort of pigs, type of stable, slurry storage and ventilation rates. While the guideline lays strong accent upon slurry management and ventilation, some points may be reached by ***the presence of trees*** downwind and the active ***greening*** (*Eingrünung*) of stables. These site-specific factors can make good for a maximum of 20 points. However, the efficiency of tree, hedgerow and wall-climber plantings have never been quantified in practice. The positive optical impression neighbours get on the view of farms with sufficient plantings around stables is obviously the excuse for not investigating the suitability of plants as biofilters. The statement '*das Auge riecht mit*' (the eye may smell it as well) of Hüffmeier (1992) finely discloses this lack of knowledge.

VDI 3471 originally referred to stables with a maximum of 700 GV (*Großvieheinheiten*, i.e. 1 GV = 500 kg live weight). The applicability of the guideline was tested and discussed in detail by Schirz (1989) and Hüffmeier (1992). The authors state that the VDI guideline is of **use in the rural planning process** because it may be used as a tool to restrict the further expansion of livestock farming. In fact, it may also be used to restrict the expansion of human settlements closer to already existing farm buildings. Since the late 80s a re-structuring of European agriculture has taken place leading to the expansion of livestock farming in some regions, so that the method presented in VDI 3471 may be out-dated. Still, Andree (1998) showed that even in the vicinity of pig-industrial complexes with more than 60 000 animals in the Eastern German concentration areas the guideline could be well applied.

3. Existing information on buffer plantings as pollutant traps

3.1 Experiments on landscape elements reducing air pollution

Although field studies on a meso-scale have shown that edge effects (see chapter 2.2) generally result in higher scavenging rates at forest margins, there is not much information with regard to micro-scale effects of landscape elements acting as biofilters. From studies dealing with the dispersion of emissions from linear sources like traffic exhausts it is established that *green barriers* like buffer plantings effectively reduce the impact of gaseous and particle-bound air pollutants (e.g. Freer-Smith *et al.*, 1997). In Figure 5 the more or less steep gradient of a green 'pollutant trap' for particulate lead emitted from cars is compared to the gradually decreasing lead concentrations in a situation where no barriers or noise reduction walls are used.

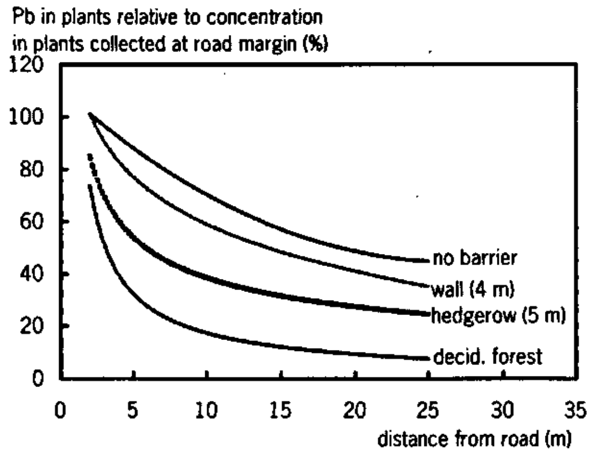

Figure 5. *Effects of barriers (no barriers, noise reduction walls, hedgerows and close deciduous forest) on relative lead concentrations in plant samples collected along roadsides in Baden-Württemberg, Germany (after data from Schweikle, 1999).*

The effect of a reduced spread of gaseous NO_2 by buffer plantings along roads was investigated by Nasrullah *et al.* (1994). Roadside plantings at a level road structure were found to reduce the NO_2 concentration by 3.5 ppb at 10 m and by 2.3 ppb at 150 m from the road. This makes good for a reduction of average NO_2 emissions by roughly 10%. The effects of hedgerows on aqueous spray deposition and biological impact of pesticide drift was studied by Davis *et al.* (1994). Receptors (a plant and an insect species) showed to be less affected in the protected shelter-zone of the hedge but at high wind speeds the hedge did not reduce negative effects.

Vegetation structure is thought to be crucial to scavenge gaseous and particulate air pollutants. Plantings must be somewhat transmissive to let the emissions pass through the canopy in order to filter out particles and absorb gases and odours. The VDI 3471 guideline on emission control, livestock management - pigs and chicken of 1986 (VDI, 1986) gives a value of 40-50% for hedge porosity and the guideline states that shelter belts should posses a 'highly structured' crown. However, the impacts of vegetation structure and the combination of different tree species on scavenging and biofiltering of air pollutants have never been actually studied.

Only one reference was found, in which experimental approaches were used to study the impact of dusts from livestock farming (Bottcher *et al.*, 1998). In that study the effect of walls to reduce emissions from pig stables in North Carolina was practically tested using smoke candles. Airflow patterns and dusts measurements showed that the walls redirected the airflow upward. Strong dust build-up was observed on wall surfaces facing the source of exhausts.

At the Iowa State University several approaches are currently performed investigating the reduction of emissions of odours from pig stables and slurry storing facilities with the aid of plants. Two of these studies deal with the use of plants as biofilters.

Project A (text from the Internet): Tunnel Testing of Dust and Gaseous Emissions from Swine Production Facilities - James Iverson, William James, and Bruce Munson, Iowa State University

A considerable amount of the odour from swine confinement facilities comes from wind-carried dust particles blown from the buildings. A set of experiments utilising model buildings within an environmental wind tunnel was conducted to investigate how the dust is eventually deposited downstream of the facility and what can be done to cause more of the dust to be deposited near the facility rather than on adjoining property. Specifically, the role that shelterbelts have in this situation was investigated. It is shown that appropriate use of shelterbelts can significantly reduce the amount of odour-bearing dust that gets transported to adjoining property.

Project B (text from the Internet): Use of Plants and Plant-Associated Microbes to Reduce Odour Emission from Livestock Production Facilities - G. A. Beattie1, A. DiSpirito2 and L. Halverson1,2. 1Dept of Microbiology, Immunology and Preventive Medicine, and 2 Dept of Agronomy, Iowa State University

The authors are exploring the potential use of terrestrial plants and their associated microbial communities for reducing the intensity of odours emitted from livestock production facilities. The large surface area of a stand of plants may serve as a natural biofilter for the odours emitted by an odour source, such as a waste lagoon or a confinement building. They are exploring both the ability of plants to adsorb odours, by gaseous diffusion as well as impacting and sedimentation of particles, and the ability of plant-associated microorganisms to degrade those odours as they become available on the plant surface.

Project B appears to be very promising with respect to plants helping to degrade voltatile organic compounds (VOC) emitted from pig stables. Plants or plant tissue can remove much more of the target VOCs in a set period of time than ever expected (Gwynn Beattie, pers. communication). For microbiologists, particular interest exists in whether the compounds become available for degradation by the leaf microflora after sorption to the leaves.

While windbreaks (being it hedges, walls or other landscape features) may significantly reduce (dilute and redirect flows) exhausts from stables, positive effects might also occur inside the stables. On the one hand, windbreaks may reduce the number of germs entering the stables via the ventilation and on the other the microclimate within the stables may profit as well. Positive effects on microclimate may be the reduction of temperatures by the shade from hedges and trees planted in close vicinity of the stables. Rows of trees and hedgerows will also increase air humidity, which may be positive to animal health. Another advantage may be that higher moisture in the vicinity of green (transpiring) plants may increase the weight of airborne particles due to the condensing water vapour (Lohr *et al.*, 1996).

3.2 Examples using modelling approaches

Gross (1998) dealt with the **dispersion modelling** of organic particles emitted from stables and other agricultural installations. The results of the micro-meteorological calculations showed a strong dependency on the configuration of the direct neighbourhood (trees and other buildings) and meteorological conditions (wind speed, thermal stratification). The authors demonstrated the **inability of simple Gaussian models** in complex situations to predict deposition. Numerical simulation models were suited much better to describe the local situation but are generally rather impracticable as they need a lot of additional input data on topography and meteorology. Irrespectively of the exact calculation of concentration fields, the general effect of a tree line in the lee of a stable in unstructured terrain is presented in Figure 6.

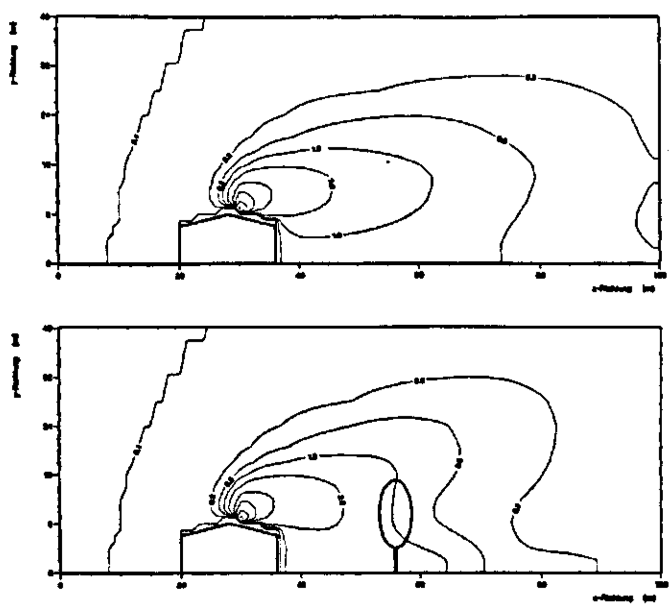

Figure 6. *The effect of a tree line on particulate concentrations in the lee of a stable (Gross, 1998). While the laminar flow causes a far reaching spread of immissions (isolines above diagram), the tree-line (situation below) causes much turbulence and hence emissions are deposited in close vicinity of the farm.*

Besides the atmospheric stability the mechanical friction at the surface is also of importance in creating air turbulence. The friction at the surface depends on the presence of vegetation, buildings or other obstacles. Therefore a surface roughness parameter (dimension meters) is included in most dispersion models. An increase in **surface roughness** (for a classification of terrain see Table 3) will eventually lead to higher deposition rates in the vicinity of an air pollution source.

In the case of emissions from livestock farming, ammonia will be dispersed and diluted over relatively wide areas if the terrain is unstructured, i.e. open. The same amounts of ammonia may be deposited within a much smaller radius around the source when surface roughness is high. Moving away from the source brings about a significantly sharper decrease in concentrations of ammonia compared to the previous case. Examples for this are given in Figure 7.

Table 3. Description of types of terrain after surface roughness (Wieringa & Rijkoort, 1983).

Terrain	Description and examples	Surface roughness (m)
Open	Flat land with short vegetation (grass) and some small obstacles. Examples: roads, short grassland and fallow.	0.03
Less open	Arable land with low crops and some obstacles like short hedgerows, trees without leaves in a single row and freestanding farm buildings.	0.10
Rough	Arable land with both high and low vegetation. Larger obstacles like trees in more than one row, orchards, vineyards and fields of maize.	0.25
Very rough	Terrain with groups of taller obstacles like farm buildings, trees; tall shrubs scattered with open space.	0.50
Closed	Area almost completely covered with large obstacles like woods and villages	1.00
City	City with high and low buildings. Also woods with large trees and irregular open space.	3.00

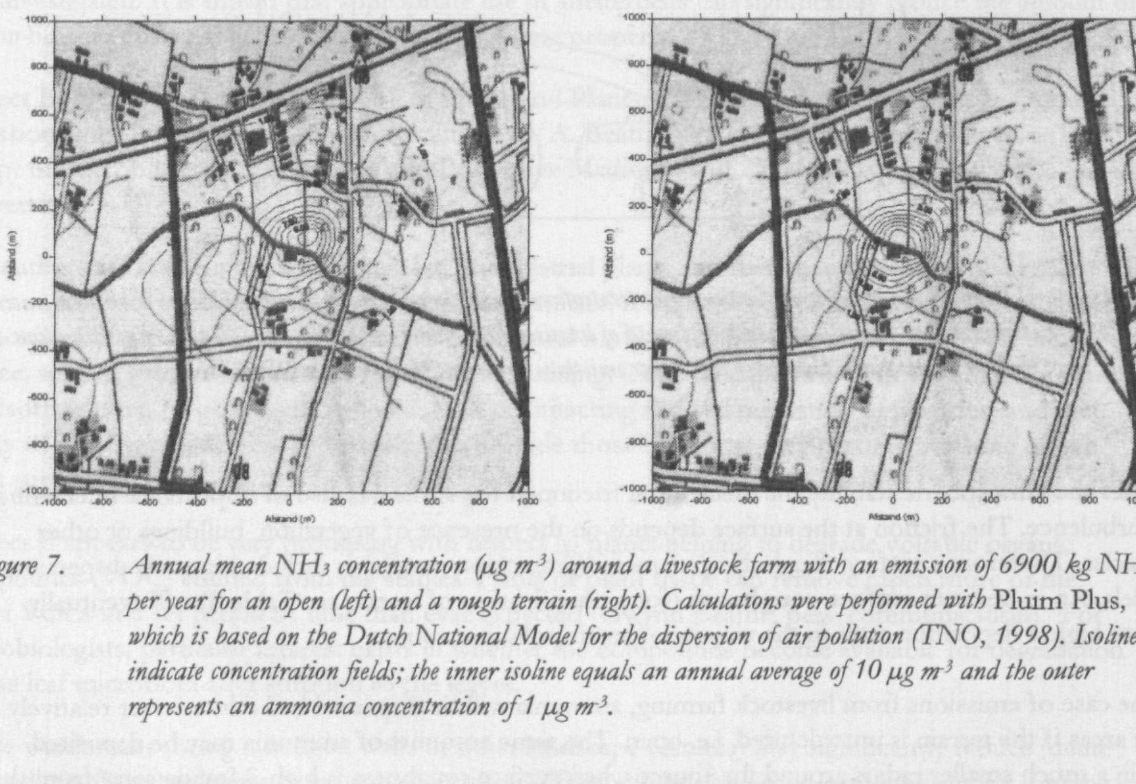

Figure 7. Annual mean NH_3 concentration (μg m^{-3}) around a livestock farm with an emission of 6900 kg NH_3 per year for an open (left) and a rough terrain (right). Calculations were performed with Pluim Plus, *which is based on the Dutch National Model for the dispersion of air pollution (TNO, 1998). Isolines indicate concentration fields; the inner isoline equals an annual average of 10 μg m^{-3} and the outer represents an ammonia concentration of 1 μg m^{-3}.*

4. Recommendation for the creation of buffer plantings

4.1 The principle motivation to plant landscape elements

In the Netherlands and elsewhere, green barriers had always been a decisive component of the cultural landscape. Despite the relatively open agricultural landscape, plantings of trees and hedgerows are traditionally used to **structure the multi-functional land-use**. Especially the plantings around farm buildings (farm woodlands, Dutch: *erfbeplanting*) have been lacking nowhere and, like architecture, have always been important for the *esteem of a region* (te Boekhorst-van Maren *et al.*, 1987). One motivation to keep or to re-install landscape elements is thus keeping and caring for the **cultural-historical** identity of a region, which must not be offered to the supposed demand for agricultural intensification.

Another principal motivation for the re-introduction and improvement of landscape elements is the **ecological importance** of green lines and structures in the landscape. Burel (1996) and Burel *et al.* (1998) describe the role of hedgerows on ecological processes operating at the agricultural landscape level. One important feature is of course that hedgerows possess the function as **habitat corridors** for the spread of plants and animals. If hedgerows are more than 4 m wide they can even serve as a migration corridor for forest species. But even if relatively poorly structured buffer plantings are not included in a pattern of landscape elements they may have important multiple ecological functions. These are related to increasing biodiversity and maintaining ecological services.

The Dutch concept of ecological main structures (EHS, *ecologische hoofdstructuur*), that was suggested and developed in the 90s has already had large impact on the public awareness. The need for improving nature in the Netherlands has been recognised. While the EHS will be designed by the provinces, local authorities will have to deal with creating more green and blue corridors on a local scale. In this process participation of local groups is anticipated, which sometimes may somewhat irritate landowners. Burel (1996) addressed the obvious conflicts between aesthetical, ecological and farming objectives. In her account she differentiates between the perception of hedgerows by farmers and non-farmers. According to the farmers only hedgerows on their property limits should be maintained, while for ecological reasons non-farmers favour the expansion of hedgerows to larger areas of the farming land.

Apart from aesthetical, ecological and farming objectives the **environmental motivation** to plant landscape elements is not much developed (see chapter 5). While many studies on nature value and biodiversity of/within landscape elements have been performed in the past, the potential of buffer plantings to redirect, absorb and biodegrade emissions from livestock farms as well as industrial sources has not been recognised. Correspondingly, research in this field of applied environmental phytotechnology has not yet been initiated.

4.2 Integrating the functions of buffer plantings - choice of suited plant species

Although the environmental **amenity function** of landscape elements has not been much recognised, scientifically addressed and proven, this chapter deals with the recommendation of how buffer plantings could be designed in order to achieve a high efficiency in reducing air pollution loads. Botanical and plant physiological knowledge and practical considerations are thus integrated in order to develop landscape elements, which serve cultural, ecological and environmental functions.

Certainly, plant species to be used in buffer plantings, should be native and should also suit cultural demands, i.e. both with respect to regional culture and habitat condition. Weber (1975) gives an evaluation of hedgerows and the ecological demands of typical native tree species in them. Taking into account the traditional managing practices of windbreaks in north-western Europe over the past 200 years, the author suggests the choice of **suited plant species** according to different exposition (N-S, E-W) as well as to microclimatic demands. Copping should optimally take place once every 9-11 years. Further recommendations on the managing of landscape elements (farm woodlands and hedgerows) are given in Bohn & Krause (1999), Zundel (1999) and StMLV (1995).

A **planting scheme** including a decision support system for calculating the costs of initial afforestation as well as the nursing in the first 15 years has been proposed by IMAG (Instituut voor Milieuhygiene en Agritechniek, see Centen & Rutyen, 1998). A so-called 'blijvers-wijkers' and an 'integraal' system have been introduced therein depending on whether the planting includes all the plant components from the beginning.

Generally, some of the costs may be covered by subsidies to the farmers. The money can be made available from local and national authorities and/or agri-environmental programs of the EU. LNV (1999) has recently presented a brochure on how the planting of new landscape elements may be subsidised and performed. For ecologically wealthy plantings (not specified what this means) a maximum subsidy of 10.000 Dfl per ha may be paid.

Table 4. *Recommendations (in order of importance and chronology) for the creation of multi-functional hedgerows or tree lines acting as biofilters and redistributors of emissions from livestock facilities (for actual choice of species, refer to Appendix 3):*

1. Choose relatively NH_3-tolerant species, which tolerate copping as well. It should be native European species with some ecological value, so that feeder (e.g. birds on berries) can profit from the hedge or tree line.

2. Use several species to enhance diversity (of the vegetation and its users) and promote ecosystem stability. Along with deciduous, use evergreen species, which will be actively filtering emissions in wintertime, too. Use species with a high surface area (high LAI or SLA).

3. Use a minimum width of hedgerow to enhance diversity and filter capacity. Only hedgerows with a width of 3-4 m have some ecological value. Tree lines should be even broader but high trees will have greater shadow impacts on fields.

4. Maintain functioning of hedgerow/tree line by regular copping. Do not let the hedgerow/tree line grow too dense in order to enable air masses to pass through it. Maintain porosity of 40-50%. Copping inside the *green line* after about 5 years.

5. Replace tree species when they have grown too tall in order to avoid over-maturation and loss of vitality. Stop forest succession - don't let trees grow too high (shadow impacts).

4.3 Choice of plant traits for ideal pollutant traps

A classification of common hedgerow and forest species after NH_3-tolerance, leaf area, height, winter hardiness and ecology is given in Appendix 3. Apart from tolerance to air pollutants, important plant traits have been compiled from the literature, which determine the function of plants as pollutant traps.

The effectiveness of a tree or a *green line* to filter/absorb ammonia, odours and particulates will largely depend on the **total surface** of the plant leaves. Twig and bark surfaces will also add to the potential of trees to ad- and absorb air pollutants from the atmosphere. During evolution the plant organs have optimised surface area and spatial orientation in order to maximise light reception and gas exchange. **Removal efficiencies** of air pollutants are strongly correlated with surface-volume ratios of vegetation. These are represented by specific leaf area (SLA) on the leaf level and leaf area index (LAI) on a whole plant level. Gond *et al.* (1999) followed the seasonal change of LAI in three tree species and related these to specific leaf area. Both do not necessarily show the same temporal rends. LAI differs strongly between species and varies within the life of a plant and the season. For the creation of effective buffer plantings, the choice of species and species combinations will have to make sure that leaf area of the whole landscape element remains as high as possible over a long time.

Another plant trait determining the ability of plants to work as an active pollutant trap is the **physiological activity** of plants, which may be expressed by the photosynthetic activity, gas-exchange rates and relative growth rates (RGR) of plants. Schulze *et al.* (1986) and Küppers (1987) followed the variation of photosynthetic activity (seasonally and in efficiency) in various tree species. While it was highest in the summer in deciduous species, values are much lower in evergreens. Still, the cumulative assimilation of conifers is not much lower because these remain active in the winter (Figure 8). A major aim of creating ideal buffer plantings may thus be to create landscape elements maintaining relatively high LAIs and assimilation rates throughout the whole year. This safeguards that significant amounts of gaseous pollutants will be taken up via stomata in plant leaves. Inside the leaf tissue and plant cells the

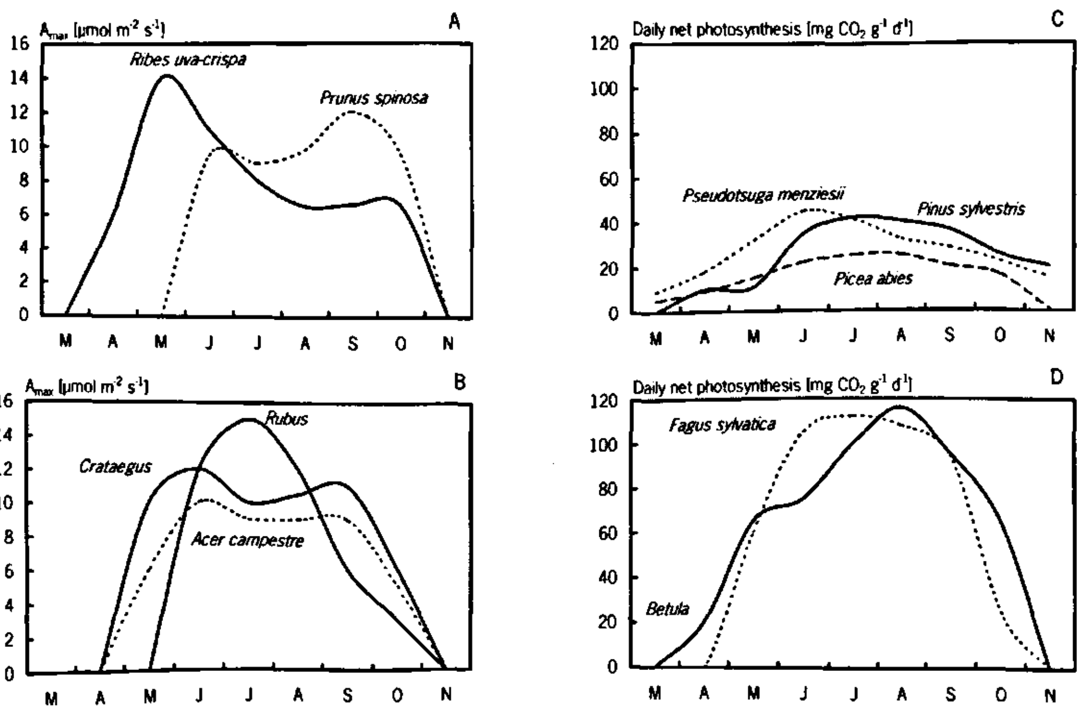

Figure 8. *Variation of photosynthesis of 10 characteristic European hedge and forest species throughout the year. Data for maximum photosynthesis (A_{max}) are from Küppers (1987) and data for net photosynthesis from Schulze* et al. *(1986).*

The ability to **scavenge** gaseous and particulate components is also affected by the **leaf morphology** of plants. Highly structured, feathery or curly leaves are better suited as biofilters than flat leaves because the higher surface roughness decreases the laminar airflow around leaves. The polluted air will thus pass more slowly through the plant crown if plants have structured leaves. Hairy surfaces are also thought to scavenge more pollutants. However if hairs are small, PM_{10} particles may have insufficient inertia to penetrate the stable boundary layer created by the hairy leaves (Smith & Staskawicz, 1977). Finally, the **surface structure** of a leaf also determines the uptake of air pollutants. Especially, the christalline wax structure (rods or plates) and the size of these structures may have importance for the scavenging of dust associated air pollutants. Wax chemistry determines whether a plant cuticle is crystalline or amorphous, but will also affect the uptake of gaseous components in the wax layer of a plant. It is well known that high quantities of lipophilic (semi-) volatile air pollutants (VOCs, which are also present in odours from livestock farms) may be taken up in the lipophilic compartments (cuticles and membranes) of plants (Simonich & Hites, 1994; Wagrowski & Hites, 1997).

5. A round table meeting on landscape elements

In order to get an overview on current issues and policies referring to landscape elements in the Netherlands we decided to organise a small workshop. We invited people from different administrative bodies, nature conservation and farmer organisations, as well as scientists dealing with questions related to the topic. In the afternoon of June 7th 2000 a *round table meeting* was held at Plant Research International in Wageningen (for announcement, see Appendix 2a). The discussion was split up into three blocks relating to the ecological and environmental services of multifunctional landscapes, administrative issues and the practical implementation of planting landscape elements. Unfortunately, the contribution to and the participation of the meeting (list in Appendix 2b) were not satisfactory for:

- There were no attendants from farmer organisations
- There were no attendants from administrative bodies (like LASER)

The participants expected 'hard information' on positive environmental services of landscape elements (i.e. the reduction of environmental pressure) after reading the announcement of the meeting. However, they expressed their feeling that such information may help promote the planting of landscape elements in the future.

The organisers stated that to date there is not much quantitative information on the function of landscape elements and buffer plantings as pollutant traps. Such information would have to be first generated by doing research.

During the first discussion block it became evident that unlike the environmental services, the ecological and aesthetical function of landscape elements are widely recognised. Increasing the biodiversity within the agro-ecosystems is the main motivation for the planting of farm woodlands and hedgerows. Current research activities dealing with landscape elements are primarily based on studying floristic and faunistic diversities and modelling the effects of habitat corridors in the framework of the EHS and other national landscape ecology concepts. Some of the participants emphasised that another study field should be the general recreational profit a region would have if more landscape elements were introduced.

In the second block general national and provincial plans for the future of landscape elements and administrative questions should be addressed. Again, diversification within the agro-ecosystems was seen as a major motivation for the planting of farm woodlands, tree lines and hedgerows, while environmental functions of buffer plantings were not recognised. It was agreed that the socio-economic background of farmers in a region is the most important factor, which determines the participation of people in agro-environmental programmes. Farmers from small farms are generally more easily inclined to plant landscape elements on their agricultural property and older farmers tend to be slightly more open to extensification processes on their land.

Information on the current share in agro-environmental programmes of Dutch farmers remained unclear during the workshop. In comparison to other EU countries, agriculture in the Netherlands is still intensive but there is undoubtedly a rising demand of the society for more nature which could create a better climate for introducing and managing more landscape elements. National guidelines and reglemetation of subsidies for the planting of landscape elements have recently come into action in the Netherlands (LNV, 1999). According to LASER Zuid-Oost a strong increase in numbers of farmers asking for subsidies to plant landscape elements has been noted in the past months. However, no information was available on the farm types, farm sizes and regional distribution of the participating farms. It also remained unclear in the discussion at the round table meeting, whether the success and impact of these plantings will be monitored in future years. While this was strongly recommended by the organiser, the representative of LNV did not feel much for doing so.

In the third, least controversial discussion block of the meeting, information on planting and practical aspects relating to the managing of landscape elements was given by two speakers. In the subsequent final discussion several participants expressed their feeling that notably the multifunctional character of landscape elements may rise the demand for them in the future development of Dutch landscapes. However, communicating this to administrative bodies and including the planting of landscape elements in the rural planning process may be somewhat more difficult than merely increasing the public acceptance. An option for the future may thus be to strive for so-called *win-win situations* in landscape designing, i.e. compensating negative effects of various operations at the same time. If quantitative evidence for the scavenging of air pollutants by landscape elements was adduced, landscape planning in the rural area could be espoused by strong environmental criteria.

6. Outlook

In the coming years, the calculation of **cost-benefit analyses** for reaching different environmental standards in European agriculture will be performed in the framework of a regional analysis (e.g. Ahrens & Bernhardt 2000). In the underlying models various scenarios with different frequency and expansion of landscape elements may be included, too. Furthermore, special instruments will be introduced in the future within European agriculture, which help to evaluate and measure to what degree a farm fulfils ecological standards. First concepts have already been suggested (but not yet introduced) in the Netherlands (*natuurmeetlat* by CLM) and in Germany (*Ökokonto*). An example could be that a farmer will be allowed to have higher animal numbers, if he plants and manages landscape elements on his land.

Although up to now landscape elements are primarily recognised for increasing nature values (e.g. biodiversity) and aesthetical attractivity of a region, the importance of buffer plantings may be of the same - or even a higher- meaning. While it is difficult to express nature wealth and aesthetic attractivity in economic terms, the profit for a reduction of emissions into the environment may be clearly specified. Because the knowledge on the functioning of buffer plantings as pollutant traps is limited, basic research on scavenging, taking up, storing and detoxifying air pollutants is desirable. After the identification of optimal plant traits and suited plant species, phytoextractors may undergo further plant development, including classical breeding programmes and biotechnology.

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Appendix I.
Agri-environment Programmes of the EU

A. The European Commission working document - (source DG VI Internet) entitled:
State of application of regulation no. 2078/92: Evaluation of Agri-environment Programmes

Objectives and key elements of the programmes are that member States are required to apply agri-environment measures throughout their territories, according to the environmental needs and potential.
Two broad types of environmental objective are evident:
To **reduce** the negative pressures of farming on the environment, in particular on water quality, soil and biodiversity;
To **promote farm practices** necessary for the maintenance of biodiversity and landscape, including avoiding degradation and fire risk from under-use.
The main elements, which characterise agri-environment agreements, are the following:
Farmers **deliver an environmental service;**
Agreements are **voluntary** for the farmers;
Measures apply **only on farmland;**
Payments cover the income foregone, costs incurred and necessary incentive;

The **application of agri-environment contracts** concerns 1 farmer in every 7 and delivering environmental services over 20% of European farmland and marks a very significant step towards sustainability. The target set in the 5th Environmental Action Programme of 15% coverage by 2000 has thus already been exceeded. The requirement on Member States to apply the regulation throughout their territories according to their needs has stimulated a very rapid expansion of initiatives and measures, which otherwise may have taken many years to be launched and developed. The evidence presented from programmes is on the whole positive and shows that substantial environmental benefits accrue from agri-environment programmes: reductions in the use of N-fertiliser; better application techniques; positive activities for nature protection; and conservation of landscape features. An increase in employment is recorded in some cases, for example where **labour intensive environmental management replaces a low-labour intensive activity**. Evaluation reports show that programmes provide value in terms of environmental benefits for a relatively modest cost to the Community budget: 4% of EAGGF guarantee section.

The **Netherlands** have not yet well participated in these programmes but the target in the 5th Environmental Action Programme (EAP) of at least 15% of EU farmland under agri-environmental agreement by the year 2000 is already exceeded on the EU level, although in 6 Member States (incl. NL) implementation remains below 15%. The agri-environment regulation requires Member States to apply measures throughout their territories according to their needs. The pattern of implementation, in terms of the rate of application of the programmes differs between the Member States. In the Netherlands measures like the re-introduction of hedgerows might especially be a suited agri-environmental measure to reduce emissions from agriculture.

B. Summary concerning the relationship between farming and the environment (Part I) :

1. The European farmed landscape is the product of farming over centuries. Biodiversity and the traditional landscape depend on certain farming practices;

2. Some agriculture, particularly intensive systems, is the source of pressure on the environment, including water pollution and abstraction, soil degradation and loss of nature value;

3. Driving forces result in intensification, marginalisation, concentration and specialisation of farming, all of which further imbalance the agriculture–environment relationship; policy responses include application of compulsory regulation to ensure minimum standards and promotion of agri-environment programmes to secure environmental services;

4. Agri-environment programmes ask farmers to undertake environmental activities and pay any income losses and costs. The programmes apply to 900.000 farms (excluding D) and 27 million ha, or 20% of EU farmland, although application is considerably more widespread in five Member States. Expenditure for EU-12 has risen from ECU 0.1 billion in 1993 to an estimated ECU 1.2 billion in 1998 (ECU 1.7 billion for EU-15). This represents about 4% EAGGF, Guarantee expenditure.

Tabel I -1. List of agri-environment undertakings in programmes approved under Regulation 2078/92.

Undertaking type	Sub-classification	Environmental elements				
		Air	Biodi-versity	Land-scape	Soil and land	Water
Input use						
(pesticide)	Zero use	A	B		S	W
	Reduced use	A	B		S	W
	Restriction on type of product	A	B		S	W
	Restriction on method/timing of use	A	B		S	W
	Restriction on zone of application		B		S	W
	Use of infective thresholds	A	B			W
	Use of insect traps	A	B			W
	Requirement to use pesticide		B	L		
(fertiliser)	Zero use	A	B		S	W
	Reduced use	A	B		S	W
	Restriction on type of product	A	B		S	W
	Restriction on method/timing of use	A	B		S	W
	Restriction on zone of application		B		S	W
	Manure use requirements		B		S	W
	Manure disposal restrictions	A	B	L	S	W
	Use of seaweed and other fertilisers		B		S	
(lime)	Restrictions on use of lime		B		S	
	Restrictions on method of use		B		S	
(water)	Cessation of irrigation		B	L	S	W
	Reduction in irrigation		B	L	S	W
	Restriction on method of irrigation				S	W
	Watering restriction		B			W
(energy)	Restrictions on use of energy	A				
Use of grassland and rough land						
	Stocking limits	A	B	L	S	W
	Grazing management specifications		B	L	S	W
	Removing stock for a few years		B	L	S	W
	Removing stock for seasons		B	L	S	W
	Restrictions on type of stock		B	L		
	Specification of breed to be used		B	L		
	Rearing farm breeds under threat		B	L		
	Restrictions on supplementary feed		B			
	Specification of method of feeding			L		
	Prohibition of surface disturbance		B		S	
	Seeding restrictions		B	L		
	Seeding requirements		B			
	Controlled burning of vegetation	A	B	L		
	Prevention of burning	A	B	L		
	Mechanical control of invasive plants		B			
	Clearance of scrub and trees		B	L		
	Hay production requirement		B	L		W
	Other vegetation production		B	L		W

Tabel I-1. Continued.

Undertaking type	Sub-classification	Environmental elements				
		Air	Biodiversity	Landscape	Soil and land	Water
	Grass cutting requirement		B	L		
	Requirement for number of cuts		B	L		
	Limitations on grass cutting dates		B			
	Specification of grass cutting method		B			
	Limitations on use of machinery		B		S	
	Maintenance of old orchards		B	L		
	Avoid abandonment		B	L		
Cultivation of arable and permanent crops						
	Specification of crop type		B	L	S	W
	Specification of crop variety		B	L		W
	Saving seed of variety under threat		B			
	Spacing seed drills				S	W
	Varying seeding rates				S	W
	Mulch seeding				S	W
	Limit use of growth regulators		B			W
	Undersowing cover crops (inc. grass)		B	L	S	W
	Scheduling of cultivation activities		B	L	S	W
	Ploughing restrictions		B	L	S	W
	Techniques to minimise erosion			L	S	W
	Perennial ley requirement		B	L	S	W
	Use rotation measures		B	L	S	W
	Harvesting limitations		B		S	
	Retain stubble after harvest		B		S	W
	Allow weeds to grow after harvest		B		S	W
	Limitations on use of machinery		B		S	
	Cultivation to avoid abandonment		B	L		
	Cessation of arable use		B	L	S	W
Landscape conservation						
(whole fields)	Prevent topographical changes		B	L		
	Use sloped land		B	L	S	
	Maintain terracing		B	L	S	W
	Create new terracing		B	L	S	W
	Undertake works to cause flooding	A	B	L	S	W
	Raise water table	A	B	L	S	W
	Cause land to flood	A	B	L	S	W
	Cause seasonal flooding	A	B	L	S	W
	Prevent new drainage	A	B	L	S	W
	Reduce drainage efficiency	A	B	L	S	W
	Restrictions on works in soil or rocks		B	L	S	
	Set-aside: creation of biotopes		B	L	S	W
	Maintain abandoned farmland	A		L	S	
	Re-farm abandoned land		B	L	S	

Tabel I-1. Continued.

Undertaking type	Sub-classification	Environmental elements				
		Air	Biodi-versity	Land-scape	Soil and land	Water
(field margins)	Create unsprayed strips		B	L		W
	Maintain unsprayed strips		B	L		W
	Create uncultivated/buffer strips		B	L		W
	Maintain uncultivated/buffer strips		B	L		W
	Create beetle banks		B	L		W
	Maintain beetle banks		B	L		W
	Create stone walls/fences		B	L		
	Maintain stone walls/fences		B	L		
	Create hedgerows		B	L		
	Maintain hedgerows		B	L		
	Create banks		B	L	S	
	Maintain banks		B	L	S	
	Create ponds, scrapes, pits		B	L		
	Maintain ponds, scrapes, pits		B	L		
	Create biotope zones		B	L		
	Maintain biotope zones		B	L		
(trees)	Regeneration of farm woodlands		B	L		
	Maintain unused woodland	A		L		
	Maintain farm woodlands		B	L		
	Use grazing to maintain fire breaks			L		
	Maintain single trees		B	L		
	Pollarding and pruning		B	L		
(other)	Other conservation activities			L		
Farm administration and planning						
	Identification of historical sites			L		
	Identification of archaeological sites			L		
	Identification of historical landscapes			L		
	Identification of landscape features			L		
	Monitoring of wild fauna		B			
	Monitoring flora/vegetation condition		B			
	Attain permissions for activities		B	L		
	Map environmental aspects of farm		B	L		
	Nutrient management planning		B		S	W
	Grassland management planning		B		S	
	Other environmental farm planning		B	L	S	W
	Soil and other sampling					W
	Adherence to organic organisation		B	L	S	W
	Adherence to IP organisation		B			W
	Adherence to other organisation					
	Record use of inputs		B		S	W
	Record other farm practices					
	Requirement to attend training		B	L	S	W

Appendix II.

Announcement of a *round table meeting* on the potential use of landscape elements in restructuring Dutch agriculture (in Dutch)

(see enclosure backside cover)

Appendix III.
Programme and participation of the *round table meeting* (in Dutch)

Programma

14:00-14:05	Welkom op *Plant Research International*, Haverkort (BU Manager Gewas- en Productie Ecologie)
14:05-14:15	Introductie Cluster *Plant en Milieu*, Blom-Zandstra (Clusterleidster)
14:15-14:35	Voorstelronde
14:35-14:45	Introductie Ronde -Tafel-Bijeenkomst, Franzaring (Onderzoeker)
14:45-15:30	Blok I: *Multifunctionele landschappen* met bijdragen van Schotman (Alterra) en Kloen (CLM), daarna discussie
15:30-16:00	Blok II: *Beleidsvragen* met bijdrage van Brummelman (LNV Oost), daarna discussie
16:00	Pauze
16:15-17:00	Blok III: *Praktijk* met bijdragen van Ruyten (Landschapsarchitect) en Geurts (IKL Limburg), daarna discussie/eindevaluatie
Ca. 17:00	Einde

Deelnemerslijst

Naam	Organisatie/Instituut
Alex Schotman	ALTERRA Multifunctionele landschappen
Henk Kloen	Centrum voor Landbouw en Milieu (CLM)
van Zeyts	Centrum voor Landbouw en Milieu (CLM)
Aad van Pasen	Landschapsbeheer Noord-Holland
Frits Ruyten	Tuin- en landschapsarchitekt
Rob Hendriks	IKC-Natuurbeheer
Manon Wolterink	DLV Adviesgroep, Groen & Natuurbeheer
Gert-Jan Elbers	DLV Adviesgroep, Groen & Natuurbeheer
Jantine van Veldhuizen	DLV Adviesgroep, Groen & Natuurbeheer
G. Brummelman	LNV Directie Landbouw/Oost
Bertjan Oosterbeek	Provincie Noord Brabant
Wouter van Heusden	Dienst Landelijk Gebied
J. Geurts	Instandhouding Kleine Landschapselementen
Jürgen Franzaring	Plant Research International
Greet Blom-Zandstra	Plant Research International
Bert Smit	Plant Research International
Klaas Metselaar	Plant Research International
Hein Korevaar	Plant Research International
Peter Hofschreuder	Wageningen UR, Meteorologie en Luchtkwaliteit

Appendix IV.

Classification of common hedgerow and forest species after NH_3-tolerance, leaf area, height, winter hardiness and ecology

Table IV-1.

Species	Whole plant characteristics					Leaf characteristics			Wax, hair and stomata characteristics [g]						
	Ever-green	Height [m]	Sensitivity [a] [relative]	N-indicator [b] [ranks]	Exposition [c] [direction]	LAI [d] [m^2 m^{-2}]	SLA [e] [m^2 kg^{-1}]	N-content [f] [% leaf dm]	Wax layer [leaf sides]	Wax type [descript.]	Hairs [leaf sides]	Hair length [µm]	Stomata [no. mm^{-2}]	Length [µm]	Width [µm]
Native to Europe:															
Acer campestre		>10	ins	6	ind	8,9	19		no		both	500	198	23	15
Acer negundo		>10	ins	7					no		both	350	198	20	16
Ligustrum vulgare	•	<5	ins	3					no		adax	90	165	41	34
Crataegus spec.		<5	ins	4	ind	8,5			no		both	750	90	40	27
Rosa canina		<5	ins		S		33		both	platelets	no		99	25	14
Pinus mugo	•	<5	ins	2											
Pinus sylvestris	•	>10	ins				3	1,39							
Pinus nigra	•	>10	ins	2											
Quercus robur		>10	ins		W		19		both	platelets	both	130	385	33	23
Buxus sempervirens	•	<5	ins	4					both	rods	no			29	27
Rhododendron spec.	•	<5	ins	2					no		no		77	33	29
Berberis vulgaris	•	<5	mod-ins	3			26		both	platelets	no		110	37	30
Hedera helix	•	<5	mod-ins						no		abax	750	440	32	26
Acer pseudoplatanus		>10	mod	7			25		both	platelets	abax	800	165	30	20
Betula pubescens		<10	mod		S		15		adax	platelets	both	700	165	35	36
Cornus mas		<5	mod	4					no		both	750	110	34	27
Fagus sylvatica		>10	mod		W	6,3	17		no		both	3000	132	30	22
Fraxinus excelsior		>10	mod	7	ind		14		no		no		220	32	27
Larix decidua		>10	mod	3			14	2,1							
Alnus glutinosa		<10	sens		ind	4,8	14		no		both	475	154	30	31
Carpinus betulus		>10	sens		ind		18		no		both	1700	143	25	22
Picea abies	•	>10	sens			4	11								
Sambucus nigra		<5	sens-mod	9	ind		34		no		both	450	55	55	35
Sorbus aucuparia		<5	sens		ind		34		both	rods	both	600	220	27	20
Tilia cordata		>10	sens				19		no		both	400	132	25	11

Continued Table IV.

Species	Whole plant characteristics					Leaf characteristics			Wax, hair and stomata characteristics [g]						
	Ever-green	Height [m]	Sensitivity [a] [relative]	N-indicator [b] [ranks]	Exposition [c] [direction]	LAI [d] [m^2 m^{-2}]	SLA [e] [m^2 kg^{-1}]	N-content [f] [% leaf dm]	Wax layer [leaf sides]	Wax type [descript.]	Hairs [leaf sides]	Hair length [µm]	Stomata [no. mm^{-2}]	Length [µm]	Width [µm]
Taxus baccata	•	<10	sens-mod												
Viburnum opulus		<5	unknown	6	S		27		no		both	300	88	43	29
Rubus fruticosus	(•)	<5	unknown	6	S	3,3			no		both	1000	330	31	16
Rubus idaeus		<5	unknown						both	degen	both	160		15	12
Rhamnus frangula		<5	unknown		E				adax	degen	both	450	440	25	25
Prunus spinosa		<5	unknown		ind	3,8	42		no		both	400	550	26	18
Prunus avium		<10	unknown	6					no		abax	900		29	17
Ilex aquifolium	•	<5	unknown	5	N		16		no		no		407	31	18
Corylus avellana		<5	unknown	5	N				no		both	1300	143	31	30
Sorbus aria		<10	unknown	3					no		both	500	605	27	15
Euonymus europaea		<5	unknown	5	ind				no		no		330	33	23
Ribes uva-crispa		<5	unknown	6		4,3			no		both	550	44	40	27
Prunus padus		>10	unknown	6					abax	rods	both	650	555	25	19
Prunus serotina		>5	unknown				10	2,07	no		both	400	198	32	12
Rhamnus carthartica		<5	unknown	4			12	2,3	no		no		440	26	18
Lonicera xylosteum		<5	unknown						both	platelets	both	800	341	36	22
Lonicera periclymenum		<5	unknown	4	N		31								
Not native to Europe:															
Tsuga canadensis	•	<10	ins				8	0,99							
Hamamelis spec.		<10	ins												
Quercus rubra		>10	ins						both	platelets	both	115	462	29	23
Robinia pseudoacacia		>10	ins	8			26	4,3	both	platelets	both	325		15	8
Thuja occidentalis	•	<10	ins-sen				5	0,76							
Picea omorika	•	>10	mod												
Pinus strobus	•	>10	ins-sens				9	1,35							

Continued Table IV.

Species	Whole plant characteristics					Leaf characteristics			Wax, hair and stomata characteristics [g]						
	Ever-green	Height [m]	Sensitivity [a] [relative]	N-indicator [b] [ranks]	Exposition [c] [direction]	LAI [d] [m^2 m^{-2}]	SLA [e] [m^2 kg^{-1}]	N-content [f] [% leaf dm]	Wax layer [leaf sides]	Wax type [descript.]	Hairs [leaf sides]	Hair length [µm]	Stomata [no. mm^{-2}]	Length [µm]	Width [µm]
Pseudotsuga menziesii	•	>10	sens			15									
Amelanchier lamarckii		<5	unknown						both	rods	abax	600		33	23
Cotoneaster integerrimus	•	<5	unknown						both	rods	absx	800	495	4	15
Fast growing															
Salix alba		<10	unknown				17		both	unaligned	both	525	99	22	17
Populus nigra		>10	ins-sens				14	2,2	no		abax	230	88	40	31

[a] ins=insensitive, mod=moderately sensitive, sens=sensitive after literature study of Adaros & Dämmgen (1994)
[b] after Ellenberg *et al.* (1991), where 2 represents a species preferring poor soils and 9 one preferring very rich soils
[c] after Weber (1975) addressing preferred exposition of hedgerow species, ind=indifferent, N=north, S=south, E=east, W=west
[d] after Küppers (1982), Schulze (1982) und Eschenbach & Kappen (1996)
[e] after Bartelink (1997), Reich (1999), Ermolova (1998)
[f] after Reich *et al.* (1999)
[g] after Westerkamp & Demmelmeyer (1997)

Appendix V.
Additional information

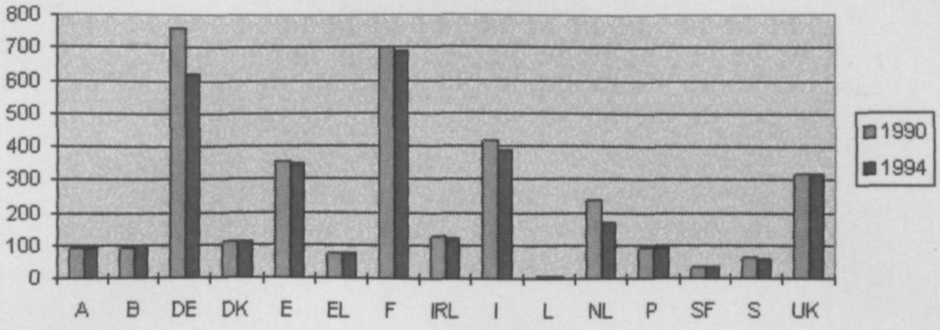

Figure V-1. *NH3 Emissions by country expressed in 1000t. Source: Europe's Environment, The Statistical Compendium, 1998.*

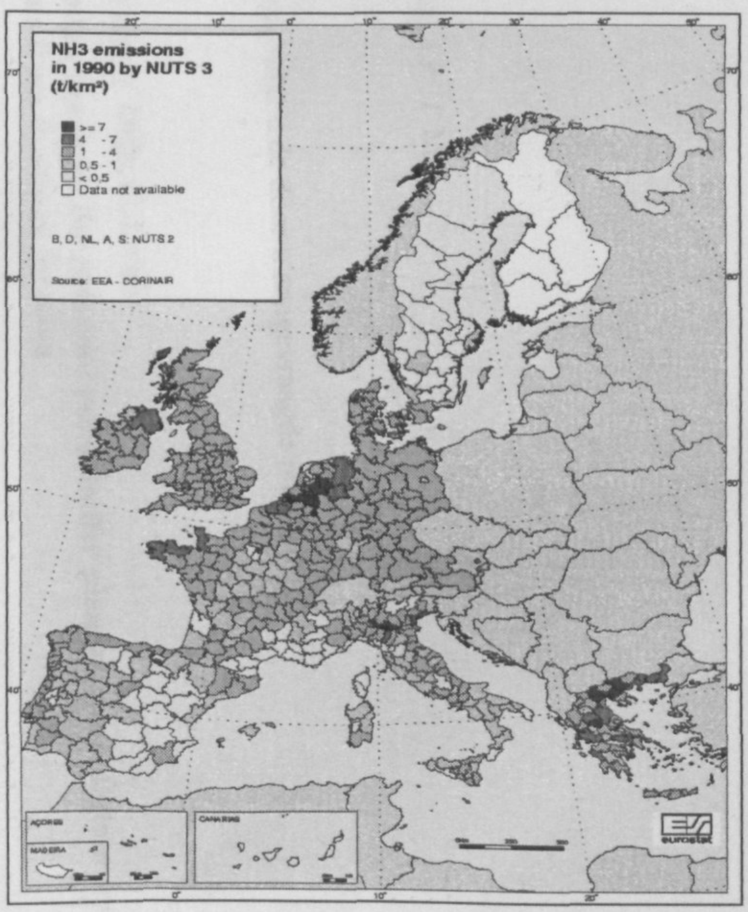

Figure V-2. *NH3-emissions by EU regions expressed in t km-2. Source: Europe's Environment, The Statistical Compendium, 1998.*