DYNAMIX

Decoupling growth from resource use and environmental impacts

DYNAMIX policy mix evaluation

Reducing fertiliser use in Denmark

European Commission

SEVENTH FRAMEWORK PROGRAMME

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1 Resource/Issue

Name of resource targeted (or focus of the case study, if the policy mix is broader than the specific resource(s) we have decided to analyse).

The case study focuses on the use of fertilisers in agriculture. Fertilisers are added to soils to improve the growth, yield and quality of crops. Fertilisers can be organic (e.g. manure) or inorganic (e.g. phosphate and synthetic fertilisers). The main problem related to the use of fertilisers is the run-off and leaching of (excessive) fertilisers that lead to eutrophication, which is the primary cause of oxygen depletion in water bodies. Besides eutrophication, the diminishing reserves of phosphorus are also of global resource concern (Cordell 2010).[1]

2 Geographical area of policy mix coverage

Country name, and region or city if appropriate (if policy mix is applied regionally or locally)

This case study covers policies in Denmark including the transposition of EU policies and a period of time of almost 30 years from the 1980s to today.

3 Policy context

3.1 Needs assessment: The environmental problem/resource challenge

What is the environmental problem/concern (consider both quantity and quality), e.g. soil erosion, excessive use of non-renewable or renewable resources and the crossing of environmental thresholds/tipping points for impact, resource scarcity concerns?

Are there any economic or social problems related to the issue and environmental problems – e.g. is there important price volatility, (risk of) unavailability of resources for the economy or society?

Who is the target group affected that have been, are or will be beneficiaries of the policy response?

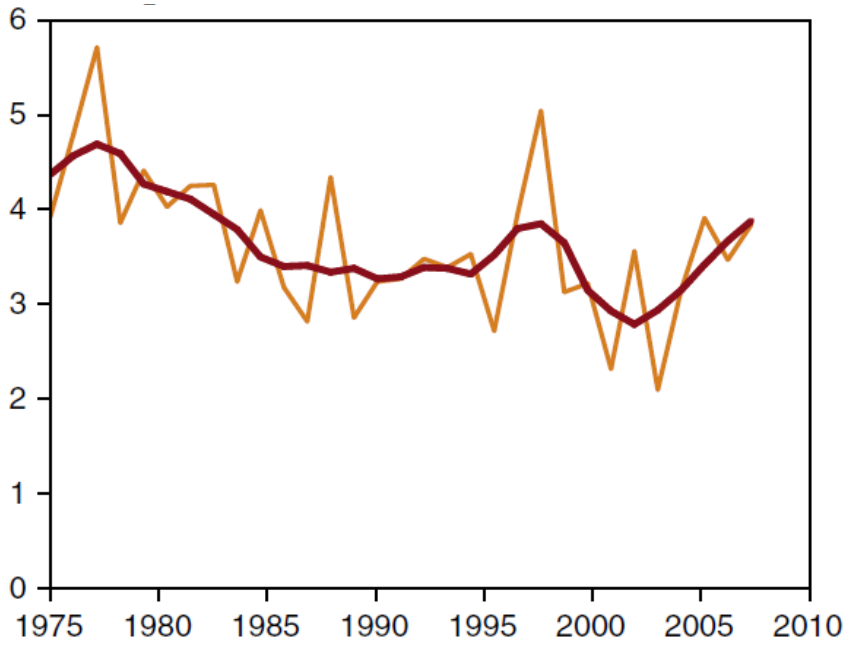
Direct discharges of manure and excessive or inappropriate use of fertiliser lead to leaching of nutrients to aquatic environments and can cause eutrophication or nutrient enrichment and algae blooms, which in turn lead to hypoxia (oxygen depletion) in water bodies, extensive fish death and ultimately loss of biodiversity. Hypoxia can also pose considerable negative impacts on fisheries and aquaculture as well as on tourism.

Although hypoxia is a natural occurring phenomenon, throughout the 1980s it seemed to occur more often and to more coastal areas around Denmark than before (Christensen,

Hansen and Ærteberg 2004).[2] Figure 1 shows the development of oxygen concentration in one of the main coastal areas in Denmark. After investigating this issue studies showed that the main cause of the changes in oxygen concentration was the use of fertilisers and manure in the agriculture sector (EEA 2012).[3]

In the past 50 years, agricultural production in Denmark has considerably developed through improved techniques and intensification (Jensen n.d.).[4] Throughout this improvement the use of fertilisers, in particular inorganic commercial fertilisers, has significantly increased.

Figure 1: Oxygen concentration (mg O_2/l) at the seabed in the Belt Sea (the coastal areas around Funen, Denmark), 1975-2010

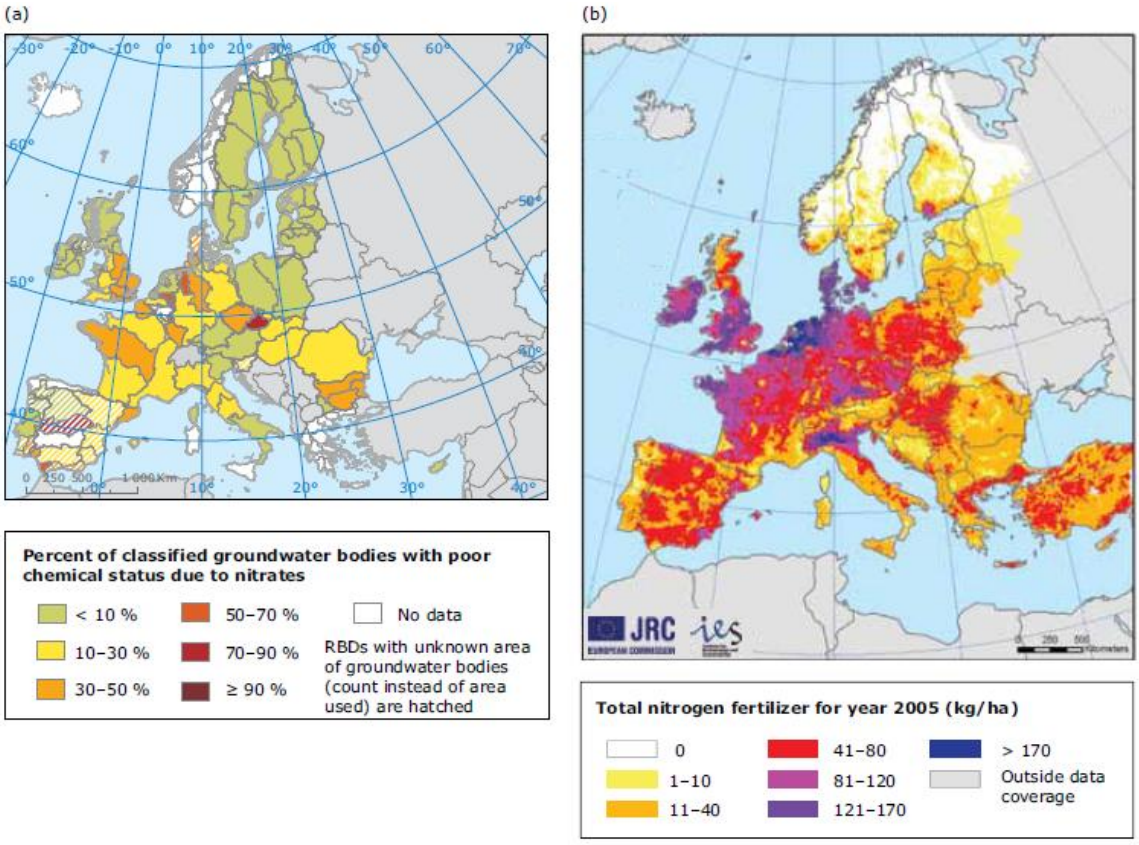


Note: The orange line shows the annual measurements (average measurements in the period August to October). The red line shows the long term trend.

Source: DMU. 2009b. *Natur og miljø 2009 – Fakta om natur og miljø. Del B.* Danmarks Miljøundersøgelser (DMU)/National Environmental Research Institute (NERI), Aarhus University, p.56

Besides causing hypoxia and algae blooms, nitrogen fertilisers also pollute groundwater sources that provide fresh drinking water. Figure 2 shows that a large amount of nitrogen fertiliser is used per land area in Denmark compared to many other countries in Europe.

Figure 2: Proportion of EU groundwater bodies not achieving good chemical status due to nitrate (a) and total nitrogen input from organic and inorganic fertilisers (b), 2005



Note: Groundwater bodies of unknown status are not included in the calculation of the percentage of poor chemical status due to nitrate.

Source: EEA. 2012. *European waters — current status and future challenges*. EEA Report No 9/2012. Denmark. European Environment Agency

The rapid diminishing of phosphorus reserves also represents another significant resource challenge. Peak phosphorus is likely to occur around 2035 (Cordell, Drangert, et al. 2009).[5] In 2050, it is projected that all phosphate rock used in the EU will come from Morocco (Cordell, 2010)[6], which will make all EU Member States highly dependent on Moroccan imports.

3.2 Policy context and policy needs

What policy challenge(s) did the problem pose and what policy challenges does it still pose?

What is the policy context related to the policy mix being evaluated? What policies have been put in place to address the issues, what policies are currently in place and which ones are already foreseen for future introduction (e.g. to address past, existing and future objectives)?

What sort of policy response did (and does) the problem call for?

Before the 1970s Denmark did not have much environmental regulation (Rehling 1996).[7] The first environmental ministry was established in 1971. The tremendous pace of industrialisation and growth in the 1960s – and the realisation of lack of pollution control – led to an environmental reform and to the introduction of the Environmental Protection Act

(Miljøbeskyttelsesloven) in 1973. This Act gathered the existing laws on water supply and water ways.

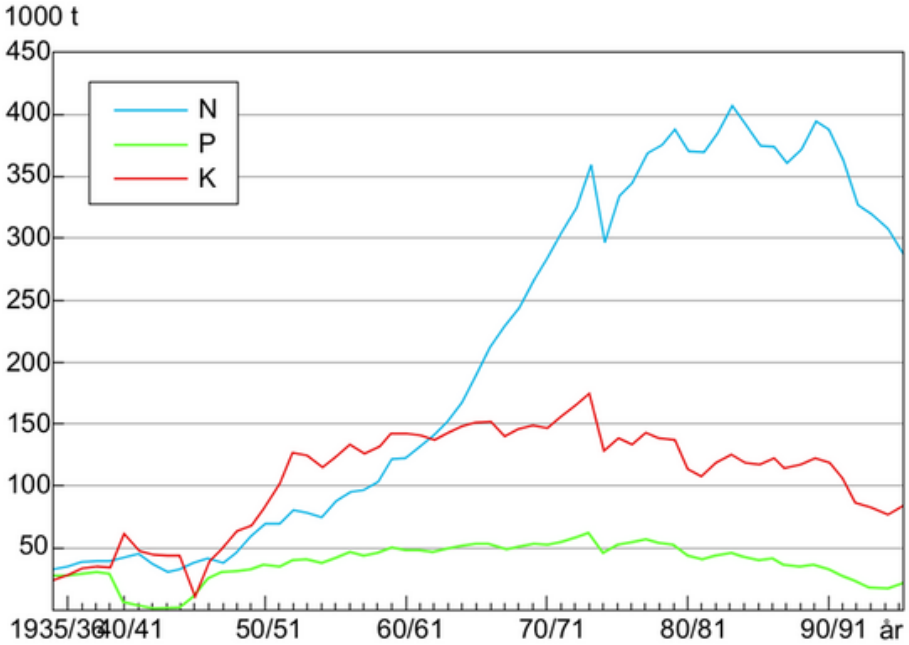
Although hypoxia was common in the coastal areas around Denmark, the problem only caught the attention of the media and politicians when dead fish started to wash up on to the shores in the early 1980s (Christensen, Hansen and Ærteberg 2004).[8] It became apparent that the increasing occurrence and area of oxygen depletion in Danish waters destroyed nature, which also resulted in significant societal costs. This led to greater awareness of the degradation of the aquatic environment in Denmark and the first action plans in the mid-1980s.

3.3 Historical performance and projections into the future: Insights on decoupling

What has been the trend vs. GDP (or other economic performance metrics, such as sectoral growth) and what type of decoupling has been achieved?

The use of fertilisers in Danish agriculture had increased considerably since the Second World War (Den Store Danske 2013).[9] This was partly due to a 50 % increase in crop land, but also a reduction of clover as animal feed. The energy crisis in the mid -1970s stopped this trend as the price of oil rose drastically. The use of nitrogen fertilisers continued to rise until the 1980s. Figure 3shows the used amount of nitrogen, phosphorus and potassium since the 1930s.

Figure 3: Danish use of nitrogen (N), phosphorus (P) and potassium (K) fertilisers, 1935-1991

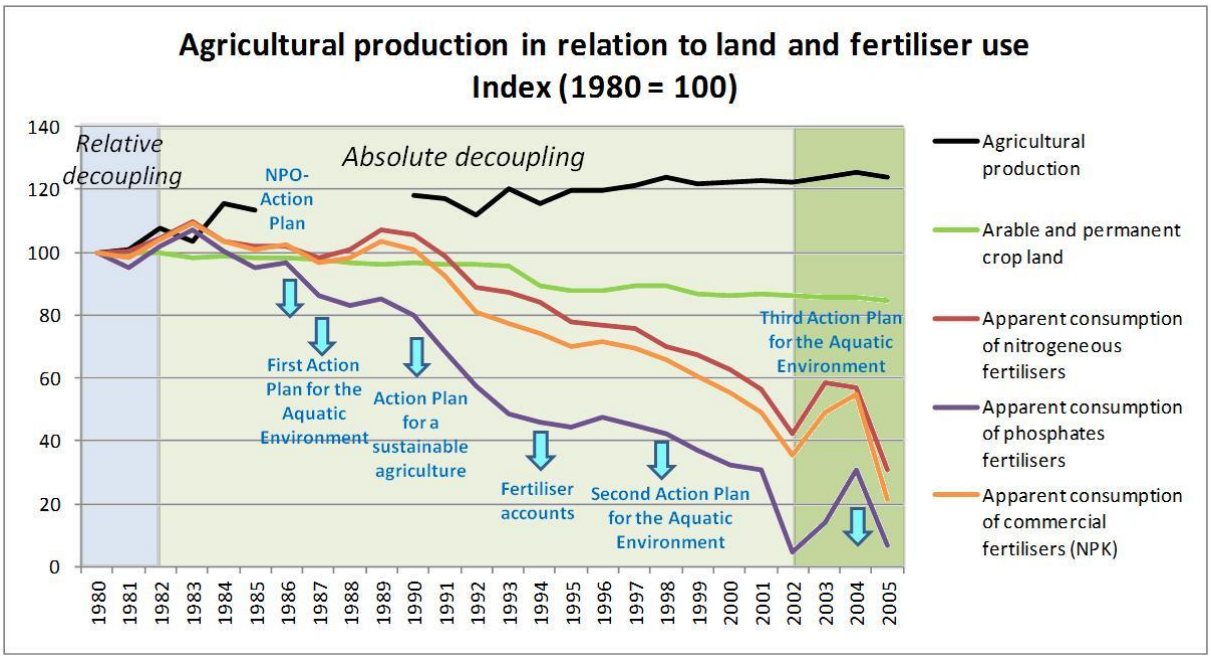


Source: Den Store Danske, 2013, ©John Fowlie/Danmarks Statistik

Since the 1980s fertiliser use has decreased drastically in Denmark, whilst agricultural production has slightly increased. The amount of arable and permanent cropland has decreased in the early 1990, but has otherwise remained fairly stable. Figure 4 indicates that

fertiliser use in Denmark has been absolutely decoupled from economic development in the agricultural sector.

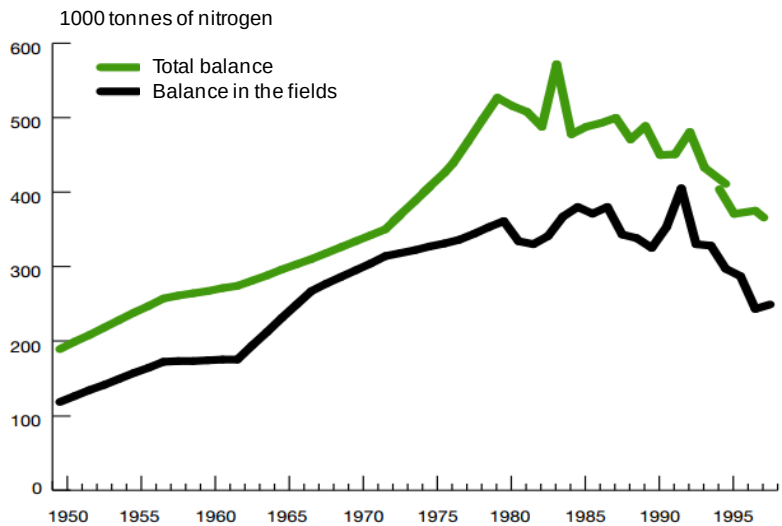
Figure 4: Decoupling trends in the Danish agriculture sector, agricultural production versus apparent consumption of various fertilisers, 1980-2005



Source: OECD n.d. Environmental Data. Compendium 2008. Agriculture.

Figure 5 presents the development of nitrogen balance, i.e. the difference between nitrogen inputs in the form of fertilisers, manure, seeds and planting material, biological fixation and atmospheric deposition, and nitrogen outputs from the harvest of crops and residues removed from the field. The surplus of nitrogen has steadily increased from the 1950s, stabilised in the 1980s and then started to fall considerably in the 1990s.

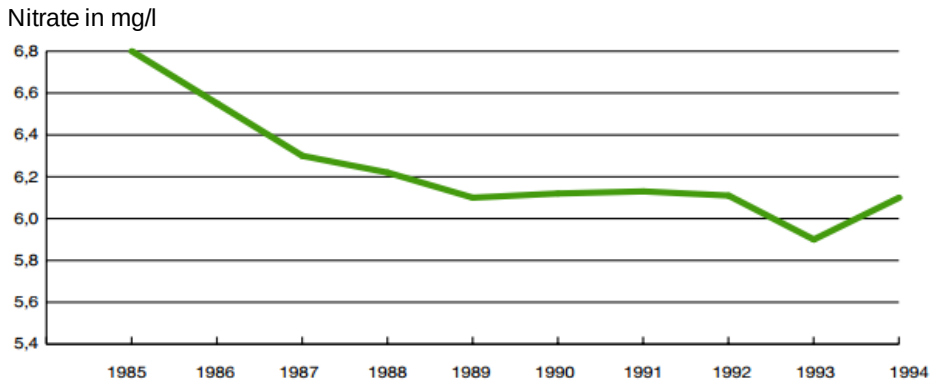
Figure 5: Nitrogen balance in Danish agriculture, 1950-1998



Source: Knudsen, Leif, Hans Spelling Østergaard, and Ejnar Schultz. 2000. *Kvælstof – et næringsstof og et miljøproblem.* Landbrugets Rådgivningscenter

The nitrate content in drinking water also improved in the period 1985 - 1990 (Knudsen, Østergaard and Schultz 2000) (see Figure 6).[10] However, this is likely to be the result of extracting drinking water from greater depths than before instead of the reduction of the use of nitrogen fertilisers.

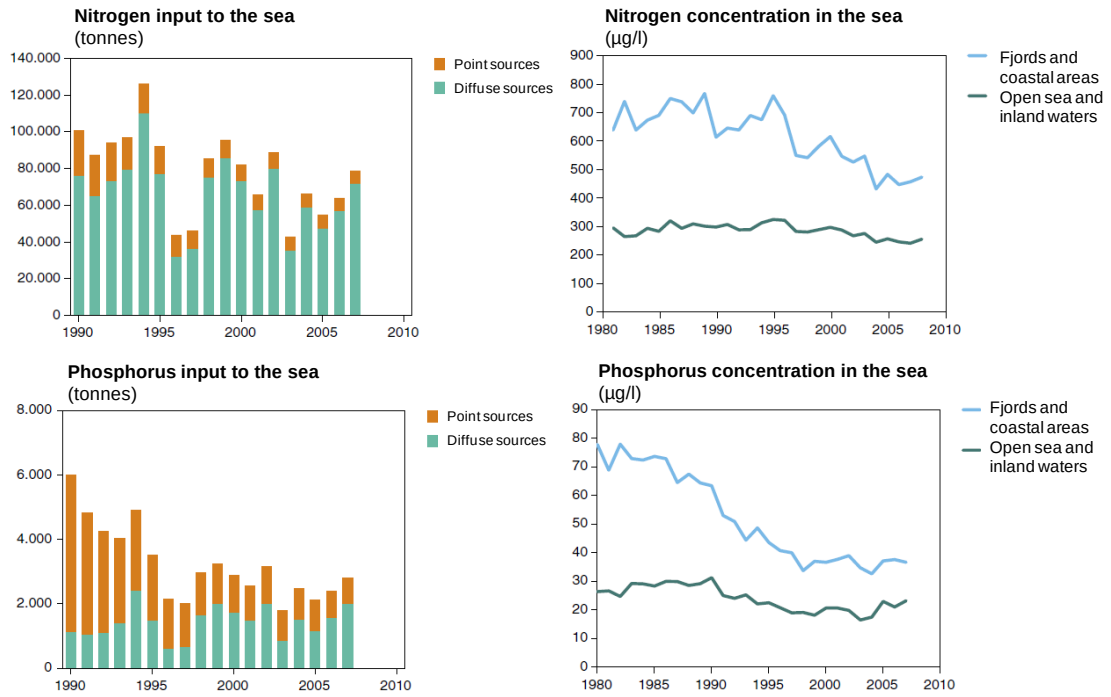
Figure 6: Nitrate content in Danish drinking water, 1985-1994



Source: Knudsen, Leif, Hans Spelling Østergaard, and Ejnar Schultz. 2000. *Kvælstof – et næringsstof og et miljøproblem.* Landbrugets Rådgivningscenter

The amount of nitrogen and phosphorus reaching the sea also indicates the trends of nutrient input and surplus (DMU 2009b).[11] Since 1990, the amount of nitrogen and phosphorous entering the sea has decreased, likewise their concentration in the Danish waters. The drop in nutrient concentration has been greatest in open seas and inland waters. Nevertheless, in fjords and areas close to the coast only a slight drop has been observed.

Figure 7: Input and concentration of nutrients (nitrogen and phosphorus) in the sea, 1990-2010



Source: DMU. 2009b. *Natur og miljø 2009 – Fakta om natur og miljø. Del B.* Danmarks Miljøundersøgelser (DMU)/National Environmental Research Institute (NERI), Aarhus University, p.54-55

Despite these reductions in nutrient use and leaching, the oxygen conditions in Danish waters have not improved (DMU 2009b).[12] This is seen as a result of the still relatively high intensity of nutrients used per hectare in Danish agriculture compared with other OECD countries (OECD 2008)[13], but also because of the increasing temperatures caused by climate change. Despite the signs of absolute decoupling of fertiliser use in agriculture in Denmark, we cannot say yet that this has achieved a sustainable level. With temperatures set to increase further, the state of Danish waters will continue to degrade if the flow of nutrients is not further reduced.

4 Drivers affecting change: resource use/ environmental issues

What are the drivers affecting resource use (driving demand for the resource and leading to resource overuse) or other environmental impacts?

Crops require nutrients such as nitrogen (N), phosphorus (P) and potassium (K) to grow. In order to increase yields (and profits) farmers apply these nutrients to fields in the form of fertilisers. Since the 1950s, Denmark has tripled its agricultural production due to modern farming techniques, mechanisation and intensive farming, including an increased use of fertilisers (Den Store Danske 2013).[14] The increased production and general economic

growth has led to food representing an even smaller share of total private expenditure. The demand for low food prices drove intensive agricultural production and thereby also fertiliser application. Together with the relatively low cost of fossil energy, commercial fertilisers are fairly cheap. In the 1960s and 1970s the agricultural sector in Denmark used increasing and excessive amounts of fertilisers. The EU Common Agricultural Policy (CAP) in the 1970s to 1990s also contributed to the intensive agricultural production system in Denmark (Kjær and Madsen 1998).[15] Danish farmers responded well to the incentives that CAP offered by guaranteed prices. Investments and the use of inputs like concentrate feeds, commercial fertilisers, pesticides and energy have increased.

The magnitude of nutrient loss depends on agricultural practices,[16] (Dobbs, et al. 2011) such as tillage techniques, the quality and quantity of fertiliser used, (Basset-Mens 2005)[17] leaching (Czymmek, et al. 2005)[18] and application techniques[19,20] (INRA 2012) (Alterra 2012) in relation to climatic and geographical conditions (Moncrief et Bloom 1999).[21]

The greatest losses of nitrogen are direct discharges, nitrate leaching, ammonia evaporation and de-nitrification (Jensen n.d.).[22] Direct discharges of nitrogen occur when manure is not collected or stored correctly. Nitrate leaching mainly happens when there is nitrate in soils without green cover or when the plants do not absorb nutrients because of poor growth. When precipitation in autumn and winter is greater than evaporation, nitrate will wash out or move towards the groundwater. Ammonia evaporation mainly occurs when manure is exposed to air, e.g. from intensive livestock breeding and when manure is spread out on the fields. There is a high correlation between livestock density and ammonia evaporation. Finally, nitrification is when bacteria transform nitrate to nitrous oxide (N_2O) and nitrogen gas (N_2). Nitrous oxide is a potent greenhouse gas that leads to global warming. While nitrogen gas is a harmless gas, de-nitrification is still considered as a loss of nitrogen input to agriculture.

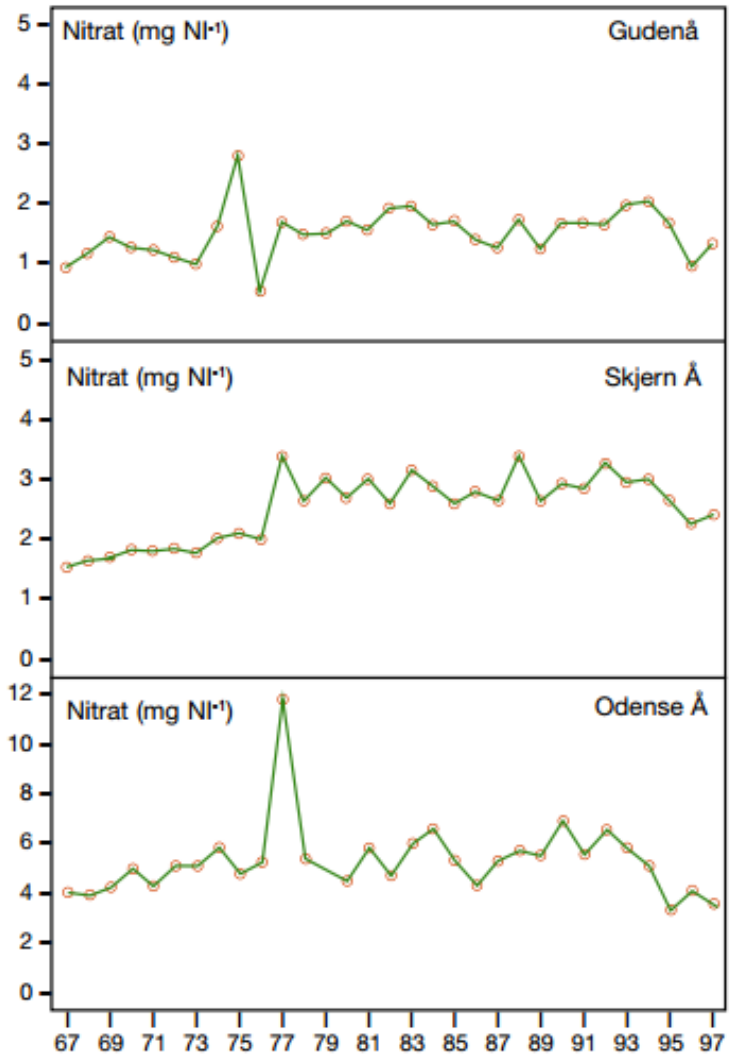
Although it is possible to optimise yields and minimise nutrient losses, many farmers lack knowledge on the environmental impacts of their practices and do not have information on best practices. In addition, many farmers do not believe that it is possible to reduce nitrogen input without decreasing yields. Another contributing factor to inefficient fertiliser management is the use of inappropriate equipment, which is often due to the high investment costs of more efficient equipment.

5 Situation/trend prior to introduction of policy mix

Information on the baseline situation before the policy mix was introduced.

Nitrogen flows to the marine environment have only been properly calculated since 1989(Knudsen, Østergaard and Schultz 2000).[23] The nitrate concentrations in the three biggest rivers in Denmark show an increasing trend towards the 1990s – before the policies on fertiliser use had any effect (see Figure 8).

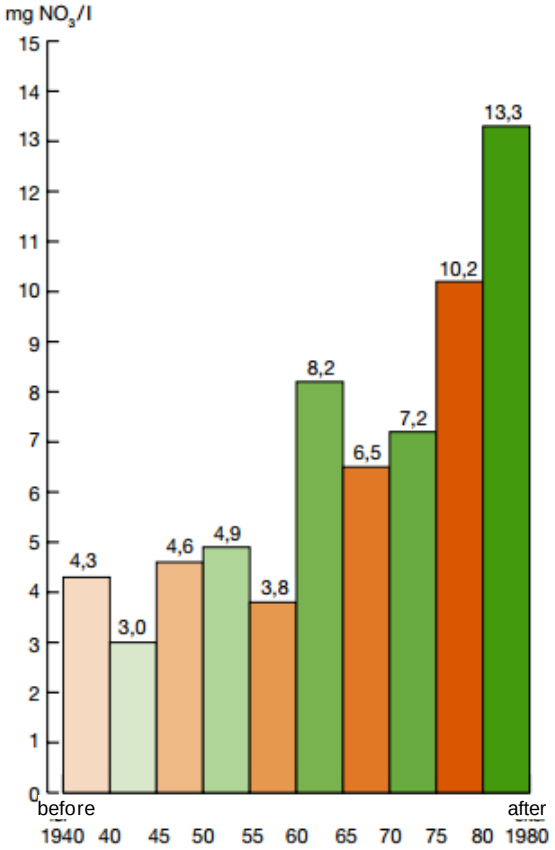
Figure 8: Nitrate concentration in three major rivers in Denmark, 1967-1997



Source: Knudsen, Leif, Hans Spelling Østergaard, and Ejnar Schultz. 2000. Kvælstof – et næringsstof og et miljøproblem. Landbrugets Rådgivningscenter

The quality of groundwater was deteriorating before 1980 (Knudsen, Østergaard and Schultz 2000) (see Figure 9).[24] The nitrate content in groundwater was one of the reasons to regulate the use of fertilisers in agriculture.

Figure 9: Nitrate content in Danish drinking water from the analyses of drillings deeper than 10m before 1980



Source: Knudsen, Leif, Hans Spelling Østergaard, and Ejnar Schultz. 2000. *Kvælstof – et næringsstof og et miljøproblem.* Landbrugets Rådgivningscenter

6 Description of policy mix(es)

This section presents the main policy mix that will be the focus of this ex-post assessment.

Lifecycle focus (point of application(s) of the policy mix): Production (farming)

Sector(s) covered: Agriculture

Scale of application of policy mix: National (Denmark) or community level (EU)

Implementing body: Danish agencies

Objective of policy mix: improve the quality of the aquatic environment (decrease use of fertilisers)

The main policies which are the focus of this case study are listed in the following table. The majority of the policies have an overall aim to improve the quality of the aquatic environment. They therefore also address other issues not related to agriculture or fertiliser use. These parts of the policies are not included in the table below and only the measures related to fertiliser use are listed. The policy mix includes both Danish and EU policies. EU policies have required that the Danish policies be strengthened over time.

Table 1: Overview of Danish fertiliser use policies considered in the case study

Policy	Type of instrument	Life cycle focus	Sector covered	Scale of application	Implementing body	Objective	Entered into force
NPO Action Plan *(NPO-handlings-planen)*	Regulation	Farming	Agriculture	National (Denmark)	Various Danish agencies	Ban of direct discharge No application of manure on frozen grounds	1985
First Action Plan for the Aquatic Environment *(Vandmiljøplan I)*	Regulation	Farming	Agriculture	National (Denmark)	Various Danish agencies	Nitrogen discharges from agriculture to be reduced by 50 % by 1993 compared to 1985 *(from 260,000 tonnes N to 127,000 tonnes N)* Phosphorus discharges to be reduced by 80 % by 1993 - Requirement of storage of manure - Ban of applying manure in the autumn and winter on bare fields - Green cover (a further 6 % of farmland to be sown in catch crops) - Crop rotation and fertiliser plans - Requirement of fertiliser accounts (from 1991)	1987
Action Plan for a Sustainable Agriculture *(Handlings-planen for bæredygtigt landbrug)*	Regulation	Farming	Agriculture	National (Denmark)	Various Danish agencies	Mandatory regulations for nitrogen standards for crops and fertiliser accounts Requirement of using nitrogen in manure	1990
Fertiliser accounts *(Gødnings-*	Mandatory	Farming	Agriculture	National (Denmark)	Various Danish agencies	Regulate fertiliser use and management Introduced in 1991 to encourage farmers to use fertilisers optimally, but when this did not	1991, 1993/1994

Policy	Type of instrument	Life cycle focus	Sector covered	Scale of application	Implementing body	Objective	Entered into force
regnskaber)						happen on a voluntary basis, requirements were set in 1993/1994 with the Action Plan for a Sustainable Agriculture	
Action Plan for a sustainable agriculture *(Handlings-planen for bæredygtigt landbrug)*	Regulation	Farming	Agriculture	National (Denmark)	Various Danish agencies	Mandatory regulations for nitrogen standards for crops and fertiliser accounts Requirement of using nitrogen in manure	1996
Fertiliser accounts *(Gødnings-regnskaber)*	Voluntary	Farming	Agriculture	National (Denmark)	Various Danish agencies	Regulate fertiliser use and management	1993/1994
Second Action Plan for the Aquatic Environment *(Vandmiljøplan II)*	Regulation Financial incentives Voluntary measure (shift to feed with low nitrogen content)	Farming	Agriculture	National (Denmark)	Various Danish agencies	Organic farming (organic farmers must not use chemical fertilisers, must limit the use of manure to 1.4 LU/ha/year, and, after four years, must organically farm all the land) Additional requirements for green cover (a further 6 % of farmland to be sown in catch crops) Reduced fertiliser standards (a 10 % reduction from the economical optimum nitrogen commercial fertiliser application) Increased requirements of use of manure (a 15 % increase over 1991 rules) Limits on livestock density (2.3 LU/ha/year for cattle farms and 1.4 LU/ha/year for other farms (pigs and poultry)- EU requirement under the Nitrates Directive	1998

Policy	Type of instrument	Life cycle focus	Sector covered	Scale of application	Implementing body	Objective	Entered into force
Mid-term assessment of the Second Action Plan for the Aquatic Environment *(Politisk midtvejsevaluering af Vandmiljøplan II)*	Regulation	Farming	Agriculture	National (Denmark)	Various Danish agencies	Changed rules for the establishment of wetlands Reduction of wheat tillage Stricter standards for grass, green cover, winter wheat and barley	2001
EU Nitrates Directive	Regulation	Farming	Agriculture	EU Directive National regulations (Denmark)	Various Danish agencies	Application of N on agricultural land in the form of animal manure should not exceed 170 kg N per ha. However, for certain situations a higher rate can be allowed, provided that it is made plausible that N demand is high and nitrate levels in groundwater do not exceed 50 mg per litre	2002 (passed in 1991)
EU Water Framework Directive	Regulation			EU Directive National regulations (Denmark)	Various Danish agencies	All of Europe's water should be in good status by 2015	2003 (passed in 2000)
Third Action Plan for the Aquatic Environment *(Vandmiljøplan III)*	Regulation Financial incentives *(additional financial incentives to expand wetlands, afforestation and sensitive*	Farming	Agriculture	National (Denmark)	Various Danish agencies	Further reduce nitrogen leaching by 9,950 tonnes a year by 2015 Additional requirements for green cover (from 6-10 % to 10-14 % of farmland to be sown in catch crops), Strengthen regulations on use of nitrogen in manure (a 5 % increase over 2003 standards) Further establishment of wetlands and afforestation	2004

Policy	Type of instrument	Life cycle focus	Sector covered	Scale of application	Implementing body	Objective	Entered into force
	farming areas) Tax on mineral phosphorous in feed					Environmental farm management (sensitive farming areas) Tax on mineral phosphorous in feed Introduction of buffer zones to sensitive areas Manure action plans Nature protection anticipating EU Water Framework Directive and Habitats Directive	
Green Growth *(Grøn Vækst)*	Regulation	Farming	Agriculture	National (Denmark)	Various Danish agencies	Reduction of the discharge of nitrogen and phosphorus to 19,000 tonnes and 210 tonnes respectively from 2010 to 2012 The government will work towards introducing nitrogen quotas that will come into force in 2012 Up to 75 000 hectares of new nature will be established towards 2015 The plan aims to double the area for organic agriculture in 2020 compared to 2007, bringing organic area to 15 % in 2020 compared with 5.6 % in 2008. The plan stipulated that 50 % of farm animal manure must be used to produce biogas in 2020 and that, with time, all farm animal manure must be used as a source of renewable energy	2009

Sources: Kjær, S, and J Madsen. 1998. "Environmental Policy for Intensive Livestock Production in Denmark." Proceeding of the Regional Workshop on Area-Wide Integration of Crop-Livestock Actvitities; OECD. 2007. OECD Environmental Performance Reviews - Denmark. Organisation for Economic Co-operation and Development; van Dijk, Wim, and Hein ten Berge. 2009. Agricultural nitrogen use in selected EU countries. A comparison of N recommendations, and restrictions in response to the EU Nitrates Directive. Wageninger UR; Blicher-Mathiesen, Gitte, Ruth Grant, Pia Grewy Jensen, Birgitte Hansen, and Lærke Thorling. 2012. Landovervågningsoplande 2011. Aarhus Universitet, DCE – Nationalt Center for Miljø og Energi

6a. Supplementary context questions including elements pertinent to paradigm discussions

Timeline for the different phases of the policy cycle (i.e. rationale & objective-setting; appraisal; implementation & monitoring).

Description of the government in power during each of the three following policy phases: rationale and objective-setting; appraisal; and implementation and monitoring.

Does the mix contain policies that are unusual or not typical of the country/ies or regional/local administration that implemented it?

Names of resource efficiency concepts, terms, models, ranking/classification systems, accounting methods etc. used or relied upon in each of the three phases of the policy cycle: rationale and objective-setting; appraisal; and implementation and monitoring, and how they were used (e.g.: 'waste hierarchy' – used in objective-setting to link policy objectives to more desirable uses for waste).

Each of the Action Plans for the Aquatic Environment set clear objectives and timelines. Their progress was monitored and they were followed up by mid-term and ex-post evaluations of the various policy instruments. For example, the Third Action Plan for the Aquatic Environment (2004) was assessed in 2008 and 2011.

Most of the agricultural policies in Denmark are based on broad agreements across political parties, which ensure that they are carried out even though the government changes.

The Action Plans were initially based on voluntary actions of farmers and by establishing good agricultural practices to reduce the use of fertilisers. Even though farmers complied with most of the requirements by the end of the 1980s, it was only in the 1990s when significant change had occurred in fertiliser application practices.

6b. Instruments and orientation of policy mix

Instruments in the mix and whether one type of tool (i.e. regulatory, economic, information) is dominant.

For each instrument, what is its aim? What requirements does it place on relevant players (for example, phasing out a certain substance, meeting minimum recycling targets, etc.)? What reporting requirements exist?

A wide range of policy instruments were introduced helping to reduce fertiliser use and nutrient losses in agriculture in Denmark. For each of the Action Plans a clear target (i.e. quantitative objective to be achieved by a certain time period) was set and the estimated contribution of the various initiatives was also provided. This helped guide the instruments and allowed the government to adjust their policies according to progress and achievement of targets.

Regulatory instruments, such as bans, limits and requirements were the primary instruments. Bans of direct discharges from manure were accompanied with government subsidies for investments in animal manure storage capacity.

Standards for crop nitrogen demand were developed for each crop as a function of climate and soil type (Kjær and Madsen 1998).[25] These were used as a basis for the mandatory

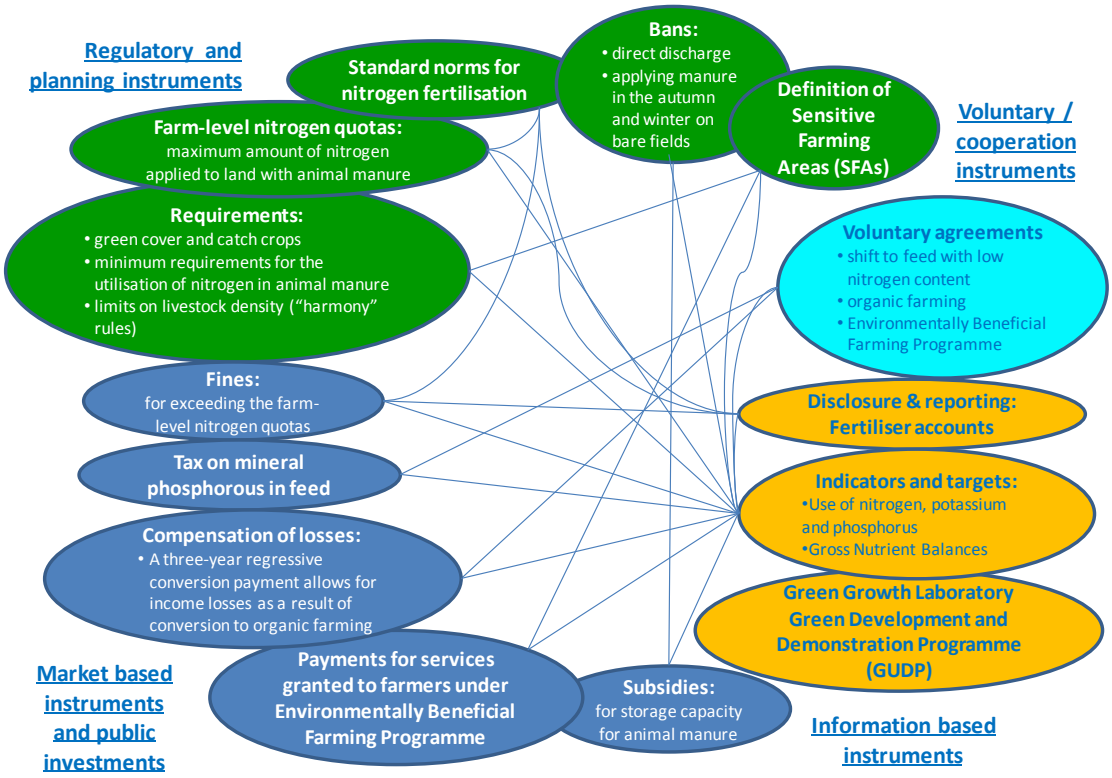
fertiliser accounts that farmers had to report as well as the fines, if excessive fertilisers were used. The fertiliser account is based on the soil types and crops grown on each individual farm. The fertiliser application standard for each crop and soil is estimated as the economically optimal dosage minus 10 %. The previous crop on the field and precipitation were also taken into consideration. Farmers must submit a plan for nitrogen use to the Danish Plant Directorate, with a request for a nitrogen fertiliser quota as well as a report on compliance with the previous fertiliser account (the quotas are subsequently adjusted depending on weather conditions). The plan must contain a map of the crops and a soil classification. If the farmer buys fertilisers or produces manure, which in total represents too much fertiliser, he or she must store, sell, or give away the surplus to another registered business. Fertiliser sellers control whether the buyer is registered as a “user of manure and fertilisers” and report the sale to the Danish Plant Directorate (OECD 2007).[26] A non-compliance fine applies to use of nitrogen beyond the amount allowed by the fertiliser account (up to DKK 20 (EUR 2.70) /kg nitrogen).

The definition of Sensitive Farming Areas restricted agro-environmental payments as incentives for farmers who: reduce nitrogen fertiliser application to 60 % of the needs defined by national standards; re-establish wetlands; establish 12-metre pesticide-free margins or (since 2005) 10-metre uncultivated buffer zones along watercourses and lakes; practice extensive permanent grassland management; cultivate catch crops; or set aside land over a 20-year period (OECD 2007).[27] Compensation of production losses was also given to farmers voluntarily converting to organic farming or re-established former wetlands.

Changes to animal feed were first encouraged through voluntary measures and then more recently through a tax on the amount of mineral phosphorus in feed.

Figure 10 presents the main policy instruments and how they mutually support each other in the achievement of policy objectives. Subsidies have been provided for investments in manure storage. The standard norms for nitrogen fertilisation provide the basis for the fertiliser accounts, but also the regulatory framework for farm-level quotas and fines when quotas are exceeded. The definition of Sensitive Farming Areas is linked with certain requirements and also payments to farmers. Economic incentives are provided for farmers that adopt agri-environmental practices beyond regulations. Close monitoring and clear targets are used to encourage and measure progress of all instruments.

Figure 10: Links between Danish fertiliser use policy instruments



Source: Own compilation

6c. Evolution of policy mix

Evolution of the policy mix throughout its existence –details of the introduction of the first policy tool(s), then all subsequent relevant tools, and related revisions/reforms (e.g. progressive increases in rates applied through economic tools, broader extension of regulation requirements, etc.).

Policies that aim to improve the water quality and aquatic environment have been the main driver behind the reduction of fertiliser use in Denmark. In the 1980's awareness of the poor state of the aquatic environment in Denmark led to the NPO (Nutrients-Phosphorus-Oxygen) Action Plan in 1985, which focused on direct pollution from farms and fields (Blicher-Mathiesen, et al. 2012).[28] In 1987, the First Action Plan for the Aquatic Environment (Vandmiljøplan I) was passed by the parliament. It stated that the leaching of phosphorus from sewage treatment plants should be reduced by 80 % and nitrogen leaching (including fields) should be reduced by 50 % (or 130,000 tonnes) by 1993 (Christensen, Hansen and Ærteberg 2004).[29] The Action Plan led to requirements for manure storage and use as well as how much nitrogen fertiliser could be used and when (Kjær and Madsen 1998).[30] In 1991, when it was clear that the 130,000 tonnes reduction could not be achieved, the policy was strengthened with an Action Plan for Sustainable Development in Agriculture (Handlingsplan for en bæredygtig udvikling i landbruget). By the mid-1990s only a half of the planned reduction of nitrogen leaching was achieved (Blicher-Mathiesen, et al. 2012).[31]

The regulations for use of fertilisers in Denmark are contained in the 1998 Regulation on agricultural use of fertilisers and plant cover. Accounts to track fertiliser use ("Gødningsregnskaber") have existed since the First Action Plan for the Aquatic Environment,

but norms for the use of fertilisers were only introduced in 1993/94 (OECD 2007).[32] These are used to regulate fertiliser use and management.

In order to achieve the policy targets, the requirements to farmers where increased in the Second Action Plan for the Aquatic Environment (Vandmiljøplan II). Stricter requirements were implemented for the use of nitrogen fertilisers, and for low nitrogen feed, and targets were set for increasing the area of forests, organic agriculture and wet areas. In 2000, a mid-term assessment of the Aquatic Plans revealed that the leaching of nitrogen had decreased by about a third. This was achieved by better use of manure as a fertiliser resulting in a 50 % decrease of commercial nitrogen fertiliser (from about 400,000 tonnes in 1990 to about 200,000 tonnes in 2003).

Limits on livestock density (the so-called “harmony” rules) where introduced to balance livestock manure production and the area of adjoining farmland on which it is applied (OECD 2007).[33] The Second Action Plan set limits of 2.3 LU/ha/year for cattle farms and 1.4 LU/ha/year for other farms (pigs and poultry), through derogation to the 1991 EU Nitrates Directive granted by the European Commission in 2002.

The Third Action Plan for the Aquatic Environment (Vandmiljøplan III) in 2004 aimed to further reduce nitrogen and phosphorus leaching from agriculture. The plan included subsidies for establishing buffer zones between fields and water bodies to stop phosphorus leaching. The Third Action Plan’s objectives are:

- A 13 % reduction of nitrogen leaching in 2015 compared to 2003.
- A 50 % reduction of phosphorus balance in 2015 compared to 2001/2002.
- Establishment of 50,000 ha of new buffer zones to reduce phosphorous leaching to rivers and lakes.

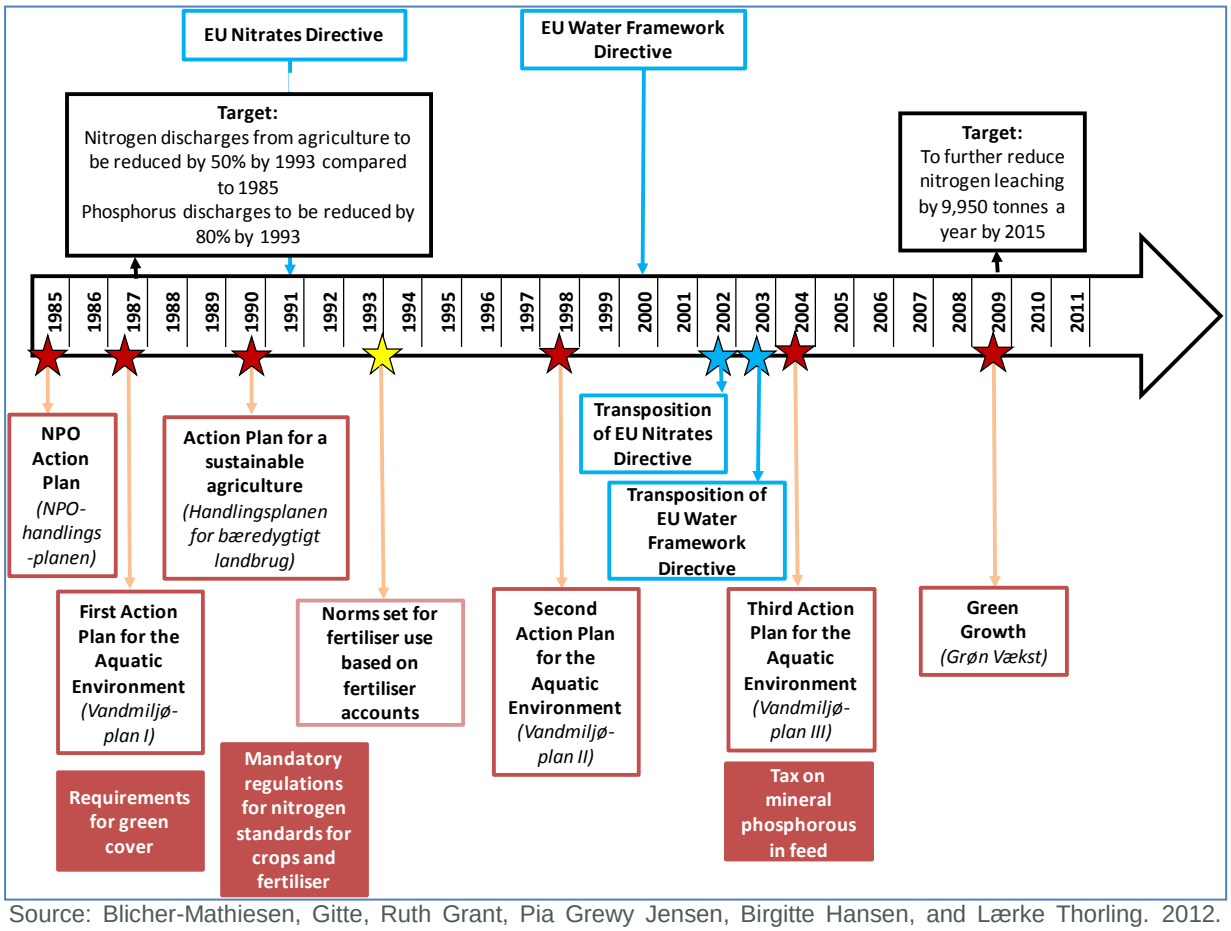
The Third Action Plan introduced a tax on mineral phosphorus added to feed (DKK 4 or EUR 0.50 / kg). Revenues from the tax are returned to the agricultural sector through a reduction in land taxes.

Since 2005, farmers have had to comply with the Danish regulatory measures as a condition for benefiting from EU Common Agricultural Policy support (cross-compliance).

In 2009, the Danish government launched a Green Growth Plan (Grøn Vækst)[34] (The Danish Government 2009) providing DKK 13.5 billion (EUR 1.8 billion) until 2015 to ensure better conditions for the country’s nature and environment while allowing agriculture to develop. The Green Growth Plan is a strategy that combines agricultural and environmental policies. A considerable part of the strategy will be financed through a full transfer of funds to Denmark under EU's Rural Development Programme. In 2010, DKK 2.2 billion (EUR 0.3 billion) were earmarked for the Green Growth Plan.

Among the targets and measures in the Green Growth Plan there is a reduction of the discharge of nitrogen and phosphorus to 19,000 tonnes and 210 tonnes, respectively, from 2010 to 2012. Nitrogen quotas will also come into force in 2012. Furthermore, the plan stipulates that 50 % of farm animal manure must be used to produce biogas in 2020 and that, over time, all farm animal manure must be used as a source of renewable energy.

Figure 11: Implementation timeline of Danish fertiliser use policies, 1985-2011



Source: Blicher-Mathiesen, Gitte, Ruth Grant, Pia Grewy Jensen, Birgitte Hansen, and Lærke Thorling. 2012. *Landovervågningsoplande 2011.* Aarhus Universitet, DCE – Nationalt Center for Miljø og Energi

7 Evaluation of policy mix: effectiveness (environmental sustainability)

Does/did the policy mix result in a positive environmental outcome?

Were its stated objective(s) met? Were the instruments used sufficient to meet the objectives?

Did other, unforeseen/unintended positive outcomes or impacts (environmental, social, economic) result? Did other such negative outcomes or impacts result?

Were these objectives set at a level to meet environmental needs (e.g. avoid crossing environmental thresholds/tipping points or achieve more sustainable levels of resource use/extraction (e.g. maximum sustainable yield (MSY) in fisheries)?

Which sectors/actors were identified as having key impacts/influences on the problem/issue? (e.g. specific industrial/ business sectors, consumers, economy as a whole?) Did any of the instruments specifically target these key sectors/actors? Was there significant take-up/implementation of (voluntary) instruments by these sectors?

Was the policy mix applied to a sector previously not targeted by policies on the issue under question, or in a new area/issue – thereby aiming to stimulate change?

What were the anticipated and actual outcomes, impacts and effects of the policy mix on the behaviour of sectors and actors targeted? (e.g. reductions in emissions from industry, increased recycling rates, increase/decrease in certain product purchases, etc.).

Relationships between the instruments, identifying positive/negative influences on the overall policy mix or on key instruments in the mix, as well as any positive or negative impacts from changes to the mix (introduction or termination of instrument(s), increase or decrease in tax/levy/charge, etc.). Level of 'connectivity' (strong, weak) between each instrument and the primary one(s).

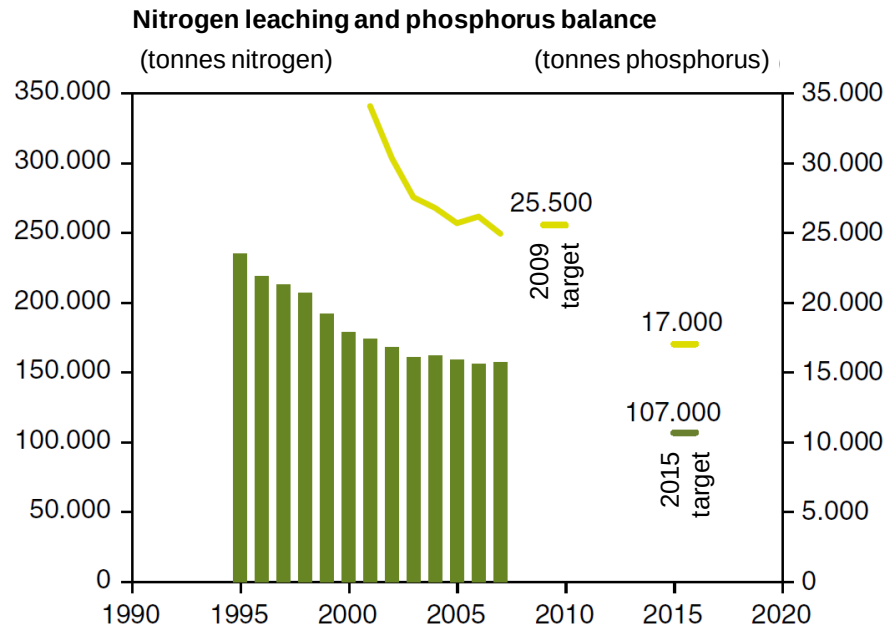
Are there any indicators, monitoring systems, review processes or other monitoring mechanisms in place to track progress?

The use of commercial nitrogen fertiliser in Denmark has dropped from 394,000 tonnes N in 1990 to 203,900 tonnes N in 2011. The use of nitrogen in manure has dropped from 244,000 to 226,000 tonnes N in the same period. Overall the nutrient balance has decreased from 397,000 tonnes N in 1990 to 211,400 tonnes N in 2011, representing a reduction of 45 %.

Although Denmark has succeeded in decoupling farm inputs of nitrogen and phosphorus fertiliser from agricultural production, average nitrogen surpluses in Denmark (76 kg N/ha in 2009) still remain over the EU average (49 kg N/ha in 2008). Phosphorous surpluses are now closer to EU averages.

The target of reducing nitrogen leaching by half from 1985 levels was met in 2003 (rather than 1993, the initial deadline) (OECD 2007).[35] Denmark now complies with requirements of the EU Nitrates Directive.

Figure 12: Reduction of Danish nitrogen leaching and phosphorus balance, 1995-2007



Source: DMU. 2009a. *Natur og Miljø 2009. Del A: Danmarks miljø under globale udfordringer.* Danmarks Miljøundersøgelser, Aarhus Universitet p.58

Hypoxia now occurs in about 3000 km^2 of Danish water bodies (Andersen and Carstensen 2011).[36] If the Action Plans for the Aquatic Environment were not implemented, it is thought that hypoxia would occur in more than 7000 km^2 of Danish water bodies.

Despite the achievements made in reducing the use of fertilisers and nutrient losses from agriculture, Denmark still has severe water quality problems such as oxygen depletion, particularly in lakes and coastal areas (fjords), but also in rivers and groundwater (i.e. nitrate pollution). In Denmark only half the water bodies were in good or very good status in 2007 (DMU 2009a).[37] The poor quality of water bodies in Denmark is still primarily due to nutrient enrichment of which fertilisers and manure in agriculture are a main source of pollution (EEA 2012)[i].[38]

8 Evaluation of policy mix: efficiency (economic sustainability)

Is/was the policy mix considered cost-effective?

What has been the level of impact on resource use of the policy mix (the effect)?

What have been the costs of implementing the policy mix for target audience (e.g. business, households, etc.)?

What are the costs (financial, human) of implementing the policy mix for the implementing authority – i.e. the administrative/transaction costs?

Were sufficient resources made available to ensure an effective implementation of the policy-mix?

Was anything foreseen in the policy-mix to address competitiveness concerns (e.g. use of exemptions) or minimise transaction costs (e.g. thresholds below which monitoring wasn't required)?

Did the policy mix involve providing financial support (e.g. subsidies, low interest loans, tax breaks etc.) to key actors (e.g. sector, households, etc.)?

Did the measures generate revenues (e.g. in the case of taxes) and if so, was revenue recycled/re-injected into the economy, and to what levels and activities? Did revenue recycling have positive amplifying effects?

In synthesis - was the policy mix cost-effective?

What elements of the mix were (un)helpful in improving cost-effectiveness?

How was relative/absolute decoupling achieved?

Were resource limits or other thresholds taken into account and how were they addressed?

Farmers bear the greatest costs of implementing the policy measures to reduce the use of fertilisers and nutrient losses. The majority of government costs for implementing the various policy measures are subsidies and payments to farmers for environmental actions and

[i] Discharges from wastewater contributes to a lesser extent.

compensation for losses. A minor part of the costs are administrative, for instance it is estimated that DKK 17 (EUR 2.3) million a year was spent under the Second Action Plan for the Environment (Vandmiljøplan II) on enforcement of the farm-level fertiliser accounts and quotas (OECD 2007).[39]

Under the Second Action Plan for the Aquatic Environment (Vandmiljøplan II), among the financial measures related to land area, the re-establishment of wetlands was seen to be more cost-effective than afforestation and encouraging organic farming (OECD 2007).[40] Increasing the use of nitrogen in manure is the most cost-effective regulatory farm-related measure. The voluntary measure to shift towards low nitrogen content animal feed is also very cost-effective. The table below presents the total costs and abatement costs for each of the measures under the Second Action Plan.

Table 2: Measures to reduce nitrogen discharges from agriculture under the Second Action Plan for the Aquatic Environment, 2003

	Reduced N leaching	Government costs	Farm costs	Abatement costs (EUR/kg N)	
Measures	**Tonnes N/year**	**EUR million/year**		**Actual (2003)**	**Ex ante prediction**
Area-related measures	6000	27.1		0.8	
Wetlands	800	0.7		0.9	
Organic farming	3700	14.0		3.8	
Afforestation	800	4.7		5.9	
Sensitive farming areas	700	7.7		11.0	
Farm-related measures	29900		43.1	1.4	2.5
Use of nitrogen in manure	10110		6.7	0.7	2.6
Improved feed	3800		5.7	1.5	0.0
Fertiliser application standards	12850		22.8	1.8	1.5
Green cover	3000		6.4	2.1	6.8
Livestock density	140		1.5	10.7	13.7
Total	**35900**	**27.1**	**43.1**	**2.0**	

Sources: OECD. 2007. *OECD Environmental Performance Reviews - Denmark.* Organisation for Economic Co-operation and Development

Additional financial incentives were given in the Third Plan for the Aquatic Environment (Vandmiljøplan III) to expand wetlands, afforestation and sensitive farming areas, as well as strengthened regulations on the use of nitrogen from manure and on green cover. Compared to the Second Action Plan the expected abatement costs are higher under the Third Action Plan as it is marginally more costly to further reduce nutrient losses. According to the latest Midterm Evaluation of the Third Plan for the Aquatic Environment (Vandmiljøplan III), the creation of wetlands was more cost effective under the Second Action Plan (DJF 2009).[41] Increasing the number of catch crops and increasing the utilisation of manure remain to be cost-effective. Afforestation was the least cost-effective measure under the Third Action Plan.

Table 3: Measures to reduce nitrogen discharges from agriculture under the Danish Third Action Plan for the Aquatic Environment, 2005 - 2014

	Estimated costs in the Third Action Plan					Estimated costs in the Mid-term Evaluation				
	Costs per hectare per year		Effectiveness	Costs per kg N		Costs per hectare per year		Effectiveness	Costs per kg N	
	DKK	*EUR*	kg N/ha	DKK	*EUR*	DKK	*EUR*	kg N/ha	DKK	*EUR*
Afforestation	2700	*362.4*	39	69	*9.3*	2860	*383.9*			*0.0*
Wetlands	3050	*409.4*	265	12	*1.6*	4479	*601.2*	245	18	*2.4*
Environmentally Sensitive Farming Area measure	5000	*671.1*	100	40	*5.4*	4800	*644.3*	100	36	*4.8*
Catch crops	250-500	*33.6 - 67.1*	37	7 - 14	*0.9 - 1.8*	330	*44.3*	32	10	*1.3*
Improved utilisation of mink manure				4	*0.5*				4	*0.5*
Total assessment of the period 2005 - 2009				**19**	***2.6***				**41**	***5.5***

Sources: DJF. 2009. *Midtvejsevaluering af Vandmiljøplan III. Hoved- og baggrundsnotater.* Det Jordbrugsvidenskabelige Fakultet

Overall, the total annual cost to reduce nitrogen losses was slightly less than expected. However, in terms of cost efficiency the mid-term evaluation shows a doubling in costs - an average increase from 19 DKK (2.60 EUR) to 41 DKK (5.5 EUR) - as cheap measures have not achieved the expected effect. The overall total annual cost for phosphorus reduction is higher than originally estimated and the tax on mineral phosphorus has not reached the expected impact.

Table 4: Annual costs of reducing nitrogen discharges from agriculture under the Danish Third Action Plan for the Aquatic Environment, 2005 - 2014

Third Action Plan for the Aquatic Environment (Vandmiljøplan III)	Agreement (Annual costs)		Midterm Evaluation (Annual costs)	
	DKK (million)	EUR (million)	DKK (million)	EUR (million)
Nitrogen reduction	164	22.0	159	21.3
Phosphorus reduction	35	4.7	41	5.5
Total	**198**	**26.6**	**201**	**27.0**
- Government share	173	23.2	150	20.1
- Agriculture's share	26	3.5	51	6.8

Sources: DJF. 2009. *Midtvejsevaluering af Vandmiljøplan III. Hoved- og baggrundsnotater.* Det Jordbrugsvidenskabelige Fakultet

According to an association of farmers called Bæredygtigt Landbrug (Sustainable Agriculture), the Danish rules for the use of nitrogen fertilisers has resulted in yield losses of seven billion DKK (almost one billion EUR), when compared to fertiliser use in Germany (Bæredygtigt Landbrug 2012).[42] The association claims that the strict Danish rules lead to

increased imports of protein in feed and that an increasing number of fields are showing signs of nutrient depletion resulting in lower yields. The association generally questions the economic and environmental effectiveness of the measures that have been implemented.

9 Evaluation of policy mix: welfare (social sustainability)

What social impacts have you found associated with the policy mix? E.g. jobs created, reduced health impacts, distributional impacts etc.

Were social aspects included in an ex-ante impact assessment of the policy mix if one was undertaken? What were these?

Has monitoring of social impacts been included in implementation, to identify actual effects compared to anticipated ones?

Was the policy mix designed to not be socially regressive? What measures were undertaken to ensure this?

Were equity concerns addressed and, in case of re-structuring of the economy/sector, measures in the area of reskilling of the workforce foreseen?

What other public acceptability elements were addressed or considered?

Although no specific evaluation has been carried out on the social effects of the policy mix to reduce fertiliser use and nutrient losses, it is believed that the general public is interested in improving the environmental performance of the agricultural sector in Denmark. Besides clean water and rich natural environment, odours from animal production (pig production in particular) are a major concern. The action plans analysed in this policy mix have all contributed to a reduction in spillage and odours from manure use (DJF 2009).[43] The conversion of cropland to natural areas is also expected to contribute to more and better access to natural areas for the general public (The Danish Government 2009).[44]

10 Overall assessment

What is your overall view on the success(es) or failure(s) of this policy mix?

How did the policy mix enable decoupling?

How could it have been improved to achieve its original objective(s) and to achieve absolute decoupling?

The introduction of various policy measures with clear reduction targets for nutrient losses together with constant monitoring, enforcement and follow up appears to be a good approach for decoupling. The policy mix applied a wide range of instruments, such as regulatory, voluntary, economic and information based instruments that each addressed a specific contribution to the nutrient reduction targets. In general, the implementation of the Action

Plans for the Aquatic Environment has been a success, even though this may have come at a price. EU policies have contributed to setting stricter requirements in Danish policies.

According to the OECD the farm-level nitrogen quota has proved to be effective but costly(OECD 2007).[45] The regulatory measures have forced farmers to better plan and actually reduce the use of nutrients (with associated financial gains) dramatically.

Although there has been a decoupling of fertiliser use and agricultural production, nitrogen balance seems to remain high compared to other EU countries. While the concentration of nitrogen and phosphorous in water bodies have generally been decreasing over the past 20 years, severe oxygen depletion in Danish waterways still occurs regularly (DMU 2009a).[46] There is, therefore, still a need to improve fertiliser use and reduce leaching in order to achieve a sustainable level.

11 Relevance to the EU and transferability

Can the policy mix be applied at the EU level? Is it transferable to other Member States/countries?

What lessons are there that may be of general interest regarding policy mixes and what issues are there as regards transferability of the insights?

There have been different approaches to reducing fertiliser use in agriculture in EU Member States (van Dijk and ten Berge 2009).[47] Although there are considerable variation in rules, regulations and application standards, the general approach to setting clear targets using regulatory instruments that are supported by economic incentives and voluntary measures could be transferred to other countries. A consistent monitoring system is however fundamental for the policy to be successful.

12 Stakeholder contribution

What insights did stakeholders provide?

Contact to Leif Knudsen, Knowledge Centre for Agriculture, Danish Agricultural Advisory Service (DAAS).

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