Involving the farmer to improve the ecological status in surface waters

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Title page

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Preface

This work marks the end of my master's degree in Agro Environmental Management (Science and Technology, Aarhus University) and is a collaboration with the Department of Agroecology (Aarhus University) and SEGES within the BufferTech project.

This project has given me the opportunity to apply knowledge acquired through my first four years of my studies to new aspects. I have had the opportunity to meet with experts on all subjects included in this work, most of whom I have met during my studies. This has been a most valuable experience, though challenging to demarcate the project and to find my own direction. Through the project I have experienced the complexity of applying natural science on "the real world". Working with a highly relevant and to-date problem has been very exciting. Being a part of the BufferTech research project has been a great learning experience both personally and professionally.

Great thanks for inspiration and guidance to my supervisors Tommy Dalgaard and Irene Wiborg. In the first confusing time of the thesis Flemming Gertz kindly spent time in conversation with me and contributed with material. Invaluable technical help was given from Eva Overby Bach. She was always enthusiastic and encouraging. Goswin Heckrath has elaborately answered numerous questions. Likewise, Brian Kronvang and Ane Kjeldgaard have kindly answered all my questions. Kristoffer Piil was also helpful with technical questions.

Søren Søndergaard helped me to find the farmers I have talked to, to whom I am grateful for participating, and he also showed me around Spjald. Chris Kjeldsen, Egon Noe and Martin H. Thorsøe have been helpeful with forming the interview questions.

The office companions Malene Theligaard, Maja Eline Pedersen and Betina Zacher Jensen have been supportive and always reassuring. Thanks to Lone Juul and Trine Schwennesen for sparring. Big thanks to Berit and Åmund Skjellerudsveen for proofreading with scrutiny and a fine-toothed comb.

Kennet Ugeldal and Mette Vestergaard Odgaard must also be mentioned for their valuable contributions.

Last but not least thanks to Jason Ginter for never failing encouragement even on great distance.

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2. Abstract

In this thesis GIS analysis and semi-structured interviews were conducted to investigate strategies for the successful implementation of Integrated Buffer Zones (IBZ) in Danish landscapes, and to propose recommendations for the development of an advisory strategy to support the IBZ implementation[1].

The GIS analysis has revealed technical issues that need to be solved in order to be able to more accurately pinpoint a location for an IBZ. The main outcome of the interviews was that the farmers were willing to contribute with land for targeted agro environmental measures and collaborative projects. The economic incentive was increased fertilizer norms on the remaining land and this seemed to be the main driver for change. Most farmers were positive towards the concept of a catchment advisor that could manage the consulting of larger collaborative projects.

The present work has resulted in recommendations for use in further development of advisory tools in relation to IBZ. The recommendations are based on risk assessment maps and questions developed to facilitate a constructive dialogue between farmers and the advisory service. Maps made in ArcGIS based on biophysical data can make it possible to point out risk areas for nutrient losses. The main objective of the questions developed is to act as an exploratory approach to reveal the farmers' objectives, values and preferences so that a tailored strategy supporting the farmers' rationale can be made for implementing IBZ. This approach requires that the advisor possesses both knowledge of natural science and social skills (the so-called T-shaped skills) and enters the situation with an open mind and with compassion. To avoid relying solely on the most precise data, an approach based on farmers' motivation and indicators of IBZ effects that can support this motivation is proposed.

Keywords: *nutrient loss, erosion, soil deposition, sedimentation, qualitative interview, advisory strategy, advisory tool, GIS, targeted agro environmental measure, integrated buffer zones.*

Aarhus, May 2016

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Martina Skjellerudsveen

[1] This work was an independent part of the BufferTech (2016b) project, work package 5.

2. Sammendrag

I dette speciale er GIS-analyse og semistrukturerede interviews blevet udviklet og testet for at undersøge strategier til implementering af intelligente bufferzoner (IBZ) i det danske landskab. Disse analyser og international litteratur danner baggrunden for anbefalinger til udviklingen af et rådgivningsværktøj til at støtte gennemførelsen af IBZ[2] i form af en 8 punkts anbefaling.

GIS analysen har afsløret tekniske spørgsmål, der skal løses for at være i stand til at identificere en mere nøjagtig placering af en IBZ. Hovedresultatet af interviewene var, at landmændene var villige til at bidrage med jord til målrettede miljøvirkemidler og samarbejdsprojekter med andre landmænd. Det økonomiske incitament var en øget gødningsnorm på de resterende marker og dette syntes især at være den vigtigste drivkraft for ændring. De fleste landmænd var positive over for idéen om en oplandsrådgiver, der vil kunne styre rådgivning af større samarbejdsprojekter.

Dette arbejde har resulteret i anbefalinger til brug i den videre udvikling af et rådgivningsværktøj i forhold til IBZ. Anbefalingerne er baseret på risikovurderingskort og et sæt af spørgsmål, der er udviklet til at fremme en konstruktiv dialog mellem landmænd og rådgiverne. De GIS kort der er lavet er baseret på biofysiske data, der kan gøre det muligt at udpege risikoområder for tab af næringsstoffer. Hovedformålet med de udviklede spørgsmål er at de skal fungere som et redskab for en udforskende tilgang til at afdække landmændenes mål, værdier og præferencer. Ud i fra denne viden kan så en skræddersyet strategi udvikles, der støtter landmændenes motivation og rationale, og derefter blive videre udviklet for at gennemføre IBZ. Denne tilgang kræver, at rådgiveren er i besiddelse af både hårde (naturvidenskabelige) kundskaber og sociale færdigheder (de såkaldte T-formede færdigheder) og kommer ind i situationen med åbenhed og indlevelse. For at undgå at være ensidig afhængig af de mest præcise data, foreslås en tilgang baseret på landmandens motivation og benyttelse af indikatorer for at synliggøre IBZ effekter der kan underbygge denne motivation.

Nøgleord: *tab af næringsstoffer, erosion, jord deposition, kvalitative interviews, rådgivningsstrategi, rådgivningsværktøj, GIS, målrettede miljømæssige virkemidler, intelligente bufferzoner.*

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[2] Dette arbejde var en selvstædig del af BufferTech (2016b) projektet, arbejdspakke 5.

3. Abbreviations

Abbreviations

AEM	Agro environmental measures
AES	Agro environmental schemes
C&C	Command and control
DTM	Digital terrain model
GES	Good ecological status
IBZ	Integrated Buffer Zones
ID15	Watersheds of app. 1500 ha
N	Nitrogen
P	Phosphorus
WDF	Water Frame Directive
Werodep	WaTEM model for erosion and soil deposition
WExport	WaTEM model for export of eroded soil

The farmer is referred to as he, knowing that there of course are also female farmers.

4. Introduction

The member states of the European Union are starting the second plan-period of the Water Frame Directive (2015 – 2021). The goal of the Water Framework Directive (WFD) is to achieve good ecological status (GES) in all surface and ground waters (The European Parliament and the Council of the European Union 2000). Many fjords and lakes in Denmark still do not fulfil this target due to excess amounts of nitrogen (N), phosphorus (P) and physical disturbances (Miljøministeriet 2014). It is therefore important to develop new strategies and methods in order to work toward this goal while at the same time making farming in Denmark feasible. This has been emphasized in the new agricultural action plan[3] of the current government (Miljø- og Fødevareministeriet 2015) and researched in among others the AGWAPLAN (2009b), Aquarius (2012), dNmark research alliance (2016) and Soils2Sea (www.soil2sea.eu) projects.

General regulations and the use of command and control (C&C) as political tools have dominated the way in which Denmark has enforced the EU directive through national water plans (Dalgaard et al. 2014). There has been heavy focus on reducing the input of nutrients with emphasis on N, via statutory fertilization norms, which until this year have been set at approximately 20 % below the production economical optimum, or even lower according to the agricultural sector (Pedersen 2015). This strategy combined with reduction of point source pollution (waste water treatment) has greatly lowered the nutrient load to lakes and estuaries but has not been enough to reach the goal of GES (Wiberg-Larsen et al. 2013). The question of how to define GES is also an ongoing discussion (Gertz 2015), but will not be further discussed here.

Another example of general regulations has been the legislation on mandatory standard sized buffer zones. This particular measure has proven insufficient, both in terms of the effect on nutrient retention (Kronvang et al. 2015), and also in terms of including the farmer as a key stakeholder in the process of implementing environmental regulations. The introduction of mandatory buffer strips in combination with very low fertilizer norms have thus among many farmers created a distrusting attitude towards environmental regulations and towards those responsible i.e. regulators and researchers and furthermore distrust in the output from models for nutrient losses (Wiborg 2015, pers.comm).

From general to targeted regulations

The new agricultural action plan was approved in February 2016 (Miljø- og Fødevareministeriet 2015) and one of the changes is increased norms for nutrient application, supporting the possibility to better crop production. The plan is thereby designed to help a sector that has become economically pressed. To avoid increased nutrient load to surface and ground water as a result of this, there is a heavy focus on geographically differentiated restrictions and effective measures outside the managed field (Miljø- og Fødevareministeriet 2015), but these will not be implemented until 2017. Adding to the challenging situation Olesen (2016) writes that farmers today are paying for past times' "*sinners*" because ecological systems are reacting very slowly to changes in

[3] In EC (2016) it is referred to as the "agricultural package".

nutrient loads. Furthermore, he writes that well-functioning ecosystems could probably handle the nutrient loads of today, but the state they are in today makes them more vulnerable.

During the last 10 years there has already been a shift in Denmark, from general regulations being mostly a C&C and input-based strategy, towards geographically specified measures (i.e. wetlands and general buffer zones) with a more output-based approach (Dalgaard et al., 2015). The big shift came in 2013, when the Nature and agricultural commission (*Natur og Landbrugskomissionen*) (Jespersen 2013) proposed a more differentiated approach to environmental regulations because of the large variations in landscapes representing substantial differences in vulnerability to nutrient loads. Likewise, guidelines from the EU propose a strategy based on local knowledge, inviting stakeholders to a dialogue, for efficiently achieving GES in all fresh waters of Denmark (Guidance Document No. 8, 2003).

Implementing differentiated restrictions and effective measures in the context of farmers that are not kindly disposed to environmental authorities is a challenging task. Working towards achieving GES in surface and ground waters in Denmark with many contradicting and opposing voices can therefore be called a wicked problem. The term "*wicked problem*" is used by Bouma et al. (2011) for describing a societal problem distinguished by its complexity and messiness. Several projects have contributed to knowledge about developing strategies for such a problem. These wicked problems include what Bogetoft and Pruzan (1997) call "*systemic conflicts*", when the objective of the planner (environmental authorities) does not coincide with the objective of the receivers of the planning (the farmers).

Among others, the projects AGWAPLAN (2009b), Aquarius (2012), the ongoing dNmark research alliance (2016) and Soils2sea (www.soils2sea.eu) investigate how to integrate the role of agricultural extension and the farmers' possibilities for participating in differentiated planning, respectively. In particular, the AGWAPLAN project emphasized the need for including the farmer's motivation, and behavioral assumptions in relations to the actions of the farmer in order to facilitate a constructive dialogue and finding collaborative solutions. Further effort in this line of strategy may help reinstating the farmers' trust and willingness to collaborate with environmental authorities and research institutions in Denmark.

Scope of the study

The overall aim of this work is to contribute to the development of an advisory strategy based on multiple criteria for improving the ecological conditions of water bodies in Denmark. In this work, I use Integrated Buffer Zones (IBZ) as an example of an agro environmental measure (AEM).

The IBZ efficiency is founded on the site specificity. Taking the biophysical parameters into account as part of implementing targeted regulation is therefore crucial to ensure evidence based efficiency of nutrient removal. This method requires a large amount of measurements and field data that inherently contains degrees of uncertainty. However, the process of making the practical decision on what action to take is complex and involves additional criteria than biophysical parameters. The success of implementing environmental measures on farmland is highly influenced by the farmers' motivation, current frame conditions and economic implications for the farmer (Lastra-Bravo et al. 2015; Gachango, Andersen, and Pedersen 2015).

On the basis of the above mentioned challenges I state the following hypothesis:

A strategy based on risk assessment maps and related interview procedures to reveal the farmers' motivation for implementing Integrated Buffer Zones can help to implement the Danish Water Plans. Thereby, the strategy can contribute to fulfilling the goal of achieving a good ecological status in the surface waters by effectively targeting nutrient losses in the buffer zone between farmland and water bodies. To do this, two barriers must be overcome:

Barrier 1: creating consensus on the need for collective efforts to improve the ecological status in the water environment.

Barrier 2: finding the optimal placing for and establishing of the Integrated Buffer Zone.

The different nature of the two barriers is reflected in this study by making two analyses: A) A GIS model is developed for the identification of areas with high risk of soil deposition entering surface water, relating to barrier 2.

B) A case study is conducted using semi structured qualitative interviews. A list of recommendations for a proposed strategy to establish Integrated Buffer Zones and environmental measures in general is made and discussed, relating to barrier 1.

The objective is therby to, independently, carry out a pilot study investigating these research questions as a part of work package 5 in the BufferTech (2016d) project.

In order to demarcate the focus of this study it was necessary to create an overview of the various elements in implementing a national strategy for establishing IBZ. This process led me to choose not to focus on the legal aspects of implementing IBZs nor the nation-wide potential for the number of IBZs. On the other hand I found that the core of the problem was the interaction between natural science and the tacit knowledge of the farmers and the transformation of this knowledge into action that can improve the ecological status of surface waters focusing on nutrient losses. This process is what the front page depicts; natural science is a necessary tool for placing an IBZ and the farmers with their knowledge need to be included to create synergy leading to action. Furthermore, the illustration shows that this interaction can create valuable input for improving the modelling work and is thus an iterative process.

5. Theory and background

The theoretical background is presented below to demarcate the research area in question where nutrient dynamics (section 5.1 and 5.2), the modelling of nutrient losses (section 5.3) and theories behind farmers' behavior (section 5.4 and 5.5) are all vast topics. This is necessary to create the overview of the investigated problem. As the drawing on the front page suggests, these three areas all needs to be investigated and comprehended to develop an advisory tool that can facilitate a process that leads to action.

The word deposition is used in the meaning of soil deposition and is equivalent to sedimentation. Deposition is the word used by professionals in the field and in the literature (e.g. Van Oost, Govers, and Desmet 2000).

P losses will indirectly through erosion be further included in the GIS analysis.

5.1 Biophysical mechanisms

Both nitrogen (N) and phosphorus (P) are vital plant nutrients. N is the limiting factor for protein production in cereals (Vinther 2016, pers.comm) and is the reason why farmers want to fertilize at production economical N optimum. In general P is the limiting factor for algae bloom in fresh water bodies and N is the limiting factor in estuaries (Kronvang et al. 1993). Source, mobilization, transport and ecological effects of nutrients are briefly described in this section. The source of both nutrients is the application of manure and artificial fertilizer but the mechanisms of mobilization of N and P respectively are very different. The losses of P an N to watercourses occur when conditions facilitating mechanism of mobilization and transport coincide (Haygarth and Jarvis 2002; Rubæk, Kronvang, and Heckrath 2005).

Nitrogen

Large amounts of N exist in the soil system, bound in complex organic compounds. Microbial activity is responsible for the mineralization and mobilization of the plant available ion ammonium (NH_4^+) and subsequent nitrification of the ammonium facilitated by nitrifying bacteria to produce the other plant available ion: nitrate (NO_3^-) (Brady and Weil 2010). Because of its negative charge nitrate is not bound to clay particles, which is the case for the ammonium ion. The content of ammonium in soil is usually low because of non-limiting conditions for the nitrifying bacteria. Because nitrate is soluble in water it follows the movement of the water and may be transported to watercourses. The majority of N leached from agricultural fields is in the form of nitrate (Haygarth and Jarvis 2002, Chap. 1).

Nitrate can be permanently removed from the soil system and refrained from entering the aquatic system by the process of denitrification. This reaction is carried out by denitrifying bacteria under anaerobic conditions and requires energy in the form of an electron donor, typically organic matter (Golterman 1983). The degree of denitrification is highly dependent on soil type because the reaction is sensitive to oxygen levels. Soils with large amounts of coarse sand have a lower water holding capacity than soils with high content of clay, and thus the denitrification potential is higher in soils containing more clay because saturated soils will contain less oxygen (Vinther 1990). Reaction 1 shows how organic matter is needed as an electron donor and how nitrate is utilized to produce the inert gas dinitrogen (N_2) (Golterman 1983).

$$\text{Reaction 1: } 4\ HNO_3 + 5\ C\ (H_2O) \rightarrow 5\ CO_2 + 7\ H_2O + 2\ N_2$$

The rate of denitrification is also dependent on temperature. Rates are low under +10°C and thereafter increase exponentially with increasing temperature (Vinther 1990). For denitrification to occur, sufficient time, in which the conditions are favorable are needed. The retention time in for example a wetland is therefore one of the most important aspects in removing nitrate from saturated soils (Dorioz et al. 2006; Schultz et al. 1995; Golterman 1983). It is a challenge to synchronize the optimal temperature for denitrification with the timing of the need for high demineralization when heavy rain during low temperatures in winter and spring is coupled with high losses of excess nitrate in the soil water.

Phosphorus

The bulk of P in soil is tightly bound to particles, interacting with the soil minerals iron (Fe), aluminium (Al) and calcium (Ca) in clay (Pionke et al. 1997). A small portion, relative to the total P in soil, is on soluble form and only this portion is bioavailable. Increased fertilizer input increases this portion, known as the P status of the soil (Rubæk, Kronvang, and Heckrath 2005). The potential for leaching of soluble P increases as the P status (labile P) of the soil increases (Glaesner et al. 2013).

Erosion is an important transport mechanism for P through transportation of soil particles. The erodibility of a soil is determined by its combination of particle size (soil texture) and aggregation of particles (soil structure). The intermediate particle size of silt is most susceptible to erosion. The weight of sand particles, and the strength of cohersion between clay particles also makes them both less susceptible to erosion (Morgan 2005, chap. 2). The accumulation of water running on the surface on a slope or on funneling shapes in the landscape is the erosive force. Water can therefore transport both dissolved P and particle bound P. The above ground plant cover contributes to absorb some of the energy of running water, and also the energy of falling rain drops. Roots strengthen the soil and thus make it less susceptible to water erosion (Morgan 2005, chap. 3).

Areas with a high amount of mobilized P and high potential transport can be very small and difficult to predict. These critical source areas can therefore account for a large amount of P losses, and predicting how much P is lost requires detailed knowledge of mechanisms of mobilization release, transportation processes, and the P status of the soil (Pionke et al. 1997; Rubæk, Kronvang, and Heckrath 2005). The average amount of P in 1 kg soil in Denmark is 527 mg/kg soil, varying from 326 mg/kg soil on a coarse sandy soil (JB 1) to 849 mg/kg soil on a heavier soil (JB 8) (Rubæk et al. 2000).

Nutrient retention

There are two ways in which soil particles potentially rich in P can be prevented from entering watercourses; either the measure implemented prevents erosion on the sloping part of the field where the soil particles are mobilized, or the mobilized soil particles (deposition) are stopped and retained from entering the stream or lake. Rough vegetation has the possibility to lower the kinetic energy of surface runoff and thereby both alleviate erosion and retain deposition. Vegetation (in e.g. a buffer zone) therefore has the possibility to prohibit erosion, and in addition retaining particle-bound organic N by slowing down the speed of the water (Morgan 2005; Dorioz et al. 2006). Contrary to nitrate, P can only be permanently removed from the buffer by removing sediment or biomass. P is primarily lost by surface runoffs and erosion, and nitrate is primarily lost through leaching. The differences in nutrient mobilization and transportation lead to the measures preventing losses being inherently different, with only a few measures targeting both nutrients.

As can be seen in Figure 1 nitrate rich water can take different routes from the root zone to the stream. The figure shows the fate of nitrate. The transportation of P happens mainly by runoff. Only small amount of P is transported by leaching. Nitrate entering the redox zone can be reduced through denitrification. To evaluate the potential for this removal in Danish catchments a national N model has been developed. This has been done on a resolution of approximately 1500 ha, the so called ID15 catchments (Højberg et al. 2015).

Figure 1 shows how the drainage pipes shortcuts the buffering system by drastically shortening the natural retention time for potential denitrification happening in the buffer zone. Macro pores connected to drains can also contribute with substantial P losses (Rubæk, Greve, and Hansen 2005)

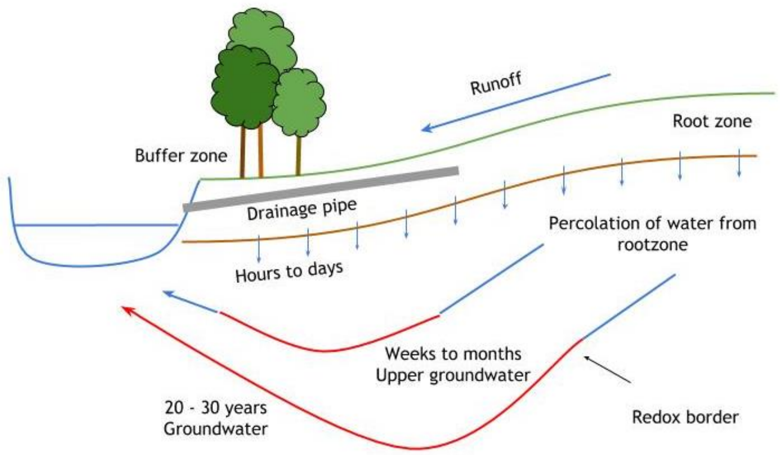


Figure 1, conceptual model showing the time frame of nitrate transport, and how drainage shortcuts a buffer zone. Adopted from Kronvang et al. (2014).

Table 1 shows the average values of nutrient levels in drainage water measured at 700 locations in Denmark in the period of 2012 – 2014. The average content of total N shows a large variation, from 0,4 to 39 mg total-N per liter but with statistical normal distribution (Piil and Knudsen 2014). On the other hand, low amounts of dissolved inorganic P (ortho-

P) have been measured in most fields, whereas measurements from a few fields show large amounts of P.

Table 1, average values of measurements of drainage water. Adapted from Piil and Knudsen (2014)

Average over three years (2012 – 2014)		
Total-N	**Nitrate-N**	**Ortho-P**
7.6 mg/l	6.5 mg/l	0.07 mg/l

5.2 The Integrated Buffer Zones

The buffer zone is in Denmark mostly understood as the area in-between the field and the stream, as a parallel strip of more or less managed land of varying width. The word "*buffer zone*" implies that the zone has a cushioning function of absorbing some of the impact that the surrounding area (the farmed land) has on the recipient waterbody. Various studies have investigated the optimal width of a buffer strip (Kronvang et al. 2000; Dorioz et al. 2006), the design (Schultz et al. 1995; Schultz et al. 2004) and function (Stutter, Chardon, and Kronvang 2012; Christen and Dalgaard 2013). A buffer zone is not limited to an area along the stream, but can also be an area with buffering effects inside farmed fields.

However, in this study the term will refer to an area with buffering effect placed along the stream.

The term "*integrated*" in the name of the measure refers to the variety of functions that are included in the measure. Several nutrient loss processes can be mitigated through the IBZ and more widespread effects like biodiversity and biomass production can be emphasized more or less according to the farmers' interests (to be discussed). The diversity of functions and the targeted effect highlights the innovativeness of the measure (BufferTech 2016b). A schematic drawing of an IBZ is shown in Figure 2 and a photograph of the measure can be seen in Appendix 5.

The drainage system is cut back so that the drainage water enters a ditch that is excavated parallel to the stream and this water subsequently infiltrates the zone closest to the stream where trees are planted (Gertz 2012). P is sedimented in the pond and denitrification occurs in the saturated soil under the trees (active zone in Figure 2).

Principles of nutrient movement as presented in section 5.1 are exploited to target nutrient losses. The drainage system functions as a means to collect nutrient rich water, and the properties of a well-established IBZ can treat the water through naturally occurring processes before it enters the water environment.

Trees play several roles affecting the ecology of the stream. There are indications that the trees enhance the infiltration of water further down in the soil (Christen and Dalgaard 2013) and trees stabilize the stream bank and reduce stream bank erosion. Furthermore the trees provide shade that cools the stream and prevents excess growth of water plants (Kronvang 2015). This will prevent large amounts of water plants affecting the water conductivity (and water level rise) and regular cutting and plant removal can be avoided (Kronvang et al. 2014). The trees also produce biomass that can be harvested and thereby nutrients are removed from the system (Christen and Dalgaard 2013), which is the main source of P removal.

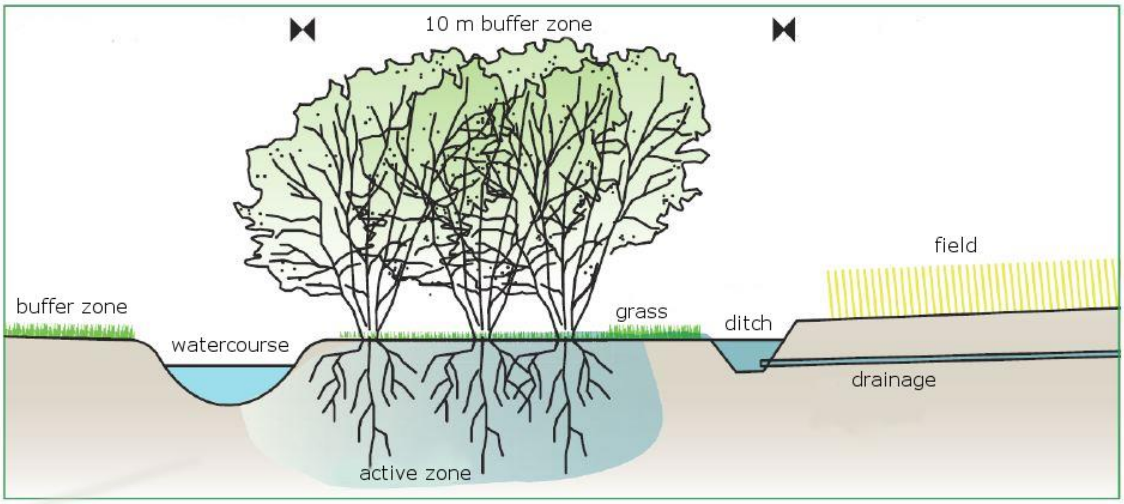


Figure 2, schematic drawing of an Integrated Buffer Zone (IBZ) (Gertz 2012)

Cutting back the drains (like in Figure 2) will lead to elevation of the groundwater table that creates anaerobic conditions promoting denitrification. If soil saturation occurs in the field it can impair growing conditions and the possibility to drive in the field.

Two pilot IBZs have been established in the BufferTech (2016b) project, one in the catchment of Spjald in Western Jutland and one in Fillerup in the catchment of Norsminde fjord in Eastern Jutland. To be able to monitor the research facilities, certain requirements made the pilot facilities different from how they will look in the future. (E.g. the dimensions are smaller to be able to have a measurable outflow from the system). The size of the pilot facilities is 12 m wide and 35 m long. Also, it is placed further from the stream and technical installations make it look less natural than the goal for the final design. The final dimensions for the design and the scale of the facility have not yet been clarified.

The IBZ at Fillerup was established July 2014 and monitoring started in the early spring of 2015. Results exist therefore only for the first 7 – 8 months. Development of vegetation in the IBZ and the effect this has on the retention time needs to be monitored over a longer period. This is also true regarding climatic variations that have implications for the hydrology and input concentrations, and therefore needs minimum two years of monitoring to be able to draw more reliable conclusions (Kronvang 2016b, pers.comm).

Preliminary results from the Norsminde pilot area show an N removal of 1400 kg total N/ha year^{-1} (equivalent to a removal rate of 23,7 % nitrate-N (note, different unit)) and a P retention of 23 kg total P/ ha year^{-1} (equivalent to a removal rate of 44 % total P) (Zak 2016).

No preliminary results are yet available from the pilot area of Spjald. It was established in November 2014. Prior to the establishment of the facility in Spjald clear signs of erosion were detected and photographed (Figure 3). This shows how important knowledge about topography and hydrology is to capture the surface runoff. The Spjald facility receive surface runoff from 4 ha and drainage water from 20 ha (Kronvang 2016a).

Figure 3, example of a photography of water erosion taken by a drone at the location of the IBZ at Spjald (photo: René Larsen, Department of Agroecology – Climate and Water, Aarhus University).

The following are requirements for establishing an effective IBZ (Kronvang and Kjeldgaard 2016, pers.comm):

- Drainage allows for collecting and treating nutrient rich water from the contributing area i.e. the fields that are drained.
- Sufficient elevation is needed to avoid drainage water being backed up in the field and higher slope gives in general higher infiltration.
- The facility needs to be scaled according to catchment size and nitrate concentration input.
- In order to target nutrients transported by surface flow, the placement of and IBZ must coincide with patterns of water flow and potential erosion as exemplified in Figure 4 in section 5.3.

5.3 Modelling erosion

In the present study the WaTEM model is used to make a prediction of soil erosion (Van Oost, Govers, and Desmet 2000), it uses the American Universal Soil Loss Equation (USLE) to explain the erosion (equation 2). It is an empirical model and contains factors that are grouped together. The equation for potential erosion (E_{pot}) is shown in equation 1. It is multiplicative, meaning that even if some of the factors are unknown, the factor is set to 1, the model can still function. If one factor is zero then everything is zero, e.g. if there is no slope, then the potential erosion of course will be zero.

$$\text{Equation 1: } E_{pot} = (R*K)*(L*S)*(C*P)$$

R: index of kinetic energy of rainfall, a measure of the erosive forces.
K: index of the soil properties and the resistance to erosion, the erodibility.
L: topographic index of upslope contributing area, this is the area in which water accumulates and what runs through one point in the raster data of a digital terrain model can be calculated.
S: slope steepness index.
C: crop factor
P: management factor

The input C factor used in the present work is based on the Basemap (10x10 m resolution) (Levin, Kastrup Blemmer, and Nielsen 2012) in which all land use characterized as intensive agriculture have the same crop and management factor, namely winter wheat as an example of a worst case scenario. This model does not yet take into account changing crops from year to year, and thus estimates only the long term average erosion risk. All other land uses have different C factors indicating very low risk of erosion, i.e. grass, forest and other vegetation that would prevent erosion. The Basemap layer can only detect streams that are wider than the cell size of 10x10 m and many smaller streams are therefore not accounted for. This is true for many streams and ditches in Spjald catchment (this can be seen in the difference between Figure d) and e) in Appendix 5). Because many landscape elements are smaller than 10x10 m and the Basemap is not originally developed for agricultural research, e.g. roads are prioritized over streams if they appear in the same cell.

The output layer of the WaTEM model for erosion and deposition (Werodep) only shows what is happening within the specific cell, it depicts the pattern of erosion and deposition in the landscape. Each cell contains a number representing either loss or gain of soil. A positive number represents deposition and a negative number represents erosion. There is an obvious connection of soil being transported from areas of erosion to areas of deposition, but Werodep does not show the quantitative accumulation of soil or the transportation of material. The main function of the modelling output is not to quantify soil loss from fields or sediments entering streams, it is to be able to identify the critical source area of erosion and deposition in the landscape (Heckrath 2016a, pers.comm).

The WaTEM model is used to generate a second output that calculates the export of accumulated material (WExport). It measures the transport of soil leaving the edge of the land use feature of agriculture entering neighboring features classified as streams or another bordering landscape element feature in the Basemap. The total amount of soil that passes through a cell at the border of fields next to streams is assumed to be delivered to the stream.

Nitrogen losses are more difficult to visualize on farm scale (cf. section 5.2) and this is the reason for focusing on P losses in this work. Making an interactive tool for farmers and advisory service to visualize N losses is one of the tasks in the dNmark research alliance (Christensen and Piil 2015; dNmark research alliance 2016). Current available data on nitrate leaching and retention potential is on a catchment scale and is more relevant for comparison of different catchments as part of planning on a larger scale (Højberg et al. 2015).

Soil transportation to streams

A flow chart consisting of four parts was developed for this study in collaboration with Kronvang and Kjeldgaard (2016, pers.comm). The goal was to sketch out the whole process, including the main criteria, of deciding where the placement of IBZ would be effective. The main source of data used was the WExport data layer, showing risk of deposition entering the stream. The flow chart was also a starting point for developing an over-all GIS-technical procedure for analyzing where this risk was at the highest. The WExport layer and maps made in the analysis in the present study was not used when visiting the farmers due to technical limitation and practical considerations. These issues will be discussed later. The meeting with Kronvang and Kjeldgaard (2016, pers.comm) led to the decision to concentrate the GIS analysis on the ID15 catchment of Spjald. This catchment is much smaller than Norsminde fjord, which is an advantage because a visual evaluation was needed to make continuos assesment of the application of the various tools used to build the model in ArcGIS (ESRI 2014).

The initial flow chart can be seen in Appendix 1, but the description of the approach will be related to Figure 4. Figure 4 is also related to the front page drawing. The first part is symbolized with the layers of data analyzed with GIS software. Part 3 is depicted as the conversation and the field observations. The reason for part 3 also being connected to the starting point (as in the drawing) is that the farmer and the local advisors can contribute with local knowledge that can help further development of the model input and subsequent maps.

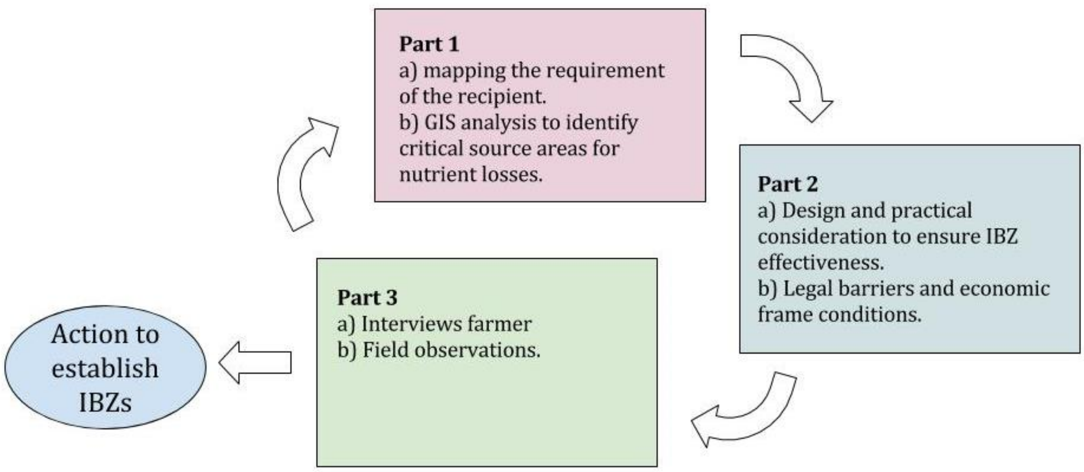


Figure 4, a schematic overview of the iterative process leading to action of implementing an Integrated Buffer Zone. Part 1 b) is further developed and will be explained in section 6.2. Part 3 a) is the subject of the case study conducted, see section 5.4 and 5.5.

Part 1 a) in Figure 4 focuses on the requirements of the recipient; as a first step it is important to determine the focus of the analysis. If the recipient is a lake the criteria of retaining P is weighted more, and in that case drainage and nitrate gets less weight. If the recipient is the fjord, the nitrate removal is the most important criteria (Hinsby et al. 2012; Kronvang et al. 2005). Sedimentation loading to streams can undermine efforts made for establishing spawning grounds in streams because the gravel that is put out will lose its effect. If the recipient is a lake with short retention time and is transported to a fjord both N and P must be targeted. The analysis conducted in the present study only focus on the criteria of erosion risk and risk of soil deposition entering streams simulating a scenario of a stream with spawning habitats.

Part 1 b) in Figure 4 focus on the GIS analysis, which will be further described in section 6.2. As only erosion will be included in the GIS analysis, the result is segments of the stream showing categories of kg soil with risk of being transported to the stream.

Part 2 a) comprise practical considerations and requirements for establishment are listed in the end of section 5.2. A high resolution digital terrain model (DTM) is a prerequisite for executing this part. A DTM of 48x48 m resolution was used in this study, but a resolution of below 2x2 m is needed to detect the required elevation for establishing an IBZ and the resulting width. Knowledge about the drainage system is an important part of the decision process, but was not available for this study. Part 2 b) points at an additional important aspect to investigate: The legal barriers for establishing an IBZ in or close to protected areas. As the map in Figure 8 in section 6.1 shows there are protected nature types along the stream. Therefore, §3 areas and other protected nature types need to be thoroughly mapped, but these issues have not been further investigated in this study.

Part 3 involves the farmers' knowledge and thorough field observations. The case study will elaborate on the involvement of the farmer. Both Figure 4 and the illustration on the front page imply that the process is iterative because the farmer and local advisors can contribute with local knowledge that can improve the modelled maps. The goal of this process is to gather information and to transform it into the action of establishing IBZs.

5.4 Farmers' acceptance and motivation

The first barrier that was identified in this work was the lack of consensus on the environmental problem in lakes, streams and estuaries among the farmers. This barrier ws noted by the AGWAPLAN (2009b) project. It concluded that "*A common professional starting point – and a common understanding of the problem – is a key issue that takes long time to build*". The project also found that the causal relationship between fields and the environmental problems must be understood by the farmer to ensure that they take an active part (Madsen and Noe 2009).

This section will investigate factors influencing the farmers' acceptance of environmental measures (AEM) and agro environmental schemes (AES). Experiences from implementation of environmental action in the international literature, the Danish project AGWAPLAN (2009b) and personal communication with Noe (2016, pers.comm) is the background for understanding the factors that influence farmers' decisions and the development of the interview questions.

The conversation with the farmers does not happen in a vacuum; Previous environmental regulations, the public debate and discourse form the basis for how the farmers act today (Noe 2016). Currently there is a widespread discontent among farmers and the formation organisations like Bæredygtig Landbrug (2016) is an indicator of this discontent.

There are widespread conceptions such as: National models of nutrient losses does not contribute with relevant results on field scale; the Danish level of environmental regulation makes a distorted competition; farmers do care about the nature and it makes no sense to squander the available nutrients (Wiborg 2015, pers.comm). These views were also expressed during the conducted interviews in the present study. Such statements are some of the reasons why the necessity for additional environmental measures would be hard to accept for some farmers. A combination of many years of top-down, C&C regulation has created an hostile environment and a lack of trust in which communication is fraught with tention.

Two barriers

In the research community it is agreed that there is a need for improving the ecological conditions in many lakes, streams and estuaries (Dalgaard 2016, pers. comm). Expanding this agreement to also be embraced by the farmers and agreeing on the necessity for a collective effort is the first barrier for the implementation of IBZ. The second barrier concerns the challenges in placing the IBZ. The challenge here is pointing out areas that fulfill all the biochemical conditions explained in the two previous sections. During the process of mapping the landscape to point out IBZ locations it is also important to find out how well the maps correspond with reality. Furthermore, implications from previous and future establishment of AEM are determined by frame conditions and are important issues to clarify for the IBZ measure. Insight in economic barriers and understanding the implications and possibilities of frame conditions is crucial. This constitutes a big part of the farmers concerns, but was not possible to incorporate in the present work.

The advisor can potentially be involved in overcomming both barriers. He or she can be seen as a facilitator, but is not the one excecuting a decision and cannot force something to happen. It is the farmer who has the possibility to make changes, he is the expert on his land and therefore has the key to the second barrier of actually establishing environmental measures (of any kind).

The main function of the primary advisor for land management (usually the crop advisor) is to optimize production and make sure all possibilities for making economic return are explored. The focus here is on the single field and the single farm, and one cannot assume that this person has the motivation to also suggest collaboration between more farmers and the establishment of AEMs. Findings from the Soils2Sea project regarding differentiated nitrate restrictions, state that it could not be expected that all farmers would be able to make a joint strategy on their own (Stelljes and Knoblauch 2015). Therefore, in order to nudge the beginning of a fundamental shift towards thinking of the single field as a piece of the larger catchment puzzle, the idea (developed by Wiborg and Gertz (2016, pers.comm)) of a catchment advisor is incorporated in this work.

A catchment advisor would be a person (or team) with extensive professional knowledge on environmental measures such as drainage measures, constructed wetlands, IBZ etc. This person or people would also need social skills regarding the process of interviewing, planning and a thorough knowledge of regulations and support schemes. This type of person with both "hard" (natural science) knowledge and social skills, the so-called T-shaped skills, is described by Bouma et al. (2011) as the "new extension agent", the knowledge broker for innovative development. These qualities were also noted in the AGWAPLAN (2009a) project, as the advisor had the advantage of having the farmers trust, he or she was seen as a knowledge communicator, especially by those with environmental experience (Stubsgaard 2009).

Creating a space for open conversation

When trying to understand what drives a farmers' decision, the assumption that farmers' only motivation is utility optimizing might not capture the broad variety of the farmers rationale (Ryan, Erickson, and De Young 2003). Gachango, Andersen, and Pedersen (2015) point out that application of a strictly economic or sociological approach to implementation of environmental measures excludes important factors affecting farmers' decision rationale. The farm is not only a product of the general frame conditions. It is a result of the farmer and his family's values and goals, to mention a few (Højring et al. 2005).

Different values lead to different use of the knowledge that the farmer holds, and the combination of values and knowledge is strongly connected to the way that the farmer acts and makes decisions. The specific way of doing things based on values and knowledge is the basis of the farmer's management style (Noe and Langvad 2006). The objectives and goals are shaped by the underlying values, and the cognitive synthesis of these two aspects creates a persons' preferences that leads to making decisions (Bogetoft and Pruzan 1997).

One of the questions investigated in the AGWAPLAN (2009b) was how to integrate the otherwise separate functions of the crop advisors and the environmental advisors. As a result, an alternative advisory strategy integrating the environmental issues in the primary production on the farm was proposed. The AGWAPLAN project concluded that the farmers' lack of understanding of the environmental condition (ecological status) and not seeing the necessity of acting was the biggest obstacle for implementing a new integrated advisory strategy (Noe 2016, pers. comm).

To overcome the first barrier and create consensus to make a collective effort, an advisor acting as a facilitator has to understand the different motivation basis of the farmers. The evaluation of the AGWAPLAN project emphasized the importance of meeting the farmer within his frame of management style and respecting the values on which his management is founded (Madsen and Noe 2008). Based on the knowledge on farmers' motivation and on what basis they make their decisions a space for this conversation can be established. To do this the advisor has to be genuinely interested in making the inquiry with the farmer to establish an understanding of the farmers' rationale (Noe 2016, pers.comm).

In the AGWAPLAN project a typology of farmers' management strategy was developed to prepare the advisor for a conversation to understand differences between farms and farmers and to ease communication in discussing how to include considerations to the landscape. This categorization was developed to reveal why farmers had different views on Good Agricultural Practice as a normative concept based on their management style. It proved useful as a tool for the advisors to be aware that different farmer types would respond differently to a planning approach/strategy. A similar typology was developed by Højring et al. (2005 chap. 4) and is shown in Figure 5.

The development of the questions about the farmers' management strategy for the present study is inspired by these typologies and correspondence with Noe (2016) and Kjeldsen (2016) (Appendix 3).

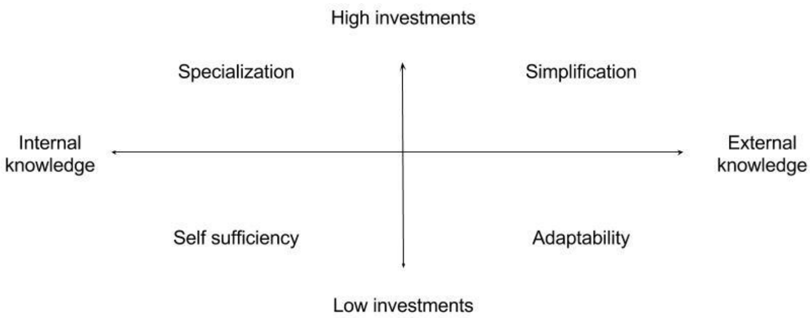


Figure 5, typology of farmers' management style, adopted from Højring et al. (2005).

There are several articles on the topic of the way farmers make decisions (e.g. Gachango, Andersen, and Pedersen 2015; Fleury et al. 2015; Schroeder, Chaplin, and Isselstein 2015; Lastra-Bravo et al. 2015) and how new ideas are assimilated (Sattler and Nagel 2010; Bouma et al. 2011; Rogers 1983). These studies have stressed the need for assessing what influences farmers in making decisions and what factors are important for successfully implementing agro environmental schemes (AES). This insight is valuable when developing a decision making tool for the advisory service.

Making decisions with multiple criteria

The intrinsic differences between the two barriers require different methodological approach. There are, however, great similarities, both barriers includes making decisions involving trade-offs and data with uncertainties.

Barrier one, creating consensus on the need to improve the ecological status, is of a more profound nature. A standardized mechanistic approach cannot make a farmer agree to make an IBZ if he does not regard the current ecological status in the water environment as a problem. However, other criteria supporting his values and preferences as a farmer could persuade him to make an IBZ for other reasons than the ecological status of the water environment. Overcoming the first barrier is the threshold for getting started on the process of what to do and how to make it happen. If this first barrier is not overcome there will still be the question of *why* to make an effort towards the improvement of the water environment.

Barrier two was outlined in section 5.2 and 5.3 and is further discussed in later sections.

In the work of Bogetoft and Pruzan (1997) the "*internal-personal*" conflict is described as having to make a choice as a single person, in this case the farmer, that might include conflicting options. However, a "*systemic conflict*" occurs when planning and decisions are made on multiple levels including parties with different values. In this case the decision receiver is the farmer in the sense that the government has a strategy for implementing the Water Plans and the establishment of AEM in the country. The farmer is not merely the decision receiver because the farmer has a great deal of autonomy in making his own decisions regardless of the plan of the government because many of the AEM are now voluntary. Bogetoft and Pruzan (1997) put it this way: "*…in order for a social system of pluralistic society to be able to pursue its own objectives in the best possible way, it must support the objectives of its sub- and suprasystems*[4]". The object of the social system here is to achieve GES in the water environment and the sub system constitutes the farmers, the decision receivers.

Incorporating multiple criteria in this work

The aspiration of this work is to create an advisory strategy to encourage farmers to establish IBZ. Since there is an element of persuasion of a heterogeneous group, a mechanistic approach is not attempted, but rather emphasizing the pedagogical element and the need for reinstating trust in the environmental authorities from the agricultural sector. Therefore, the method is used as an approach to analyze the different elements involved in a decision making process with concepts of values, objectives and preferences/criteria formulated by Bogetoft and Pruzan (1997).

The concept of incorporating multiple criteria is widely used in combination with geographical information systems (GIS) and mostly in environmental science (Malczewski 2006). In this work, criteria for establishing an IBZ are handled and criteria for locating risk areas for erosion and deposition are discussed. Regarding the interview process, the method is applied as an exploratory approach (contrary to a mechanistic approach) by investigating criteria involved in motivation and obstacles for implementing environmental measures.

Making decisions based on multiple criteria has been used in many fields. Its strength is that it can combine and weight various parameters against each other without having a common unit like money (Christensen et al. 2012). The following are some examples of its use. A quantitative approach setting up equations for weighted environmental parameters is used for pointing out optimal location for biogas plants (Olsen et al. 2014).

[4] The over-all system including all subsystems.

Janssen (2001) describes the evaluation of impact assessments of different project proposals by weighted environmental criteria. An advantage is pointed out that large number of aggregated criteria can be communicated to the public (Janssen 2001).

To evaluate sustainability of farms quantitative and qualitative indicators for sustainability are aggregated to a score (Bacchin 2010). This method have been used to evaluate organic agriculture (Christensen et al. 2012) and as a decision tool for consumers (Læssøe et al. 2013).

What makes change happen?

When participation in AES is voluntary, acceptance and understanding of the environmental issue is crucial. Schroeder, Chaplin, and Isselstein (2015) emphasize that acceptance comes from participation when it is supported by the awareness of the policy objectives behind the AES. Their study is an ex-post study of farmers attending the British AES of Environmental Stewardship using the Theory of Planning Behavior (TPB). Equations were constructs for multiplying underlying factors resulting in a score representing the intention determining behavior. The above mentioned authors claim that their method is a good tool for explaining behavior because it clearly defines the elements in what the drivers are for the performance of certain behavior. It was not used to predict behavior, as the method was originally intended for, but to assess aspects that influence the decision to participate in AES and thereby the understanding of what drives farmers in accepting AES.

Gachango, Andersen, and Pedersen (2015) found that there is a connection between farmers' previous establisment of AEM and their perception of water quality. Farmers that have implemented environmental measures percieve the water quality to be above-average. The opposite was tested, but they found no correlation between the perception of water quality and the future establishment of AEM (Gachango 2016, pers.comm).

Fleury et al. (2015) investigated the effect of a result oriented AEM on farmers' motivation. They found that coupling payment for participating in measures with the results of the measure was motivating. This implies that the effect can be seen, as in this case the flower diversity in grass fields. Seeing the effect in their fields also created an understanding of biodiversity, and was suggested to create a broader change of perception of connections of biodiversity and farming.

The Sattler and Nagel (2010) study on farmers' acceptance of conservation measures builds on Rogers (1983) theory of the diffusion of innovation, of how new ideas spread and are adopted or not. They use his categories for conducting a survey to investigate factors affecting the acceptance of environmental measures. Environmental measures were rated in relation to the following categories; relative advantage (in terms of time, cost and risk), compatibility with values, experience and needs. They found that the category of relative advantages got the highest scores for being the most important criteria for acceptance.

5.5 Case theory

Investigating explanatory questions like "*how*" (how can the barriers be overcome? How does the farmer make a decision?) and "*why*" (why is the farmer reluctant?) are adequate questions for using the approach of a case study. A case study has the opportunity to examine contemporary events without manipulating the subjects' behavior, and it allows for the interview of subjects that are involved in the events (Yin 2013). Furthermore, experiencing the real world and can give insight in the event (Brinkmann and Tanggaard 2010).

Flyvbjerg (2010) points out that the demand for generalization is one of the main criticisms of case studies, but he argues that generalization is not a necessity for creating new knowledge; it is one of many. Furthermore he writes that a case can help develop a nuanced view on human behavior and not only understood as a product of generalizable actions. Yin (2013) on the other hand, argues that generalizations made from case studies are possible, but calls them "*analytical generalizations*". Analytical generalization can be made when a lesson learned from a case can be "*posed at a conceptual level higher than that of a specific case*".

The present case study is an example of an iterative process (as illustrated by the front page drawing and Figure 4) where results from a small number of interviews in a specific catchment produce experiences on how to construct further interviews in the process of developing a national strategy for a complex problem, i.e. implementing the IBZ as part of a differentiated regulation. How criteria are selected for the interview will be explained for in section 6.3.

6. Materials and methods

Section 6.1 consists of a description of the water catchment used in this study. Section 6.2 and 6.3 is an account for the method developed for the GIS analysis and the interviews conducted respectively.

6.1 Physical description of pilot area

The ID15 water catchment of Hover Å in Spjald (Højberg et al. 2015) used in the present work is placed in Western Jutland and the area is more hilly than is typical for the region. There are many springs from shalow groundwater being pushed to the surface, both because of the topography but also because of layers of clay in the deeper horizon (Søndergaard 2016, pers.comm).

Figure 6 shows the placement of Spjald catchment in Denmark and the output of the digital terrain model showing the valley of the watercourse and that the water runs out of the catchment in the the north west corner.

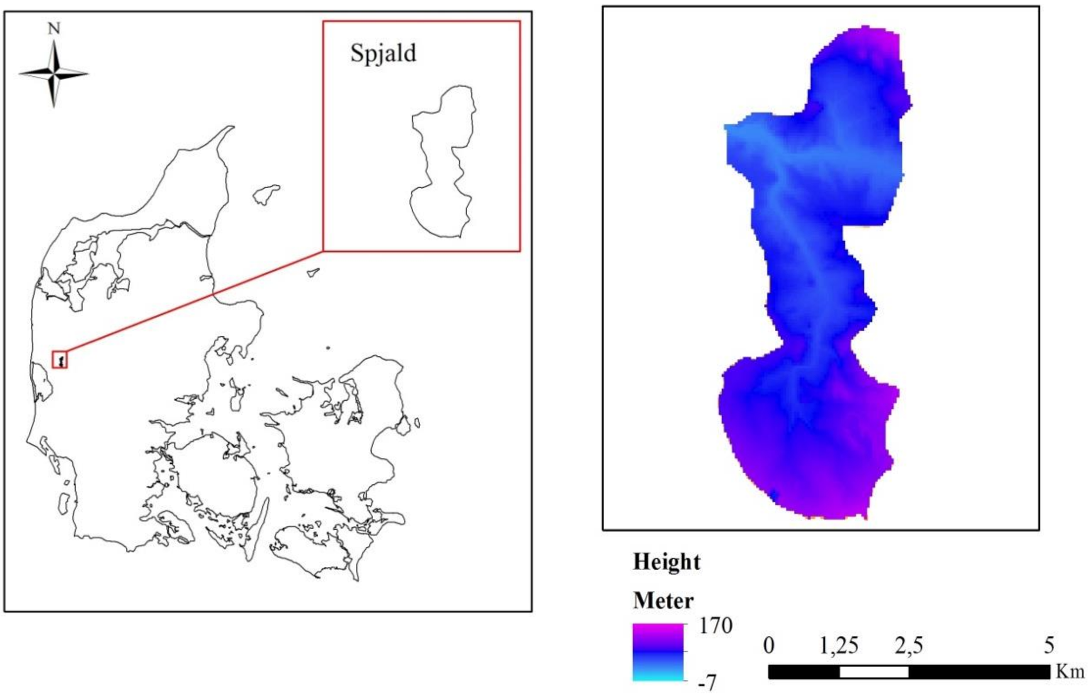


Figure 6, placement of Spjald catchment in western Denmark (left) and a digital terrain model showing height above sea level (in a 48x48 m resolution) made available by Mette Vestergaard Odgaard, department of Agroecology, Aarhus University.

Spjald has a high percentage of coarse sandy soil in the north and fine loamy sand in the south (see Figure 7 and Table 3). Fine loamy sand consists of 40 - 95% silt (Greve 2016) and combined with the fact that this region receives the most precipitation in the whole of Denmark (DMI 2016) this makes the risk of erosion high. The BufferTech pilot facility is placed in the south-western part of this catchment (Appendix 5 e).

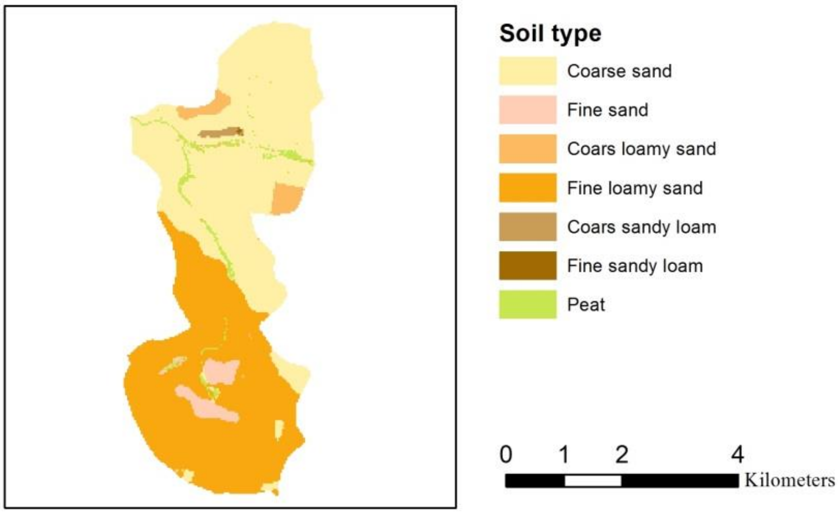


Figure 7, soil types in the 20 cm topsoil in Spjald (in a 10x10m resolution)(Adhikari et al. 2013)

Table 2, plow layer soil types in Spjald

Soil type in topsoil	% of cachtment
Coarse sand	48.44
Fine sand	2.89
Coarse loamy sand	2.62
Fine loamy sand	43.29
Coarse sandy loam	0.49
Fine sandy loam	0.04
Sandy clay loam	0.00
Clay	0.00
Humus (peat)	2.23

Table 3, land use in Spjald, related to the Basemap in Figure 8.

Land use	%
Agriculture	76.5
Forest	4.6
Urban	12.9
Water	3.2
Open nature	2.8

Figure 8 shows the land use in Spjald. Besides the urban area of Spjald town, intensive agriculture dominates the catchment (76.5 %). There are areas of open nature in connection to the watercourse, however (Table 3 and Figure 8), which functions as a natural buffers for agricultural runoffs. Wet meadow (bright green), bogs (gray-blue) and wetlands (blue-spotted) along the watercourse are categorized as protected nature types according to Arealinfo (2016).

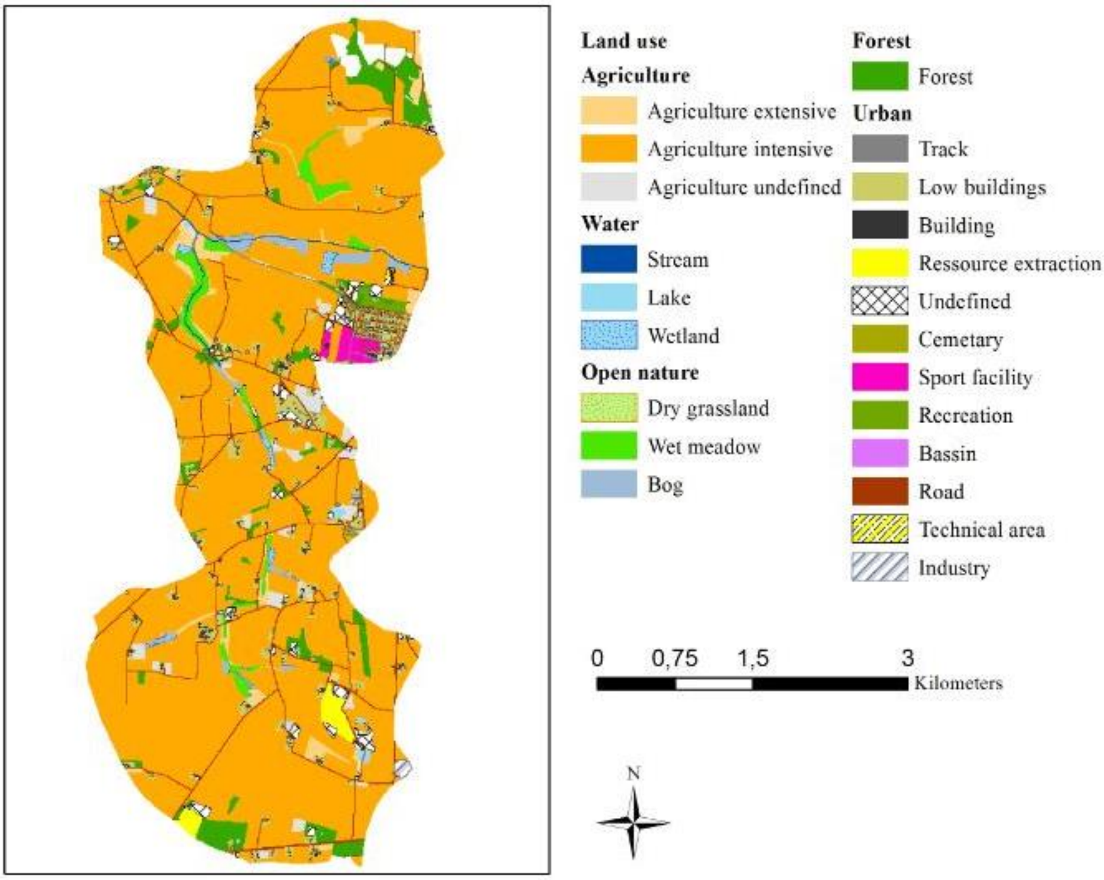


Figure 8, Basemap (in a 10x10m resolution) (Levin, Kastrup Blemmer, and Nielsen 2012) of the ID15 catchment of Spjald (Højberg et al. 2015).

Detailed knowledge of nationwide drainage has not yet been systematized, but as this information is important in many circumstances, there have been attempts to model the need of drainage and thereby calculate the probability of drainage. This method does not take groundwater into account and has a higher uncertainty in sandy soils (Olesen 2009). Existing data presenting the need for drainage in Spjald would therefore be of limited use and is therefore not included in this study.

6.2 GIS analysis

The software ArcGIS (ESRI 2014) was used to process data and conduct the analysis visualized by maps. With the Figure 4 part 1 b) (description in section 5.3) as starting point, a model for identifying high risk deposition areas was developed (Appendix 2). The input data were outputs made in the WATEM model and was made available by Heckrath (2015, pers.comm)

There are two separate processes; one for making of the maps for the farmers and one identifying high risk of soil deposition entering the water body. The main data input and the generated output is shown in Table 4.

Table 4, input data and data generated in ArcGIS. See Appendix 2 for model builder.

Input data layers	Generated output
Watercourses (FOT)*	Main watercourse for simplification
Werodep (ton/ha)**	Pattern of erosion and deposition (Fig. 11)
WExport (kg/100m^2 (one 10x10 m cell))**	Deposition in segments (Figure 12 and 13)

*Data was made available by Ane Kjeldgaard, department of Bioscience, Aarhus University. **The data was made available by Goswin Heckrath, department of Agroecology, Aarhus University.

Patterns of erosion and deposition in the landscape

The layer Werodep was used as input for visualizing erosion and deposition and maps for the farmer were made from this data. (Examples of maps shown to the farmers can be seen in Appendix 5 a) and b)).

Identifying watercourse segments of high risk

To simplify the method a main stream was marked by using the FOT watercourse layer and side branches were excluded. The simplified watercourse is shown in Figure 11 in section 7.1 and the original watercourses can be seen in the Appendix 5 e. The goal of the analysis was to calculate number of kg soil entering per meter stream.

Figure 9 shows a schematic overview of some of the steps made in the ArcGIS program. To create the stream segments, points distributed on the stream (Figure 9 a) were used to generate Thiessen polygons (Figure 9 b), which then were cut with a buffer (Figure 8 c). In this way the WExport layer showing the accumulative deposition is segmented and can be categorized (Figure 9 d). See Appendix 2 for the GIS model builder.

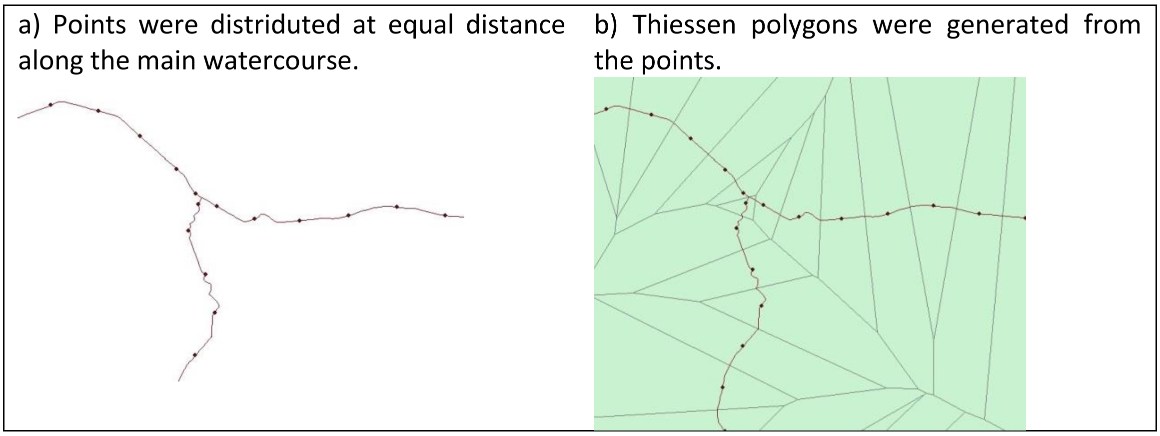


Figure 9 a), b), schematic display of procedure made in GIS to divide the stream into segment and calculate the sediments entering the stream.

c) The Thiessen polygons were cut with a 20 m buffer.

d) Calculations of deposition segment were made on the basis of the polygons and the WExport layer.

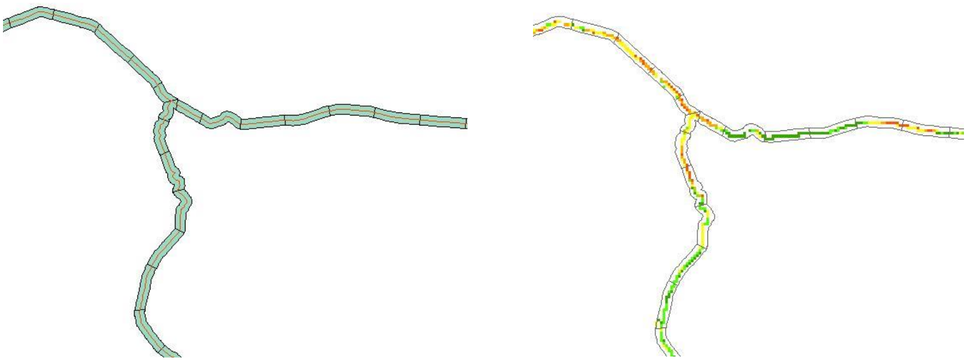


Figure 9 c), d), schematic display of procedure made in GIS to divide the stream into segment and calculate the sediments entering the stream.

6.3 Case interviews

The conducted interviews were carried out as a part of the last step in Figure 4 section 5.3. The questions in Danish can be found in Appendices 3 and 4. These interviews are based on the idea of treating the farmer as a part of the solution, the key stakeholder having the local knowledge. The semi-structured interview (Brinkmann and Tanggaard 2010) consists of very open questions designed so that they could be answered within the rationale of the farmer, and for the interviewer not to impose with her own rationale. This will hopefully lead to a humble communication between the parties, realizing that there are many connotations in the semiotic of the questions that can be undertood very differently (Noe and Alrøe 2012).

To avoid getting into a track of the farmer feeling attacked or accused for not doing enough the interview question deliberatly tries to avoid words with perceived negative associations to the farmer (e.g. WFD and reduction targets). Technical terms are kept to a minimum to avoid alienation and also to avoid association with words used in the press by the "*environmental side*" or the government (representing the C&C). This is also the reason for not using the maps showing risk of deposition entering the stream, but instead showing maps of erosion patterns, as they are more intuitive.

The goal of the interviews is to explore the two levels of barriers in the implementation of IBZ. Furthermore it investigates whether a conversation about the farmers' management style and motivational factors can be a space for working towards consensus on the need for targeted measures and collective effort on the issue of the ecological state of water bodies.

The local crop advisor (Søndergaard 2016) was contacted to help finding farmers for the interview. The farmers were chosen on the basis of having fields neighboring streams. Appointments were made with the farmers over the phone. Table 5 shows an overview over the farmers participating in the interview and some inforation about them.

Table 5, an overview of the farmers and their production.

Farmer (colour)	Education	Production	Hectares farmed	Organic/ conventional	Crops grown	Age
1 (blue)	Farmer	Dairy cows	90	Conventional	Maize, clover grass, cereals	60
2 (orange)	Agronomist	Meat cattle and sheep	102	Organic	Vegetables, grass seed, cereals	61
3 (black)	Farmer	Slaughter pigs	51	Conventional	Cereals, grass seeds	52
4 (red)	Farmer	Dairy cows	344	Organic	Clover grass, cereals	45
5 (green)	Farmer	Dairy cows	546	Conventional	Maize, clover grass, cereals, grass seeds	42

The questionnaire was made up of three parts. Part one (questions 1.1 – 1.5) consists of questions about their management style to get an understanding of the different types of logic of production. In part two the questions are focused on motivation and factors affecting decision on establishing IBZ. The third part investigates the idea of having a new type of advisor, a catchment advisor. The questions are meant as a starting point of a conversation but the structure was followed so that the different interviews could be compared to some degree.

Figures 1.4 and 1.5 in the questionnaire in Appendix 4 are based on a typology made by Højring et al. (2005) (Figure 2, section 5.4). It depicts the cross field of how the farmer utilizes knowledge and how he creates economic return on the farm. This single figure was modified into two separate fields of tension to invite the farmer to talk about his style of management. The separation of the vertical and the horizontal axis was done to avoid the answer being vague, in the line of "*somewhere in the middle*".

Four statements based on the concept of the same figure were set up in a table (see Appendix 4) and the farmers were asked to rate them according to how well they described their management style (1, being the highest rating). They were also asked to state which statement was the best fit overall.

Table 6, statements regarding the management style of the farmer, modification of Figure 1.2 in Appendix 4.

The four statements	Relating to fig. 2
The main purpose of the farm is to secure high yields	Specialization
I want to minimize the work effort to maximize my leisure	Simplification
I want to produce as much as possible on my own farm to minimize import	Self-sufficient
The most important for me is to be flexible so I quickly can adapt to changing prices or frame conditions	Adaptability

Part 2, (questions 2.1 – 2.5 in Appendix 3) consisted of questions that wanted to investigate the farmers' attitude to the environment, nutrient losses and their role as a nutrient manager. Figure 10 shows a web with associated motivational criteria that was developed on the background of international literature and collaboration with participants in the BufferTech project (BufferTech 2016a). The farmers were asked "*how important are the following criteria regarding your motivation for establishing an Integrated Buffer Zone*".

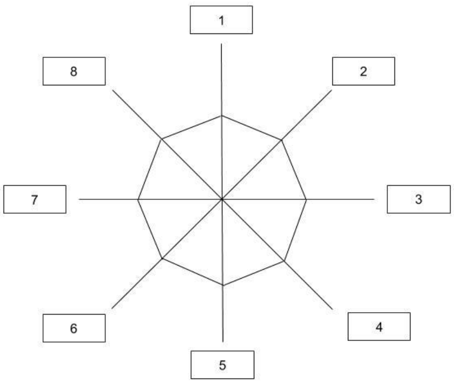


Figure 10, a web with eight motivational criteria, see the text for explanation of each criterion. The intersecting line represents the criteria having neither increasing or decreasing impact on motivation.

Describing the different criteria in Figure 10, clockwise from the top:

1: "Easy to establish". The question is inspired by Sattler and Nagel (2010) and their investigation of the importance of factors regarding farmers' acceptance of concervation measures. The assumption is that different aspects of establishing AEM have different influences on the farmers decision depending on their values and objectives. They found that time and effort spent as a result of the meassure was an important factor, but there were large differences regarding how the need for training would affect their acceptance.

2) "See an effect of the measure". Fleury et al. (2015) found that when the farmers could see the effect of the measure it contributed to a more thorough understanding of the ecological connections in the farm ecosystem.

3) "Receive recognition for the effort". The study of Fleury et al. (2015) found that being recognized for the effort was a major source of motivation to participate in environmental measures. E.g. the effect of an official price ceremony and result oriented measures was examined. Sattler and Nagel (2010) also found that a measure is rated important if it can improve a farmers' image in society.

4) "See indications on leaching". Farmers have experiences in seeing signs in nature of nutrients accumulating in the landscape and reoccurring erosion pattern in fields (Wiborg 2016, pers.comm). This question was therefore relevant to include.

5) "Look at maps that show e.g. erosion". This question is investigating if personal experiences and knowledge about their fields can be related to the maps. How the farmers

interpreted the maps was a question mentioned early in the project by Heckrath (2015, pers.comm). The question is further investigated in part three of the interview

6) "Economic return from the measure e.g. production of biomass". The idea of the making revenue from the IBZ is founded in the BufferTech project and was therefore investigated (BufferTech 2016a).

7) "High enough payment". This question is based on the assumption that this is a general concern by the farmers. Sattler and Nagel (2010) found that cost neutrality or cost reduction as a result of a measure was an important factor for acceptance.

8) "The establishment is a part of a collaboration on catchment level". This question was asked to explore the concept of a catchment advisor proposed by Wiborg and Gertz. This question is further investigated in the interview part three.

Part three (questions 3.1 – 3.5) makes an additional inquiry about the farmer as a nutrient manager and explores the farmers' own thought about different ways to hinder nutrients reaching the surface waters. This part also includes questions about the farmers' understanding of the maps as a tool in planning.

The farmers were shown maps of erosion/deposition pattern in his fields, a map showing slope, the Basemap, an overview map and a schematic drawing and a photo of the IBZ (Appendix 5)

7. Results

The key results of the GIS analysis are displayed in section 7.1, a simple statistical analysis is made to evaluate the GIS method. Complete data output from ArcGIS and Excel are found in Appendix 6. A synthesis of results from the developed interview method is described in section 7.2. Selected quotes in Danish are found in Appendix 7.

7.1 Results of GIS analysis

Figure 11 shows a section of the main watercourse and the pattern of erosion and soil deposition. This section is the only part of the stream that is detected in Basemap and subsequently WExport and this section (Figure 11 – 13) is therefore chosen. Examples of the maps shown to the farmers can be seen Appendix (5 a).

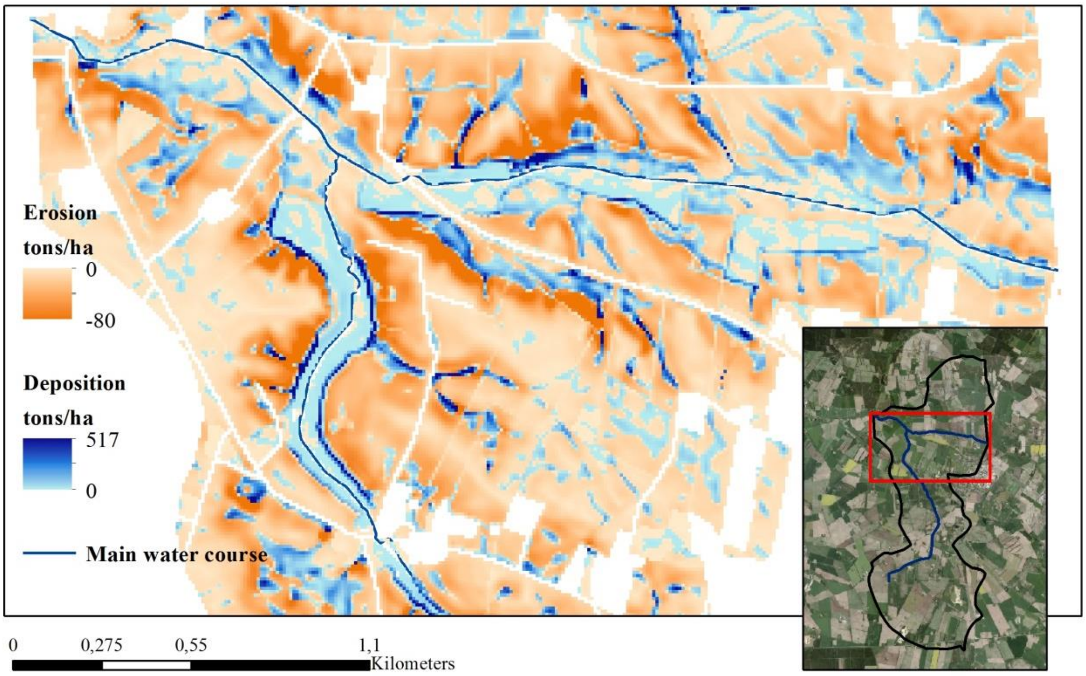


Figure 11, example of selected data of erosion and soil deposition pattern in the landscape, north in Spjald. The map to the right shows the main watercourse without any branching, this was necessary to simplify the analysis.

Figure 12 shows the visual connection between the pattern of erosion and deposition and the accumulative soil deposition that is at risk of entering the main watercourse. The pattern is *directional* towards the stream as the lowest point in the landscape, as can be seen in the terrain model in Figure 6 (left) section 6.1. Where there are blue areas of deposition, less deposition enters the stream, and where red areas are close to the stream more sediment is at risk of entering the stream.

The accumulated soil deposition is modelled by calculating what leaves one type of land use and enters the land use that is characterized as watercourse in the Basemap layer. Therefore, the watercourse feature in Figure 11 is replaced by the data layer of soil deposition in Figure 12.

The boxes in Figure 12 point out examples of differences in risk of soil deposition in the stream, as a consequence of the surrounding conditions. In box 1 there are patches of both small amounts of erosion (light orange) and deposition (light blue) close to the stream, which results in medium to high risk of soil entering the stream visualized by yellow and red pixels respectively. The contrary is the case in box 2 where there are high amounts of erosion and subsequent deposition, but because most of the deposition occurs at a distance from the stream there is little risk of the sediments entering the stream. This effect was described earlier in section 6.1 in relation to Figure 8 where wet meadows and wetlands function as a natural buffer for soil deposition to the stream. This is an example of the effect of different land use in the erosion model as the C*P factor, described in section 5.3, is different on farmed land and on permanent grass. Box 3 depicts a similar scenario as in box 1, both areas have agricultural fields next to the stream with no buffering effect.

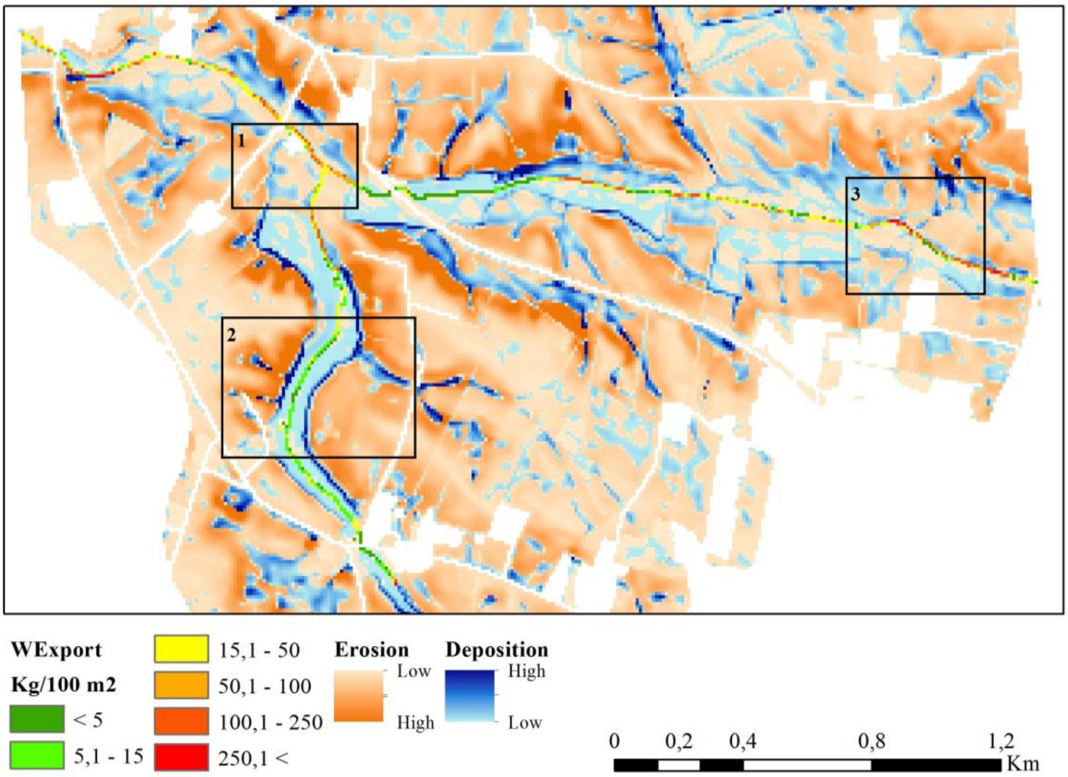


Figure 12, the visual connection between patterns of erosion, deposition and the accumulative deposition that risk entering the watercourse.

Table 7 shows the number of cells in each color category and confirm that there are few cells with very high amounts of deposition and most cells in the three lowest categories. The number of categories and the spacing is an expression of the accuracy of the data (Heckrath 2016b, pers.comm).

Table 7, number of cells within each category of soil deposition within the research area equivalent to the demarcation shown in Figure 11 - 13. Very few cells of soil deposition were detected further south in the stream, but they are also included in this table.

Number of cells 100 m² in each color category
132
131
185
96
84
15

The sum of deposition within each segment was calculated (Appendix 6). Based on this sum a classification of 6 classes was made and each segment was then given a color from low (dark green) to high (red). Figure 13 gives an indicator to identify hotspots in the WExport data layer. The categorization of the deposition in each cell does not correspond perfectly with the categories of segments.

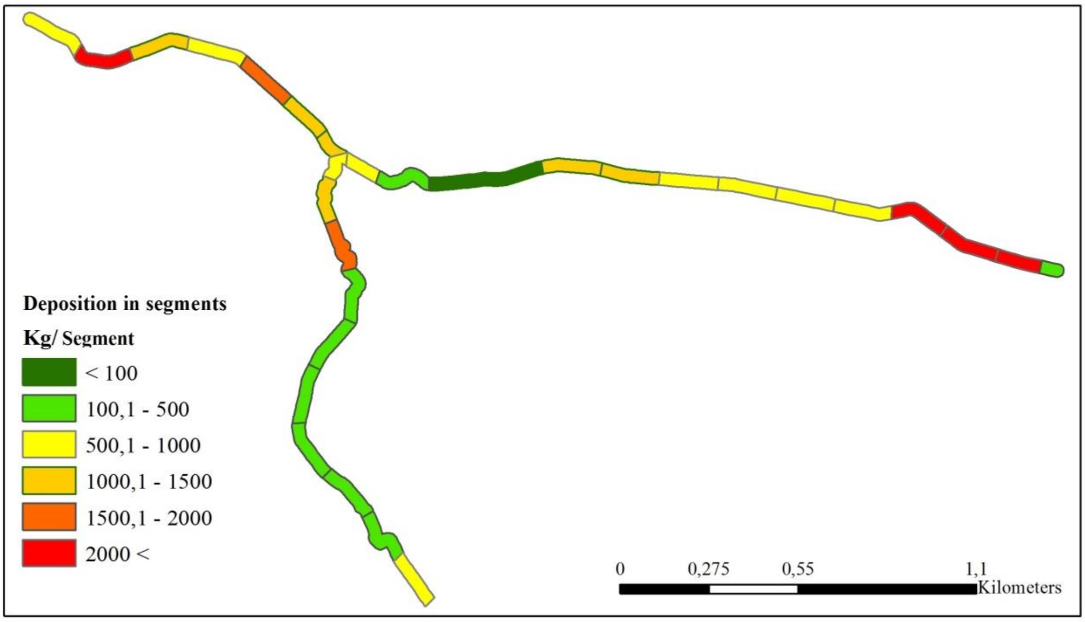


Figure 13, segments are given a color based on the sum of deposition within the segment.

35 segments are (of which 31 are visible in Figure 13) included in the analysis. With a buffer width of 40 m the average size of the segments is calculated to be 6600 m², which gives an average length of 166 m. From this, the kg soil per meter stream was calculated. Data is shown in Appendix 7.

Simple statistical analysis of method for detecting high risk of soil deposition

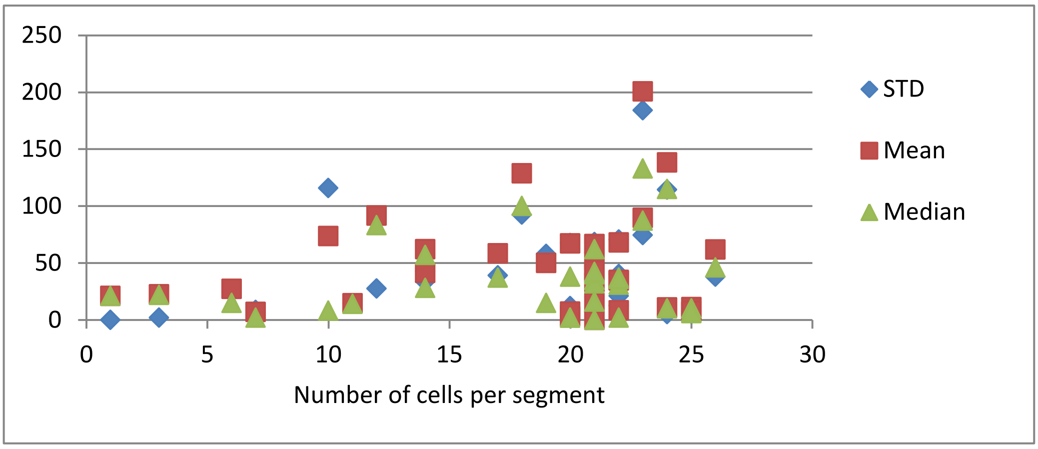
Figure 14 a show that there are large variations of deposition within each segment. The variation of the mean, median and the standard deviation (STD) somewhat follow each other indicating that high values of mean deposition per segment also have high values of STD and the median. The median of number of cells within a segment is 21.

Figure 14 b shows the coefficient of variance (CV). It is a measure of the ratio of the STD to the mean expressed as a percentage. Very small and very large values are highly influential and if these are excluded, there is no trend and the CV coefficient is constant around 100. The majority of values lie around 50 – 150 indicating that the variation constitutes 100 % of the mean value. The figure indicates that the data is highly variable.

Visually one can detect an upward trend in the data points in Figure 14 a, this is due to the fact that more cells with deposition data can contain more variation, but when the STD is corrected for the mean there is no trend as shown with the coefficient variance (Figure 14 b).

The data used to generate these figures are shown in Appendix 6.

14 a



14 b

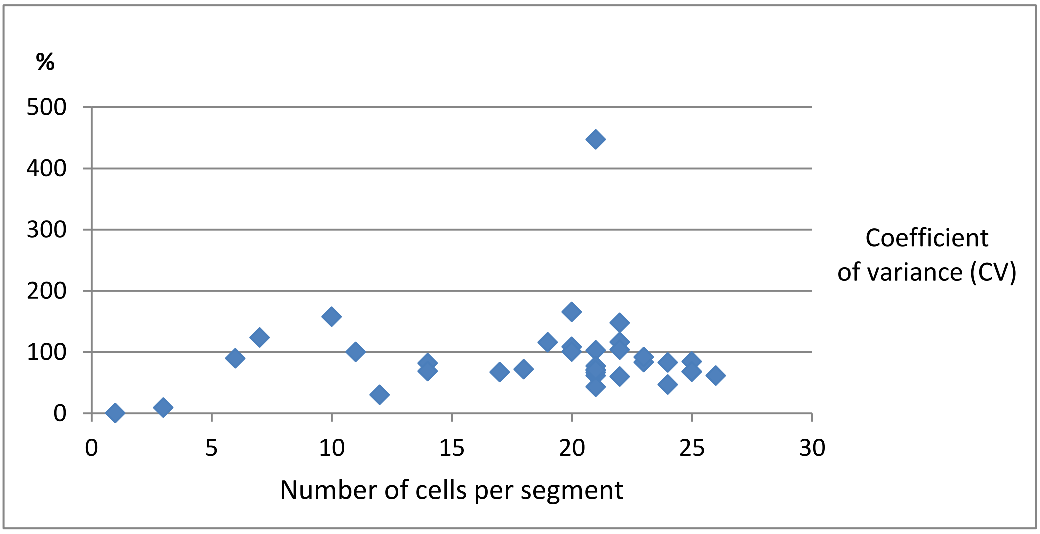


Figure14 a; variation of data plotted against the number of cells in each segment and 14 b; coefficient of variance (CV) plotted against number of cells in each segment.

7.2 Results of case interviews

The contextual meaning is interpreted as truthfully and sober as possible. Boxes 1 – 6 contain records of conversation with farmers. Selected Danish quotes can be found in Appendix 5.

Table 8, a translation of the table shown to the farmer at the interview. The question being: how would you rate the following statement describing your management style; 1 = fitting well and 6 = not fitting at all. The farmer (color coded 1 – 5) was also asked to range which statement would describe his management style the best (question 1.3 in Appendix 3)

Statement	Rating						Best fit overall
	1	2	3	4	5	6	
The main purpose of the farm is to make high yields	1, 3, 4	5				2	2, 4, 5
I would like to minimize the work effort to have more leisure	3	1	2, 5	4			
I want to produce as much as possible on my own farm to minimize import	1, 2, 3, 4, 5						1
It is important to be flexible for rapid adaptation to changing prices or frame condition	3, 4	5				2	3

Farmer no. 1, 2 and 5 showed me around some of their fields. Farmer no. 1 and 2 showed me where they thought an IBZ could be placed.

Four of the five farmers that were interviewed had a good understanding of the mechanisms of nutrient transportation and removal. Farmer no. 2 is an agronomist, and farmer no. 5 mentioned that when water was retained for a certain time both ocher and nitrate would be removed. Farmer number 3 however, had a poor understanding of these mechanisms. This was maybe the reason for sometimes giving inconsistent and contradictory answers. His answers are therefore not included in Figure 17. Nevertheless, he had strong opinions on environmental issues and some of his answers are therefore included as he might represent a group of farmers with less understanding of the fate of nutrient and their environmental effect. When there was no clear response from the farmer in terms of a single number (in Table 8), the answers have been translated into a number based on what was said in the conversation. At one point there was a discrepancy between how the farmer described the way he acquired knowledge before he saw the Figure 16 and after.

Box1. Main answers from part one regarding his values as a farmer (1.1 – 1-5).

"*What is good farming?*" Farmer no. 2 said that he wants his farm to be in balance, he defined the word "balance" as having a good crop rotation that is in balance so that soil fertility doesn't deteriorate but is improved. On the same question farmer no. 4 answered that he aimed at optimal use of his land; everything is in rotation. He wanted to get the most out of what he has got, also the wet areas that are difficult to cultivate. Farmer no. 5 also valued the optimal use of resources and also mentioned his employees as a resource that needed perform as optimal as possible.

Box continuous on next page.

"*What aspect of the farm that is especially important to have under control*". Farmer no. 4 answered that he really tries to pollute as little as possible, but that farmers are not credited for this. Farmer no. 5 pointed out that they as professionals are interested in developing new production methods. Nevertheless he is aware that even sensible agricultural production inevitably does pollute.

In Figure 15 the two younger farmers (no. 5 (42 y.) and no. 4 (45 y.)) with bigger farms (546 and 344 ha respectively) place themselves further to the left, towards high input/output as a strategy to create revenue. The two older farmers (no. 1 (60 y.) and no. 2 (61 y.)) with smaller farms (90 and 101 ha respectively) place themselves further towards the strategy of minimizing costs to make revenue.

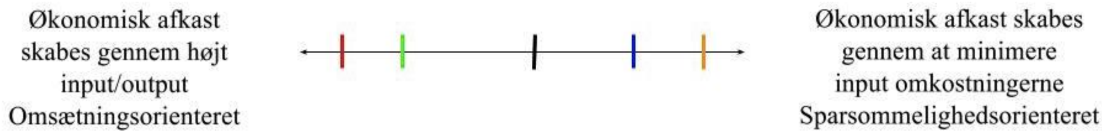


Figure 15, shows the answers from farmers 1 – 5 (see color coding) regarding whether economic return is made by high input/output, turnover oriented (left) or by minimizing input costs, thrift oriented (right) (Figure 1.4 Appendix 4).

In figure 16 the two organic farmers (no. 2 and no. 4) place themselves to the left where knowledge is generate through their own experiences and observations in the field. The two conventional dairy farmers (no. 1 and no. 5) place themselves in the middle. Though the older farmer (blue line) was very particular about the quality of the advisory service, if he didn't agree with the advisor, then they were of no use. Farmer no. 3 talked mainly about using external knowledge and advisors, but did also place himself in the middle.

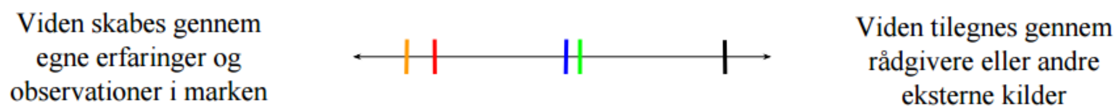


Figure 16, shows answers from farmers 1 – 5 (se color coding) regarding acquisition and creation of knowledge, whether it is dominantly from own experiences and observations in the field (left) or from external sources like advisors, professional magazines etc.

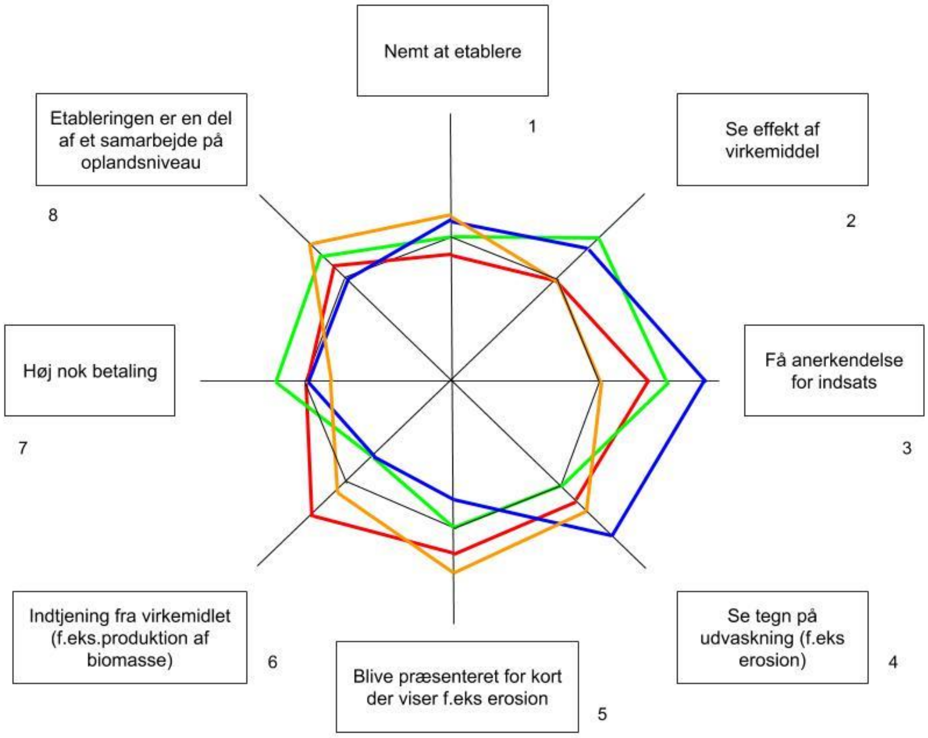


Figure 17, answers from 4 out of 5 interviewed farmers. For translation of the 8 criteria see section 6.3. For description of the farmers and their color code see Table 5 in section 6.3.

The different rating of the importance of the same questions cannot be compared between farmers. The rating was interpreted from how strongly the farmers would word their answers, and in that sense they can be compared to some degree. Farmer number 1, 3 and 5 expressed frustration about how farmers are perceived in society and by politicians and felt strongly about criteria no. 3 ("getting recognition for the effort"), but farmer no. 2 seemed indifferent about it as he said, "that's always nice to get", and judging by the tone and the context his answer was rated as "neither nor".

As can be seen in Figure 17, there were no strong feelings about criteria no. 1 ("easy to establish) affecting the motivation.

Box 2. Main answers from part two, the farmers' role in environmental issues (2.1 – 2.5).

Criteria 4 and 5 in Figure 17 were discussed in connection to each other because they could be understood as opposites. Farmer no. 1 had very strong opinions about the motivation being strongly connected to seeing signs yourself and not being told by someone else that there would be areas on his land at risk of nutrient losses. Contrary, farmer no. 2 and 3 both said that they could be convinced by an advisor with a proposal of some sort of environmental action. Nevertheless, farmer no. 3 pointed out that seeing the signs yourself was tied to a professional pride of knowing your land. Farmer no. 2 said that he could be persuaded to making an IBZ if he was convinced that leading the drainage water over grass was not enough. Farmer no. 4 and 5 said that they imagined that a combination of the two would suit them best. Seeing the effect of a measure was very important to farmer no. 5 who was of the opinion that if the effect could not be seen, then the measure should not be established. *Box continuous on the next page.*

Farmer no. 5 was pessimistic regarding the possibilities of an income from biomass production in the measure. He had had willow for 3 years, but due to high costs of planting and harvesting he was not able to make a profit from it. He did not see this as a motivational factor because he thought it was unrealistic. Farmer no. 4 was more optimistic.

Box 3. Not for the money?

Figure 17 shows that getting enough payment for establishing a measure was not a major issue for the farmers. Farmer no. 2 was very explicit about not being motivated by payment nor getting revenue from the measure. In an earlier project he could have gotten compensation for some land that was submitted to a re-meandering project, but instead the municipality helped him making a small lake on his land.

The motivation of farmer no. 4 for participating in environmental action was tied to the possibility for cultivating the remaining land more intensive and having a long-term economic incentive for participating in environmental schemes. Farmer no. 1 was of similar opinion. Farmer no. 5 said that the economic incitement was the strongest motivation, but contrary to farmer 2 and 4 he seemed more motivated by being paid for the actual establishment of a measure.

"*How do you see the connection of leaching, the effect in the water environment and what you do on your land?*" Farmer no. 1 was of the clear opinion that 30 years ago something really had to be done and the effect of too much nutrients and inefficient techniques was to blame. Now, on the other hand he was more uncertain of what is actually leached, but he knew that farmers are really struggling to keep up the quality and competitiveness and was sure that 10% higher fertilizer load could not be measured in the water environment. Regardless, he would consider establishing a buffer zone measure like an IBZ. Farmer no. 4 saw economic incitement as in broad terms as the main source of change. He said that if there is a real income for a pig farmer in having grazing animals, they would come.

Box 4. Main answers from part three, a new catchment advisor (3.1 – 3.5).

Farmer no. 4 was positive towards the establishment of environmental measures on catchment level as part of a collaborative process. Also, farmer no. 2 said that making connected projects would be more beneficial for the status of the water course and overall nature.

On the question whether farmer no. 2 could picture the IBZ being used to recycle nutrients, he answered that the animals would do that, so grazing would be better than trees. He would be more interested in grazing schemes than planting and harvesting trees.

"*What responsibility do you feel that farmers have to protect the water bodies?*" Farmer no. 4 answered that it is in our own interest to take as good care of the environment as possible. Farmer no. 5 answered somewhat like the question was a sign of distrust in farmers and said that they of course did not spray chemicals or fertilizers directly into the stream.

Box 5. Reactions to the maps.

"*Can the maps be used as inspiration for planning environmental action*?" Farmer no. 4 was excited to see the maps and thought they were interesting. Farmer no. 5 was more of the opinion that the farmer himself would be able to point out areas that he was willing to submit for AEMs. Furthermore, he expressed that most farmers would be willing to participate and contribute with land. Farmer no. 1 said that he thought all farmers would be interested in collaborating to secure further reduction of nutrient losses to rectify the use of more nutrients on the field.

A great deal of frustrations was registered when talking about farmers' own ideas for securing nutrient retention. Farmer no. 5 wished that farmers would be allowed to fertilize more if they somehow could prove that no nutrients were leached, and for that they had many ideas that were not acknowledged. Both farmer no. 3 and no. 1 expressed frustrations about environmental regulations, some rules did not make sense and were a bureaucratic nuisance. Money, that could have been spent elsewhere, was spent to check up on them, undermining the farmers' sense of professionalism.

What about §3? Box 6.

The issue of §3 areas was not discussed with all farmers, but when mentioned during the conversation with farmer no. 4, he said it was very important to get a guarantee that the area is not "stolen" after a certain period. "*What if the area is taken permanently out of production to establish an IBZ*?" Farmer no. 4 answered that if the other areas could produce more by being cultivated more intensive, it could be tolerated. Additionally, he pointed out that taking land permanently out of production would have implications on administrating a farmers' debt. Farmer no. 2 was not concerned about areas on his farm growing into a §3 areas, he thought of these areas as permanently converted to nature areas anyway.

8. Discussion

In this section the results of the two analyses will be discussed. Section 8.1 discusses the effect of the IBZ and the GIS analysis is discussed in 8.2. The interviews conducted are discussed in section 8.3. Section 8.4 discusses elements that may lead to changed behavior of farmers and what leads to the action of implementing IBZs.

8.1 The effect of the IBZ

The preliminary results from Fillerup pilot area in Norsminde show promising results, but there are several issues that need to be clarified. Infiltration of water is said to be enhanced with trees (Christen and Dalgaard 2013), but the study of Dittert, Wotzel, and Sattelmacher (2006) shows that root growth can be negatively affected by saturated soil. The tree roots exudates also function as an energy source (an electron donor) for denitrifying bacteria in the soil, and water-plants provide energy for denitrifyers in the sediment in the ditch. It can be questioned if these are the optimal sources or whether the source of electron donor can be enhanced. Several studies have been conducted on optimizing denitrification in what is known as bioreactors (Schipper et al. 2010; Christianson et al. 2011; Bock et al. 2015) and constructed wetlands with filter matrices (Kjærgaard and Hoffmann 2013).

Nitrate losses are at the highest during high rates of mineralization combined with high water flow (precipitation). Mineralized N that is not taken up during the growth period may leach during the winter and early spring months with high precipitation. During winter months mineralization and denitrification rates are low due to low temperature and low biological activity. Table 9 shows results of denitrification rates affected by soil type and temperature (Vinther 1990). Denitrification rates are significantly higher on heavier soils (JB 5) at higher temperature and higher water saturation. Therefore it is difficult to synchronize the timing of high risk of nitrate losses to high denitrification rates.

Table 9, denitrification is low in winter (Vinther 1990).

Temperature °C	Jyndevad (JB1)		Askov (JB5)	
	80% FC*	140% FC	75% FC	125%FC
+10	0.01	0.01	0.05	0.44
+20	0.05	0.08	0.34	2.49

*Field Capacity

Soil structure and soil texture are important factors for erosion and hydrology. The way water move preferentially through soil determines the sub surface route that the nutrients take and is thus important for the retention time and subsequently the rates of denitrification. This can be seen in Table 9. Soil with higher clay content has higher water holding capacity (or field capacity), which creates lower oxygen levels, promoting the activity of denitrifying bacteria.

The current soil mapping in Denmark is based on soil samples and interpolation between the measuring points that are from 7 – 60 km apart (Adhikari et al. 2013). This creates uncertainties when the maps are used on a small scale (i.e. farm scale). The scale of the accuracy of measurements to make maps is a big challenge when planning on a farm and field scale and this is further discussed in section 8.2 and 8.3.

Creating the proper scaling of the facility requires thorough knowledge on topography and hydrology of the contributing area. As the retention time is a key factor in nitrate removal, it is important to know the nitrate load that is fed into the drainage system. The reduction potential of nitrate moving from the root zone through the soil and towards the stream includes many unknown factors and data on field level is not available. Groundwater that enters the drains will dilute the nitrate concentration, and is also difficult to estimate. Additionally, knowledge about surface water flow, erosion rates and P status of the soil in the field are all factors that require detailed data if quantitative prediction on efficiency of nutrient removal is to be made.

Saturation of soil promotes denitrification, but can then lead to release of P when ferric hydroxides carrying P are dissolved by reduction (Shenker et al. 2005).

8.2 GIS analysis

The GIS analysis conducted in this study is a pilot study testing a possible approach for identifying stretches of the stream that are at risk of receiving high amounts of sediments. The accuracy of the results indicates that alternative methods must be developed in order to more precisely pinpoint hotspots of soil deposition entering streams.

In this small scale trial, a visual evaluation can be made to determine how well the method and the length of segments is to catch the hotspots of soil deposition. As can be seen Figure 18 a) and b) the red segment contains cells with high amounts (red cells with over 2500 kg soil /100m^2) of deposition and thus gives this segment a high value. On the other hand, Figure 18 c) shows an example of a segment containing both green and dark orange cells and therefor the segment is given an intermediate value. If this segment had been placed differently this hotspot would have been targeted and the segment would receive an equally higher value and point to this hotspot. Critical source areas of erosion (and therefore also deposition) can be concentrated within small areas, so the smaller the segments are the higher the possibility is to target the hot spots in the WExport data. Figure 14 b in section 7.1 indicates that the method of segmenting the stream was not suitable for detecting significant differences between high and low deposition.

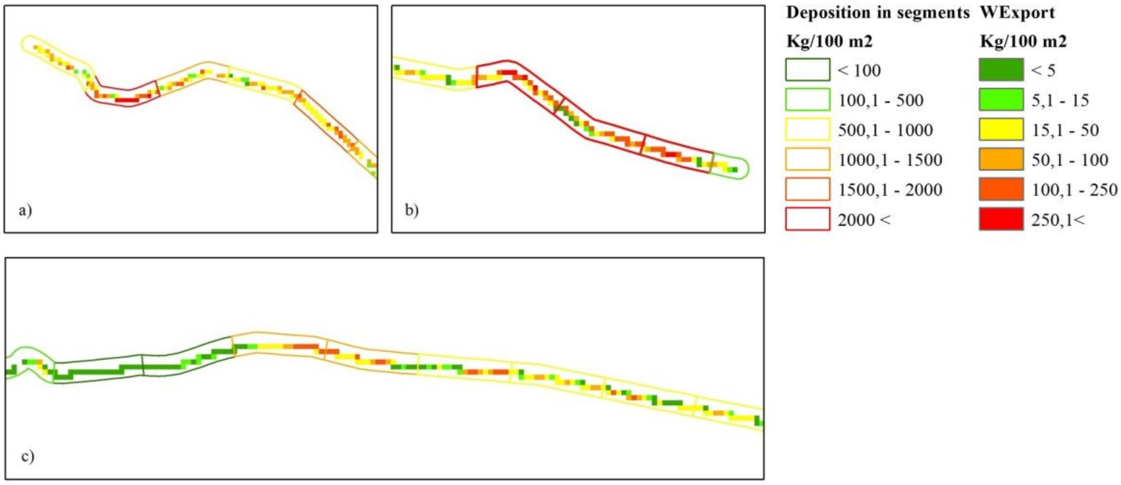


Figure 18, accumulated soil deposition is shown within segments. A) and b) shows where a segments gets a high value due to capturing a hot spot, while c) shows a hot spot being divided by two segments and therefore getting a lower value.

Figure 18 also shows that the method is not able to cut perpendicular on the stream. They are cut perpendicular between two points (Figure 13 b). The method must also be able to handle how to segment broad areas of deposition along twisted and or branched stretches of the stream in a consistent way. Ditches in agricultural areas must also be included.

In the literature there are usually only three categories of erosion risk and one category for deposition shown in the symbology[5]; low, medium, high plus one category of soil deposition (e.g. Heckrath, Andersen, and Jensen 2015). Six categories for deposition as shown in the present study (Figure 13) may therefore suggest a higher degree of accuracy than actually achieved. The display of categories of kg/segment also implies that the losses can be quantified with this accuracy. The amounts of soil and P lost to the watercourse will not be discussed further because the data is not validated and therefore contain large uncertainties.

The buffer around the constructed main watercourse was not used as such; it was merely a method for dividing the stream into segments. In Figure 14 one can easily see the effect on the size of the segments of only one branch, the segments at the crossing is much smaller than the rest. The constructed main watercourse also served the purpose to ensure that the stream was a continuous feature as the equal spacing of the segmentation process required this. The smaller segments in the branching of the stream are a result of a discontinuous stream data layer.

Equally spaced segments always have a risk of not detecting hotspots of deposition. Therefore, a method of segmenting based on the difference between values of cell clusters is one possibility. Alternative methods, not using segmentation, to detect clusters of cells with high deposition should also be explored.

[5] The coloring of the maps and legend.

As the data used in the model (WaTEM and WExport) are not aimed at being used for quantitative assessment, it is less relevant to look at the specific number of amount of soil entering the stream. What is more relevant is to look at the differences between segments and whether the method can detect high risk areas for deposition entering the watercourse. Furthermore because the data is not properly validated either, maximum and minimum values might be abnormal.

When placing an IBZ it is of great relevance to know on which side of the stream the IBZ should be placed. At the moment it is not possible to determine from which side of the watercourse the deposition is coming from and splitting the stream segments in left/right is challenging as the streams vector layer is not always recorded in the same direction. The background data does contain this information so it would be a matter of setting model criteria to make this information accessible. This separation is also important regarding drainage, but due to lack of systematic data about drainage this must, in many cases, be determined by visiting the actual field.

As have been mentioned, the Basemap does not detect small watercourses, which is the case of the watercourse going north-south in Spjald. Therefore there are no output data on the sediment transportation into smaller streams. This could have been overcome by looking at high values of export out of the field (in the data from WExport) close to the vector layer of watercourses (FOT watercourses) (Heckrath 2016b, pers.comm).

Future improvements

To further develop the model, the representation of streams needs to be improved. The representation of plant cover and management (C*P factor, see section 5.6) are factors that are currently being developed to be more differentiated (Heckrath 2016a, pers.comm). Buffer zone scenarios based on an alternative method for pointing out hot spots of deposition potentially entering the watercourse are made by the Department of Agroecology (Heckrath 2016c, pers.comm).

The importance of drainage on the placement and effect of the IBZ and the lack of knowledge on this area emphasises the need for direct interaction with the farmers holding the local knowledge. Though information about drainage exists in private companies it is not readily available. The same holds for information about the P status of the soil. The farmer usually has knowledge about this, which is an important criterion in assessing the risk of P loss as a result of soil erosion.

This method of GIS analysis only targets nutrient losses by overland sediment transport, and is but one issue that an IBZ can handle.

The reduction target determining whether to focus on N or P in part 1 of the flowchart and practical requirements for IBZ establishment in part 3 of the flowchart should be incorporated as weighted criteria in the spatial analysis in the GIS analysis. Also, a more thorough mapping of protected nature must be included. Meadows and wetlands around streams function as natural buffers between intensively farmed fields and the stream, but excess nutrient load is detrimental to the biodiversity in these nature types. The IBZ can possibly also function as a buffer not only for the watercourses but also for the protected nature.

8.3 Case interview analysis

Two main points were made from the interviews and can be summarized as the following:

1. Farmers are willing to participate with land for targeted AEM and collaborative projects.

2. The economic incentive in increased fertilizer norms is the main driver for change.

The maps shown to the farmers only show the erosion/deposition pattern and not the accumulative transport (Figure 11 and 12). The reason for this was that the latter might be perceived as a blueprint or as an absolute end result of what is going on in the landscape. This could possibly confirm the perception of models as being impossible to understand and to trust. It was assessed that showing patterns of erosion and deposition would be a more pedagogical approach and more fruitful as a starting point for an open discussion. A map like Figure 11 is more intuitive than showing only the accumulated deposition in the stream, because the pattern also coincides with other landscape elements like elevation and water flow. It was also stressed not to focus on the values of maximum and minimum deposition and erosion. In that regard the numbers should not have been showed on the maps at all but rather the labels "high" and "low" as in Figure 11 and 12 opposed to the map in Appendix 5 a.

All farmers agreed that less productive areas that were sometimes more of a nuisance could be found on most farms and used for environmental measures, but there were different opinions on what kind of measures that should be used. Most farmers, with the exception of farmer no. 2, said that the motivation for giving up "bad" land was being able to cultivate the good land more intensively. The issue of needing to take "good" land out of production due to high risk of nutrient losses was not discussed, but is important to investigate further.

Reactions to the maps

The maps were recognized as representing the landscape and there was an understanding of the premise that the erosion was based on a worst case scenario of winter wheat. So it seems like the maps that were shown (Appendix 5) were accepted as representative for their land. If there is a visual recognition of the pattern in the landscape, they can be accepted even if the maps were based on models with simplified assumptions. Maps with marking of possible locations for an IBZ were not made because the maps of accumulated transport (Figure 12) did not cover the area of all the farmers' fields. Reactions to this type of maps are also important to investigate, but must be introduced very carefully not to impose a top-down approach.

A map of topography was also included in the material shown to the farmer (Appendix 5 b), the intention was to show the connection to the erosion/deposition map. The topographical map proved less helpful because the resolution was 48x48 m opposed to 10x10 m in the erosion/deposition map. Digital terrain models (DTM) exist in higher resolution but were not available for this study. As topography, hydrology and soil type are very important factors in both nitrate and P losses visualization of connection between these factors could be a powerful pedagogical tool for dissemination of nutrient losses.

The maps were accepted as a planning tool to some degree, but monitoring and sampling of drainage water was mentioned by farmer no. 3, 4 and 5 as the most reliable source for knowledge. This can again be seen as a representation of the two barriers; if the terms for participation in an AEM are accepted, then the maps can be useful. Models and their outputs are invaluable tools in planning. However, they have been perceived by the farmer as a "truth" that could not be trusted because their background assumptions and limitations have not been understood by the farmers. To build trust around the use of models, these issues have to be disseminated to the farmers in an understandable and pedagogical way.

It was interesting to drive around the area that was so intensively studied from a map perspective and in spite of that being disorientated. The same experience was noticed when the farmers tried to orient himself in the map. This shows the importance of being aware that farmers and non-local advisors have literally different views on an area.

Seeing the results of environmental measures

The visual effect of a measure seems to be an important factor. What led to this assumption was the emphasis farmer no. 5 had on ocher lake projects; he could see that now all the rocks downstream were uncolored. He concluded that this measure gave "the highest environmental effect for the money spent", and regarded ocher as a bigger problem than nitrate leaching. He also had successful experiences with catch crops in maize for preventing erosion. Fleury et al. (2015) points out the connection between the function of the measure to the production on the farm being a motivational factor. Their study used few flower species as indicators, which made results easy to see and measure. Because the effect on water quality of an IBZ is impossible to measure (without technical set up), this points out a difficulty in promoting the IBZ. Concrete derived effects are also difficult to quantify and synergy effects for the farm production are even more challenging to pinpoint.

Signs of erosion and deposition might be one of the most visible signs of nutrient losses, something that also was exemplified in the recognition in the maps. Battling erosion in the fields with cover crops is an example of a win-win situation for the farmer to both maintain fertile soil and maintain the improvement of the water environment. The IBZ does not target in-field erosion, only deposition, but developing ways to recirculate the nutrient rich material in the IBZ could potentially create another win-win situation.

Receiving recognition as a motivational factor

There were strong feelings about the motivational criteria "*receive recognition for effort*", but it could be an expression of general frustration of the societal opinion of agriculture and farmers. The thought of participating with areas of "bad" land as part of a bigger collaborative project on catchment scale was not opposed. The incentive again being that the good land might be more intensively cultivated. In connection to the talk about collaborative projects farmer no. 1 felt strongly about the possibility that the projects would result in the agricultural sector getting recognition and being able to prove that there are no nutrient losses. Exactly how motivation could be created through ensuring recognition was not discussed.

This is consistent with the findings of Sattler and Nagel (2010) and Fleury et al. (2015). The latter found positive responses on motivation as a result of a competition of flower diversity, an official ceremony with a prize and dissemination of the effort and results. Though the project recognizes motivational factors, many of the participants were already a part of the AES to promote pasture biodiversity, and farmers who were not, had no intention to join. This somewhat undermines the potential of the motivational measures that were investigated in the latter study.

Farmers interviewed by Schroeder, Chaplin, and Isselstein (2015) were of the opinion that management flexibility was reduced by AES partly through excess paperwork, and it had a negative influence on participating in AES. Farmer no. 1, in this current study, had likewise strong opinions on the amount of bureaucracy as a modern farmer. He suggested that the resources spent on "checking" them could be spent on the suggested catchment advisor instead (se section 5.2). Farmer no. 3 said that if the state took over his farm land and all the paper work, he would gladly do as he was told and drive the tractor, but then the sense of connection and responsibility to the land would be lost. The interview reveals that the farmers want to farm the land in a way that they see as good agricultural practice. They are proud professionals, they do not want to spend their time filling out forms and being checked up on.

Because farmer no. 2 and 4 were dairy farmers, they were more interested in land for grazing or hay production than a smaller area planted with trees (an IBZ). The underlying logic might also be that it is *his* land, he paid for it. As farmer no. 4 said: He is much more interested in actually cultivating his land. Farmer no. 3 was a pig farmer and had recently participated with some land for a nature project managed by the municipality. The land was currently in-between regulations. He felt conflicted between fulfilling EU regulations of having no trees on the land and not wanting to cut down the trees so that the land could contribute with some biodiversity. Even though he was a pig farmer he was still open to the possibility to contribute with permanent grass on areas of peat soil along the stream, showing that one cannot make generalizations or prediction of motivation based on production system.

Case interview method

Because of a small sample size, there are no obvious patterns or categorization of the farmers based on size, age and production system (organic /conventional), but this could also suggest that a generalization of farmers' decision making is in itself difficult to make. There are some answers, however, that coincide with age and production system. The two age groups used knowledge more similarly and farmers with different production systems though similarly about strategies to make revenue. Ultimately, this categorization could also be a product of biased expectations prior to the interviews.

Farmer no. 2 had a mixed farm with grazing animals and vegetable production and was therefore a poor representative for the majority of farmers in the area. Dairy farmers represent the majority of the production types in Western Jutland (Dst 2012). The three dairy farmers represent a cropping system that includes grass and clover, whereas the farmer no. 3 was the only pig farmer representing a cereal crop rotation. Cereal crops are more prone to erosion (Morgan 2005) and because the pig farmer has no way of utilizing grass, there is no incentive for incorporating this in the rotation. The pig farmer probably would be more interested in taking out less land to establish e.g. an IBZ in contrast to the farmers with grazing animals that were more interested in utilizing all their land for production. This aspect was not possible to investigate further in this study.

Wording the questions

The questions were worded quite simple for the reasons explained in the section 6.3. Questions in part 2 and part 3 did not work as intended in the interview setting, they were too long and abstract, and should have been formulated in a more oral language. Even though the farmer did not have to read them, it was clear that they did not work well as a conversation starter, because the conversation became interrupted and diverted from a normal conversation (Brinkmann and Tanggaard 2010). The fact that contradictory answers were given before and after the farmer saw the question also confirms the importance of wording the questions and how the question itself can shape the answer.

Results from the web (Figure 17), question 7 ("high enough payment") got surprisingly insignificant reaction, no strong feeling were recorded. The answers could have been better interpreted with more specific knowledge about how the farm economics is constructed and how farmers use financial support or compensation schemes for environmental measures.

Numerous factors and multiple aspects

No generalization can be made on the basis of the five interviews conducted in this study, but they have contributed with valuable and nuanced insight in a complex matter. The statements of the farmers are also easily recognized in the literature used in this work.

Helping a farmer make a decision regarding an IBZ is a complex matter and a simplification of this choice to fit into a scheme with a logic causality of "if the farmer has the management style of A, and the objective of B – then the strategy is C" is evaluated not to be a fruitful approach for overcoming the first barrier. Though, a carefully planned and well tested survey to record criteria for decision-making could create a meaningful score. This could create insight to the farmers' rationale. The score could then function as a pointer towards a limited number of implementation strategies. E.g. if the farmer is interested in possibilities for hunting on his land, then the IBZs' possibility to attract wildlife could be a better argument than for a farmer that is interested in biomass production.

Schroeder, Chaplin, and Isselstein (2015) evaluated the method of Theory of Planning Behavior to be highly useful. Due to the intricate technicalities of the method expressing further criticism to the method is challenging. Though, it is a concern that the method is overly mechanistic for capturing the complexity of making a choice. The study is unfortunately not particular about what factors specifically made the farmer join the AES in the first place (it is mentioned that many farmers joined more than 5 years before the interview), but rather that the farmers now recognize various positive effects of the AES.

The question whether a conversation about the farmers' management style and motivational factors can be a space for working towards consensus on environmental issues is not easily answered. More interviews, time to follow up and register potential changes would be needed to further investigate the potential for achieving consensus through conversation. Making an in-depth interview session with every farmer in Denmark may also be unrealistic, and the interview in itself might not be the determining factor that makes farmers change their opinion about the ecological status of the water environment or the need for action. The AGWAPLAN project assumes that knowledge and involvement will lead to the farmer understanding the causal effect of what is done on the fields and how that effects the surrounding environment.

Realizing that achieving consensus about the current ecological status in the water environment is not the sole cause of action and that action can be spurred in other ways makes the need for consensus less urgent. Building the strategy on motivations makes it is less important what the farmer thinks about the ecological status of the water environment. Nevertheless the fact that all farmers expressed (except farmer no. 2) frustration about current frame conditions and the lack of recognition, suggests that *not* talking to the farmer and including their opinions is not a viable strategy. Therefore, a list of recommended criteria to discuss should be part of an exploratory approach and could potentially result in creating consensus on the need for a collective effort to improve the ecological state of water bodies.

If/when the first barrier is overcome, the setting of the advisory process can provide guidance about how the farmer can make an informed choice that is compatible with the farmers' values *and* helps improve the ecological status of the water bodies.

8.4 Making change happen

Farmers and their interest organizations are requesting more measurements, which is one of the elements in the new agricultural action plan (Miljø- og Fødevareministeriet 2015). Conclusions from the AGWAPLAN (2009a) project state that "*data must be precise, relevant and effective if they are to be acted on*" and this is still relevant, but the question is *how* precise. The research community continuosly work on data collection to increase the resolution of the national models to improve model predictions of nutrient losses on a smaller scale. Fleury et al. (2015) questions whether the farmers must go through a cultural change "*by developing an environmental ethic and mind-set in order for [these] changes in practice to be sustainable*". This raises the question of whether the resolution and specificity of the data is the catalyst for changing the farmers' attitude and creating consensus about the environmental impact from farming. What resolution of data and measurements are needed to convince farmers of collaborative action? Is the uncertainty in models (and the fact that every drain cannot be monitored) always going be an argument for not acting before more data is available? These are important questions for the development of an advisory tool for collaborating with farmers to make real improvement in the ecological status in surface waters threatened by pollution. Data collection may be a never ending task, therefore, continuous development of strategies to give the farmers the possibility to act on new knowledge is important.

A single focus on coupling the farm advisory approaches to monitoring data could maintain the implementation process within the paradigm of always needing data in the highest resolution to get credibility, and thereby delay necessary actions. Any amount of uncertainty can then be used to undermine credibility. Many more questions are spurred by this issue: Can the farmers' attitude change without farmspecific measurements and specific reduction targets? Or can motivational factors be used to persuade farmers to act and thus change the focus away from reduced nutrient concentrations (mg/l) as the sole measure of effect? Is a constructive discussion with the farmer dependent solely on quantitative results and specific reduction targets? Could a holistic method, using indicators of the derived effect of nutrient removal and other services like more wildlife, a beautiful landscape, potential harvest of biomass, be developed for IBZ function to better support motivational factors?

Experiences from the present case study indicate that these questions need to be addressed to facilitate a successful implementation of IBZ.

The laymans report from the AGWAPLAN (2009b) project state that change of land use (to decrease nutrient losses) "*…demands that the farmer has knowledge, acceptance and motivation to reach the objectives*" and that the objective must be a well-defined target that the farmer can pursue. As have been argued in the present work, not all farmers have this knowledge, acceptance and motivation. This work is therefore in pursuit of an approach to fulfill the demand that the AGWAPLAN project puts forward as a requirement for action. The demand of a common objective also relates to the systemic conflict desribed by Bogetoft and Pruzan (1997) (see section 5.4). In order for the suprasystem (the over-all system, including all subsystems, the government) to pursue its own objectives (GES), the objectives of the subsystems (the farmers) must also be supported. According to AGWAPLAN (2009a) the way that farmers are persuaded to agree on the objective (changed behavior) is through knowledge and involvement. The assumption is that knowledge through informing the farmer, related to the reduction demands creates acceptance of the action needed. Dialogue creates motivation through involvement, leading to action through integrated advising (AGWAPLAN 2009a).

All conclusions from the AQWAPLAN project are in line with findings in the present case study, but the nature of the information and the transfer of knowledge as a factor for change is questioned.

The diffusion of innovation

Læssøe et al. (2013) discuss what aspect of motivation leads to action and change. They state that motivation can have many causes (e.g. core values) and can be influenced by communication, negotiation and knowledge.

An alternative approach to implement IBZs and transfer of knowledge that may bypass the first barrier (the need for consensus) is proposed based on experiences from AGWAPLAN and findings in the present work. The strategy can make the measure attractive for the farmer without requiring the acceptance of an environmental problem. Rogers (1983) concept of diffusion of innovation (also referred to in section 5.3 in Sattler and Nagel (2010)) states that an innovation must have a relative advantage; it is not enough to state that an IBZ has an "objective" advantage. The individual needs to perceive the measure as an advantage. Furthermore the measure needs to be perceived as compatible with existing values, not too complicated to understand, possible to test and produce visible results.

These principles are the reason for suggesting that the development of visible indicators for IBZ effect is needed. Indicators can function as motivational factors for public recognition and increased biodiversity (ecosystem services) as investigated in the study of Fleury et al. (2015). Also in this current approach the catchment advisor has the important role of a facilitator and communicator and needs the T-shaped skills (Bouma et al. 2011) (see section 5.4).

The importance of a well-functioning advisory service is also confirmed by Schroeder, Chaplin, and Isselstein (2015) as the majority of the farmers in the survey were of the opinion that the amount of environmental advice had "…*a big impact on a better understanding of ecological processes*" that would make it easier to join AES. Madsen and Noe (2009) also noted that the farmers' understanding changed as a result of the integrated advising used in the AGWAPLAN (2009b) project.

A parallel can be drawn to the comment of farmer no. 1 in the current investigation; he agreed that a new type of catchment advisor could become a platform for disseminate a better understanding for technical issues like results from modelling and biological processes. Transfer of knowledge that can lead to changing mindsets and subsequent action is therefore also an important part of a future strategy for implementing IBZ.

The wicked problem

The various possible approaches and the lack of achieving GES in surface waters confirm that engaging farmers in the establishment of IBZs as a differentiated regulation is indeed a wicked problem: "*There are no simple recipes to successfully manage wicked problems associated with innovation and sustainable development*" (Bouma et al. 2011). They require many different types of skills c.f. the need for T-shaped skills and also the abilities listed for the idea of a catchment advisor proposed by Wiborg and Gertz (2016, pers.comm) (see section 5.4).

Announcements of e.g. new regulations from authorities and advisors that try to impose a change of behavior can be seen disturbances to the complex farming system, and the reaction of the system cannot be predicted or controlled, the logic within the system decides how it reacts on the disturbance. The farmers' decision is taken within the farming system with its own logic and semantic (Noe and Alrøe 2012). This is an argument for an advisory tool to remain curious and exploratory instead of trying to impose a "correct choice" (Læssøe et al. 2013) and predict the optimal strategy for implementing IBZs or other AEMs based on survey scores and typologies.

Furthermore, the systemic conflict described by Bogetoft and Pruzan (1997) must be acknowledged; just as the farmers values and objectives needs to be regarded, it is also important to acknowledge that environmental researchers and authorities also have their own set of values and objectives. This may be another reason for the lack of consensus of the perception on the environmental problem and is similar to what Christen et al. (2015) found.

Overcoming the first barrier is in this work seen as essential to the process of working together with the farmer in improving the water environment. Nevertheless, agreeing on the need for collaborative action and knowing the optimal placement for an IBZ (second barrier) is not the same as actually establishing x number of IBZs. The establishment of IBZ or any other AES requires the right structure of funding, frame conditions and knowledge of future legal and economic implication for the farmer. These issues are not a part of this work, but are included as an element in Figure 4 part 2 b).

The fact that literature referred to in this work originates from other EU countries than Denmark, makes it challenging to transfer knowledge to Danish conditions. The farming sector and the environment are equally under pressure in Denmark. The country has both one of the strongest national environmental regulation in EU and is the most intensively farmed country in EU. Combined with not yet fulfilling the goals of the WFD of achieving GES in surface water makes the situation unique and not easily comparable to other EU countries.

9. Recommendations

Based on experiences from the GIS analysis, the literature reviewed and the analysis of farmers interviewed, the recommendations made here is a strategy to overcome the two preliminary barriers for implementing IBZ: Barrier 1; creating consensus on the need for collective efforts to improve the ecological status in the water environment (section 5.4, 7.2 and 8.4). Barrier 2; finding the optimal placing and establishing the Integrated Buffer Zone (section 5.2, 5.3, 7.1 and 8.2).

Tackling the first barrier is based on revealing motivation for action and for overcoming the second barrier, a method for placing the IBZ is proposed. In the present study, during the process of investigation, additional barriers have become apparent. Overcoming the two initially selected barriers does not necessarily ensure concrete action and tangible improvement on the water environment. Supporting the farmers' motivation with a strategy doesn't necessarily result in the farmer being able to establish an environmental measure. The IBZ, and the incorporation of the measure on the farm, needs to be supported with means to make it feasible. Furthermore, the environmental advising should not be funded by the farmers themselves, a system needs to support the advising of measures that farmers do not benefit from directly.

Answers to the question "reason for being a farmer", point towards similar ideas. Letting the farmer be a farmer seems to be the overall objective and core value for the farmer and being allowed to fertilize economically optimally is the main incentive for contributing with land for environmental projects. Therefore, ensuring flexibility in the production system and keeping the bureaucracy to a minimum should therefore be at the basis of a targeted regulation. This strategy builds on the possibility to bypass the first barrier ("*creating consensus on the need for collective effort to improve the ecological status in the water environment*") in several different ways so that the advisor can tailor a strategy for the farmer supporting his motivation.

These thoughts relate well to the idea of a catchment advisor (or team) (Wiborg and Gertz 2016) and also the notion that the farmers should not have to administrate differentiated restrictions themselves (Stelljes and Knoblauch 2015).

The outcome of the present study, supported by international literature, has pointed out the importance of visible results of environmental measures. Development of tangible indicators for nutrient removal could be a solution to this. An example of an illustrative indicator could be plant species that thrive in very nutrient rich environment as an indicator for high nutrient levels in the IBZ facility, and plants thriving in nutrient poor conditions in and around the stream, indicating that nutrients are removed. Species community development and biodiversity potential in buffer zones are investigated as part of work package 2 in the BufferTech project (BufferTech 2016c), and can potentially result in indicators for this purpose.

Indicators may support alternative reasons for establishing an IBZ, other than agreeing on poor water environment. Farmers that are interested in hunting could be presented with the possibilities of how an IBZ could attract wild life. Moreover, such indicators could also be used for disseminating to the public and in this way be used to honour the action and effort made by the farmers. Finding good indicators is challenging, and incorporating derived effects in GIS analysis is likewise complicated. Combining existing data on high nature value with data needed for localizing the placement for IBZ and other parameters, e.g., public access can subsequently be used to create different scenarios for collective environmental effort accommodating the different farmers' values, motivation, objectives and preferences.

When using maps as a communication tool, the most important factor is that the farmer can relate to the information shown on the map. The result of this case study shows that the patterns of erosion were relatable and that the farmers could recognize where events of heavy rain would cause erosion. Maps showing soil types are more difficult to relate to partly because of how the maps are constructed, see section 8.1 and because knowledge about soil conditions are complex and more indirect. An alternative strategy to using maps as the conversation starter could be to ask the farmer to tell about his experiences with his soil types, as a farmer. His experiences on soil P status and drainage could also be discussed in this more examining way. Personal experiences of disorientation and the differences between looking at the map and being in the landscape (and *vice versa* for the farmer) are also worth noting as part of the use and design of maps.

A detailed topographical map would be a neutral map to use as a starting point of talking about the connections to hydrology and soil types. Discussing the recommended topics below can make it possible for the advisor to contribute to the understanding of biophysical relationships and communicate possibilities and limitations of current models.

An additional note must be made on acquiring knowledge on values and motivation through interview questions (regarding recommendation 5 b in the following section). These questions must be very well thought out to be relatable for the farmer and reveal his more philosophical thoughts on his values as a farmer and his view on nature. What influences motivation and also realizing what your own motivations and values actually are, are complex issues.

Eight steps for implementing Integrated Buffer Zones(IBZ)

This work can be synthesized in the following recommendations for elements to include in an advisory tool:

1. Modelling of the risk of N and P losses to streams targeting recipient requirements.
2. Mapping of nature values, ecosystem services, the potential for hunting, bird watching and public access.
3. Mapping of the location suitable for IBZ and other agro environmental measures relevant for targeting recipient requirements.
4. Preparation of maps for presenting to farmers showing critical areas. Design and symbology (coloring of the maps) must be carefully thought out to avoid interpreting the maps as blueprints for placements. Pedagogical methods to explain connections between biophysical elements should be considered.
5. Conversation with farmers performed by the catchment advisor with T-shaped skills (section 5.4):
    a. Making inquiries about their values as a farmer, how they view nature, environmental impact and nature related interests (hunting, bird watching, interactions with the public etc.).
    b. Finding out what motivates the farmer, his motivation for collaborating with other farmers, the importance of societal recognition and interests in promoting public access.
    c. Getting the farmer to talk about his land and his observations of soil conditions, erosion, yield differences, drainage and soil P status.
    d. Invite the farmer to word his ideas of enhancing nature value on his land, protecting the watercourse and his motivation for doing this. This can be combined with a walk in his fields.
6. Only after conversation as described above should maps be presented.
    a. Asking if the farmer can recognize the critical areas of nutrient losses.
    b. Using this opportunity to explain the modeled background of the maps, their limitations and possibilities.
7. After summarizing the information about the farmer and his farm, suggestions on a forward strategy supporting the farmers profile can be presented to the farmer.
8. After evaluating answers from farmers in one region, groups of coherent farmers can be established and a collective strategy with a broad pallet of environmental measures can be developed.

Thereby, this recommendation is a procedure following four preparatory steps (1 – 4 above) and four additional steps of working together with the farmer (5 – 8 above). The application of this strategy must moreover be financially and legally supported to secure predictable and feasible frame conditions for the farmer. These elements relate to Figure 4 in section 5.3 and the front page illustration. Steps 1 – 4 above relate to part 1 a) and b) in Figure 4. Steps 5 and 6 relate to part 3 a) and b) in Figure 4. Steps 7 and 8 above also relate to the latter, but also towards the action itself (Figure 4) if legal barriers and frame conditions (part 2 b) in same figure) are viable.

10. Conclusions

In this thesis a GIS analysis and semi-structured interviews were conducted to investigate elements that influence the implementation of Integrated Buffer Zones (IBZ) and the subsequent improvement of surface waters in Denmark. With the use of concepts from the litterature on multiple criteria assessment, this investigation was done to be able to make recommendations for the development of a related advisory strategy. This work is also a primary test of the procedure depicted on the front page and contributes with input for a further iterative process as the front page illustration indicates.

Based on the results of the GIS analysis and the interviews conducted, an eight step strategy for overcoming two of the initial barriers in implementing IBZs is proposed (section 9). Steps 1 – 4 ensure mapping of risk areas for nutrient losses and of valuable nature. Step 5 relates to the conversation with the farmer and steps 7 and 8 points towards action for implementing an IBZ. Ensuring that the proposed strategy contributes to real improvement of the ecological status of surface waters, an economical and legal frame to support the establishment of differentiated and targeted environmental measures needs to be in place. These elements are incorporated in Figure 4 section 5.3.

The interviews have contributed with valuable and nuanced insight in a complex matter. The interviews and literature indicate that supporting the farmers' motivation can promote environmentally friendly action. Therefore, the recommendations are built on the utilization of motivational factors and to take fully advantage of this element the development of indicators of Integrated Buffer Zones (IBZ) effects is encouraged. Diversified strategies to encourage the implementation of IBZs can be created with the use of visual indicators for nutrient removal and other ecosystem services. This is to avoid a unilateral focus on the need for the most precise data as the sole argument for changing the perception of environmental issues and for action.

Geographical Information System (GIS) is a necessary tool for analyzing the placement of the IBZ, and through the analysis it became apparent what technical issues in conducting the GIS analysis need to be further developed. The analysis needs to differentiate on different nutrient targets, include mapping of valuable nature and legal barriers (such as protected nature). The exact identification of critical source areas of deposition must be more accurate, additionally a method to identify nitrate losses must be included in the analysis. Risk assessment maps are highly relevant tools in planning, but to avoid aversion, these maps must be used with caution. The setting in which they are introduced must be carefully considered so that they are not perceived as a "*blueprint*" solution.

The question still remains on *how* accurate the biophysical data and pinpointing of risk areas need to be in order to motivate farmers who do not agree on the need for targeted agro environmental measures.

12. Future perspectives

The IBZ is one of many measures that can be used for protecting the water environment. Because the two barriers are of a general nature (section 4 and 5.4), these barriers are similar for the implementation of other environmental measures as well. The recommendations listed in section 9 may therefore be used as a strategy for implementing the most feasible measure on the farm as mentioned in step no. 3.

If a new type of catchment advisory strategy is to be implemented, it needs to be backed up by the society; it cannot be an economic burden on the farmers alone. The skills listed for the catchment advisor are substantial and an education program is probably necessary. Lack of funding was the reason for the integrated advisory system proposed by the AGWAPLAN project not being implemented nationally. Time may now be more mature for targeted regulations as the Nature- and Agricultural commission from 2013 (Jespersen 2013) and the new agricultural action plan (Miljø- og Fødevareministeriet 2015) now also emphasize the need for targeted solutions.

Further investigation on reactions to taking out "*good*" land for environmental measures and including more pig farmers is needed to acquire more knowledge about obstacles of establishing IBZ and other AEM in cereal dominated production systems.

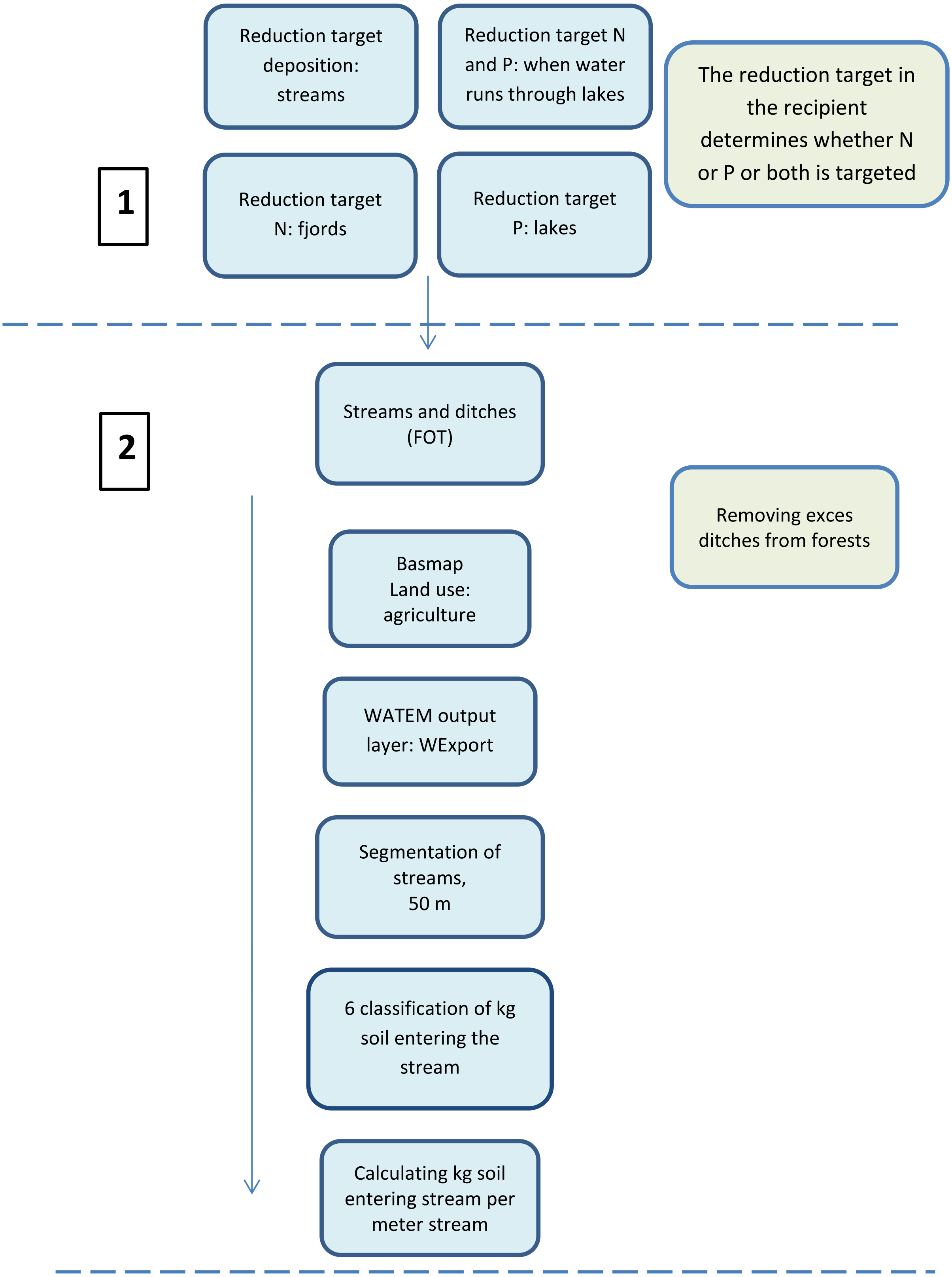
The GIS technology presents many possibilities. To avoid that data may be unsuitable for analysis on field scale, GIS analysis and available data could point out larger catchments and possibly identify problematic nutrient losses on a larger scale. Thereafter, the knowledge within local environmental authorities, advisory sector and selected key farmers could further narrow down and identify problems and seek solutions.

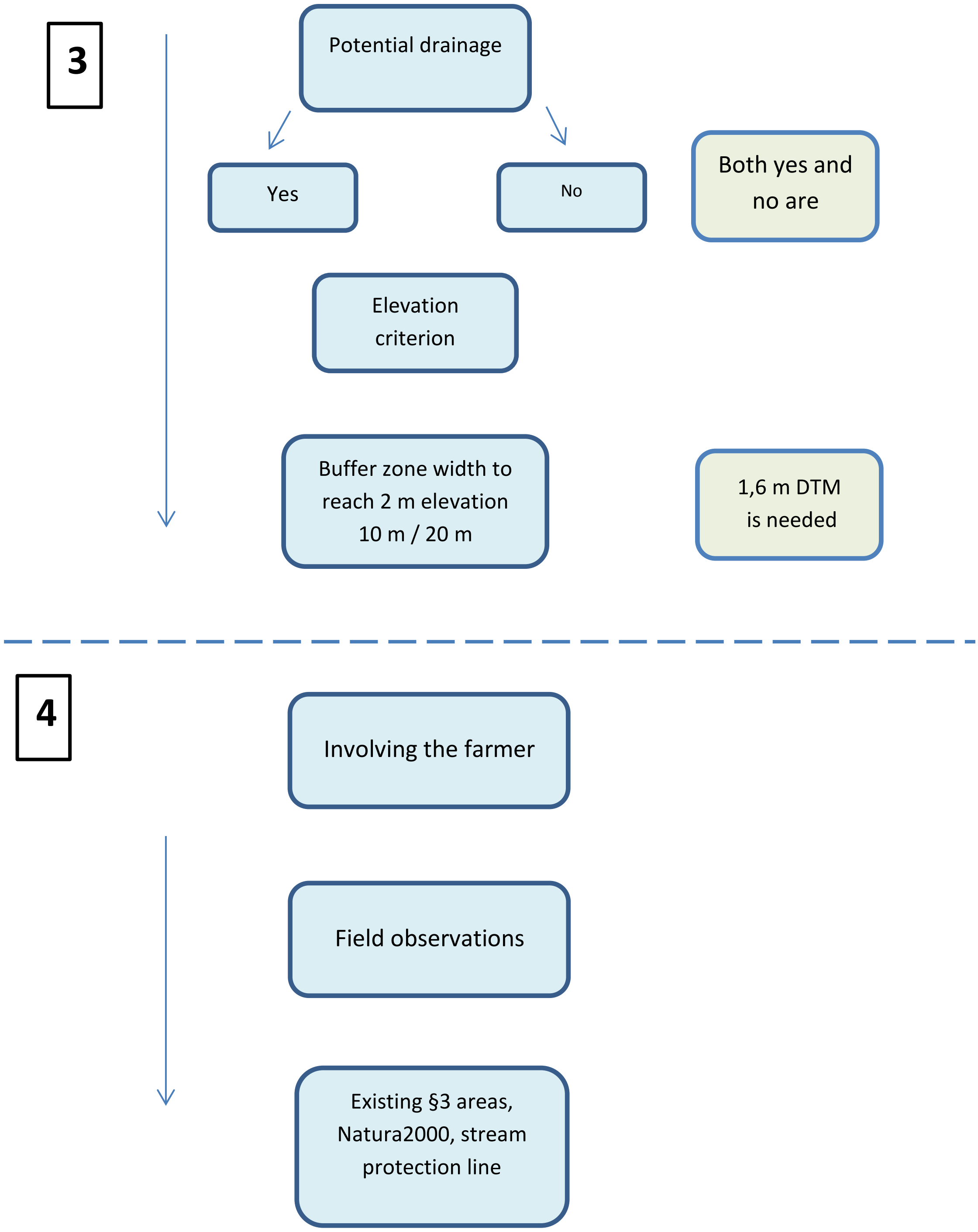
Bouma et al. (2008) has made long term studies on knowledge transfer and underlines the need for incorporating the tacit practical expertise of farmers. In depth interviews with key farmers in the line of the recommendations made in the present work may reveal this knowledge and lead to better collaboration between environmental authorities, researchers and agriculture. To fully understand the transfer of knowledge and take advantage of the iterative process depicted in Figure 4 and the front page, it may be fruitful to conduct investigation in line with the principles of "action research" (Brinkmann and Tanggaard 2010).

Facilitating action with the current available data, with all its uncertainties, requires researchers that are able to understand the whole process of implementing agro environmental measures. With a multidisciplinary approach it may be possible to answer the question of how accurate the biophysical data needs to be in order to facilitate action for improving the ecological status of surface waters in Denmark.

13. Appendices

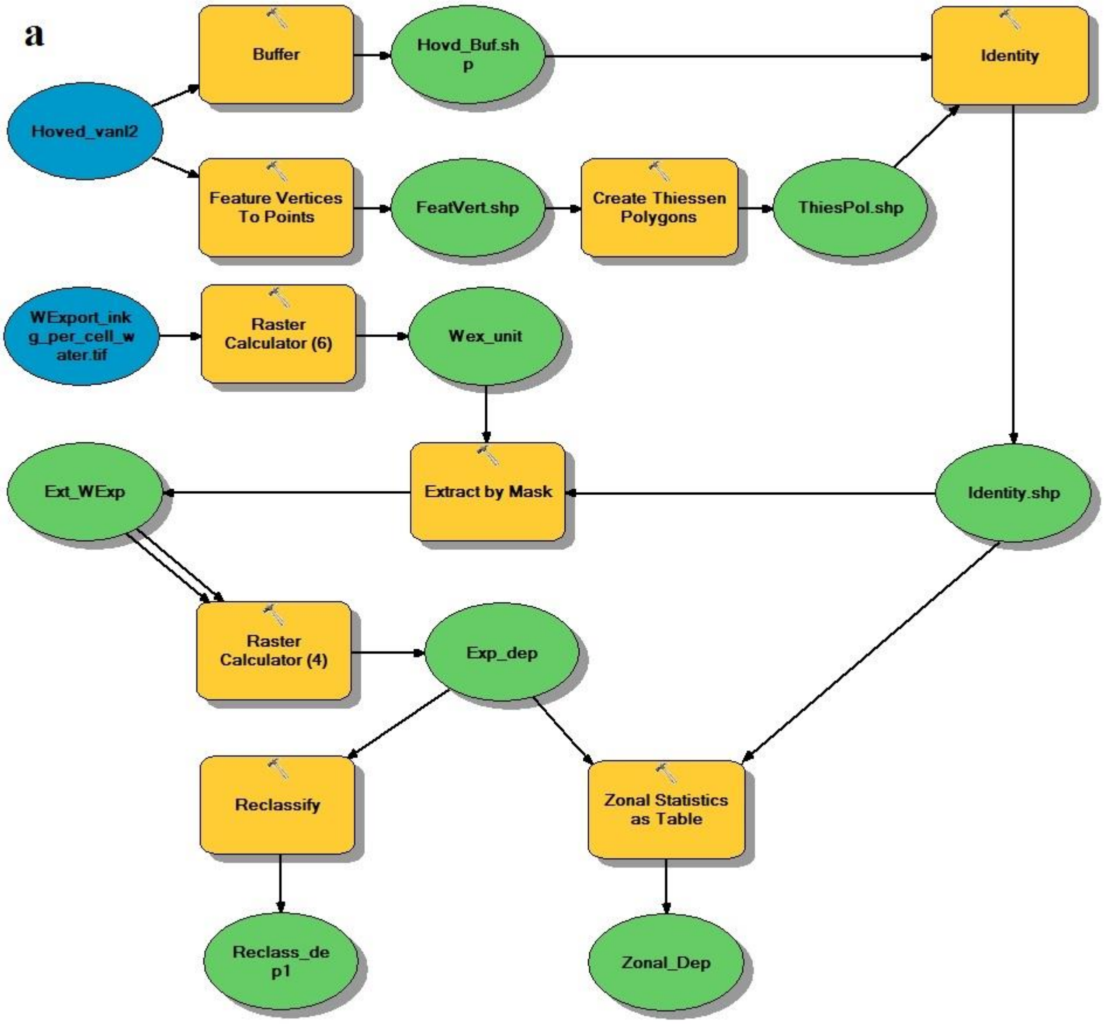
Appendix 1. The initial flow chart developed in collaboration with Brian Kronvang and Ane Kjeldgaard, later synthesized in Figure 4 and related to illustration on the front page.



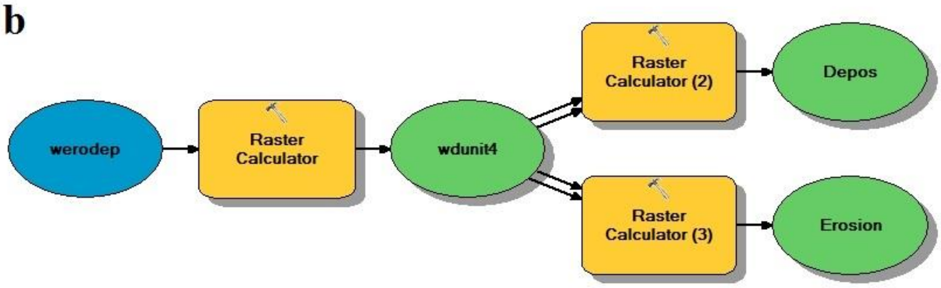

3
Potential drainage
Yes
No
Both yes and no are
Elevation criterion
Buffer zone width to reach 2 m elevation 10 m / 20 m
1,6 m DTM is needed
4
Involving the farmer
Field observations
Existing §3 areas, Natura2000, stream protection line

Appendix 2. ArcGIS modelbuilder. Blue circles are data input, yellow boxes are tools used to trasform data and green circles are generated outputs. Part a) was developed to generate data for risk of soil deposition entering the stream in the research area of Spjald to be targeted by the IBZ. Part b) was developed to create the map used in the case interview.

a



b



Appendix 3. Questions for the farmers divided in three parts (1.1 – 1.5, 2.1 – 2.5, 3.1 – 3-5). Not all questions were worded the same and were asked to all farmers as the interview took place as a normal (as possible) conversation.

Værdier som landmand
1.1 Hvad er vigtig for dig som landmand?

1.2 Hvad går du særlig op i skal være i orden? Hvordan tager du valg?

1.3 Hvorfor er du landmand. Hvad er godt landmandskab?

1.4 Hvad er god driftsøkonom for dig? Kan du beskrive dig som driftsleder.

1.5 Hvor får du din viden fra? inspiration (rådgiver, internet, fagblade og aviser, økonomisk rådgivning)?

Landmandens rolle i miljøspørgsmål – hvordan opfattes problemstillingen?
2.1 Hvad ser du som den vigtigste måde landmænd kan sikre at der ikke sker udvaskning fra marker? Hvad kan man som landmænd gøre?

2.2 Hvilken rolle ser du at landmænd har for at hindre udvaskning og at næringsstoffer kommer ud i søer og vandløb?

2.3 Hvordan ser du sammenhængen mellem eventuel udvaskning fra dine marker og den tilstanden i nærliggende søer, vandløb og fjorde?

2.5 Hvad vil du sige er den afgørende faktor for at du vil overveje at etablere en Integrerede Buffer Zone på din bedrift?

Forestil dig en ny slags rådgivning der sker på oplandsniveau, en oplandsrådgiver som er gratis at benytte.
3.1 Hvordan kan du se for dig samarbejde med andre landmænd i forhold til miljøspørgsmål?

3.2 Hvordan kunne du konkret bruge han/hende til eventuelle nye miljøtiltag på din bedrift? Hvilke forventninger har du til din rådgiver?

Myndighederne beder forskere om at lave landsdækkende modeller og kort.

3.3 Hvordan kan disse give mening, og kan de bruges som inspiration?

3.4 De kort jeg har med viser mulige risiko for erosion og deposition og kunne bruges til placeringer af Integrerede Buffer Zoner. Kortene er baseret på modelberegninger. Hvad tænker du om disse kort? Giver de mening?

Hvad er den relevante skala – enkelt landmand? På hvilken skala kan problemet løses

3.5 Hypotetisk scenario: HVIS du kunne se ideen i at etablere et sådant virkemiddel på din bedrift: Hvor på bedriften kunne du se for dig dette virkemiddel placeret? Hvad vil være din grænse for hvor langt ind i marken (buffer zones bredde i meter) den Integrerede Buffer Zone kan etableres?

Appendix 4. Figures shown to the farmers during the interview.

1.2 Hvordan vil du rangere nedenstående udsagn for at beskrive din egen driftsledelsesstil, hvor 1 = passer godt, og 6 = passer slet ikke.

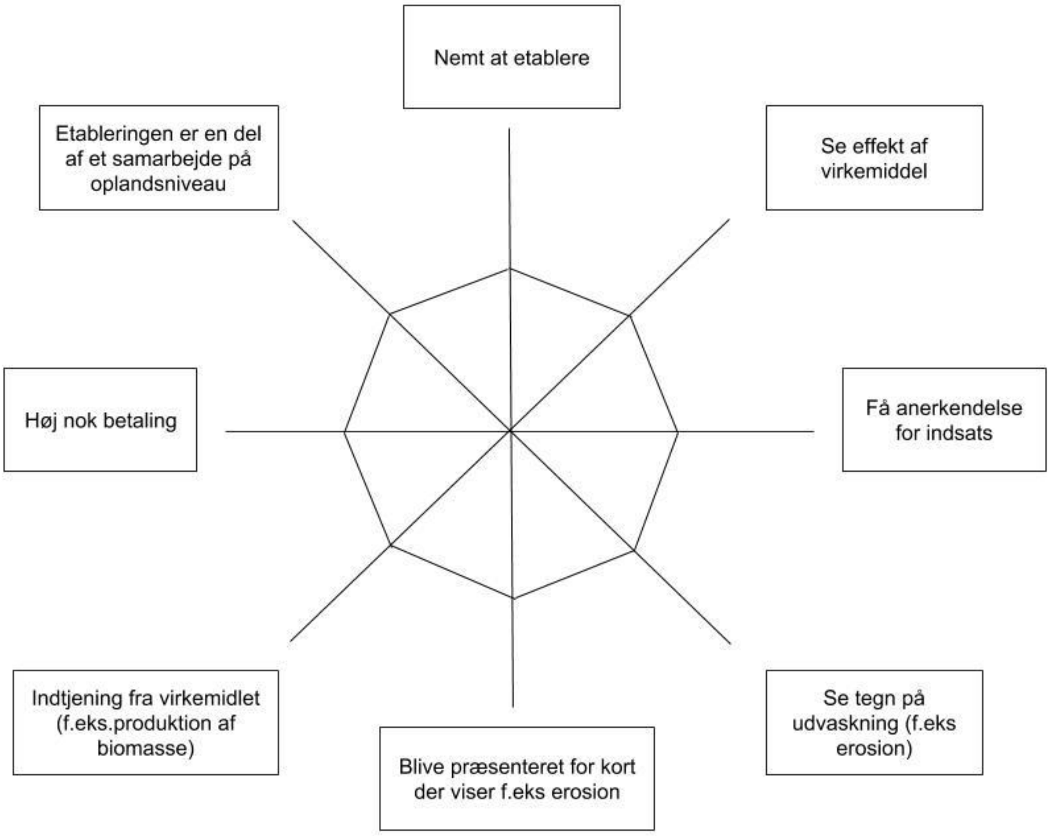
	1	2	3	4	5	6
Hovedformålet med bedriften er at sikre høj ydelse (hvis du har dyr) og/eller høje udbytter						
Jeg vil gerne minimere arbejdsindsatsen således at jeg har mere fritid						
Jeg går efter at producere mest mulig på min egen bedrift, således at jeg skal importere mindst mulig.						
Det vigtigste for mig er at jeg er fleksibel og hurtig kan tilpasse driften efter ændring i priser eller ændrede rammevilkår						

1.3 Hvilket af ovenstående udsagn er vigtigst for dig?

1.4 Hvor vil du placere dig selv i forhold til dit fokus for at sikre god økonomi? Hvad gør du konkret for at opnå dette?

1.5 Bruger du mest din egne erfaringer eller mest fra eksterne kilder (rådgiver, internet, blade og aviser)?

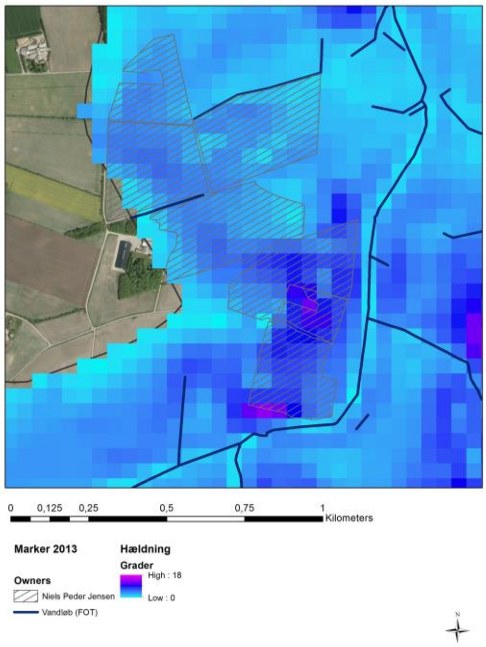
2.4 Hvor vigtig er følgende kriterier i forhold til din motivation til at etablere en Integreret Buffer Zone? Den sorte linje repræsenterer "hverken eller", udenfor = stor indvirkning, indenfor = lille indvirkning.



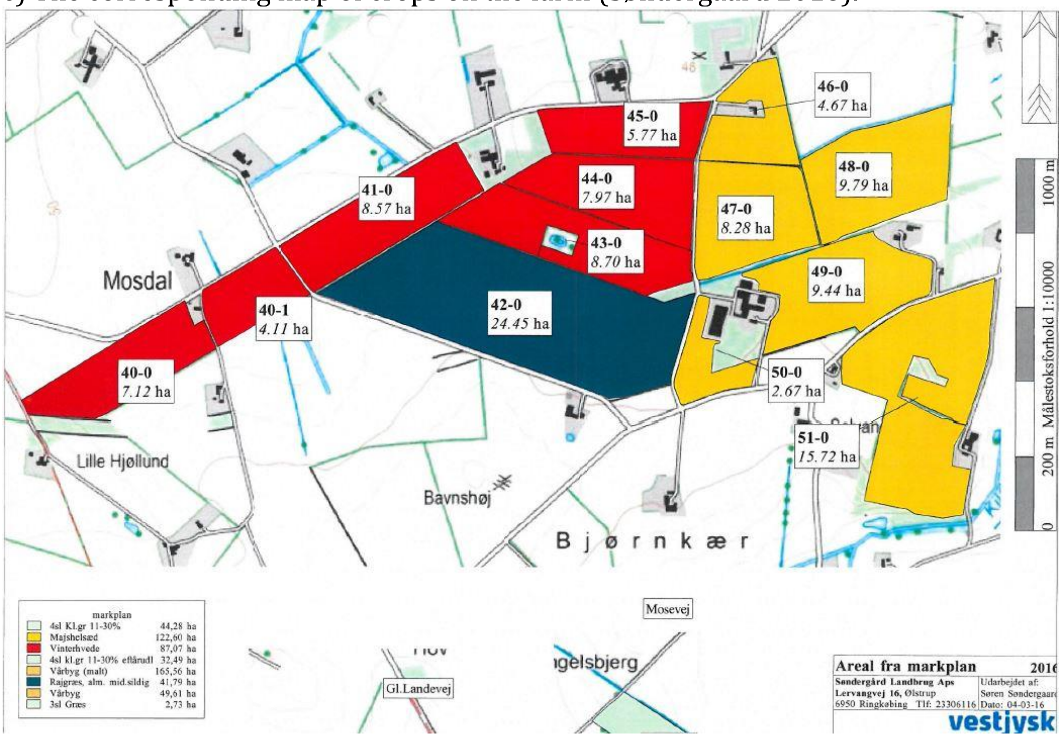
Appendix 5. Maps shown to the farmers. All maps were shown in A4 format.

a) Example of maps of erosion patter in the farmers' own fieldsshown to farmer.

b) Example of DTM map of elevation in the farmers' own fields shown to farmer.



c) The corresponding map of crops on the farm (Søndergaard 2016).

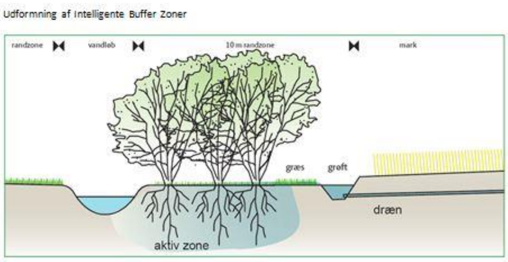


d) Basemap shown to farmers (Levin, Kastrup Blemmer, and Nielsen 2012).

e) Overview of the fields of the farmers. The layout have been modified and translated for the Appendix. The fields have the same color code as the farmers in the text.

Orthophoto: *Copyright COWI DDO®Land 2014*

f) Schematic explanation and photo of an Integrated Buffer Zone shown to farmers (Gertz 2012).



Appendix 6. Data generated in GIS (from the model shown in Appendix 2 a) additional calculated are made in Excel (CV coefficient and Kg soil per m stream).

Number of cells in segment	SUM kg soil per segment	Median	Mean	CV coefficient of variation	STD	Kg soil per m stream
21	1	0	0.0	447.2	0.2	0.0
1	21	21	21.0	0.0	0.0	0.1
7	49	2	7.0	123.8	8.7	0.3
20	60	2	3.0	108.5	3.3	0.4
3	67	22	22.3	9.2	2.1	0.4
20	146	2	7.3	165.2	12.1	0.9
11	161	14	14.6	100.0	14.6	1.0
6	164	15	27.3	89.8	24.6	1.0
25	172	6	6.9	84.4	5.8	1.0
22	186	2	8.5	147.7	12.5	1.1
25	196	7	7.8	68.0	5.3	1.2
24	264	10	11.0	46.7	5.1	1.6
25	283	10	11.3	67.7	7.7	1.7
21	315	16	15.0	43.3	6.5	1.9
14	576	28	41.1	81.8	33.7	3.5
21	693	32	33.0	61.6	20.3	4.2
10	735	8	73.5	157.4	115.7	4.4
22	761	31	34.6	116.1	40.2	4.6
22	775	37	35.2	59.6	21.0	4.7
14	870	57	62.1	68.6	42.6	5.2
21	877	41	41.8	66.7	27.9	5.3
21	902	42	43.0	71.0	30.5	5.4
19	948	15	49.9	115.8	57.8	5.7
17	993	37	58.4	67.1	39.2	6.0
21	1094	40	52.1	77.3	40.3	6.6
12	1098	83	91.5	30.1	27.6	6.6
20	1344	38	67.2	100.4	67.4	8.1
21	1393	62	66.3	70.5	46.8	8.4
21	1395	35	66.4	102.8	68.3	8.4
22	1495	36	68.0	103.8	70.6	9.0
26	1609	46	61.9	61.3	38.0	9.7
23	2058	87	89.5	83.3	74.6	12.4
18	2318	100	128.8	71.9	92.5	14.0
24	3320	115	138.3	82.7	114.4	20.0
23	4615	133	200.7	91.6	183.8	27.8

Appendix 7. Selected Danish quotes from the interviewed farmers. Audio recordings of all 5 interviews are available if requested.

What is important for you as a farmer? What is especially important to control?
Farmer no. 2: "*det er at det er balance i tingene*".

Farmer no. 4: "*prøver at forurene så lidt som mulig og udnytte de næringsstoffer vi har. Der er da en hel del byfolk der tror vi helt bevidst prøver at forurene, men det har vi ingen intentioner om, det får vi jo ikke noget ud af. Vi vil da gerne have nogle intelligente driftsformer, det prøver vi da selv synes vi*".

Farmer no. 5 "*Det skal være en fornuftig production*, [der vi ikke] *forurener mere end højst nødvendig*".

Farmer no. 4: "*det er i vores egen interesse at passe så godt på det som mulig*".

Farmer no. 5: "*Vi sprøjter jo ikke ned i vandløbet*".

Answers related to the 8 motivation criteria in Figure 10 and 16 (section 6.3 and 7.2 respectively).
Farmer no. 5 on seeing the effect of a measure (cirterion no. 2): "*jammen, det skulle man da gerne, eller skal det da ikke laves*".

Farmer no. 4 on the importance of getting recognition (criterion no. 3): "*De fleste vil da heller have ros end skæld ud, men det er da lidt op ad bakke at få sympati i den menige befolkning*".

Farmer no. 5 on making revenue from the measure (criterion no. 6): "*Den* [mulighed] *tror jeg aldrig kommer – det er urealistisk (…). Omkostningerne er så store, det løber lige i nul - hvis man er heldig*".

Farmer no. 2 on recieving compensation (criterion no. 7): "*Vi kunne [have fået] noget erstatning, men i steder for erstatning, så gravet de [the municipality] en sø for os ".*

Farmer no. 4 on recieving compensation (criterion no. 7): "*Tilskuddet er ikke det vigtigste, men hvis man får dyrke de andre arealer mere optimalt, så ligger det økonomiske incitament her. Jeg vil sgu da hellere have noget ud af det på sigt end at jeg vil have penge. Jeg vil ikke have penge for det, jeg vil have noget ud af det. Langt de fleste landmænd er jo landmænd fordi de kan lide at dyrke arealerne (…)".*

Farmer no. 5 on recieving compensation (criterion no. 7): "*Vi har ikke ret meget lyst til at gøre noget hvis det ikke giver penge*".

Farmer no. 4 on economic incitement in general (in relation to criterion no. 7): "*Grisefolk havde* [før i tiden] *fedekvæg for at afgræsse de lave arealer. Hvis det var noget økonomi i at pleje de arealer, så vil de dyr jo automatisk komme*".

Answers related to a new kind of catchment advisor (questions 3.1 – 3.5)
Farmer no. 4 on collaboration with other farmers (question 3.1 Appendix 3): "*Der var det jo smart hvis det var flere landmænd der kunne gå sammen - få det lavet strømlinjet*".

Farmer no. 2 on recycling of nutrients: "*Det [nutrient recycling] gør det jo ved at dyrene eder det. Det var sådan man gjorde i gamle dage*".

Reaction related to maps and discussion of where to place an IBZ or other environmental measures.
Farmer no. 4: "*de passer helt 100%, det er faktisk lidt sjovt at se, fordi vi har altid en plet lige her, den er altid pisse blød, så det passer ekstremt godt*".

Farmer no. 5: "*Spørge ham der ejer jorden, hvor han kunne se for sig at der blev mest miljø for pengene. Hvor vil han så placere det*". "*du kan altid finde disse steder, hvor folk gerne vil med, ja det tror jeg*".

Farmer no. 1: "*Jeg tror mange landmænd [skulle] have lov til at bruge mere kvælstof hvis man havde en måde at holde mere på det, for så kan det retfærdiggøres, hvis det kan mindske udledning i dræn og vandløb, men stadig have en højere tilførsel. Det tror jeg samtlige landmænd ville synes er en god ide*".

What are your thoughts on IBZ (related to question 3.1 Appendix 3)?
Farmer no. 4: "*Jeg vil tror at landmænd hellere vil have flere hektar i vedvarende eller permanent græs, end at få taget noget permanent ud og tilplantet. Jeg vil nok hellere have 50 meter græs som jeg kan tage hø slet af, hvis det i teorien gav den samme miljøeffekt. Heller 50 m græs end 10 m træer*."

What can the farmers do (related to question 2.1 Appendix 3)?
Farmer no. 5: "*hvis vi kunne bevise at der ikke blev tabt noget kvælstof, kunne vi så få lov til at gøde noget mere, men det blev jo ikke til noget. Jeg tror landbruget har kommet med tusindvis af gode ideer. Vi bliver ikke hørt, vi har fået et stempel, vi er nogle svin*".

What about §3?
Farmer no. 4: "[der skal være garanti for] *at de ikke stjæler det bagefter*". "*Hver m^2* [kan være] *pantsat - så skal det jo cleares med kreditforeningen, for i lånetilbud står det jo at jorden kan dyrkes. Så det er jo ikke noget man lige gør*".

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