Cost-Effectiveness Analysis of Water Quality Improvements in the Moenchaltorf Aa Basin
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## Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summary</td>
<td>5</td>
</tr>
<tr>
<td>Glossary</td>
<td>6</td>
</tr>
<tr>
<td>Figures and Tables</td>
<td>6</td>
</tr>
<tr>
<td>1</td>
<td>Introduction</td>
</tr>
<tr>
<td>2</td>
<td>Background</td>
</tr>
<tr>
<td>3</td>
<td>Methodology</td>
</tr>
<tr>
<td>3.1</td>
<td>Cost-Effectiveness Analysis</td>
</tr>
<tr>
<td>3.2</td>
<td>Spatial analysis</td>
</tr>
<tr>
<td>3.3</td>
<td>Environmental Objective</td>
</tr>
<tr>
<td>3.3.1</td>
<td>Fertilizers</td>
</tr>
<tr>
<td>3.3.2</td>
<td>Pesticides</td>
</tr>
<tr>
<td>3.4</td>
<td>Defining Environmental Unit</td>
</tr>
<tr>
<td>3.5</td>
<td>Evaluation of the five water quality improvement measures</td>
</tr>
<tr>
<td>3.5.1</td>
<td>Measure 1: Conversion from Conventional to Organic Agriculture in the entire study area</td>
</tr>
<tr>
<td>3.5.2</td>
<td>Measure 2: Conversion to Organic Agriculture in Tile Drainage Areas</td>
</tr>
<tr>
<td>3.5.3</td>
<td>Measure 3: Implementing Grass Buffer Strips</td>
</tr>
<tr>
<td>3.5.4</td>
<td>Measure 4: Livestock Reduction</td>
</tr>
<tr>
<td>3.5.5</td>
<td>Measure 5: Conversion of agricultural land in the study area into Nature Park</td>
</tr>
<tr>
<td>3.6</td>
<td>Effects of each Measure for reducing Pesticides and Nutrients</td>
</tr>
<tr>
<td>3.6.1</td>
<td>Measure 1</td>
</tr>
<tr>
<td>3.6.2</td>
<td>Measure 2</td>
</tr>
<tr>
<td>3.6.3</td>
<td>Measure 3</td>
</tr>
<tr>
<td>3.6.4</td>
<td>Measure 4</td>
</tr>
<tr>
<td>3.6.5</td>
<td>Measure 5</td>
</tr>
<tr>
<td>3.7</td>
<td>Assessing the costs of implementing the water quality improvement measures</td>
</tr>
<tr>
<td>3.7.1</td>
<td>Costs of Measure 1: Conversion from Conventional to Organic Agriculture in the entire study area</td>
</tr>
<tr>
<td>3.7.2</td>
<td>Costs of Measure 2: Conversion from Conventional to Organic Agriculture in Tile Drainage Areas</td>
</tr>
<tr>
<td>3.7.3</td>
<td>Costs of Measure 3: Implementing Grass Buffer Strips</td>
</tr>
<tr>
<td>3.7.4</td>
<td>Costs of Measure 4: Livestock Reduction</td>
</tr>
<tr>
<td>3.7.5</td>
<td>Measure 5: Conversion of Agricultural Land in Study Area into Nature Conservation Area</td>
</tr>
<tr>
<td>3.8</td>
<td>Ranking Measures by their costs from least cost to most cost</td>
</tr>
<tr>
<td>4</td>
<td>Uncertainty Measurements</td>
</tr>
<tr>
<td>4.1</td>
<td>Range of Uncertainty Values</td>
</tr>
<tr>
<td>4.2</td>
<td>Uncertainty Results</td>
</tr>
<tr>
<td>4.2.1</td>
<td>Economic Uncertainty</td>
</tr>
<tr>
<td>4.2.2</td>
<td>Effect Uncertainties for Measure 1</td>
</tr>
<tr>
<td>4.2.3</td>
<td>Effect Uncertainties for Measure 2</td>
</tr>
<tr>
<td>4.2.4</td>
<td>Effect Uncertainties for Measure 3</td>
</tr>
<tr>
<td>4.2.5</td>
<td>Effect Uncertainties for Measure 4</td>
</tr>
<tr>
<td>4.2.6</td>
<td>Effect Uncertainties for Measure 5</td>
</tr>
<tr>
<td>Page</td>
<td>Section</td>
</tr>
<tr>
<td>------</td>
<td>----------------------</td>
</tr>
<tr>
<td>5</td>
<td>Results</td>
</tr>
<tr>
<td>6</td>
<td>Discussion</td>
</tr>
<tr>
<td>7</td>
<td>Conclusion</td>
</tr>
<tr>
<td>8</td>
<td>Bibliography</td>
</tr>
<tr>
<td></td>
<td>Annex A</td>
</tr>
<tr>
<td></td>
<td>Maps of Study Area</td>
</tr>
</tbody>
</table>
Summary

In this thesis the cost-effectiveness analysis (CEA) of different measures of water quality improvements in the Moenchaltorfer Aa stream in Switzerland is conducted. The presented cost-effectiveness analysis aims at identifying the least cost effective measure to reduce the amount of nutrient and fertilizer runoff as well as pesticide concentration in the Aa stream and sub watersheds to keep the standards below the given standards the standards set by the Swiss Water Protection Regulation (GSchV). The analyzed measures include the transition from conventional to organic agriculture in the entire area, transition from conventional to organic agriculture only on the tile-drained areas, the expansion of grass buffer strips, live stock reduction, and conversion of the study area into a nature park. Different measures are compared to each other in terms of the costs of their implementation and water pollution reduction that would be achieved. The measures are spatially extrapolated using the Arc Geographic Information System (GIS) software to integrate local differences as accurate as possible. The results from this study should help local authorities to make more informative decisions about the cost effectiveness of various policies for water quality improvement.
Glossary

BFS Bundesamt fuer Statistic
CHF Swiss Franc
CEA Cost Effectiveness Analysis
DB Deckungs Beitrag
EU European Union
GIS Geographic Information System
GSwV Gewaesserschutzverordnung
LU Livestock Unit
USA United States of America
WFD Water Framework Directive

Figures and Tables

Figure 1: Study Area: Moenchaltorf Aa basin with sub watersheds and water quality sampling locations
Figure 2: Different land uses in the study area by 1ha parcel
Figure 3: Water Sample Measuring Sites in the Study Area
Figure 4: Tile Drainage Areas in Study Site
Figure 5: Schematic representation of the functioning of a grass buffer
Figure 6: Areas for Animal Husbandry in study area
Figure 7: Locations of Nature Conservation in Study Area
Figure 8: Nitrogen Runoff Reduction after Measure 1
Figure 9: Phosphorus Runoff Reduction after Measure 1
Figure 10: Pesticides Reduces after Measure 2
Figure 11: Nitrogen Runoff Reduction after Measure 2
Figure 12: Phosphorus Runoff Reduction after Measure 2
Figure 13: Calculated Reduction Values of Nutrients and by Buffer Width and Slope
Figure 14: Calculated Reduction Values of Pesticides and by Buffer Width and Slope
Figure 15: Nitrogen Runoff Reduction after Measure 4 with LU 0.75
Figure 16: Phosphorus Runoff Reduction after Measure 4 with LU 0.75
Figure 17: Nitrogen Runoff Reduction after Measure 5
Figure 18 Phosphorus Runoff Reduction after Measure 5
Figure 19: Different Land Uses in Moenchaltorf Aa in hectares
Figure 20 Economic value generated by each land use type in the study area
Figure 21: Economic value by sub watershed in study area at status quo
Figure 22: Economic Value generated by each land use type after measure 1 (converting conventional
Figure 23: Economic Value after implementing measure 1 by sub watersheds
Figure 24: Economic Value after implementing measure 2 by sub watersheds
Figure 25: Economic Value after implementing measure 3 by sub watersheds
Figure 26: Economic Value after implementing measure 4 by sub watersheds
Table 1: Land use types in the study area
Table 2: Size of areas according to different land use types at which tile drainage is practiced
Table 3: National average rate of how much in percent and from where bio available nitrogen and phosphorus are introduced into soil
Table 4: Nitrogen and phosphorus surplus outflow by different land use types
Table 5: Total runoff of nutrients in the study area by different land use types
Table 6: Average Pesticides Use in Fruit, Field Fruit, Garden, and Croplands Areas
Table 7: Annual mean levels of nutrients and pesticides at measuring sites
Table 8: Fertilizer Runoff by Land Use Types after implementing measure 1
Table 9: National annual production of fruits
Table 10: National annual production of field fruits
Table 11: National annual production of vegetables
Table 12: Areas of different crops grown on croplands by municipalities
Table 13: Proportions of different crops grown on croplands by municipalities
Table 14: Animal produce produced in subcategories in study area
Table 15: Economic value of fruits per ha in the study area
Table 16: Economic value of field fruits per ha in the study area
Table 17: Economic value of vegetables per ha in the study area
Table 18: Economic value of crops per ha for each municipality in the study area
Table 19: Economic values of animal products per ha of home meadows
Table 20: Economic value of animal fodder produced per ha of natural meadows
Table 21: Economic value of organic field fruits per hectare in the study area
Table 22: Economic value of organic gardens per hectare in the study area
Table 23: Economic value of organic cropland per hectare for each municipality in the study area
Table 24: Economic value of organic animal products per ha of natural and home meadows
Table 25: Economic value of organic animal fodder produced per ha of natural
Table 26: Measures ranked by their costs spatially by their sub watersheds:
Table 27: Uncertainties of Costs for different Land Use Practices
Table 28: Runoff Rate Uncertainty of Nutrients from Organic Agriculture
Table 29: Uncertainties for Grass Buffer Effectiveness on Nutrients and Pesticides
Table 30: Uncertainty of Runoff from Tile Drainage on Nutrients and Pesticides
Table 31: Uncertainty of Livestock Reduction Value on Nutrients Pesticides
Table 32: Uncertainty of Generated Value in study Area under Status Quo Scenario
Table 33: Range of Runoff Reduction in Study Area after Measure 1
Table 34: Range of Nutrients and Pesticide Reduction after Measure 2
Table 35: Range of Nutrients and Pesticide Reduction in Study Area after Measure 1
Table 36: Range of Runoff in Study Area after Measure 5
Table 37: Cost effectiveness of each measure by spatial sub watersheds
1 Introduction

Cost effectiveness is seen as an important criterion in water policy. In the United States the Clean Water Act from 1972 has implemented cost effectiveness analysis to improve water quality. In Europe cost effectiveness has been used in river basin management plans since the Water Framework Directive (WFD) has been implemented in 2000. The WFD has the aim not just to improve water quality on a biochemical level, but also to establish good ecological status for bodies of water within the European Union (EU) (Brouwer and de Blois, 2008). A major contribution of water pollutants comes from the so-called non-point sources, such as agriculture. Agricultural production in western industrialized counties has increased in intensity over the last decades, partly due to the attempt of these countries’ agricultural policies to have a high degree of self-sufficiency for food production. This has led to deteriorated water quality. Politically neutral Switzerland also experienced an enormous self-sufficient increase in agricultural production due to technological development. Selective breeding of livestock, increase in livestock density, and the excessive use of synthetic fertilizers and pesticides are the most significant factors which have contributed to increased water pollution (Nemecek et al., 2011). In Switzerland, located geographically in the middle of the Alps and the place of origin for several large rivers such as the Rhine and Rhone, pollution is especially noticeable in watersheds where intensive agriculture is practiced on a large scale.

The Moenchaltrofer Aa stream feeding into the Greifensee lake, as shown in Figure 1 is known for relatively high water pollution levels resulting from agricultural and urban runoff in the Aa’s catchment area (AWEL 2004; Ko’iv at al., 2010; Volker at al. 2004; Wittmer et al., 2010). Especially high input levels of phosphorus (P) are resulting from tile drainage and erosion from agricultural and grassland fields. All these are major factors that contribute to the increase of nutrient loading into the Greifensee. This increase of P loading, with P usually being the limiting factor for plant productivity in freshwater systems, has led to an uncontrolled increase of algae productivity. Consequently, this lead to eutrophication of the Greifensee lake with substantial ecological consequences such as fish dying (Volker et al., 2004). The municipalities located within the Aa’s catchment Bubikon, Egg, Grueningen, Grossau, Hombrechtikon, Moenchaltorf, Oetwil am See, Staefa and Uster are therefore interested in how to reduce nutrient loading from agricultural runoff to comply accordingly with the WFD, measures have to be implemented to improve the status of water to “good” status for all bodies of waters which are not in conformation with the standards for water given by the WFD. Improved agricultural practices for non-point sources are associated with certain implementation costs and their effectiveness has to be analysed (Kallis and Butler, 2001). In case of Greifensee, with the Moenchaltor Aa being the main source of input of surface water, this study’s main objective is to estimate the costs and effectiveness of implementing different measures for improving the current situation of the Greifensee’s water quality. To this end, five different measures were identified and tested in which water quality could be improved.

The first measure is to convert conventional agricultural practices into organic agriculture in the entire Aa basin with the aim to reduce or eliminate the outflow of pesticides and artificial fertilizers transported through the basin into the Greifensee. The second measure is converting conventional agriculture into organic agriculture only on tile drainage areas within the Aa basin. This measure is expected to also reduce the direct input of pesticides and artificial fertilizers resulting from agricultural practices in the tile drainage areas into
the Greifensee. The third measure is the expansion of grass buffer strips along the Aa stream where no agriculture can be practiced. The aim of the buffer strips is to dilute the outflow of pesticides and fertilizers in the Aa stream which feeds into the Greifensee. The fourth measure is to reduce the livestock density on grasslands, which is expected to result in a reduction of manure fertilizer outflow in the Aa stream accumulating in the Greifensee. The fifth and final measure includes converting the entire Aa basin into a nature conservation (i.e. natural park) area with the goal to completely eliminate the outflow of pesticides and fertilizers resulting from agriculture.

To illustrate these five measures in a spatial manner the Esri Geographic Information System (GIS) was used. GIS helped to gather sufficient information about the current landscape situation and was also used to create spatial models to illustrate the impacts of these five different measures in geo referenced databases and maps. This provided information about the size and location within the study area at which different measures would be implemented. Furthermore, geomorphological, hydrological, and meteorological data about the study area was gathered and evaluated by using GIS. The economic data necessary for this study was collected via literature reviews and annual economic reports and statistics. The economic data was adapted to be spatially applicable. Agricultural land practices such as the amount of fertilizer and pesticide uses as well as livestock density in study area were collected from available local or national official statistical data, scientific literature, and data from other scientific studies. These data sets were extrapolated over the study area with the approach of integrating spatial sensitivity to the given economic and environmentally existing data. This approach contributed to achieve the overall aim of this study, which was to find the most cost-effective measure for reducing water pollution on a sub-regional scale.

2 Background

For this thesis report information and methods from previously other studies were used to illustrate the CEA in this paper. The structure of this CEA was originated out of a study conducted by (Brouwer and de Blois, 2008) were different models for measures of water quality improvements were tested by their effectiveness and uncertainty. Other scientific reports such as from (Haro et al., 2010) helped to construct a comparable model with comparable pollutant runoff from agriculture per ha of different land use types. Similar information about how to model pesticide losses in Switzerland were gathered out of a study conducted by (Siber et al., 2009). This information and the structure of these scientific reports helped to create the foundation of this thesis’ conceptual frame work. This was done by implementing different approaches and methods from the different research reports and combine their results with the intention to generate the most economical, environmental and spatial accurate data for this thesis possible.
3 Methodology

3.1 Cost-Effectiveness Analysis

Cost effectiveness is an analysis tool in economics that compares the total cost with the effects of implementing measures. This analysis allows for comparison of none economically measurable values. In this thesis the CEA is used to compare the costs of implementing the five measures to improve water quality in the Moenchaltorf Aa with their effectives in reducing nutrient and pesticide loading.

The practical application of this report’s cost-effectiveness analysis is divided into several steps. These steps are listed below.

1. The first step of the cost-effectiveness analysis is to identify the environmental objective. In this study the environmental objective is the reduction of fertilizers and pesticides found in water samples from different sampling locations within the study area. The sampling locations are illustrated in figure 1.
2. The second step is to define the environmental unit that is used for setting environmental objective(s) and determining whether these are met. In this study the environmental unit is the volume concentration of fertilizer and pesticide residues per volume of water.
3. The third step is to identify possible measures in this study and evaluate to which extent these measures contribute to lower the amount of pollutants and nutrients in the Moenchaltorf Aa from the current to the desired conditions of water quality according to the Water protection regulations of water quality within the study area.
4. The fourth step is to estimate the effectiveness of each of the five agricultural measures in reaching the improved water quality.
5. The fifth step is to estimate the costs (measured in CHF) for the implementation of each of the measures in associated with a reduction of nutrients and pesticides for each of the five measures in kg.
6. The sixth step is to rank each of the five measures for improving water quality within the study area by increasing costs effectiveness
7. The seven step is to estimate the lowest costs which are needed to minimize the gap between desired environmental conditions and current conditions.
8. The final step is a sensitivity analysis to identify the impacts of the assumptions on the outcome of the CBA.

3.2 Spatial analysis

Spatial analysis is necessary in this study since spatial distribution of different land use practices and location of these land uses in the study area has determining factors in how each of the proposed five water quality improving measures could perform. This spatial analysis was also important to see which of the five proposed measures would perform best in their CEA at different sub watersheds of the study area.
The spatial analysis for this project was created by using Arc GIS 10. The necessary GIS data for this study has been made available from the Eawag Geo database server.

Spatial Definition of Study Area:
The study area in this report was defined by using the hydraulic structure model, a layer which uses a digital map showing the hydrological units of Switzerland and combining these values in small basins for each stream section in Switzerland. From this nationwide digital map the Moenchaltorfer Aa basin area was extracted (Vector©2004, swisstopo). The location of the study area in this thesis is illustrated in Figure 1.

Figure 1: Study Area: Moenchaltorf Aa basin with sub watersheds and water quality sampling locations

Slope of Study Area:
The slope of the study area surface was created by using the SwissAT13D layer. The spatial analysis tool “Slope” was applied to compute the difference in elevations between two neighboring surface parcels. Based on this difference, the slope in degrees was created. The values for the slopes were further used to generate reduction values grass buffer strips are expected to have based on their slopes widths and annual precipitation.

Spatial Definition of Land Use:
To define the areas which are being used for different types of agriculture a 100 x 100 m raster was used which enabled calculating different land use statistics. The classifications applicable for agriculture practiced within the study area were selected and one hectare parcels with different land use categories for agricultural practices were extracted. These one ha values were further divided into raster sets with a cell size of one square meter. This measure was necessary in order to estimate the economic loss resulting from expanding grass buffer strips, since in this measure a spatial analysis in meter units was
necessary. For all other measures a spatial scale of 1ha is used (Raster©2004, Swiss areal statistic). The results are illustrated in Figure 2. Based on this information, different land uses in the study area are calculated in Ha and are presented in Table 1.

The results from this spatial analysis representing the agricultural land use areas are listed in categories as shown in the Table 1.

<table>
<thead>
<tr>
<th>Land use types</th>
<th>Area size in ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruits</td>
<td>21.00</td>
</tr>
<tr>
<td>Field Fruits</td>
<td>359.00</td>
</tr>
<tr>
<td>Garden</td>
<td>53.00</td>
</tr>
<tr>
<td>Cropland</td>
<td>1418.84</td>
</tr>
<tr>
<td>Natural Meadows</td>
<td>1275.89</td>
</tr>
<tr>
<td>Home Meadows</td>
<td>380.27</td>
</tr>
</tbody>
</table>

Table: 1. Land use types in the study area

Figure: 2. Different land uses in the study area by 1ha parcel

Ground suitability for different types of agriculture:
Agricultural areas differ and have lower or higher suitability levels for different types of agricultural produce. This results in different yields and economic values. Areas were selected after the criteria are provided by Ackerlandkarte, BFS Geostat (2004). The economic values which are generated and the environmental values such as pesticide nutrients and pesticide application per ha for different land use categories were overlaid with the land use layer in order to see the productivity level of the agricultural and their pollution potential resulting from different nutrients and pesticides runoff from different land use types within the Moenchaltorfer Aa’s basin on a one ha spatial raster size.

Spatial Analysis of crops produced in the study area:
To determine the areas where different crops and vegetables are produced the model from the agricultural operating payments was used. Different raster sets illustrating the proportion of vegetables, wheat, potatoes, maize, fruits, rape, and sugar beets grown per hectare were used to calculate the overall yields for each of these crops which are produced in the study area.

Tile Drainage Area:
The area at which tile drainage is being practiced was provided by the Swiss office for waste energy and air (AWEL) in the form of vector data. The data includes information about size of drained area. The drainage areas were overlaid with the land use area in order to determine how much and which type of agricultural area is being tile drained. The size of agricultural areas that are affected by tile drainage practices are listed in Table 2.

<table>
<thead>
<tr>
<th>Land Use Types in Tile Drainage Area</th>
<th>Size in ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruits</td>
<td>2.18</td>
</tr>
<tr>
<td>Field Fruits</td>
<td>12.85</td>
</tr>
<tr>
<td>Garden</td>
<td>4.94</td>
</tr>
<tr>
<td>Cropland</td>
<td>550.80</td>
</tr>
<tr>
<td>Natural Meadows</td>
<td>150.10</td>
</tr>
<tr>
<td>Home Meadows</td>
<td>50.49</td>
</tr>
</tbody>
</table>

Table 2: Size of areas according to different land use types at which tile drainage is practiced

3.3 Environmental Objective

Environmental objective of this study is the reduction of fertilizers and pesticides, which are annually applied in agriculture. The types of fertilizers and pesticides used as well as the annual amount applied in the study area are explained in more details in subsections 3.2.1 and 3.2.2.

3.3.1 Fertilizers
Nitrogen and phosphorus are considered the most important nutrients for agricultural production. They increase yields in crop harvests and enable intensification of livestock unit (LU) for increased production of animal produce have lead to an increase of these nutrients to be applied on agricultural land. The excessive use of these two nutrients can lead to significant environmental degradation. In this thesis study approximately 60% of all nutrients and pesticides come from agricultural sources. Recently, there has been a
decrease in the use of these nutrients in agriculture (Robertson and Swinton, 2005) which can be dated back to improved agricultural methods. Despite this, nitrogen and phosphorus can still cause environmental degradation in the study area, especially as they can lead to increase the eutrophication of aquatic ecosystems and reduce water quality (Herzog et al., 2008).

For the purpose of this study the available data from the year 2005 was used to get an estimate on how much nitrogen and phosphorus is used as Swiss average national input for agricultural land. This data is based on the study of Herzog et al. (2008). The data also shows how much is the output for nutrients such as nitrogen and phosphorus, and what the surplus of nitrogen and phosphorus is which is not used up by plants and is washed down the streams into the Greifensee lake. The estimated values of nutrients which are being applied or cycled though the soil (i.e., inputs, outputs and surpluses of nitrogen and phosphorus) are presented in Table 3.

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Input</th>
<th>%</th>
<th>Phosphorus</th>
<th>Input</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>Organic fertilizer</td>
<td>21</td>
<td>Organic fertilizer</td>
<td>46</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mineral fertilizer</td>
<td>33</td>
<td>Mineral fertilizer</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Recycled</td>
<td>2</td>
<td>Recycled</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Biological fixation</td>
<td>23</td>
<td>Biological fixation</td>
<td>na</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Atmospheric deposition</td>
<td>20</td>
<td>Atmospheric deposition</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Output</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>Organic fertilizer</td>
</tr>
<tr>
<td></td>
<td>Plant absorbed nutrients</td>
</tr>
<tr>
<td></td>
<td>Output Total</td>
</tr>
<tr>
<td>Surplus</td>
<td>Surplus</td>
</tr>
</tbody>
</table>

Table 3: National average rate of how much in percent and from where bio available nitrogen and phosphorus are introduced into soil (Herzog et al., 2008)

The values from Table 3 (Herzog et al., 2008) are used to represent the quantity of each anthropogenic mineral or organic fertilizer applied by percentage on the fields used for agriculture within the study area. This percentage of mineral and organic fertilizers is used to get an estimate on how much nitrogen and phosphorus fertilizers are reduced by applying landuse changes such as changing form conventional to organic agriculture (Prasuhn and Herzog, 2004). For tile drainage areas a increase of surface runoff by 20% higher than on regular land use types were calculated as average (Prasuhn and Herzog, 2004).

<table>
<thead>
<tr>
<th>Nutrient Runoff by Land Use Types per ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land Use Type</td>
</tr>
<tr>
<td>---------------</td>
</tr>
<tr>
<td>Cropland</td>
</tr>
<tr>
<td>Home Meadows</td>
</tr>
<tr>
<td>Natural</td>
</tr>
</tbody>
</table>
Figures and Tables

Table 4: Nitrogen and phosphorus surplus outflow by different land use types

*, **, *** For the land use types were no direct value was available the land use type which is most similar to the selected value for runoff was used. For example for fruits the value of natural meadows was used since the assumption was made that the surface runoff from grassland and grassland with some fruit trees is more similar than the runoff from cropland areas.

Even though there might be differences in how much and which fertilizer is applied on certain land use types and for various crop types, the values from Table 4 are assumed to be equally over the entire study area. This decision was made due to time limitation in this study and the vast amount of different fertilizers and their different chemical compositions.

The results in table 5 show how much nitrogen and phosphorus surplus is generated in the status quo situation in the form of runoff for different land use types (with and without tile drainage) in the study. These values are based on a one ha raster and the associated statistical runoff value depends on the relevant land use type.

Table 5: Total runoff of nutrients in the study area by different land use types

* indicates the location is an estimate of the closest related category.
3.3.2 Pesticides

Pesticides are chemical compounds of the highest concern. Their use has to be monitored and controlled because of the high toxic potential that these chemical components can have and their widespread use in agricultural as well as on fields as a post-harvest protection agent. Currently over 1000 compounds are allowed to be applied on agricultural crops in Switzerland with the goal to control undesirable moulds, insects, and weeds (Ortelli et al., 2004). Due to the time limitation, the pesticides which are being analyzed in this CEA are limited to the most important ones namely, Atrazine, Terbuthylazine, Diazinon, and Mecoprop for agricultural uses.

Atrazine is an herbicide that has been predominantly used in the corn production in the United States, the EU and Switzerland. Studies in the early 1990s indicated that increased amounts of atrazine are running off crop fields and are accumulating in surface waters (Battagline et al. 2003). Detected levels of atrazine were between 10 to 20 times higher in surface waters than the most used other herbicides used in this study (Moorman et al., 2001). In Switzerland the maximum application rate of Atrazine is limited to an annual application of one kg per hectare of corn. With Atrazine being a known carcinogen compound and possibly impacting human health, it has been banned in the EU. Because of these negative impacts the question of how to effectively prevent Atrazine from entering surface waters is raised (Lan dgern et al., 2009). In the US and in Switzerland the use of atrazine is still legal.

Terbuthylazine is a widely used herbicide for pre-emergence and post-emergence weed control for several crops. It has been largely introduced as a follow-up product of atrazine after this one has been banned in several countries in the EU. Terbuthylazine is generally mixed with other active ingredients of pesticides and is usually distributed as ready-to-use diluted product which can be directly applied on the field by the farmers without the necessity to be mixed in the right ratio by the farmers themselves. This decreases the chance of applying Terbuthylazine in excessive concentration amounts due to less diluted mixing ratio from mishandling of the pesticide. Overall, Terbuthylazine is considered to be a safe herbicide if applied correctly (Kuechler et al., 2003).

Diazinon is an organophosphorus pesticide, which is commonly used on fruits, vegetables and field crops. It is used to combat pests such as flies and cockroaches. Diazinon is an endocrine disrupter and an exposure to diazinon can cause neurological and endocrine alternations in both wildlife species and humans. In studies done on mice, the estrogenic and anti-androgenic activities of diazinon have shown negative impacts on male reproductive capacity (El Mazoudy and Attia, 2012).

Mecoprop is a universal post-emergence herbicide that is extensively used to combat pests like weeds in grain crop production. Due to its chlorinated chemical composition it causes severe environmental threat when it is degrading in the soil environments by micro organisms (Tett et al., 1994).

The above listed pesticides are the pesticides which are predominantly used in agricultural production of fruits and field fruits, as well as in gardens and croplands in this study area. The amounts of each pesticide in its pure form applied on these land used types were based on a pilot study conducted in several sub watersheds located within the Moenchaltorfer Aa watershed. This study was done by the Federal Office for Environment in 2008 (Krebs et al., 2008; Wittmer et al., 2010). For this thesis the overall application of
pesticides was calculated as a total value in Kg and homogeneously spread over the entire study area. The total values for pesticides applied in agricultural areas zoned as fruit, equally field fruit, garden, and cropland s are given in Table 6 and are expressed in kg of pesticide per hectare.

<table>
<thead>
<tr>
<th>Name of Pesticide</th>
<th>Average Use in kg/ha</th>
<th>Total Use in the Study Area in kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atrazine*</td>
<td>0.28</td>
<td>393.94</td>
</tr>
<tr>
<td>Terbuthylazine</td>
<td>2.40</td>
<td>4444.42</td>
</tr>
<tr>
<td>Diazinon</td>
<td>3.74</td>
<td>6925.88</td>
</tr>
<tr>
<td>Mecoprop</td>
<td>1.72</td>
<td>3185.16</td>
</tr>
</tbody>
</table>

*Applied only on Corn

Table 6: Average Pesticides Use in Fruit, Field Fruit, Garden, and Cropland s Areas (Krebs et al., 2008)

3.4 Defining Environmental Unit

The concentration of fertilizer and pesticides found in water samples from the Moenchaltorfer Aa were collected from different sample sites within the study area (see Figure 3). These water samples were used to see what the current status quo situation of water quality is in the study area. The status quo water conditions of each sample site are illustrated in Table 7. These values represent the mean average values collected by the Swiss Federal Institute of Aquatic Science and Technology (Eawag) in the time period from 7th October 2010 to 7th July 2011.

<table>
<thead>
<tr>
<th>Water Sample</th>
<th>Dissolved Nutrient Values in mg/l</th>
<th>Water Sample Pesticides Values in μg/l</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measure Sites</td>
<td>Nitrogen</td>
<td>Phosphorus</td>
</tr>
<tr>
<td>1</td>
<td>1.60</td>
<td>18.79</td>
</tr>
<tr>
<td>2</td>
<td>7.80</td>
<td>35.72</td>
</tr>
<tr>
<td>3</td>
<td>7.90</td>
<td>20.28</td>
</tr>
</tbody>
</table>

Table 7: Annual mean levels of nutrients and pesticides at measuring sites (Eawag, 2012)
Figure 3: Water Sample Measuring Sites in the Study Area

The results shown in table 6 indicate that the water quality is above the aimed levels of the Swiss Water Protection Regulation (Gewasserschutzverordnung) which allows for pesticides in general not being above 1 μg/l and nutrients not to be above 1.6mg/l for nitrogen and 0.025mg/l for phosphorus (GSchV, 2011). Especially in sub watershed 2 the concentration of pollutants exceeds the desired values.

3.5 Evaluation of the five water quality improvement measures

In this section the effectiveness in terms of reductions of fertilizers and pesticides resulting from the five proposed measures for improving water quality within the study area are evaluated.

3.5.1 Measure 1: Conversion from Conventional to Organic Agriculture in the entire study area

Organic agriculture is believed to have many advantages. Some benefits are that it rejects the use of anthropogenically introduced chemicals such as synthetic fertilizers and pesticides and instead relies on naturally occurring biological processes. The most common definition of organic farming is the following one: “Organic agriculture is a holistic production management system which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles, and soil biological activity. It emphasizes the use of biological management practices in preference to the use of off farm inputs” (FAO, 1999). Measure 1 has the objective to convert the entire agricultural land within the study area from conventional to organic agriculture and thereby lower or eliminate the introduction of pollutants into the water sourcing from agriculture.
3.5.2 Measure 2: Conversion to Organic Agriculture in Tile Drainage Areas

Tile Drainage is a common practice to artificially reduce the water amount found in subsurface soil to provide optimal growth conditions for crops. This practice has been long used especially in areas which were formerly known to flood on a regular basis due to lack of slope for surface water from heavy raining events to run off. With the use of tile drainage the areas which were flooded in the past were now available for aggregation. To increase runoff man made ditches or drainage pipes were installed to speed up the outflow of surface water. This increase of runoff velocity causes higher outwash and erosion. The two most negative impacts of tile drainage for the environment is that surface water runoff from tile drainage areas have increased loading rates of fertilizers and pesticides and cause surface soil erosion (Singer et al. 2011). This increase of runoff of nutrients can cause severe environmental impacts by increasingly polluting ground or surface waters in an accelerated manner. In several studies conducted in the US the average increase of nitrate and phosphorus resulting from tile drainage areas has been estimated at around 20% (Ng et al., 2002).

In the Moenchaltorf Aa basin tile drainage is a commonly used practice, especially in the flat areas around the Aa steam to make these areas arable for agricultural practiced. These tile drainage areas are illustrated in figure 4.

![Tile Drainage Areas](image)

Figure 4: Tile Drainage Areas in Study Site

Measure 2 has the objective to convert the agricultural areas which are located in tile drainage areas to be converted into organic agriculture to lower the outflow of pollutants of these areas into the Moenchaltorf Aa basin.
3.5.3 Measure 3: Implementing Grass Buffer Strips

The use of grass buffer strips has become well accepted as a mitigation measure to diffuse the flow of phosphorus and nitrogen from agricultural areas by planners, agricultural advisers, and other practitioners in landscape planning in an effective measure. Buffers are designed to filter surface and subsurface runoff from agricultural areas and capture pesticides, fertilizers, and sediments (NRCS, 1997). Especially to prevent eutrophication in surface waters resulting from intensive input of phosphorus predominantly having their source from agricultural areas buffer strips have become the mitigation of choice. Depending on the surface slope, buffer width, precipitation, and vegetation the amount of runoff can be virtually reduced to zero (Vought et al., 1995; Addiscott, 1997; NRCS, 1997; Heathwaite et al., 2000; Dosskey, 2001; Benoit et al., 2004). Preferably natural buffer zones such as riparian forests, hedges, rows are integrated in the landscape as buffer zones along rivers and lakes, but also grass areas are being commonly designated as buffer zones. These buffers are located between the agricultural areas which are the source of the pollutants and any surface water down the hydrological slope which potentially can be sinks for these pollutants. In the US this has been commonly practiced by the Natural Resource and Soil Conservation Service (NRCS) for the last 30 years (NRCS, 1999). During this time several studies have shown the positive impact buffer zones can have on reducing suspended matter, pesticides and nitrogen for surface waters (Gril et al., 1997; Souiller et al., 2002; Aora et al., 2003; Benoit et al., 2004). These studies support the fact that over time nitrogen and most other pesticides are reduced due to biochemical transformation, denitrification and chemical decomposition. With the increased time the agricultural pollutants need to be transported from their field sources to their aquatic sinks through the buffers less amounts of pesticides flow out from the buffer zones than are flowing in, as illustrated in figure 5.

Figure 5. Schematic representation of the functioning of a grass buffer. Source: Dorioz et al (2006)

In this study the area where this measure is assumed to be implemented includes all the agricultural area within the study area where agricultural land directly borders a water stream or water body excluding the tile drainage areas, since these areas’ surface runoffs exit via drainage systems and are therefore not affected by grass buffer strips.
Some studies suggest that there is an optimal width to prevent sediment loss from agricultural areas and that any further increase of the width would not significantly reduce pollutant runoff any further (Castelle et al., 2003; Abu-Zreig et al., 2003). Studies show that most pollutants are being absorbed by the first five m with a rate of up to 86%. This indicates that even slimmer buffer strips can be very effective in preventing pollution outflow to happen. According to (Dorioz et al. 2006) the optimal buffer width is between 5-12m for grass buffer strips. Overall there is still a wide variability of how much width a grass buffer strip should have is depending on several other factors such as slope, vegetation, soil texture, as well as runoff volume, catchment area (Dorioz et al., 2006).

3.5.4 Measure 4: Livestock Reduction

Livestock (LU) is grown extensively in Switzerland. To compare the different output of manure with high values of nitrogen and phosphorus from different animal horticultures the livestock unit system is used. This LU system is based on the output of manure of a 650kg heavy cow (BWL, 2011). Other animals such as hogs and poultry just produce a faction of the manure output of a cow. This method allows calculating the manure output of animals without specifically knowing which type of animals is raised. The areas used for animal raising consists of the land use category home meadows in the available GIS land use database, these areas are illustrated in figure 6.

Figure 6: Areas for Animal Husbandry in study area

The average LU for the agricultural area located within the study area is 1.2 according to the study from (Wittmer et al., 2010).
3.5.5 Measure 5: Conversion of agricultural land in the study area into Nature Park

The conversion of the entire agricultural used area into a nature park is by far the most extreme measure which could be done to eliminate the inputs of nutrients and pesticides into the Moenchaltorf Aa and Greifensee lake.

The areas which all would be converted into nature conservation areas are illustrated in figure 7.

![Nature Conservation Area](image)

Figure 7: Locations of Nature Conservation in Study Area

The amount of runoff for nitrogen and phosphorus which naturally accrues in natural grassland was conducted out of the studies by (Wittmer et al., 2010) and Herzog, et al., 2008). With these results the assumptions could have been made how much nutrients as total would still naturally accumulate in the Moenchaltorf Aa and in the Greifensee lake. For pesticides a reduction value to zero was used. This method disregards the fact that some pesticides in form of residues in soil could still leach into the surface and ground waters.
3.6 Effects of each Measure for reducing Pesticides and Nutrients

3.6.1 Measure 1

The reduction of pesticides and nutrients which would result as consequence of applying measure 1 within the study area was calculated. For the purpose of this study the assumption is made that with the ban of pesticides, the runoff rate for pesticides will be set to zero. This might not be the case in reality since some residues of pesticides which have accumulated over decades will still be washed out and accumulate in the study area’s surface and ground waters, but taking these scenarios into account is beyond the scope of this thesis.

The effectiveness of measure 1 in reducing the amount of nutrients runoff was obtained by subtracting the percentage of mineral fertilizers from the total value of fertilizers of the annual runoff from agricultural fields within the study area. Spatial analysis distinguished between the fields on which tile drainage is practiced and those on which no tile drainage is practiced. The resulting values are listed in Table 8.

<table>
<thead>
<tr>
<th>Fertilizer Runoff by different Land Use Types</th>
<th>Nitrogen kg/ha</th>
<th>Phosphorus g/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>None Tile Drainage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cropland</td>
<td>23.45</td>
<td>229.4</td>
</tr>
<tr>
<td>Home Meadows</td>
<td>6.03</td>
<td>252.96</td>
</tr>
<tr>
<td>Natural Meadows</td>
<td>6.03</td>
<td>252.96</td>
</tr>
<tr>
<td>Fruit*</td>
<td>6.03</td>
<td>252.96</td>
</tr>
<tr>
<td>Field Fruit**</td>
<td>23.45</td>
<td>229.4</td>
</tr>
<tr>
<td>Garden***</td>
<td>23.45</td>
<td>229.4</td>
</tr>
<tr>
<td>Tile Drainage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cropland</td>
<td>30.82</td>
<td>298.84</td>
</tr>
<tr>
<td>Home Meadows</td>
<td>7.236</td>
<td>303.552</td>
</tr>
<tr>
<td>Natural Meadows</td>
<td>7.236</td>
<td>303.552</td>
</tr>
<tr>
<td>Fruit*</td>
<td>7.236</td>
<td>303.552</td>
</tr>
<tr>
<td>Field Fruit**</td>
<td>28.14</td>
<td>275.28</td>
</tr>
<tr>
<td>Garden***</td>
<td>28.14</td>
<td>275.28</td>
</tr>
</tbody>
</table>

*, **, *** Estimated Value from closest related category

Table 8: Fertilizer Runoff by Land Use Types after implementing measure 1

The overall runoff reduction of nitrogen and phosphorus in the study area and sub watersheds including tile drainage and none tile drainage areas is shown in figures 8 and 9.
The Reduction values for nitrogen and phosphorus were conducted out of the study by (Herzog et al., 2008) and illustrate how much less nitrogen and phosphorus by percent is now being applied into the soil resulting from different bio available sources of nitrogen and phosphorus without the additional anthropogenic mineral fertilizers.

### 3.6.2 Measure 2

In measure 2 the effects of how much pesticides and fertilizer would be reduced if these tile drainage areas are converted to organic agriculture are estimated. These results are listed in the following paragraph. The pesticide reduction for measure 2 is calculated out of the area which is used for agriculture within the tile drainage areas and is now not available for pesticide application. These values also do not include the fact that residues of pesticides could still leach out of the soil from the tile drainage areas. The values about how much pesticides are reduced are listed in figure 10.
Figure 10: Pesticide levels in kg per ha after implementing measure 2 by study area and pesticide type

The reduction of fertilizers runoff resulting out of measure 2 was generated by using the tile drainage area which now cannot be used for mineral fertilizer application any more. The results out of this reduction are presented in figure 11 and 12.

Figure 11: Nitrogen Runoff Reduction in kg after Measure 2
3.6.3 Measure 3

In this study a grass buffer strip is chosen by Eawag with the width of 8.5m to be right in-between the minimum and maximum width of suggested buffers according to the results from the studies mentioned above. These two buffer widths were hypothetically tested for their effectiveness at different slopes in how much nutrients these buffers should be able to stop from accumulating in the Moenchaltorf Aa and conclusively in the Greifensee. To account for the amount of Pesticides which are reduced by buffers the reduction values from a study conducted by (Mander et al., 2005) were used. The reduction results of the buffers’ effectiveness are presented in figure 13 and 14.
These reductions of nutrients and pesticides are the assumed results according to measure 3. These values are equally distributed over the study area. The effectiveness of the reduction results of grass buffers are based on the results of how effective buffers at different slopes and width are from (Dorioz et al., 2006). In their results the average annual surface flow was within 650-900mm/year. In this study area the annual surface runoff was approximately 790mm/year according to (BAFU und WSL, 2006: Rasterdatensatz mittlere Abflüsse der Schweiz für die Periode 1981-2000) of annual rainfall within the study area. The slopes of the buffer strips in the study areas by (Dorioz et al., 2006) were also within a plus minus 2 percent variation of the slopes the buffer strips have in this study. Therefore the assumption can be made that these reduction results for nutrients and pesticides from (Dorioz et al., 2006) can be assumed for the Moenchaltorf Aa basin study area as well. Nevertheless these are assumptions based on averages, and local variations might accrue.

### 3.6.4 Measure 4

With the annual runoff of nitrogen with 9.00kg per ha and phosphorus with 0.41 kg per ha for home meadows in none tile drainage areas and annual runoff of nitrogen with 10.8 kg per ha and 0.49 kg per ha for home meadows the effects of livestock reduction for status quo 1.2 LU and measure 4 proposed reductions values of 0.75 LU are presented in the figure 15 and 16.
These values represent how much nutrients could be reduced resulting from LU reduction in the areas where animals are grassing within the study area. This measure will not have a reduction of pesticides since pesticides levels are not impacted by the amount of LU grassing in the study area.

3.6.5 Measure 5

The amount of nutrients and pesticides which would be reduced after measure 5 are illustrated in the following figure 17 and 18.
The results form that measures do assume that the value for pesticides will be reduced to zero since no more agriculture is practiced within the study area. The nutrient levels are reduced to the levels of what would naturally happen as consequence of surface water runoff and erosion in this area (Siber et al., 2009).
3.7 Assessing the costs of implementing the water quality improvement measures

For estimating the economic values generated within the study area at status quo, the total size of each agricultural land use type was first calculated based on the available spatial statistics as shown in Figure 19.

![Figure 19: Different Land Uses in Moenchaltorfer Aa in hectares](image)

These values provided the initial information about how much agricultural land is being used in this study area for different practices. Average values were taken from the BFS Geostat; GG25©2007. These averages consisted out of further details about which type of crop and how much of each type of crop is grown per ha of cropland. This method allowed to interoperated local differences in how much value croplands have in different municipalities, it further on accounted for the differences in production due to crop rotation, which takes place around every 5 years (Anken et al., 2004). Data that was not available on a regional scale was retrieved from the Swiss agriculture report 2011. To account for annual differences of harvesting yield the average yields from the years 2008, 2009, and 2010 was used. This data gave the most detailed information about the proportion of agricultural land that is used for different subclasses of agricultural crops in each municipality located within the study area. Alternatively, this data sets provided a national average on the percent of land used for producing different agricultural products. Since it was not possible to evaluate which crop is grown on each hectare of cropland in the study area, the proportion of agricultural products from the local or national data was applied to each hectare of agricultural land. The results of these estimations are presented in Table 9 and 10.
Table 9: National annual production of fruits (DB Catalog 2009)

<table>
<thead>
<tr>
<th>Fruit</th>
<th>Unit</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2008-2010 Average</th>
<th>% Total Fruits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apples</td>
<td>t</td>
<td>94367</td>
<td>119910</td>
<td>100300</td>
<td>104859</td>
<td>84.12%</td>
</tr>
<tr>
<td>Pears</td>
<td>t</td>
<td>9898</td>
<td>22330</td>
<td>13200</td>
<td>15142.67</td>
<td>12.15%</td>
</tr>
<tr>
<td>Cherries</td>
<td>t</td>
<td>1308</td>
<td>2225</td>
<td>1960</td>
<td>1831</td>
<td>1.47%</td>
</tr>
<tr>
<td>Plums</td>
<td>t</td>
<td>2307</td>
<td>3446</td>
<td>2716</td>
<td>2823</td>
<td>2.26%</td>
</tr>
</tbody>
</table>

Table 10: National annual production of field fruits

<table>
<thead>
<tr>
<th>Field Fruits</th>
<th>Unit</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2008-2010 Average</th>
<th>% Total Field Fruits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strawberries</td>
<td>t</td>
<td>5181</td>
<td>5199</td>
<td>5663</td>
<td>5347.667</td>
<td>100.00%</td>
</tr>
</tbody>
</table>

For the purpose of this study and on the basis of visual evaluation of the study area via high resolution images, the agricultural subcategory “garden” was assumed to be used for growing vegetables. To determine which subcategories of vegetables are grown in gardens in the study area, the proportion of subclasses of vegetables grown at a national scale was used. The results are listed in Table 11.

Table 11: National annual production of vegetables (DB Catalog 2009)

<table>
<thead>
<tr>
<th>Garden</th>
<th>Unit</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2008-10 Average</th>
<th>% Total Garden</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrots</td>
<td>t</td>
<td>61673</td>
<td>74263</td>
<td>62638</td>
<td>66191.33</td>
<td>56.85%</td>
</tr>
<tr>
<td>Onions</td>
<td>t</td>
<td>29033</td>
<td>37895</td>
<td>32716</td>
<td>33214.67</td>
<td>28.53%</td>
</tr>
<tr>
<td>Celery</td>
<td>t</td>
<td>8927</td>
<td>11203</td>
<td>9796</td>
<td>9975.33</td>
<td>8.57%</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>t</td>
<td>7166</td>
<td>6793</td>
<td>7180</td>
<td>7046.33</td>
<td>6.05%</td>
</tr>
</tbody>
</table>

For the category “cropland” local data was available. However, since it is not clear which type of crops are grown on each single hectare of cropland, the average proportion of crops grown per ha for each crop were used to come up with a total number for croplands. Since the quantities of different crops produced in each municipality vary, the proportion of crops produced depends on the municipality in which the croplands are located. Further subcategories of croplands spatially separated by municipalities are listed in Table 12. The local data on the size of agricultural land that is used for each of the cropland subcategories was provided by Geostat; GG25©2007, swisstopo). This data represents an estimation on how much of each crop is grown in each municipality. The area for each crop was then divided by the total area of cropland in order to get a fraction of each crop grown per hectare. On average, around 10% of each municipality’s cropland could not be categorized due to the lack of data and is therefore not represented in the cropland tables.
Table 12: Areas of different crops grown on croplands by municipalities (Ackerlandkarte 2004)

<table>
<thead>
<tr>
<th>Municipality</th>
<th>Wheat</th>
<th>Corn</th>
<th>Sugar Beets</th>
<th>Potatoes</th>
<th>Rapeseed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mönchaltorf</td>
<td>47.50</td>
<td>21.70</td>
<td>14.04</td>
<td>3.17</td>
<td>0.14</td>
</tr>
<tr>
<td>Egg</td>
<td>29.15</td>
<td>15.69</td>
<td>10.56</td>
<td>0.49</td>
<td>0.04</td>
</tr>
<tr>
<td>Oetwil am See</td>
<td>25.34</td>
<td>13.45</td>
<td>8.51</td>
<td>0.00</td>
<td>0.05</td>
</tr>
<tr>
<td>Gossau (ZH)</td>
<td>24.76</td>
<td>11.03</td>
<td>9.84</td>
<td>0.22</td>
<td>0.47</td>
</tr>
<tr>
<td>Grünningen</td>
<td>18.94</td>
<td>9.76</td>
<td>7.62</td>
<td>0.00</td>
<td>0.23</td>
</tr>
<tr>
<td>Staefa</td>
<td>24.01</td>
<td>12.96</td>
<td>10.29</td>
<td>0.00</td>
<td>0.07</td>
</tr>
<tr>
<td>Bubikon</td>
<td>19.86</td>
<td>7.08</td>
<td>12.04</td>
<td>0.00</td>
<td>0.04</td>
</tr>
<tr>
<td>Hombrechtikon</td>
<td>13.33</td>
<td>4.48</td>
<td>7.92</td>
<td>0.00</td>
<td>0.09</td>
</tr>
<tr>
<td>Uster</td>
<td>43.61</td>
<td>22.73</td>
<td>12.77</td>
<td>1.98</td>
<td>0.29</td>
</tr>
</tbody>
</table>

Table 13: Proportions of different crops grown on croplands by municipalities (Ackerlandkarte 2004)

<table>
<thead>
<tr>
<th>Municipality</th>
<th>Wheat</th>
<th>Corn</th>
<th>Sugar Beets</th>
<th>Potatoes</th>
<th>Rape Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mönchaltorf</td>
<td>45.68%</td>
<td>29.55%</td>
<td>6.68%</td>
<td>0.29%</td>
<td>5.35%</td>
</tr>
<tr>
<td>Egg</td>
<td>33.02%</td>
<td>22.22%</td>
<td>1.04%</td>
<td>0.07%</td>
<td>3.87%</td>
</tr>
<tr>
<td>Oetwil am See</td>
<td>28.32%</td>
<td>17.91%</td>
<td>0.00%</td>
<td>0.12%</td>
<td>4.57%</td>
</tr>
<tr>
<td>Gossau (ZH)</td>
<td>23.23%</td>
<td>20.71%</td>
<td>0.47%</td>
<td>1.00%</td>
<td>2.78%</td>
</tr>
<tr>
<td>Grünningen</td>
<td>20.55%</td>
<td>16.04%</td>
<td>0.00%</td>
<td>0.48%</td>
<td>2.15%</td>
</tr>
<tr>
<td>Staefa</td>
<td>53.98%</td>
<td>42.87%</td>
<td>0.00%</td>
<td>0.28%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Bubikon</td>
<td>35.67%</td>
<td>60.61%</td>
<td>0.00%</td>
<td>0.18%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Hombrechtikon</td>
<td>33.63%</td>
<td>59.44%</td>
<td>0.00%</td>
<td>0.68%</td>
<td>2.30%</td>
</tr>
<tr>
<td>Uster</td>
<td>52.12%</td>
<td>29.28%</td>
<td>4.54%</td>
<td>0.67%</td>
<td>11.06%</td>
</tr>
</tbody>
</table>

The categories of home meadows and natural meadows were used to get an estimate on how much livestock there is in the study area. The difference between the two categories is that on home meadows the animals are herded and natural meadows are used for growing hay as footstock for the animals during the winter season. Overall, there should not be a difference between the two categories in terms of the amount of nutrients and pesticides runoff from each of the two categories. In home meadows grass is consumed and manure deployed directly by the animals, while in the natural meadows the grass is harvested by the farmers and brought to the animals and the manure is collected by the farmers and applied as fertilizer on the field by the farmers. To assess the effects of a reduction of different livestock in a homogeneous way the livestock unit (LU) was used. This value represents the annual food consumption and manure disposal of a 650kg heavy cow, but can be applied to any livestock. Based on a study conducted by Prasuhn (2004), which included the Moenchaltorf Aa basin, the average LU value is 1.2 per hectare. This value was hence used as a LU value for the status quo in this study area for each hectare of natural and home meadows. To further divide the LU value into different animal products the national datasets were used and the results are presented in Table 14.
Figures and Tables

Table 14: Animal produce produced in subcategories in study area (DB Catalog 2009)

<table>
<thead>
<tr>
<th>Animal Product</th>
<th>Unit</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>Average Value</th>
<th>% Animal Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef</td>
<td>t</td>
<td>105143</td>
<td>109360</td>
<td>111216</td>
<td>108573</td>
<td>8.54%</td>
</tr>
<tr>
<td>Veal</td>
<td>t</td>
<td>30251</td>
<td>32238</td>
<td>31673</td>
<td>31387.33</td>
<td>2.47%</td>
</tr>
<tr>
<td>Pork</td>
<td>t</td>
<td>231013</td>
<td>237884</td>
<td>249470</td>
<td>239455.67</td>
<td>18.83%</td>
</tr>
<tr>
<td>Poultry</td>
<td>t</td>
<td>40816</td>
<td>41726</td>
<td>44050</td>
<td>42197.33</td>
<td>3.32%</td>
</tr>
<tr>
<td>Dairy Produce</td>
<td>t</td>
<td>835201</td>
<td>845357</td>
<td>848256</td>
<td>843271</td>
<td>66.32%</td>
</tr>
</tbody>
</table>

The economic value Swiss Franc (CHF) was applied to the different agricultural products by applying the contribution margin (C) used in this study is from the Deckungsbeitrag catalog of 2009 for conventional agriculture. The CB represents the marginal profit generated by unit. In this study the CB refers to the profit generated by unit ha of the different agricultural land uses practiced with in the study area.

This gave the overall value of revenue which is generated per year of work for the farmer on 1 ha of different agricultural land types. To represent the current agricultural conditions, the C values were used to illustrate the generated revenue in CHF for farmers per ha in this study area under status quo situation. In more detail, the economic values for fruits which are produced in the study area are generated out of the fraction of created produce per ha and are multiplied by the C value per ha. This gives the overall profit produced per ha of land in this study area. The results are listed in the tables 15, 16, 17, and 18.

Table 15: Economic value of fruits per ha in the study area (DB Catalog 2009)

<table>
<thead>
<tr>
<th>Fruit</th>
<th>Proportion of Fruits produced per ha</th>
<th>Contribution margin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apples</td>
<td>84.12%</td>
<td>14,815</td>
</tr>
<tr>
<td>Pears</td>
<td>12.15%</td>
<td>17,473</td>
</tr>
<tr>
<td>Cherries</td>
<td>1.47%</td>
<td>39,401</td>
</tr>
<tr>
<td>Plums</td>
<td>2.26%</td>
<td>7,557</td>
</tr>
<tr>
<td><strong>Average Value Fruit</strong></td>
<td></td>
<td><strong>19,812</strong></td>
</tr>
</tbody>
</table>

For Field Fruits only one subcategory was used, so the results are as follows.

Table 16: Economic value of field fruits per ha in the study area (DB Catalog 2009)

<table>
<thead>
<tr>
<th>Field Fruits</th>
<th>Proportion of field fruits produced per ha</th>
<th>Contribution margin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strawberries</td>
<td>100%</td>
<td>5,473</td>
</tr>
</tbody>
</table>
Table 17: Economic value of vegetables per ha in the study area (DB Catalog 2009)

To calculate the economic values for cropland, proportions of each crop produced per ha in each municipality were used. The differences in economic values of cropland result from different crop distributions across municipalities and are presented in Table 14.

Table 18: Economic value of crops per ha for each municipality in the study area (Ackerlandkarte 2004)

For animals the economic value was calculated by applying the proportion of animal production per hectare from the national data. These values were then multiplied by the average contribution margins from the DB catalog 2009 for each animal product and were further divided by working hours. Table 19 shows the proportions in production and economic values of each animal product per ha of livestock.

Table 19: Economic values of animal products per ha of home meadows (DB Catalog 2009)
The total number of livestock further has to be multiplied by 1.2 since LU in this study area is listed as intensive. This means that the overall economic value for conventional livestock is 27.48 CHF per hectare.

The amount of fodder which is produced in the study area is listed in Table x, The economic value for fodder are repressing out of the DB catalog 2009 and the level of intensification of grassland usage practiced in the study area according to (Wittmer et al., 2010).

<table>
<thead>
<tr>
<th>Natural Meadows</th>
<th>Proportion</th>
<th>Unit</th>
<th>Contribution margin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animal Fodder</td>
<td>100%</td>
<td>CHF/ha</td>
<td>1,042</td>
</tr>
</tbody>
</table>

Table 20: Economic value of animal fodder produced per ha of natural meadows (DB Catalog 2009)

In a status quo situation, the economic value generated in the study area results from different land use practices and their corresponding economic values per hectare. These values are shown according to the land use types and as a total value of agriculture in the study area in Figure 20.

![Economic Value of Agriculture in Study Area at Status Quo](image)

**Total economic value generated:** CHF 9,343,757.88

Figure 20: Economic value generated by each land use type in the study area

The economic value generated at status quo specially analyzed by the 3 sub watershed areas are presented in Figure 21.
3.7.1 Costs of Measure 1: Conversion from Conventional to Organic Agriculture in the entire study area

Organic farming on one hand reduces the costs for farmers. This happens due to the savings that farmers have from not purchasing mineral fertilizers and pesticides. It also helps farmers to have their costs and income more evenly distributed during the year, since the farmer has no single cash crop which he depends on but has a more diversified production. Overall it can be said that organic farming provides higher yield security by applying a higher diversity of crops. This reduces the dependency of farmers on external inputs (Suresh, 2010). On the other hand, organic agriculture is presumed to have lower yields (Trewavas, 2004). Especially during the time that it takes for the soil to recover after the conversion from conventional to organic agriculture a considerably lower yield may be noticed. In a study that has been going on for more than 25 years in Switzerland now organic agriculture yields similar to conventional agriculture yields have been recorded (Maeder et al., 2002). Most other scientific research, however, shows that there is on average a decrease of 20% to 40% of yields when changing from conventional to organic agriculture (Chhonkar, 2003).

In this section the costs of converting conventional agriculture to organic agriculture are estimated. The economic values are based on contribution margin which is generated from organic farming. These values were conducted out of a national scale averages from the DB Catalog of 2009. If more than a single value was listed in the DB Catalog the average values of all the listed values in the DB Catalog was used.

The results showing the economic value generated by the different types of land uses under organic agriculture are listed in Tables 21 to 25.
### Contribution margins for organic agriculture

<table>
<thead>
<tr>
<th>Fruit</th>
<th>Proportion/ha</th>
<th>Unit</th>
<th>Contribution margins for organic agriculture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apples</td>
<td>84.12%</td>
<td>CHF/Ha</td>
<td>17,419</td>
</tr>
<tr>
<td>Pears</td>
<td>12.15%</td>
<td>CHF/Ha</td>
<td>21,365</td>
</tr>
<tr>
<td>Cherries</td>
<td>1.47%</td>
<td>CHF/Ha</td>
<td>25,642</td>
</tr>
<tr>
<td>Plums</td>
<td>2.26%</td>
<td>CHF/Ha</td>
<td>39,162</td>
</tr>
</tbody>
</table>

**Average value/ha for fruits**

<table>
<thead>
<tr>
<th>Unit</th>
<th>Contribution margins</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHF/Ha</td>
<td>25,897</td>
</tr>
</tbody>
</table>

Table 17: Economic value of organic fruits per hectare in the study area (DB Catalog 2009)

### Economic value of organic field fruits per hectare

<table>
<thead>
<tr>
<th>Field Fruits</th>
<th>Proportion/ha</th>
<th>Unit</th>
<th>Contribution margin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strawberries</td>
<td>100%</td>
<td>CHF/Ha</td>
<td>5,971</td>
</tr>
</tbody>
</table>

Table 21: Economic value of organic field fruits per hectare in the study area (DB Catalog 2009)

### Economic value of organic gardens per hectare

<table>
<thead>
<tr>
<th>Garden</th>
<th>Proportion/ha</th>
<th>Unit</th>
<th>Contribution margins</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrots</td>
<td>56.85%</td>
<td>CHF/Ha</td>
<td>6,997</td>
</tr>
<tr>
<td>Onions</td>
<td>28.53%</td>
<td>CHF/Ha</td>
<td>4,610</td>
</tr>
<tr>
<td>Celery</td>
<td>8.57%</td>
<td>CHF/Ha</td>
<td>10,495</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>6.05%</td>
<td>CHF/Ha</td>
<td>12,733</td>
</tr>
</tbody>
</table>

**Average value/ha for vegetables**

<table>
<thead>
<tr>
<th>Unit</th>
<th>Contribution margins</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHF/Ha</td>
<td>8,709</td>
</tr>
</tbody>
</table>

Table 22: Economic value of organic gardens per hectare in the study area (DB Catalog 2009)

### Economic value of organic cropland per hectare

<table>
<thead>
<tr>
<th>Municipality</th>
<th>Wheat</th>
<th>Corn</th>
<th>Sugar Beats</th>
<th>Potatoes</th>
<th>Rape</th>
<th>Contribution margins</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mönchaltorf</td>
<td>45.68%</td>
<td>29.55%</td>
<td>6.68%</td>
<td>0.29%</td>
<td>5.35%</td>
<td>3,516.54</td>
</tr>
<tr>
<td>Egg</td>
<td>33.02%</td>
<td>22.22%</td>
<td>1.04%</td>
<td>0.07%</td>
<td>3.87%</td>
<td>2,346.45</td>
</tr>
<tr>
<td>Oetwil am See</td>
<td>28.32%</td>
<td>17.91%</td>
<td>0.00%</td>
<td>0.12%</td>
<td>4.57%</td>
<td>1,981.64</td>
</tr>
<tr>
<td>Gossau (ZH)</td>
<td>23.23%</td>
<td>20.71%</td>
<td>0.47%</td>
<td>1.00%</td>
<td>2.78%</td>
<td>2,025.06</td>
</tr>
<tr>
<td>Grünningen</td>
<td>20.55%</td>
<td>16.04%</td>
<td>0.00%</td>
<td>0.48%</td>
<td>2.15%</td>
<td>1,584.10</td>
</tr>
<tr>
<td>Staeifa</td>
<td>53.98%</td>
<td>42.87%</td>
<td>0.00%</td>
<td>0.28%</td>
<td>0.00%</td>
<td>3,745.57</td>
</tr>
<tr>
<td>Bubikon</td>
<td>35.67%</td>
<td>60.61%</td>
<td>0.00%</td>
<td>0.18%</td>
<td>0.00%</td>
<td>3,931.91</td>
</tr>
<tr>
<td>Hombrechtikon</td>
<td>33.63%</td>
<td>59.44%</td>
<td>0.00%</td>
<td>0.68%</td>
<td>2.30%</td>
<td>4,011.27</td>
</tr>
<tr>
<td>Uster</td>
<td>52.12%</td>
<td>29.28%</td>
<td>4.54%</td>
<td>0.67%</td>
<td>11.06%</td>
<td>3,943.07</td>
</tr>
</tbody>
</table>

Table 23: Economic value of organic cropland per hectare for each municipality in the study area
Table 24: Economic value of organic animal products per ha of natural and home meadows (DB Catalog 2009)

<table>
<thead>
<tr>
<th>Animal Product</th>
<th>Proportion/ha</th>
<th>Unit</th>
<th>Contribution margins for organic agriculture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef</td>
<td>8.54%</td>
<td>CHF/Ha</td>
<td>37.45</td>
</tr>
<tr>
<td>Veal</td>
<td>2.47%</td>
<td>CHF/Ha</td>
<td>24.53</td>
</tr>
<tr>
<td>Pork</td>
<td>18.83%</td>
<td>CHF/Ha</td>
<td>139.38</td>
</tr>
<tr>
<td>Poultry</td>
<td>3.32%</td>
<td>CHF/Ha</td>
<td>682.30</td>
</tr>
<tr>
<td>Dairy Produce</td>
<td>66.32%</td>
<td>CHF/Ha</td>
<td>952.06</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>CHF/Ha</td>
<td><strong>1,773.74</strong></td>
</tr>
</tbody>
</table>

Table 25: Economic value of organic animal fodder produced per ha of natural meadows (DB Catalog 2009)

<table>
<thead>
<tr>
<th>Natural meadows</th>
<th>Proportion/ha</th>
<th>Unit</th>
<th>Contribution margin for organic agriculture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animal fodder</td>
<td>100%</td>
<td>CHF/Ha</td>
<td><strong>1,341.16</strong></td>
</tr>
</tbody>
</table>

Figure 22: Economic Value generated by each land use type after measure 1 (converting conventional into organic agriculture in the entire study area)

The economic changes generated on a spatial pattern for all of the five measures is presented in figures 23 to 26.
3.7.2 Costs of Measure 2: Conversion from Conventional to Organic Agriculture in Tile Drainage Areas

Figure 23: Economic Value after implementing measure 1 by sub watersheds

Figure 24: Economic Value after implementing measure 2 by sub watersheds
3.7.3 Costs of Measure 3: Implementing Grass Buffer Strips

![Economic Value of Agriculture after implementing Measure 3](image1)

Figure 25: Economic Value after implementing measure 3 by sub watersheds

3.7.4 Costs of Measure 4: Livestock Reduction

![Economic Value of Agriculture after implementing Measure 4](image2)

Figure 26: Economic Value after implementing measure 4 by sub watersheds

3.7.5 Measure 5: Conversion of Agricultural Land in Study Area into Nature Conservation Area

Another common practice in improving environmental conditions is the conversion of agricultural areas into nature conservation areas. Even though the economic generated value is decreased since no cash crops can be further more produced so is this method under certain conditions a lucrative alternative for conventional agriculture, since the
investment costs are becoming quite low, whereas there is still a certain amount of profit generated by either selling timber or in this thesis’s scenario animal fodder.

![Economic Value of Agriculture after implementing Measure 5](image)

**Figure 27: Economic Value after implementing measure 5 by sub watersheds**

The economic value which is generated out of conversion to Nature Park was conducted out of the low intensive bio fodder provided by the DB 2009 catalog. This value was given to each ha of agricultural land within the study area, since now all areas are seen as grassland.

### 3.8 Ranking Measures by their costs from least cost to most cost

The following table ranks these five different measures with their subcategories by their cost.

<table>
<thead>
<tr>
<th>Ranking by Measures Costs</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Study Area</strong></td>
<td></td>
</tr>
<tr>
<td>Measure 1</td>
<td>-CHF 1,226,380.71</td>
</tr>
<tr>
<td>Measure 2</td>
<td>-CHF 1,011,918.34</td>
</tr>
<tr>
<td>Measure 3</td>
<td>CHF 280,312.74</td>
</tr>
<tr>
<td>Measure 4</td>
<td>CHF 287,256.44</td>
</tr>
<tr>
<td>Measure 5</td>
<td>CHF 4,638,968.60</td>
</tr>
<tr>
<td><strong>Sub Watershed 1</strong></td>
<td></td>
</tr>
<tr>
<td>Measure 1</td>
<td>-CHF 211,658.73</td>
</tr>
<tr>
<td>Measure 2</td>
<td>-CHF 5,514.32</td>
</tr>
<tr>
<td>Measure 4</td>
<td>CHF 27,894.33</td>
</tr>
<tr>
<td>Measure 3</td>
<td>CHF 29,266.44</td>
</tr>
<tr>
<td>Measure 5</td>
<td>CHF 634,586.23</td>
</tr>
<tr>
<td>Sub Watershed 2</td>
<td>Costs</td>
</tr>
<tr>
<td>----------------</td>
<td>---------------------------</td>
</tr>
<tr>
<td>Measure 1</td>
<td>-CHF 295,101.70</td>
</tr>
<tr>
<td>Measure 2</td>
<td>-CHF 56,516.00</td>
</tr>
<tr>
<td>Measure 3</td>
<td>CHF 75,809.30</td>
</tr>
<tr>
<td>Measure 4</td>
<td>CHF 1,125,058.91</td>
</tr>
<tr>
<td>Measure 5</td>
<td>CHF 1,579,323.01</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sub Watershed 3</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measure 1</td>
<td>-CHF 626,612.66</td>
</tr>
<tr>
<td>Measure 2</td>
<td>-CHF 205,994.80</td>
</tr>
<tr>
<td>Measure 3</td>
<td>CHF 157,031.57</td>
</tr>
<tr>
<td>Measure 4</td>
<td>CHF 183,963.17</td>
</tr>
<tr>
<td>Measure 5</td>
<td>CHF 2,329,294.00</td>
</tr>
</tbody>
</table>

Table 26: Measures ranked by their costs spatially by their sub watersheds:
The negative costs result from the fact that measure 1 and measure 2 when being implemented would reduce the costs in comparison to the status quo situation.

4 Uncertainty Measurements

Uncertainty is an unavoidable challenge that cost effectiveness analysis models are facing. According to the EPA it is the challenge not to avoid uncertainties, but to integrate uncertainties into conclusions and decisions thrived from the results cost effectiveness models generate (US EPA, 2000).

In this thesis the uncertainties result of a vast amount of environmental, economic, and spatial modelling uncertainties.

Economic uncertainty resulted out of the fact that no direct information was available to gather adequate data on what the real economic value of one ha of agricultural land under different land use practices is. Real economic values form the farmers working within the study area was not given, neither was there information on given on which type of crops and where in the study area these crops are grown. All of these information which are essential for calculating an economical estimate on how valuable a hectare of agricultural land is had to be generated either from national available data. The calculated uncertainty value for that category was generated out of the minimum and the maximum value of what the economic value per land use type could be.

The environmental uncertainty results out of empirical studies which were conducted to test how threatening the measured pollutants in this thesis are for aquatic environments. With the Moenchaltorf Aa basin and the Greifensee being a study area which has been evaluated extensively by several studies and research projects with very similar results is the uncertainty about the toxicity of the tested substances fairly low. The uncertainty arises from the limited information which was available by the farmers on how much fertilizers and pesticides they are actually applying on the agricultural available land within the study area. The available data was from national legal limits on how much pesticides and fertilizer can be applied per ha of land, or were derived from volunteering local survey. Nevertheless a
given amount of uncertainty is to be expected in each method used to gather data about how much fertilizer and pesticides are used in the study area.

Spatial uncertainty resulted out of the limited resolution and available datasets from the GIS system. With the spatial accuracy of 1 ha for defining land use type’s areas with a smaller scale of one ha could have been categorized as something different. The slope of the surface investigated to calculate runoff values was even less accurate with a raster size of 2500 square meters. Even greater uncertainty can be concluded out of the annual precipitation rates. These values are also measured over and areal accuracy of 2500 square meters, but has additionally the uncertainty of being an average of rainfall which was conducted during the last 3 decades.

These three listed uncertainties of economical, environmental, and spatial origin have different levels of impact on the accuracy of the proposed results for this cost effectiveness study.

For measure 1, as for all other measures, the uncertainty from the economic analysis of land value is given, furthermore there is a given uncertainty about spatial distribution of the different land uses within the study area. The resulting from the environmental conclusions derived from other peer reviewed studies. For example there is no conclusive data on how effective the switch from mineral to organic fertilizer on phosphorus reduction would be.

For measure 2, the same economic and environmental uncertainty is given. The uncertainty level is even increased due to the application of additional spatial uncertainties. Specifically the definition of how much and how many different land used are located in the tile drainage areas, as well as the uncertainty of how much the surface runoff rate is increased due to the tile drainage increased the uncertainty for measure 2.

Measure 3, can be said to have the highest level of uncertainty. This concludes out of the fact that for that measure most variables had to be integrated to conduct these measure results. With each variable such as land use type and area within buffer strips, the slope of the buffer areas and the annual rainfall within the study area, each having already a given uncertainty makes measure 3’s results the ones with the highest uncertainty.

Measure 4 uncertainties has is uncertainties besides the economic and environmental uncertainties on the fact that a linear assumption is made on how much nutrients are being reduced by percentage of livestock unit. Another uncertainty is that the averages of livestock unit homogeneously over the entire study area resulting from a study by (Wittmer et al., 2010) was used to get the value of the status quo situation livestock unit density. Another uncertainty is that the Livestock Unit is based already on an assumed distributed value for different animals.

For measure 5 the uncertainty results more out of the economic validation of how much the contribution margin for a nature conservation area could be. The uncertainty comes expletively from the fact that it is not known what type of nature will claim these newly available areas as their habitat. Further one has there be given a degree of uncertainty on how productive and easily accessible the generated goods are for the farmers after the land is declared as nature conservation area. The spatial uncertainty will be less of significant, since small spatial differences will be less significant, since the entire area which has a relatively high accuracy will be converted into a nature conservation area.

A final uncertainty factor which will have impact for all different measures is the factor of time and development in the study area. Under current trends it seems like that within the next 40 years the urbanization of the study area will steadily progress. This could lead to
the consequence that agricultural land will be converted into urbanized areas and the still existing agricultural areas could be intensified. The level of uncertainty for this is nearly impossible to be predicted, but is should be mentioned as additional variable of this cost effectiveness analysis.

4.1 Range of Uncertainty Values

The correspond percentage of the cost uncertainty of this reports costs effectiveness analysis was generated out of the differences the possible contribution margin for each subclass of the DB catalog 2009 of agricultural land use practice. These values as shown in table 24 were then multiplied by the percentage of how much these land use practiced within the study area according to the different five measures.

<table>
<thead>
<tr>
<th>Land Use Type</th>
<th>Conventional Agriculture</th>
<th>Organic Agriculture</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Percent lower</td>
<td>Percent higher</td>
</tr>
<tr>
<td>Fruits</td>
<td>27.6</td>
<td>25.7</td>
</tr>
<tr>
<td>Field Fruits</td>
<td>7.6</td>
<td>7.6</td>
</tr>
<tr>
<td>Gardens</td>
<td>34.2</td>
<td>26.3</td>
</tr>
<tr>
<td>Plowland</td>
<td>25.9</td>
<td>31.1</td>
</tr>
<tr>
<td>Home Meadows</td>
<td>78</td>
<td>194.2</td>
</tr>
<tr>
<td>Natural Meadows</td>
<td>137</td>
<td>190</td>
</tr>
</tbody>
</table>

Table 27: Uncertainties of Costs for different Land Use Practices

The environmental uncertainties which are the uncertainties for the effeteness of the different environmental measures was generated out of the available data from the scientific literature which was used in this thesis report and out of the range between the lowest and the highest values out of the available data sets.

The uncertainty of differences between organic and conventional agriculture and their difference in nutrient runoff are represented in figure 28, which shows how much lower or higher nutrient runoff form organic farming can be compared to conventional farming.

<table>
<thead>
<tr>
<th>Runoff Rate Uncertainty of Nutrients from Organic Agriculture in Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent lower</td>
</tr>
<tr>
<td>61.7</td>
</tr>
</tbody>
</table>

Table 28: Runoff Rate Uncertainty of Nutrients from Organic Agriculture

These uncertainties result of the averages of the comparison study from (Kirchmann and Bergstroem, 2001).
For grass buffers the range of uncertainty is shown in table 29.

<table>
<thead>
<tr>
<th>Nitrogen</th>
<th>Minimum Value in Percent lower</th>
<th>Maximum Value in Percent higher</th>
</tr>
</thead>
<tbody>
<tr>
<td>92.8</td>
<td>130.0</td>
<td></td>
</tr>
<tr>
<td>Phosphorus</td>
<td>88.4</td>
<td>121.0</td>
</tr>
<tr>
<td>Pesticides</td>
<td>72.9</td>
<td>71.7</td>
</tr>
</tbody>
</table>

Table 29: Uncertainties for Grass Buffer Effectiveness on Nutrients and Pesticides

These results are out of table 1 of the report from (Dorioz et al., 2009) and are listed in the appendix.

The range of uncertainty for the runoff rate of tile drainage areas is shown in table 30:

<table>
<thead>
<tr>
<th>Nitrogen</th>
<th>Minimum Value in Percent lower</th>
<th>Maximum Value in Percent higher</th>
</tr>
</thead>
<tbody>
<tr>
<td>33.9</td>
<td>65.4</td>
<td></td>
</tr>
</tbody>
</table>

Table 30: Uncertainty of Runoff from Tile Drainage on Nutrients and Pesticides

These results were used out of table 3 of the study by (Dury et al., 2009) see appendix.

The range of uncertainty for the livestock unit reduction was generated out of an assumed linear reduction of nutrients and pesticides with the decrease of LU per ha of land used for livestock. The range of uncertainty for LU reduction is listed in table 31:

<table>
<thead>
<tr>
<th>Nitrogen</th>
<th>Minimum Value in Percent lower</th>
<th>Maximum Value in Percent higher</th>
</tr>
</thead>
<tbody>
<tr>
<td>33.3</td>
<td>33.3</td>
<td></td>
</tr>
</tbody>
</table>

Table 31: Uncertainty of Livestock Reduction Value on Nutrients Pesticides

For the spatial uncertainty no numerical values for uncertainty could be given since the difference between the real world data and the data sets available from the geo database layers cannot be compared. The only statement that can be given is that uncertainty emerges out of the different raster parcel sizes.

The uncertainty for future development was also not included in this uncertainty models since the evaluation of different development proposals and scenarios with different development sites and practices including infrastructure would exceed the focus of this master thesis.

Conclusive the above listed uncertainties represent just a fraction of all factors which could have impacts on the accuracy of the results for the cost effectiveness analysis of this thesis report. The other uncertainties which could have impact on this theses reports were either too complex to be integrated or were simply not being thought of as potential uncertainty for this cost effectiveness analysis report.
4.2 Uncertainty Results

The uncertainty results of this study are divided into two sections, the uncertainty of the economic values presented in section 4.2.1 and the uncertainty of the effectiveness of the proposed mitigations in section 4.2.2 to 4.2.6.

4.2.1 Economic Uncertainty

The Status quo situation is based on calculations and assumptions of national average values and therefore also has a given economic uncertainty. In figure 23 the assumed calculated uncertainty for conventional and organic agricultural produce is presented.

![Economic Uncertainty for Agricultural Output in the Study Area](image)

Figure 23: Economic Uncertainty for Agricultural Output in the Study Area for Status Quo and Measure 1

The exact numerical values of uncertainty are illustrated in table 32.

<table>
<thead>
<tr>
<th>Land Use Type</th>
<th>Minimum Value</th>
<th>Maximum Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruits</td>
<td>72.40%</td>
<td>79.55%</td>
</tr>
<tr>
<td>Field Fruits</td>
<td>92.40%</td>
<td>92.94%</td>
</tr>
<tr>
<td>Garden</td>
<td>65.80%</td>
<td>79.18%</td>
</tr>
<tr>
<td>Cropland</td>
<td>74.10%</td>
<td>76.28%</td>
</tr>
<tr>
<td>Home Meadows</td>
<td>22.00%</td>
<td>33.99%</td>
</tr>
<tr>
<td>Natural Meadows</td>
<td>137.00%</td>
<td>34.48%</td>
</tr>
</tbody>
</table>

Table 32: Uncertainty of Generated Value in study Area under Status Quo Scenario
Figure 24: Economic Value of Agricultural Produce generated for conventional agriculture. For organic agriculture the economic value generated is shown in figure 25.

Figure 25: Economic Value of Agricultural Produce generated for organic agriculture.
4.2.2 Effect Uncertainties for Measure 1

For the five measures the uncertainty of their effectiveness is evaluated and is listed in the following tables and graphs.

For measure 1 the effects uncertainty is illustrated in figure 26.

![Figure 26: Uncertainties of Nitrogen and Phosphorus reduced in Study Area after Measure 1](image)

<table>
<thead>
<tr>
<th>Total Nitrogen Use in Study Area</th>
<th>Total Phosphorus Use in Study Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen in Kg</td>
<td>Phosphorus in Kg</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>Maximum Value</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>Phosphorus</td>
</tr>
<tr>
<td>42835.83</td>
<td>61003.23</td>
</tr>
<tr>
<td>370.7638</td>
<td>2048.873</td>
</tr>
</tbody>
</table>

Table 33: Range of Runoff Reduction in Study Area after Measure 1

4.2.3 Effect Uncertainties for Measure 2

The Uncertainty values for the costs of measure 2 were generated out of the cost uncertainty for conventional agriculture plus the cost uncertainty from agriculture converted into organic agriculture. The effects for pesticide and nutrients runoff reductions have also two uncertainty values with one of them resulting from the uncertainty of reduction of nutrient runoff from conversion from conventional to organic agriculture and the other uncertainty results from the tile drainage and how much more nutrient and pesticide runoff results due to the tile drainage practice. To combine the effects uncertainties the combined standard uncertainty (\(U_c\)) was used. The standard combined uncertainty was calculated by using the uncertainty from the different sources of uncertainty and calculating the root sum square for the maximum and minimum values of uncertainty.

\[
u_c(x) = \sqrt{(u_1(x))^2 + (u_2(x))^2 + (u_3(x))^2 + \ldots etc.}
\]

The effects uncertainty for Nutrient and Pesticide Reductions are listed in the following figures and tables.
Figure 27: Effects Uncertainty in Study Area after Measure 2

![Effects Uncertainty in Study Area after Measure 2](image)

| Range of Uncertainty for Effects on Nitrogen Phosphorus and Pesticides Reduction in Kg |
|---------------------------------|-----------------|-----------------|
| Minimum Value                  | Maximum Value   |
| Nitrogen                        | 40242.7627      | 74161.66        |
| Phosphorus                      | 677.048555      | 1247.704        |
| Pesticides                      | 19284.726       | 10464.58        |

Table 34  Range of Nutrients and Pesticide Reduction Levels after Measure 2

The effects uncertainty for the grass buffer strips has a high degree of uncertainty, since the reduction of nutrients and nitrogen flow from the grass buffer strips were generated out of a number of different variables which each of them already had a given degree of uncertainty. These values were conducted out of a study done by (Dorioz et al., 2009). These Uncertainty Values applied in this thesis report generated the runoff uncertainty for nutrients and pesticides for the measure 3 scenario and is shown in figure 28 and table 35.

### 4.2.4  Effect Uncertainties for Measure 3

![Effects Uncertainty in Study Area after Measure 3](image)

Figure 28: Reduction Uncertainty of Nutrients and Pesticides in Study Area after Measure 3
4.2.5  Effect Uncertainties for Measure 4

The effect uncertainty for this measure was generated out of the status quo uncertainty plus the uncertainty resulting from the assumed liner regression of livestock reduction. To combine these two uncertainties the combined standard uncertainty (Uc) was used as in measure 2. The results are listed in figure 29.

![Figure 29: Effects Uncertainty of Nutrient Reduction in Study after Measure 4](image)

### Table 35: Range of Uncertainty for Runoff Reduction in Study Area after Measure 4

<table>
<thead>
<tr>
<th></th>
<th>Minimum Value</th>
<th>Maximum Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>76179.78</td>
<td>1498.59</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>77585.12</td>
<td>1562.30</td>
</tr>
</tbody>
</table>

4.2.6  Effect Uncertainties for Measure 5

The effects uncertainty for measure 5 was generated out of the status quo scenario and the assumed reduction of pollutants according to implementing measure 5. The Uncertainty of the effects results in how effective the implementation of measure 5 in terms of nutrient reduction would be.
Figures and Tables

Figure 30: Runoff Uncertainty of Nutrients in Study Area after Measure 5

Table 36: Range of Runoff in Study Area after Measure 5

<table>
<thead>
<tr>
<th></th>
<th>Minimum value</th>
<th>Maximum Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>25257.62</td>
<td>37886.43</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>698.46</td>
<td>1047.69</td>
</tr>
</tbody>
</table>

Table 36: Range of Runoff Uncertainty in Study Area after Measure 5 in Kg
## Results

Overall results of study area for each measure in term of value generated, nutrient and pesticide reduction with integrated Uncertainty.

This table shows the effectiveness of each measure based on how much CHF a reduction of 1kg of pollutant would cost annually per ha of land in the total study area and each sub watershed. No reduction values were given if measures did not contribute in reducing certain pollutants as it happened in some of the proposed measures.

<table>
<thead>
<tr>
<th>Measures ranked by Cost Effectiveness per ha</th>
<th>Total Study Area</th>
<th>Sub Watershed 1</th>
<th>Sub Watershed 2</th>
<th>Sub Watershed 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measure 2</td>
<td>-0.00029</td>
<td>-0.99152</td>
<td>Measure 1</td>
<td>-0.42499</td>
</tr>
<tr>
<td>Measure 1</td>
<td>-0.00016</td>
<td>-0.56449</td>
<td>Measure 2</td>
<td>-0.03218</td>
</tr>
<tr>
<td>Measure 3</td>
<td>0.002343</td>
<td>0.116854</td>
<td>Measure 3</td>
<td>0.025403</td>
</tr>
<tr>
<td>Measure 4</td>
<td>0.028655</td>
<td>1.126433</td>
<td>Measure 5</td>
<td>0.121705</td>
</tr>
<tr>
<td>Measure 5</td>
<td>0.05106</td>
<td>1.856489</td>
<td>Measure 4</td>
<td>no reduction</td>
</tr>
<tr>
<td>Sub Watershed 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measure 2</td>
<td>-0.93766</td>
<td>-16.5121</td>
<td>Measure 1</td>
<td>-2.98295</td>
</tr>
<tr>
<td>Measure 1</td>
<td>-0.74001</td>
<td>-14.6729</td>
<td>Measure 2</td>
<td>-1.07884</td>
</tr>
<tr>
<td>Measure 3</td>
<td>0.045406</td>
<td>1.516717</td>
<td>Measure 3</td>
<td>0.322372</td>
</tr>
<tr>
<td>Measure 4</td>
<td>1.21502</td>
<td>16.20124</td>
<td>Measure 4</td>
<td>3.234553</td>
</tr>
<tr>
<td>Measure 5</td>
<td>1.44213</td>
<td>48.03186</td>
<td>Measure 5</td>
<td>no reduction</td>
</tr>
<tr>
<td>Sub Watershed 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measure 2</td>
<td>-0.04145</td>
<td>-2.79704</td>
<td>Measure 2</td>
<td>-0.08533</td>
</tr>
<tr>
<td>Measure 1</td>
<td>-0.02506</td>
<td>-1.343</td>
<td>Measure 1</td>
<td>-0.07892</td>
</tr>
<tr>
<td>Measure 3</td>
<td>0.004994</td>
<td>0.287409</td>
<td>Measure 3</td>
<td>0.052741</td>
</tr>
<tr>
<td>Measure 5</td>
<td>0.107309</td>
<td>56.91694</td>
<td>Measure 5</td>
<td>0.300898</td>
</tr>
<tr>
<td>Measure 4</td>
<td>3.621294</td>
<td>79.89824</td>
<td>Measure 4</td>
<td>no reduction</td>
</tr>
<tr>
<td>Sub Watershed 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measure 2</td>
<td>-0.01715</td>
<td>-1.15961</td>
<td>Measure 1</td>
<td>-0.0435</td>
</tr>
<tr>
<td>Measure 1</td>
<td>-0.01493</td>
<td>-0.79703</td>
<td>Measure 2</td>
<td>-0.0352</td>
</tr>
<tr>
<td>Measure 3</td>
<td>0.003587</td>
<td>0.194917</td>
<td>Measure 3</td>
<td>0.039306</td>
</tr>
<tr>
<td>Measure 5</td>
<td>0.053335</td>
<td>2.279951</td>
<td>Measure 5</td>
<td>0.16171</td>
</tr>
<tr>
<td>Measure 4</td>
<td>0.103361</td>
<td>3.276791</td>
<td>Measure 4</td>
<td>no reduction</td>
</tr>
</tbody>
</table>

Table 37: Cost effectiveness of each measure by spatial sub watersheds

These results were generated by dividing the total cost each measure would cost with the overall reduction of nitrogen, phosphorus, and pesticides it would reduce and the total area of agriculturally used land in the study area and each sub watershed. For measure 4 no value for pesticides reduction is recorded since in this measure the amount of pesticides
which are applied in the study area do not change with this measure from the status quo scenario.

These results show that the five measures perform different in their cost-effectiveness depending on the area they are implemented in. Nevertheless do the results show that the implementation of measure 1 and measure 2 are the most cost-effective measures in the entire study area and in any sub watershed. These measures area even assumed to generate value. This explains why in table 33 some of the values are negative.

The highest uncertainty for costs has measure 5. The highest uncertainty for effectiveness has measure 1. These effect uncertainties by measure and sub watershed are presented in figures 31 and 32.

![Nitrogen Reduction Uncertainties](image)

Figure 31: Nitrogen reduction uncertainty by sub watersheds

![Phosphorus Reduction Uncertainties](image)

Figure 32: Phosphorus reduction uncertainty by sub watersheds
6 Discussion

This paper demonstrates how cost effectiveness analysis can be done as spatial model. The results generated out of this model have to be evaluated with care. A major uncertainty point of this CEA is that nearly all data used in this model results out of calculated averages. The reason for that is that actual economic value of the evaluated study area was not available. The economic values used were provided by national or regional statistics in general came from the DB catalog of 2009. Another big uncertainty is that besides the actual value of the land limited knowledge was available about what kind of agriculture the farmers are practicing and which type of crops or livestock the farmers are raising in the study area. Another limitation of this model is that the different economic values of agriculture had to be fitted with in the six used land use types of fruit, field fruit, garden, cropland, home meadow, and natural meadow. This means that for the economic value generated by cropland is a combination out of the assumed value generated by the assumed crops which are being grown on cropland areas. For animal produced the area zoned as home meadows was used to estimate how much and were livestock horticulture is practiced. Since no data was available about which type of livestock is grown in these home meadow areas, the average value resulting out of the DB catalog 2009 animal section were used. Also this model does not include local variation of yield effectiveness different land areas might have which consequently would have an impact on the economical value generated in these areas. Further limitations of this model arise from the fact that each of the six land use types were generated on a scale of 1 ha raster cells. This means that on one ha different land use types could be practiced, but the categorization of the one ha raster’s was selected by the dominant form of land use type per ha.

To estimate the runoff values of nutrients and pesticides the national average data, or available local data was used. These data sets were homogeneously distributed in the study area without giving attention to differences in runoff due to slope and vegetation. These means that local variation of nutrient and pesticide runoff is not incorporated in this study.

For measure one the reduction of nutrients was assumed based on the reduction resulting out of elimination mineral fertilizer. This study does not include the additional amount of nutrients which are most likely to be applied in for of organic fertilizer to compensate for the loss of nutrients resulting from excluding mineral fertilizer. No scientific agreements have been made currently which show that organic agricultural nutrients runoff is lower than conventional agricultural nutrient runoff. The only thing which is different is that the bioavailability for mineral fertilizer is higher and therefore a decrease of rapid nutrients loading on a single event can be expected. The total amount of nutrients from organic fertilizers which over long term will leach into the Greifensee from the Moenchaltorf Aa cannot be accounted for in this model.

Measure 2 has a high spatial accuracy. The tile drainage areas are well documented. The inaccuracy of this method results from the fact that different tile drainage practices exist with different characteristics for surface runoff concentration. Since not the specific type drainage system was known the average values out of the most common practiced tile drainage areas was used and homogeneously distributed over the study area.

Measure 3 has values which were conducted out of studies which had similar annual runoff values, as well as slope. The influence which change of vegetation or type of soil could have was not included in the study. The variable used was the widths of the buffer strips and the areas which would become not available for agricultural land growing. Even
though there a differences in the slope within the study the reduction of nutrient and pesticides was generated out of the average slope and the frequency of the accruing slopes within the study area.

For the purpose of this study the buffer effectiveness of buffers is assumed to stay the same independent of time. Nitrogen is more effective to be diluted by grass buffers since natural denitrification of nitrogen into the atmosphere happens naturally. With Phosphorus this methodology does not work, since phosphorus is not being biochemically transformed to reduce the amount of phosphorus which is stored within the soil of the buffered area. This confirms with the definition of buffering which states to be the capacity to resist change temporarily, if the maximal saturation of phosphorus in the soil is reached the buffering capability is eliminated. With increasing widths resulting in an increased volume of soil the storable capability of pollutants regardless if the pollutant is biochemically transformable or not. Thus supported by most authors the width is seen as the predominant internal factor to mitigate pollutants runoff.

Measure 4 was generated by assuming a linear regression between the LU unit and the amount of nutrients extracted by animals. This method does not include that fact that local variation of amount of nutrients leaching out in the study areas water and sub watersheds. A homogeneous distribution of the LU over the entire study area was assumed in this study. High concentration areas of LU in form of animal stalls are not included in this study.

Measure 5 assumes to have a certain generated value due to the possible less of some products out of the nature park. The value generated out of measure 5 is assumed to consist out of hay. Other values generated such as timber is not included since the conservation area will consist out of a grass conservation area were no timber is assumed to be generated. The value generated in measure 5 has also other uncertainties for how much economical value is generated due to other externalities which make the generated value out of a nature conversation area hard to estimate.

Overall it can be said that the results out of this thesis report are based on the most accurate available data. The generated result could be significantly increased if more accurate data could have been available. Never less does this report show in a spatial referenced manner the relationship between environmental impacts and the economic consequences different measures to improve water quality within the study area could have. For future studies a further integration of actual local economic data and the implementation of local differences of agricultural land such as microclimate, precipitation, vegetations, yield productivity soil type and actual knowledge about which crops and livestock is being grown in the study area could improve the results of this CEA.
7 Conclusion

In this study different economical and environmental factors were analysed in how much these values would change according to implementing different measures to improve water quality. The study area was divided into sub watersheds to illustrate if there are local differences in the type of measure and the cost effectiveness of each measure depending on the spatial differences. The results of this study show that spatial differences are noticeable in which measure is most suitable for which part of the study area, but these changes are marginally small in comparison to the different results which arise from the implementation of the different measures as a whole in the study area. Therefore the results show that even with some uncertainty that the conversion from conventional to organic agriculture is a lucrative economic investment for farmers which under current conditions should increase the economic value of agricultural produce generated by local farmers. This thesis report also shows that other measures such as LU reduction appear to be least favourable in terms of pollutant reductions since the economic loss outweighs the effects which are assumed to be generated out of this practice. This CEA is the first step towards making a decision in the Moenchaltorf Aa to which area and with which measure water quality could be further improved to reach the anticipated water quality levels in the least cost way. This decision making could be improved by generating models with a higher accuracy, and also integrating other external factors such as pollutant runoff from urban areas to implement the most effective measure to improve water quality within the Greifensee. To do that actual local data about yield and revenue of the local farmers would be required as well as more accurate data on environmental conditions such as soil type, vegetation slope and actual land use on a higher resolution than on a one hectare parcel. Therefore it is hoped that this study provides an illustration of the use and usefulness of applying a spatially explicit approach to support policy and decision making information about the current economical and environmental situation of the study area with integrating local differences, but if the results require for a higher prediction more precise data would be needed.
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Annex A  Maps of Study Area
Different Land Uses In the Study Area

Legend
- Study Area
- Fruit
- Field Fruit
- Garden
- Cropland
- Natural Meadows
- Home Meadows

Source: Eawag Geodatabase