Adaptation to climate change on arable farms in the Dutch province of Flevoland

An inventory for the AgriAdept project

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Contents

Summary

Climate change might have a large impact on the agricultural sector and farmers will need to adapt. The role of adaptation in moderating the impacts of climate change on agriculture is increasingly recognised. Within the BSIK programme 'Climate Changes Spatial Planning', the AgriAdapt project focuses on the development of a methodology to assess climate change impacts on agriculture, including adaptation at the regional and the farm-type level, in combination with market changes. This report provides an overview of adaptation options at the farm level in the province of Flevoland, which is the regional focus of the AgriAdapt project. In Flevoland, arable farming is the most dominant land use. Adaptation options related to water, pests and diseases have been studied using a literature review.

The green-blue zone Oostvaarderswold in Flevoland contributes to water storage, to nature conservation and to recreation. Compensation costs for structural wetting that are associated with various frequencies of flooding have been calculated. At inundation frequencies greater than once in 5 years, buying the agricultural land might be a better option than compensating for inundation damage or income loss.

Creating field margins can play a role reducing the use of insecticides. The compensation costs of two designs for field margins have been calculated based on the compensation that is paid to project participants (farmers). The associated compensation costs provide some insight into the costs related to this type of green service. However, other costs - such as costs for crop inspection - have not been taken into account.

Various policies will have an effect on future agriculture in the province. A literature survey of spatial policy plans shows that urbanisation will increase and that some cities, like Almere, Lelystad, Dronten and Emmeloord, will continue to grow and expand. As a consequence, more inhabitants will require more space for nature and recreational activities, which in turn will lead to agricultural land being required. Another effect is due to the agricultural policy and succession problems creating a fall in the number of agricultural companies in the south and east of Flevoland up until 2020. The introduction of new methods and techniques will also cause a drop in the number of jobs in agriculture. A further reason is the demands for land for nature expansion, recreation and reservoirs. The introduction of new wind turbines will lead to more power being centralised at a few locations in Flevoland, and to the tidying up of the area. Taking part in these schemes is a way for farmers to guarantee themselves a decent income. Farmers, however, can no longer install new wind turbines on their property.

1 The problem

1.1 Introduction

Climate change might have a large impact on the agricultural sector and farmers will need to adapt. Sector and policy documents have so far insufficiently considered the impacts on the sector of climate change and increased climate variability. The Dutch government recently launched its Adaptation Programme for Spatial Planning and Climate (CcSP) to develop a comprehensive agenda for 'climate proofing' the Netherlands over all sectors (Kabat et al., 2005). Agricultural land accounts for 68% of the country's total land area, making it the most dominant land use and giving it a high priority in the CcSP. There is a clear need for agriculture in the Netherlands to be better prepared to deal with climate change impacts by understanding (i) the risks associated with climate change, (ii) the resilience of the agricultural sector to sustain impacts from climate change and (iii) possible options for adaptation.

It has become evident that a significant challenge for agriculture with regard to climate change will be changes in the magnitude and frequency of extreme conditions like droughts, hail, storms and excessive wet periods (Lemmen and Warren, 2004). A limitation of climate impact studies for agriculture is that adaptation is often inadequately considered. The vulnerability to climate change depends on the exposure, the sensitivity and the capacity to adapt (IPCC, 2001). Farmers, regions and countries are sensitive to exposure to climate change, but will be able to adapt through a variety of strategies. Adaptation can moderate potential damage and/or create new opportunities. Implementation of adaptation options will result in substantial benefits for certain cropping systems under moderate climate change (Howden et al., 2005; IPCC, 2001).

The role of adaptation in agriculture to moderate impacts of climate change is increasingly recognised. There is a need for a methodology to assess the impacts of climate change on agriculture at the regional and the farm-type level considering changes in socio-economic and market conditions. It is necessary to conceptually and technically link biophysical models that enable the estimation of climate impacts on, for example, crop yields and land use and associated environmental impacts (e.g. nitrogen leaching, soil carbon content or water use) with farming system and market models. Despite the significant progress that has been made in recent years as regards climate change impact and sustainability assessment, key issues of assessing responses and adaptation at the farming system and the regional level using a coherent modelling framework remain unresolved.

Within the Climate Changes Spatial Planning programme, the AgriAdapt project focuses on the development of a methodology to assess climate change impacts on agriculture, including adaptation at the regional and the farm-type level, in combination with market changes (see Wolf et al., 2010). The present paper focuses on adaptation options at the farm level in the province of Flevoland, which is the regional focus of the AgriAdapt project. In Flevoland arable farming is the most dominant land use. Adaptation options related to water, pests and diseases have been studied using a literature review. Moreover, long- and medium-term spatial plans applicable to the case study region have been studied and reviewed with regard to external effects on arable farming.

1.2 Content of this report

Section 2 focuses on three aspects of climate change: prolonged droughts and water use by agriculture; water surplus and water storage on farmland; and increasing risks of pest and diseases due to climate change and farm-level adaptation options. These three climate change aspects were chosen since they are very relevant to arable farming in Flevoland. Section 2 presents data on the current situation and describes briefly adaptation options. Section 3 provides an overview of medium- and long-term spatial planning and other relevant public policies in the province of Flevoland and their effects on arable farming. Section 4 discusses two specific services, namely water retention (blue services) and field margins (green services). This section also presents an assessment of compensation costs for such services when provided by arable farms. Section 5 concludes.

2 Agriculture and climate change

2.1 Introduction

Arable farming is weather dependent and farmers have always adapted to varying weather conditions. Infrequent events like hail, storms and flooding are difficult to adapt to and insurance is a likely adaptation to such conditions. But some climate change events might occur more frequently in the future, which will make insurance too expensive and may result in crop and yield losses. If such events occur too often, adaptation measures at the farm level might be a cost-effective way to adapt to climate changes.

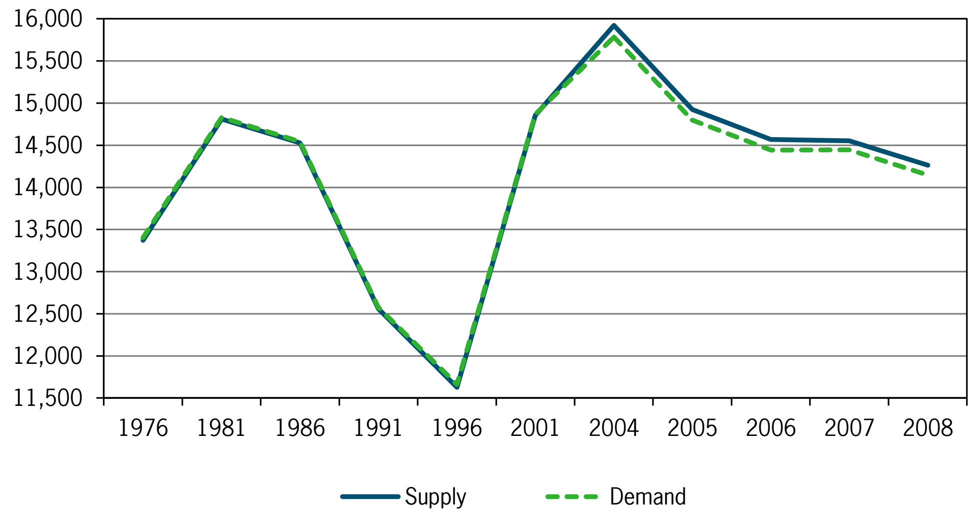
In this section the effects of droughts, water surplus, and pests and diseases are reviewed, based on the current situation and on the expected changes. Although adaptation options are discussed here, the technological implications are reviewed in the following section.

2.2 Water use in the Netherlands

According to the CBS (2011), the abstraction and use of water in the last 30 years has remained in balance, having reached the level of about 14,141-14,263m m^3 in 2008. There is no clear trend in the water balance in the period 1976-2008 (Figure 2.1), while the supply of and demand for groundwater declined slightly and fluctuated for the surface water.

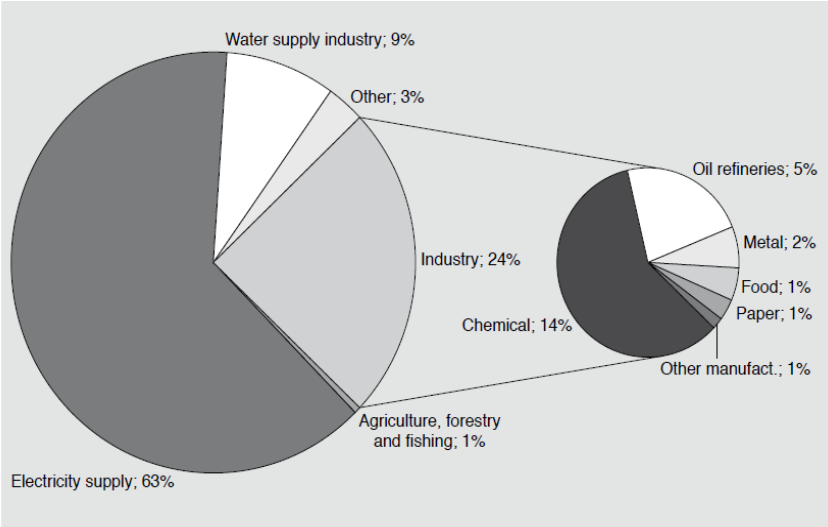
The total water abstraction by the Dutch economy in 2008 amounted to 14.3b m^3 (CBS 2011). As Figure 2.2 shows, almost two thirds of the water requirements of the Dutch economy is used for electricity supply industry. This industry abstracts all its water from surface water bodies, primarily for cooling purposes. After use, most of the cooling water is immediately returned to the surface water. The water supply industry is responsible for 9% of total water abstraction, with 61% abstracted from groundwater. The biggest user of primarily surface water within manufacturing is the chemical industry, followed by the oil industry and the manufacture of metal products, food products and paper products industries. Agriculture abstracts only 1%, which is low compared to other countries. This is because the Netherlands has a temperate climate with rainfall distributed throughout the year.

Figure 2.1 **Water supply and demand in the Netherlands 1976-2008 (million m^3)**



Source: CBS (2011).

Figure 2.2	Water abstraction by the Dutch economy in 2008



Source: CBS (2010).

Table 2.1 Water supply and demand in the Dutch sectors, 2008

	Water supply			Water demand		
	Total	**Groundwater**	**Surface water**	**Total**	**Groundwater**	**Surface water**
Water companies	1,252	762	490	0	0	0
Agriculture	71	47	24	119	47	47
Industry	3,462	155	3,308	3,643	155	181
Electric stations	9,046	2	9,044	9,050	2	3
Other business and households	432	1	431	1,329	1	905
Total	14,263	967	13,297	14,141	205	1,136

Source: CBS (2011).

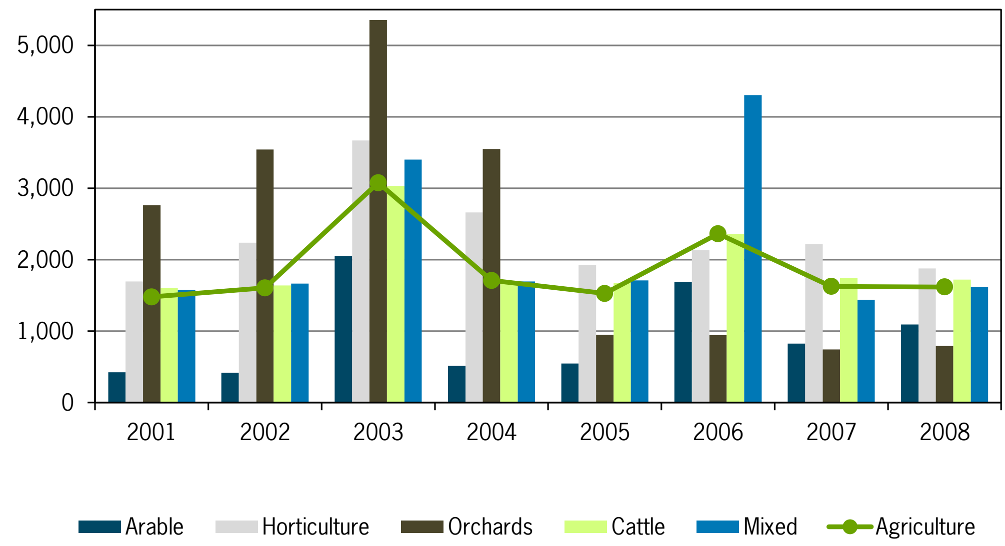
2.3 Water use in Dutch agriculture

According to the CBS (2010), agriculture and horticulture have an average 4% share in the total amount of tap water used in the Netherlands, which shows a slight downward trend. However, there is an evidential influence of the weather in warm dry years, when use is generally higher. Water use intensity - defined as the use of water (either surface, ground or tap water individually or the sum of the three) in litres divided by its value added - is the highest in the metal manufacture industry, followed by livestock production (CBS, 2010).

With a slight difference in total water use in 2008 for agriculture as presented in Table 2.1, Table 2.2 presents trends in water use by the various farming sectors. Irrigation is the second most important form of water use in agriculture, averaging about 38% of total water use (Table 2.2). It is applied to grassland, potatoes, sugar beets and maize, and vegetables in the open ground and in glasshouses. Next, water is used in orchards for spraying against frost damage.

Drinking water for livestock is the main use of water in agriculture; here, consumption remained rather stable in the period 2001-2008 at the level of 61-71m m^3 (Table 2.2). This water use is the major category of tap water use in agriculture, which accounts for on average over 70% of the tap water used in livestock production. Switching from tap water to groundwater and/or surface water for drinking by livestock provides an opportunity to further reduce tap water use in livestock production. On the other hand, the constant quality of tap water is valuable for livestock (CBS, 2011).

Figure 2.3 **Average water use per farm of different type, m^3**



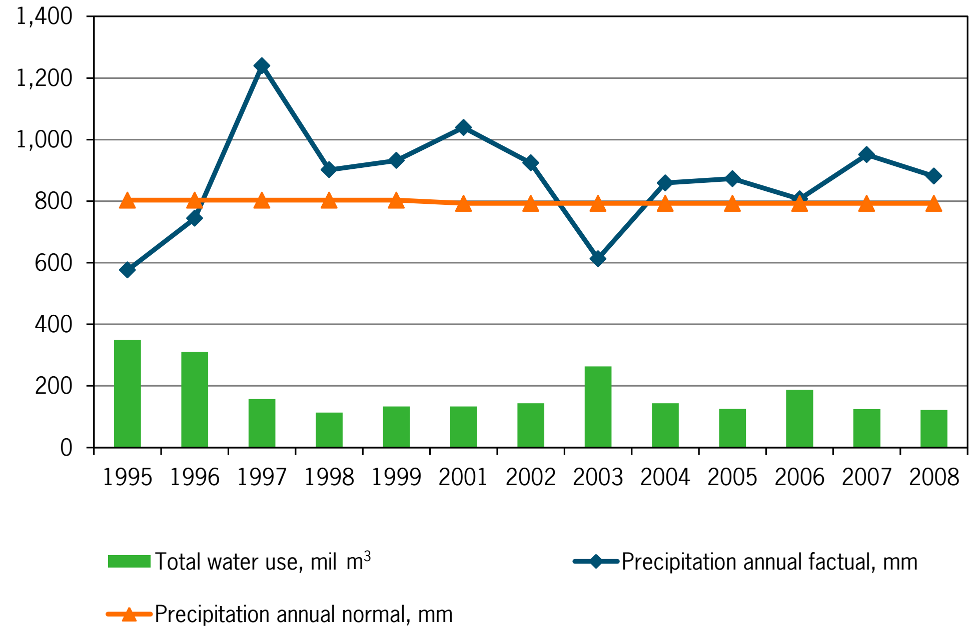
Source: Adopted from Van der Veen et al. (2010).

Table 2.2 **Use of water in agriculture, 2001-2008**

	2001 a)	2002 a)	2003	2004	2005	2006	2007	2008
Total water use, mil m^3	137	144	263	143	125	188	125	122
Irrigation total, mil m^3	45	51	161	50	36	103	36	34
- including groundwater (%)	52	53	64	53	67	68	48	51
- surface water (%)	30	29	21	30	19	16	21	21
- other sources or unknown (%)	18	18	16	17	14	16	31	28
tap water, mil m^3	52	51	58	52	49	49	50	47
including drinking water for animals, mil m^3	31	31	30	29	29	26	26	26
rain water (*gietwater* in Dutch) b), mil m^3	0.1	3.0	5.8	3.9	2.5	1.2	4.1	3.3
Irrigated area, 1,000 ha c)	.	62	.	111	89	171	110	86
arable	.	11	.	19	17	37	37	30
horticulture	.	20	.	34	25	28	30	23
orchards	.	4.9	.	6.9	1.3	1.6	0.7	1.6
cattle farming	.	18	.	33	28	76	33	22
mixed farms	.	8.7	.	17	18	29	10	8.6
Percentage of farms with irrigated area								
agriculture	.	24	16	10	16	12	11	14
arable	.	29	13	12	24	21	18	20

a) Estimate on the basis of irrigation in 2004. The data for precipitation in the growth season in 2004 is the closest to that of 2001 and 2002; b) Purified surface water of the quality less than drinking water; c) Area that is irrigated at least once a year; the total irrigated area is larger (x number of times irrigated). In 2008 the total irrigated area was 212,000 ha.
Source: Based on Van der Veen et al. (2010) and Binternet (2011).

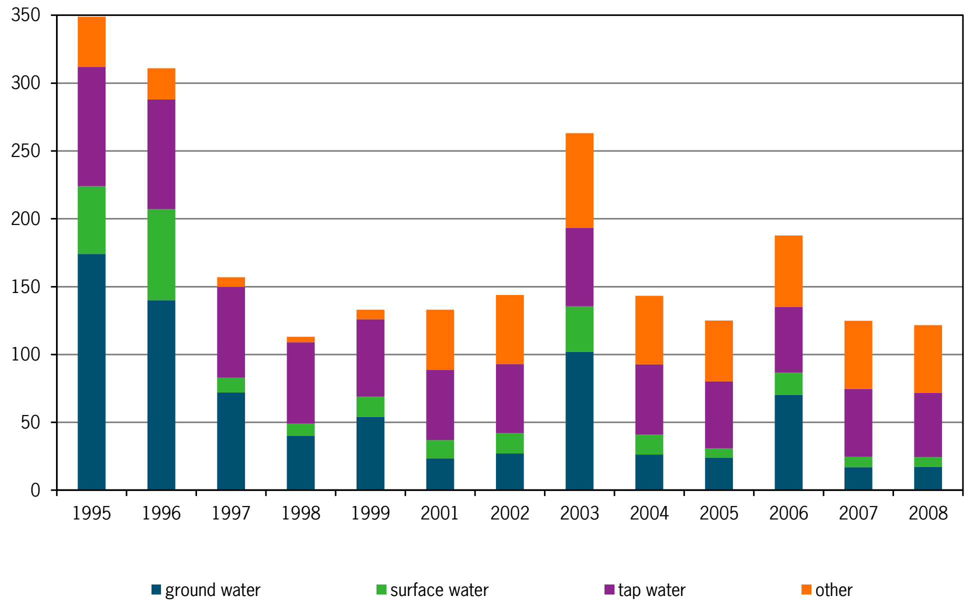
Figure 2.4	Precipitation and total water use in agriculture 1995-2008, the Netherlands



Source: Adopted from Van der Veen et al. (2010) and KNMI (2011).

Figure 2.3 illustrates the use of water per farm. While the average use of water for an average farm varies from 1,700 m^3 in relatively wet years to 3,007 m^3 in the extremely dry year of 2003, the water use per type of farm varies substantially due to purposes: irrigation, water for drinking by animals and water for the equipment. Irrigation is applied during the growth season when water shortage is evident. The sprinkling in orchards is applied mainly during the blooming season when the temperature gets too low. Especially in 2001-2004 the use of water on these farms was the highest. Arable farms (including potato growers and growers of organic crops) use the least amount of water per farm, while horticulture farms (flowers, vegetable producers), including greenhouses, use 1,700-3,670 m^3 per farm.

Figure 2.5 **Total use of water in agriculture, by source (million m³)**

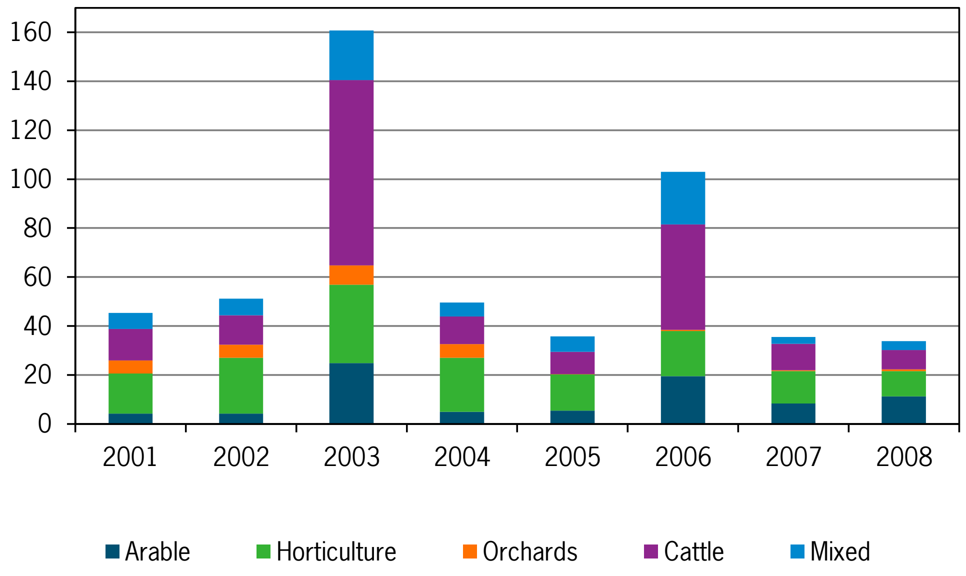


a) Source "Other" refers to groundwater and/or surface water which cannot be split in the original data.
Source: Based on Binternet (2011).

In the last 10 years the highest use of water in agriculture was in 2003 when the growing season was very dry. Figures from the Royal Netherlands Meteorological Institute on precipitation presented in the appendix (KNMI, 2011) show the monthly data for the years 1995-2009 against the normal level of precipitation. In 2003, only the month of May was wet; February and March and June-August were dry. In 2006, April, June and July were extremely dry, while February, March, May and August were rather wet. Not only the irrigation water, but also the use of water in cattle farming was higher that year (Figure 2.4). The correlation between the water use in agriculture and precipitation in 1995-2008 is -0.80, which is a logical relationship. Hoogeveen and colleagues (2003), however, found no relationship between weather variables and irrigation (irrigated area per farm, total water use per farm, use of groundwater per farm) in the years 1992 (dry) and 1997 (wet).

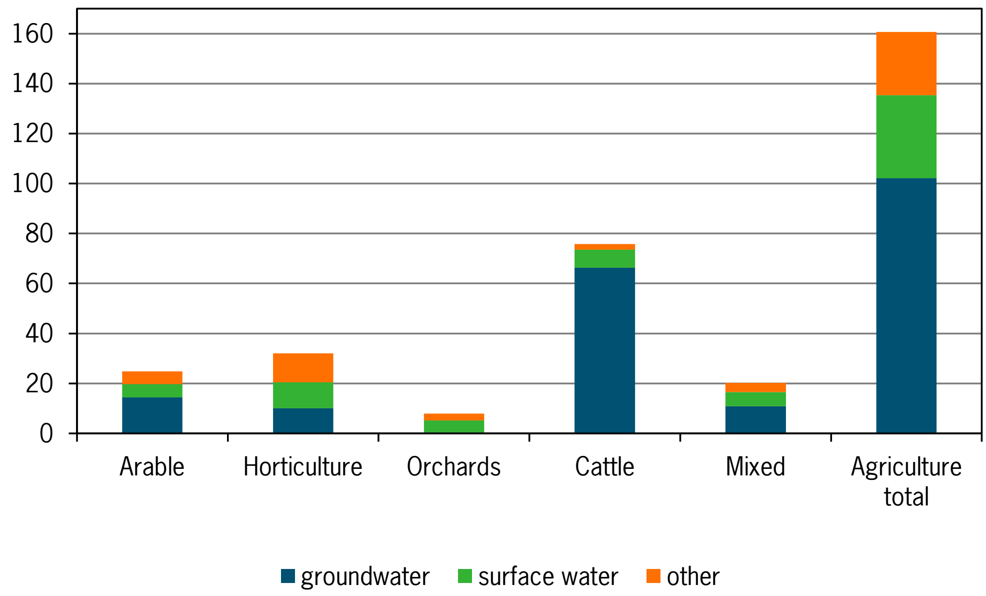
Figures 2.5 and 2.7 illustrate the use of total water in agriculture by source. The use of groundwater declined substantially in the last decade, except during very dry seasons (2003 and 2006). Cattle farming took the major share of irrigated water (grassland), especially in the dry years 2003 and 2006, while the horticultural sector was a steadily second consumer, followed by arable farming (see Figure 2.6). The irrigation is mainly done with groundwater, where again the largest share of the groundwater in irrigation is taken up by cattle farming. The sources of water used in irrigation in the dry year 2003 are shown in Figure 2.7 for various agricultural sectors.

Figure 2.6 **Use of water for irrigation on various farm types, million m³**



Source: Based on Van der Veen et al. (2010).

Figure 2.7 **Use of water for irrigation in different agricultural sectors during dry year 2003, by source (million m³)**

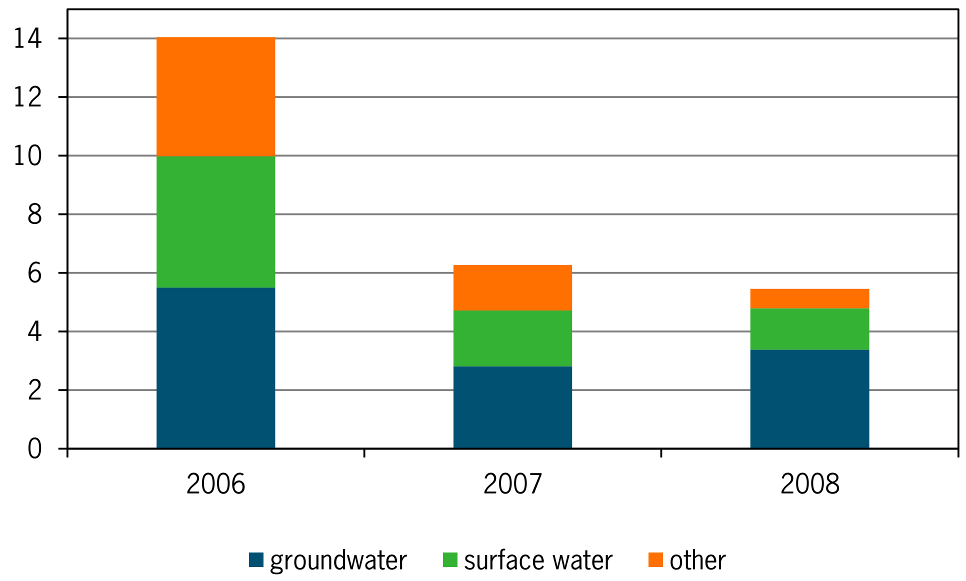


a) 'Other' refers to groundwater and/or surface water that cannot be split in the original data
Source: Based on Van der Veen et al. (2010).

2.4 Water use in Flevoland

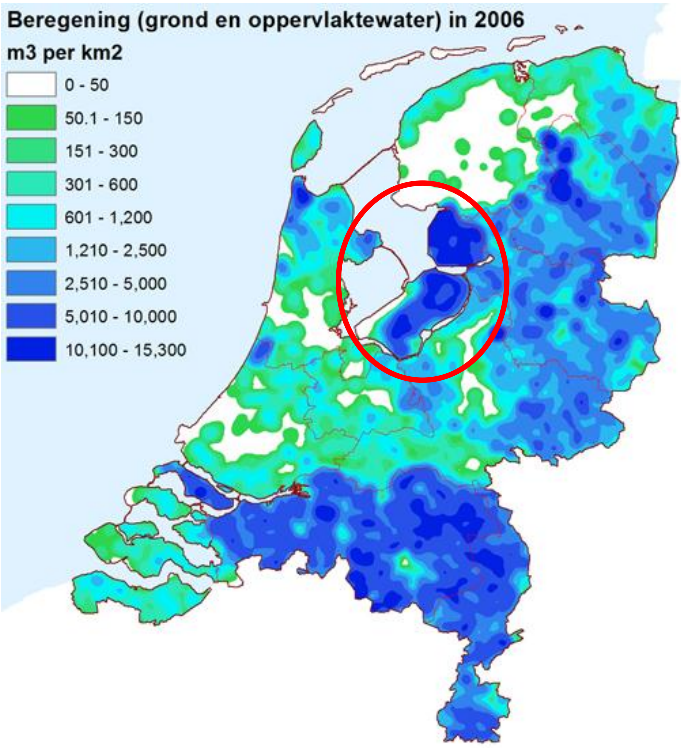
The use of water for irrigation in Flevoland was 14m m^3 in 2006, which is about 13% of the national water use for irrigation (see also Table 2.2). The shares of water used for irrigation in Flevoland are somewhat different from the national shares. In 2006, for example, in Flevoland the percentage of water from surface was twice as high compared to the whole of the Netherlands, while the share of groundwater use was 20% lower. The map in Figure 2.9 reflects the use of water for irrigation across the Netherlands in 2006 (dry year). The use of water in Flevoland per km^2 is one of the highest in the country.

Figure 2.8 Use of water for irrigation in Flevoland on all farm types, by source (million m^3)



a) 'Other' refers to groundwater and/or surface water that cannot be split in the original data
Source: Based on data received from Schouten (2011).

Figure 2.9 **Use of water for irrigation in the Netherlands in 2006, m^3 per km^2**



Note: the province Flevoland is circled.
Source: Schouten (2011).

2.5 Climate change effects

Within the climate change spatial planning programme, the Royal Netherlands Meteorological Institute (KNMI) has published climate scenarios for the Netherlands for 2050 and 2100 (van Drunen, 2006). These scenarios include changes in air flow patterns. Given the uncertainties about whether and, if so, how these flows are affected by the enhanced greenhouse effect, the KNMI developed two sets of climate scenarios: one set in which the flow patterns remain unchanged (current situation) and one in which the flow patterns do change (see van Drunen, 2006). Climate change scenarios depend on the level of temperature rise and KNMI worked out two possible sets: a 1-degree temperature rise by 2050 compared to 1990 (denoted as 'G') and a 2-degree temperature rise by 2050 (denoted as 'W'). For both scenarios air flow patterns are included: scenarios with a changed air flow pattern are denoted as '+'. The result of these calculations leads to four climate change scenarios, depicted in Figure 2.10.

Figure 2.10 **Description of the four KNMI climate change scenarios**

2050		G	G+	W	W+
Worldwide rise in temperature		+1°C	+1°C	+2°C	+2°C
Changes in air flow patterns in Western Europe		no	yes	no	yes
Winter	average temperature	+0,9°C	+1,1°C	+1,8°C	+2,3°C
	coldest winter day per year	+1,0°C	+1,5°C	+2,1°C	+2,9°C
	average precipitation	+4%	+7%	+7%	+14%
	10 day total rainfall exceeded once in 10 years	+4%	+6%	+8%	+12%
	highest average daily wind speed per year	0%	+2%	-1%	+4%
Summer	average temperature	+0,9°C	+1,4°C	+1,7°C	+2,8°C
	warmest summer day per year	+1,0°C	+1,9°C	+2,1°C	+3,8°C
	average precipitation	+3%	-10%	+6%	-19%
	10 day total rainfall exceeded once in 10 years	+13%	+5%	+27%	+10%
	potential evaporation	+3%	+8%	+7%	+15%
Sea level	absolute rise	15-25 cm	15-25 cm	20-35 cm	20-35 cm

Source: adopted from van Drunen (2006).

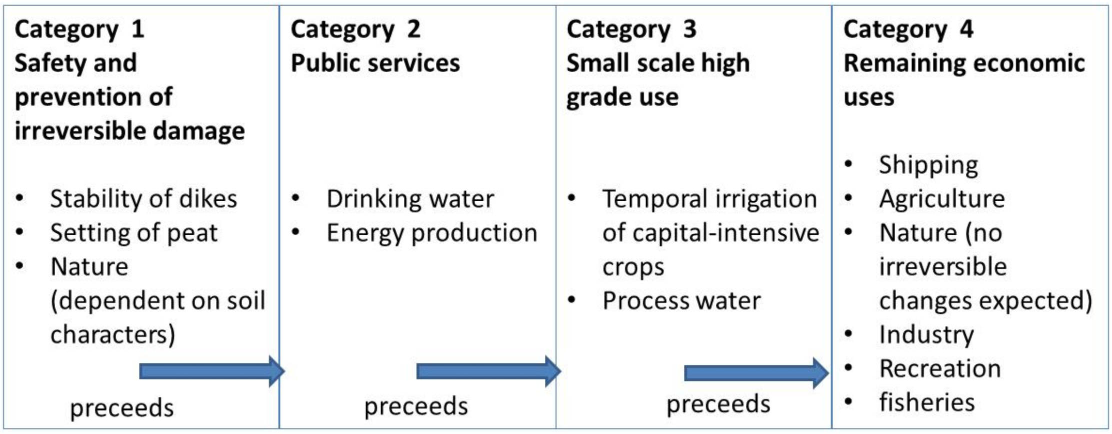
All scenarios predict increased winter precipitation and an increase in average winter temperature. For summer, however, the scenario predictions differ regarding precipitation. The scenarios without altered air flow predict increased precipitation, while the '+' scenarios, which assume air flow changes, predict decreased summer precipitation.

Van Drunen (2006) summarises climatic changes in the probability of occurrence. Both temperature changes and precipitation patterns have a high probability of extension of the growing season, a decrease in surface and groundwater levels, the salinisation of groundwater, and a high probability of surface water level increase during winter. In addition, high temperatures and a longer growing season may also increase the risks of pests and diseases.

Van Ierland and colleagues (2007) worked out climate change adaptation options for the agricultural sector. These options are manifold and range from the adjustment of crop rotation schemes to water retention. The options refer to the most likely climatic changes relevant to agriculture. They can also be seen as 'climatic services' that agriculture can provide to society. First, a likely increase in winter precipitation will result in larger river discharge (see following sections), affecting both rural and urban areas. By providing agricultural land for temporary water retention, agriculture can reduce the risk of flooding in other sectors. Second, higher temperatures, a longer growing season and more precipitation increase the risks posed by pests and diseases, including new ones (e.g. Verhagen et al., 2009). This in turn will probably increase the use of pesticides, which are harmful to the environment. Green veining of the rural landscape and herbaceous field margins can provide shelter for predators, so-called agro-biodiversity (e.g. Van Alebeek et al., 2008, Meerburg et al., 2009, Meerburg and Geerts, 2010). Provisions like water retention or greening rural landscapes can be seen as a service to society that should be financially compensated for. For most studied adaptation options in this report, such a bidirectional relation can be formulated. Hence, the adaptation options are dealt with as options for climate services.

2.6 On-farm climate adaptation: coping with water shortage

Figure 2.11 The displacement regime of water boards of water use during prolonged droughts



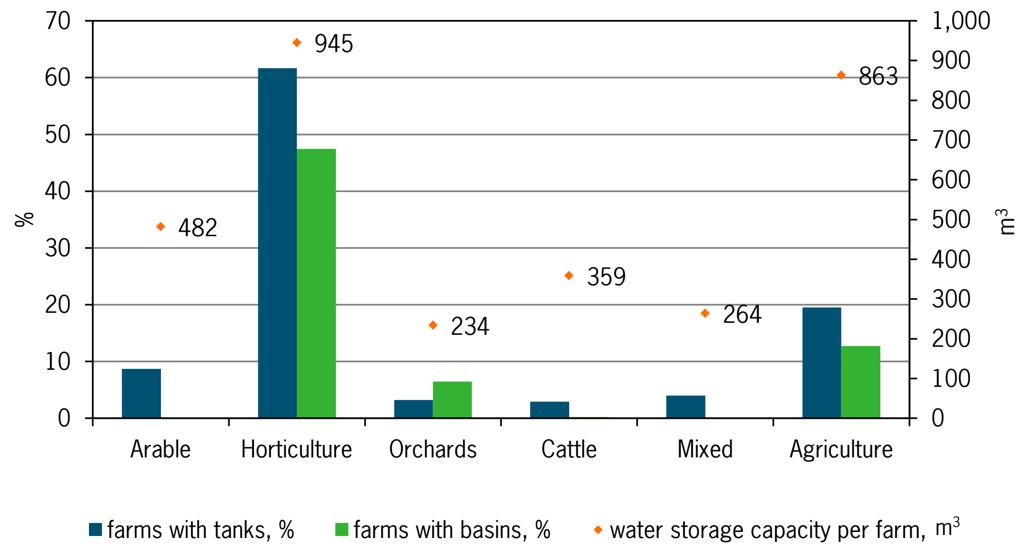
When evaporation exceeds precipitation, droughts occur. In the Netherlands, this balance is negative in normal summers; some droughts regularly occur (see previous sections). During prolonged periods of drought, arable crops need to be irrigated. When surface water is not limited, farmers are able to irrigate crops. However, when drought periods last for a longer time, water levels may drop, the salinisation of surface water may occur and other sectors also face problems due to water shortage.

Water boards in the Netherlands have introduced a so-called displacement regime. This regime includes four categories and is depicted in Figure 2.11. From Figure 2.11 it becomes clear that during prolonged and severe droughts, agriculture faces water shortages that cannot be alleviated. Only cash crops, like the production of flower bulbs in Flevoland, may extend the irrigation period for some time. Regular arable farming, however, may run a risk of yield losses and even bad harvests during prolonged droughts.

There are no farm-level data available regarding areas that are used to retain water that can be used to get through drought periods. For a sample of Dutch farms in 2001-2008 it is however known about water storage facilities such as tanks and basins and their capacity in m^3. These data for the year 2008 are summarised in Figure 2.12. Mainly horticulture farms (greenhouses) practice the storage of water in tanks or basins (about 80% of all sampled horticulture farms having either a tank of basin). Other farm types hardly do this (less than 10%). There is no correlation between water storage capacity and the water used for irrigation. The limitation of the data on storage capacity is that it does not reflect the actual use (refill) of the tanks or basins.

Adaptation options can be found in on-farm seasonal water storage. Such facilities require large areas of land and cooperation between farms to develop a common storage facility. Temporary water retention on agricultural land to get through prolonged drought periods might also be applicable in combination with water retention during periods of high precipitation. In this way both water shortage and surplus can be dealt with. This issue is further studied in the next section on adaptation options.

Figure 2.12	Average water storage capacity per farm type in 2008 (in m^3)



Source: based on farm individual data available at LEI.

2.7 Coping with water surplus

The Dutch water management policies (Commissie Waterbeheer, 2000a, b) aim to adapt the current hydrological system in an integrative way. In order to be sustainable, a phased deployment of the water management policy is constructed based on three concepts, namely:

1. retention of water upstream, in the soil, ditches and small streams;
2. increase the discharge and retention capacity of the rivers;
3. discharge of water into the sea.

The implementation of this phased deployment therefore means that the solution to the predicted increase in winter precipitation should first be adapted to water retention on land. Such retention results in less high water tables of rivers and lakes which prevent a possible uncontrolled flooding of rural or urban areas. Moreover, retention areas also decrease costly investments in larger river dykes. Therefore, water retention areas contribute to the policy target of flooding frequencies of less than once in 250 years.
If water retention upstream is not possible due to physical constraints, the retention capacity of the river should be increased, and so on. Thus, the water management policy is an example of a climate change adaptation strategy where the capacity of water retention upstream should be increased.

Water retention during peak precipitation means that water may be temporarily stored on agricultural land to avoid severe damage in high economic areas, such as urban zones. Dutch water boards started to capitalise water retention only recently. Payments to farmers for periodically flooding agricultural land can be considered a 'water service', although there is much uncertainty about whether such a service conflicts with European legislation. Water boards make a distinction between a financial mechanism in which the agricultural land is bought out when there is a flooding event, or an annual compensation for periodic flooding. In the first case, two water boards present values of respectively €2700/ha and €9985/ha for a non-recurring buyout (water boards Vallei & Eem and Regge & Dinkel, data from 2005). The water board of Aa en Maas (province of North Brabant) uses a mechanism of annual compensation, taking into account yield losses of grasslands and other arable crops like maize, potatoes and sugar beet. Where yield losses of grasslands are expected when flooding takes place before October, the annual compensation is set at €582/ha (price level 2005), while in winter (when no yield losses are expected) financial compensation for grasslands is €196/ha. These values for grassland compensation are similar in other regional water boards in the Netherlands. The study by De Vos and Hoving (2005) investigates costs and benefits of the provision of water retention on a dairy farm. When the overflow of water is stored on a 4 ha of grassland during the winter season the loss is less than €400/year and thus not substantial; however, when the same area is used for water storage throughout the year, farm losses are as high as €4,500/year.

In addition to the yield reduction caused by flooding, some water boards work with index values based on the number of days an area will be flooded. Given the range of the monetary compensatory amounts, an average amount of €395/ha would be an indication of the annual cost of water retention on grasslands. For crop land, financial compensation depends on crop type and period of the growing season. Although different water boards use various price levels of compensation and type of compensation (annual compensation and/or single pay-off; e.g. Hoekstra and Bos, 2003), the water board of Brabantse Delta provide accurate numbers (see Table 2.3). The level of compensation also depends on the amount of fertilisation and tillage (Waterschap Brabantse Delta, 2007).

Table 2.3. Financial compensation of inundation for different arable crops in €/ha, price level 2007

Period	Potato	Sugar beet	Winter wheat a)
Nov. - March	45.60	46	288
Growing season	4,346.35	2,649	1,474
End growing season-January	5,152.95	3,369	288/902 a)

a) Compensation level depends on sowing date
Source: data Waterschap Brabantse Delta, 2007

2.8 Coping with pests and diseases

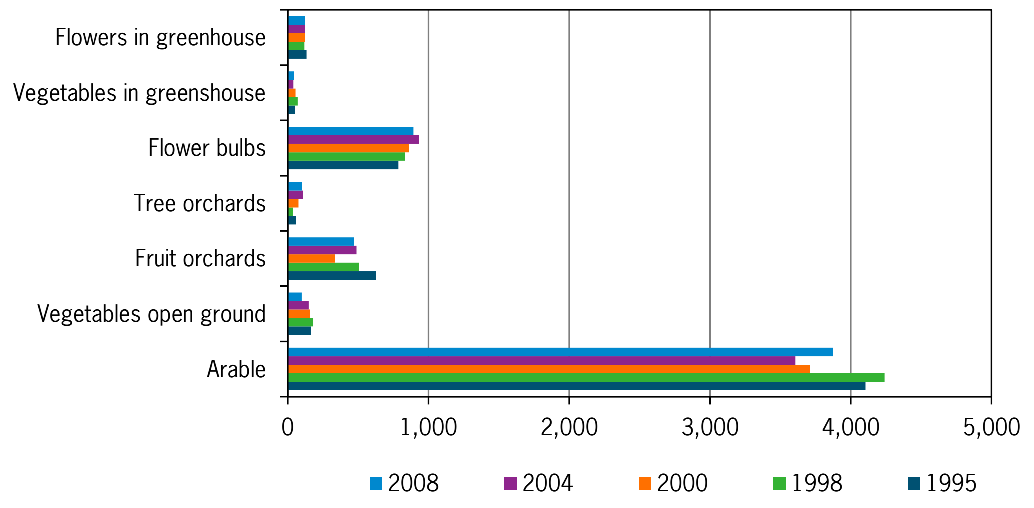
Increased precipitation and air moisture content in combination with higher temperature and a longer growing season increase the risks of outbreaks of agricultural pests and diseases (e.g. Verhagen et al., 2009). A warmer climate results in more generations of pests, and predatory insects cannot keep up with the increased generation period of pest insects (Verhagen et al., 2009). As a result more pesticides are likely to be needed.

Use of pesticides for plant protection is high in the Netherlands (van Eerdt et al., 2007). To restrict their environmental risks, the use of plant protection products was reduced by 50% in 2000 compared to 1984-1988 as planned by the national pesticide policy adopted in 1991. According to van Eerdt and colleagues (2007), the Dutch plant protection policy aims at achieving sustainable agriculture in the Netherlands in 2010. For 2010 (and for interim 2005, respectively) the following goals were set: a 95% (75%) reduction of the environmental impact on surface water compared to 1998, a 95% (50%) reduction of bottlenecks in the production of drinking water from surface water compared to 1998, and a 50% reduction (no interim target) of the maximum residue limits in agricultural products compared to 2003.

According to van der Linden and colleagues (2006), the calculated environmental impact as a result of drift emissions to surface water was reduced by 86% by the year 2005. Drift reduction measures, imposed since 2000, contributed most (75%) to this calculated reduction. The second most important contribution came from the use of less toxic plant protection products. Concentrations of plant protection product residues measured in surface waters declined over the study period, but concentrations above maximum permissible levels still occurred in 2004.

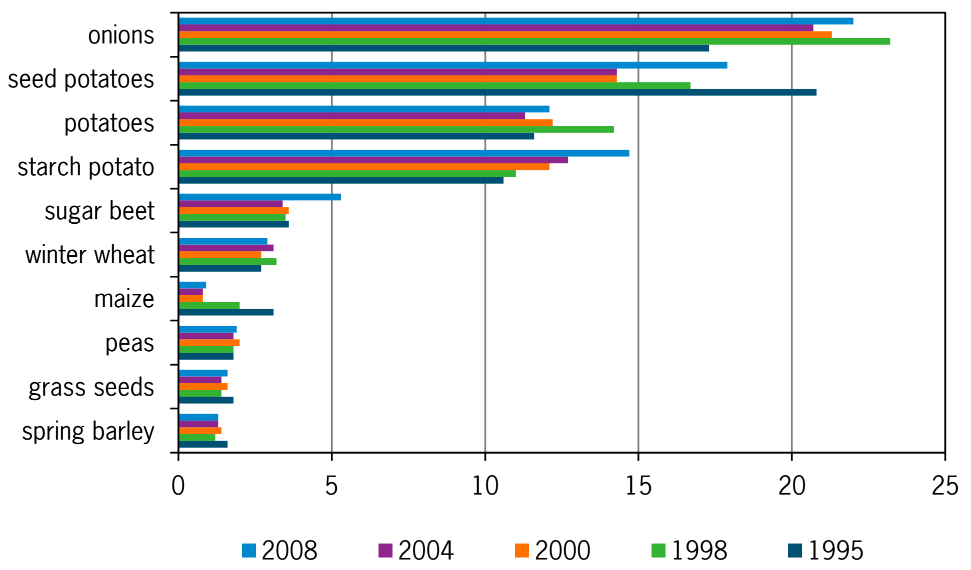
With regard to the total use of crop protection measures, about 5,600-6,000 tons of active substance were applied in agriculture annually in 1995-2008, 2/3 of which was applied in the arable sector (Figure 2.13). The use of crop protection measures in the arable sector remained rather stable in the period 2000-2008. In 2005, on average 4.7 kg of active ingredients were used per hectare of arable land (CBS, 2005).

Figure 2.13	Annual application of crop protection in agricultural sectors, 1,000 kg of active substance



Source: CBS, PBL 2011.

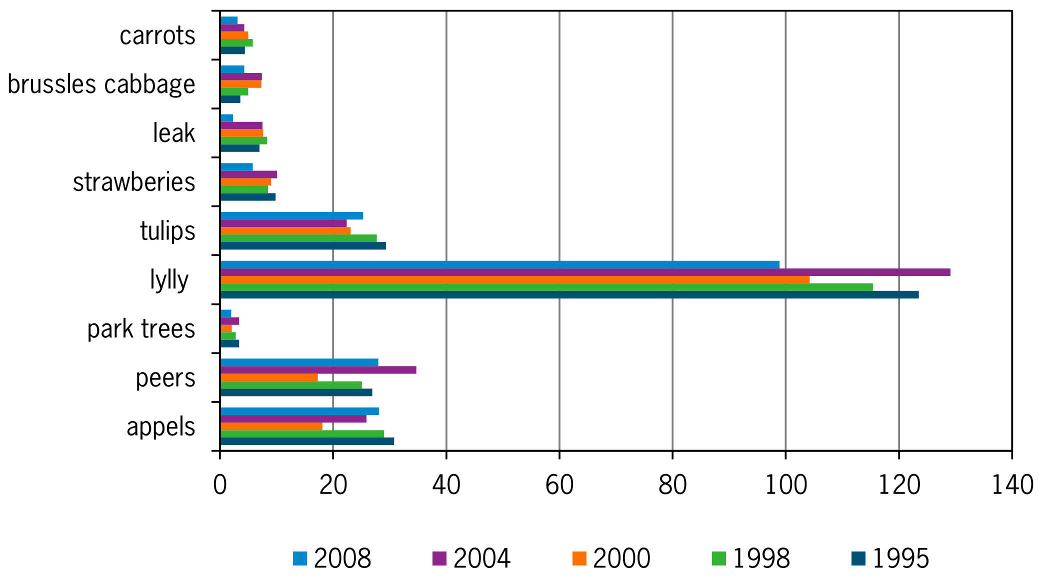
Figure 2.14	Application of crop protection on arable crops, kg active substance per ha



Source: CBS, PBL 2011.

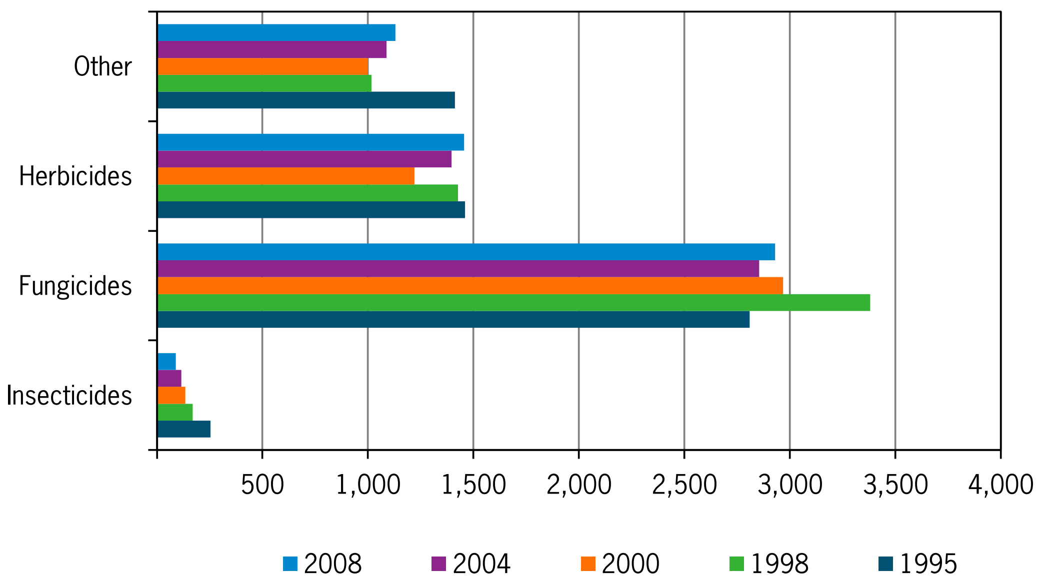
About 87% of total crop protection is applied to just 11 of 60 crops (CBS, 2011). Of arable crops, onions and potato require the largest amount of crop protection (Figure 2.14). The applied amounts per crop vary enormously, ranging from 0.9 kg per hectare of silage maize to over 100 kg for lilies (flower bulbs, see Figure 2.15).

Figure 2.15 **Application of crop protection in horticulture, kg active substance per ha**



Source: CBS, PBL (2011).

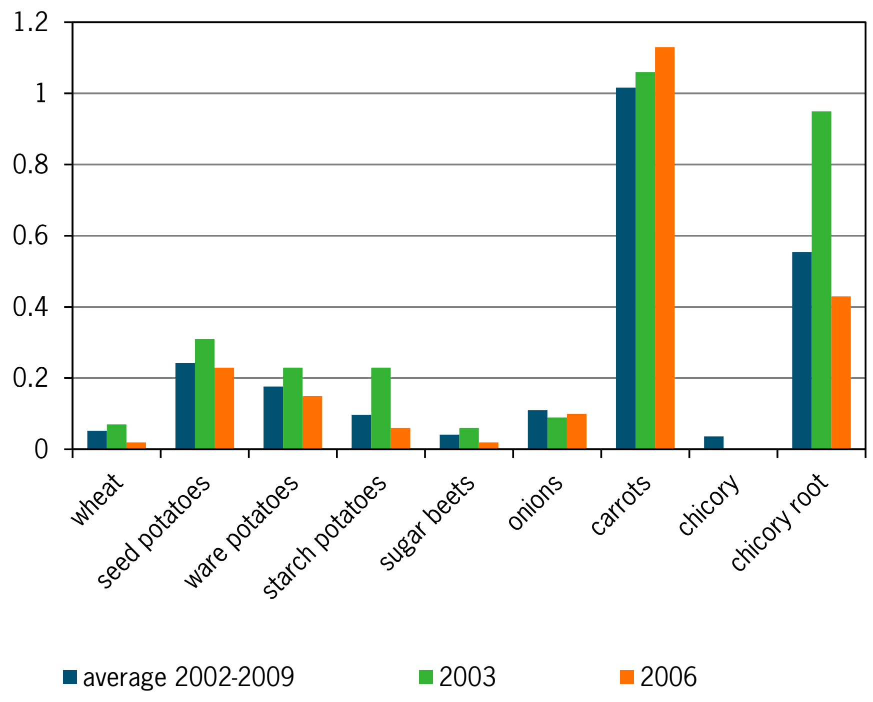
Figure 2.16 **Types of crop protection measures in agriculture, 1,000 kg active substance**



Source: CBS, PBL (2011).

Fungicides and to a lesser extent herbicides are the most commonly used crop protection measures in arable farming (Figure 2.16). With regard to the total use of crop protection measures, insecticides are used only in small portions (about 2.5% of total crop protection) and their use declined in the period 1995-2008 (Figure 2.16). The highest applications of insecticides are observed in root crops (carrots, chicory) (Figure 2.17).

Figure 2.17 **Application of insecticides, kg active substance per ha**



Source: CBS, PBL 2011.

In the case of climate changes, increased use of pesticides and insecticides will negatively affect environmental quality, and studies have focused on the use of natural predators to limit chemical use. Research (e.g. den Belder et al., 2007, Van Alebeek et al., 2007) has shown natural predators like fly wasps, ladybirds and predator mites are effective in suppressing pest insect populations, but due to the mono-functional design of many rural areas, natural vegetation is scarce and predator populations have very low densities. Hence, research has focused on the landscape design of rural areas towards green veining (e.g. Van Alebeek et al., 2008, Geertsema et al., 2004, Vosman et al., 2007. This research show that: 1) rural areas should include patches of natural vegetation like small woodlands and 2) margins of arable fields should be sown with herbaceous vegetation to attract predators. A study on green-blue veining in Flevoland (Van Alebeek et al., 2008) indicates that the rural area in this province is not very suitable for agro-biodiversity (i.e. the suppression of pests by natural predators). For this, wooded parcels should be introduced in the rural area, while field margin strips should be approximately 5 m wide. Moreover, arable fields should not be wider than 150 m. This requires strong spatial adaptation at the farm level.

2.9 Coping with the salinisation of groundwater

The report of Verhagen and colleagues (2009) also shows that the province of Flevoland is sensitive to the salinisation of groundwater. Salinisation occurs due to salty seepage, which is the result of sea level rise. The deep polders in the Netherlands, like those in Flevoland, are very sensitive to this. Salt groundwater is damaging to many arable crops in Flevoland, and Verhagen and colleagues (2009) suggest switching to crops that are tolerant to salt water as an adaptation option at the farm level. This issue, however, is not studied in this report.

2.10 Conclusions

The following adaptation options are considered for dealing with described effects of climate change in Flevoland for agriculture. First, water storage in times of water surplus might be an effective measure; in addition, stored water can be used in times of extreme and prolonged droughts. Second, redesigning the rural landscape to include patches of natural vegetation, such as small wooded parcels and field margins along large arable fields, may help suppress future pests and diseases by providing a habitat for the natural enemies of those pests. Third, due to the salinisation of groundwater, breeding crops that are tolerant to salt water are considered as an adaptation option.

3 Outlook on spatial planning in Flevoland

3.1 Introduction

Along with the effects of climate change and market change, large spatial developments also have an effect on agriculture and horticulture in Flevoland. The province of Flevoland has developed a spatial development plan ('Omgevingsplan' in Dutch). This is a structural vision on the land territory in the province and the land claims of different sectors for the coming decades, with a time horizon set at 2030 (Flevoland, 2006). This section focuses on the following developments in the use of space in Flevoland in the coming years until 2030: urban development, industrial development, sustainable energy development, agricultural development, nature development and water management. At the end of this section we try to answer the question whether less space will be available for agriculture in Flevoland in the coming 20 years.

The majority of the land in Flevoland is currently used for agriculture and horticulture: in 2008 70% of the total land area (1,416 km^2). Of it, 16% is covered by forest and nature areas and about 10% is infrastructure and development/semi-development. However, the amount of land used for agriculture and horticulture has shrunk in recent years. In 1996, almost 74% of the land was used for agriculture and horticulture. In contrast, 726 ha of new business space was created between 1996 and 2008, while thetotal area of developed land in Flevoland has risen by more than 2,400 ha to almost 8,200 ha (CBS, 2011).

3.2 Spatial development

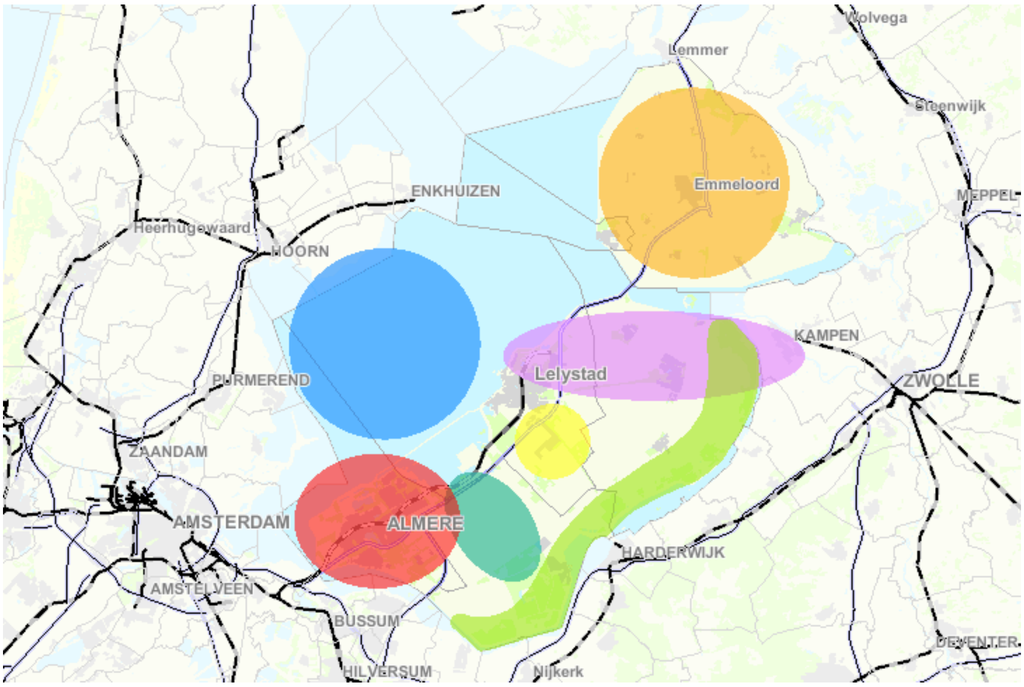
3.2.1 Urban development, population and employment

Between 1996 and 2008, urbanisation grew in Flevoland by circa 2,400 ha. This figure includes housing (1,345 ha) and new business space (726 hectare) (CBS, 2011).

The province wants to allow space for the projected urbanisation to a total of about 650,000 inhabitants by 2030 (Flevoland, 2006). Flevoland had circa 387,900 inhabitants in 2010. The prognosis is that the housing stock in Flevoland will grow by 4,400 houses per year in 2010-2015, 4,320 houses per year in 2015-2020 and 3,970 houses per year in 2020-2030.

The coming decades will see the urbanisation continuing especially in the south of Flevoland, mainly in Almere (see the red spot in Figure 3.1). Flevoland province wants to offer its inhabitants a good standard of living. Part of this is to create more nature space and recreational areas. The creation of the ecological 'open area' Oostvaarderswold in south Flevoland is an example of this (see the blue green spot in Figure 3.1).

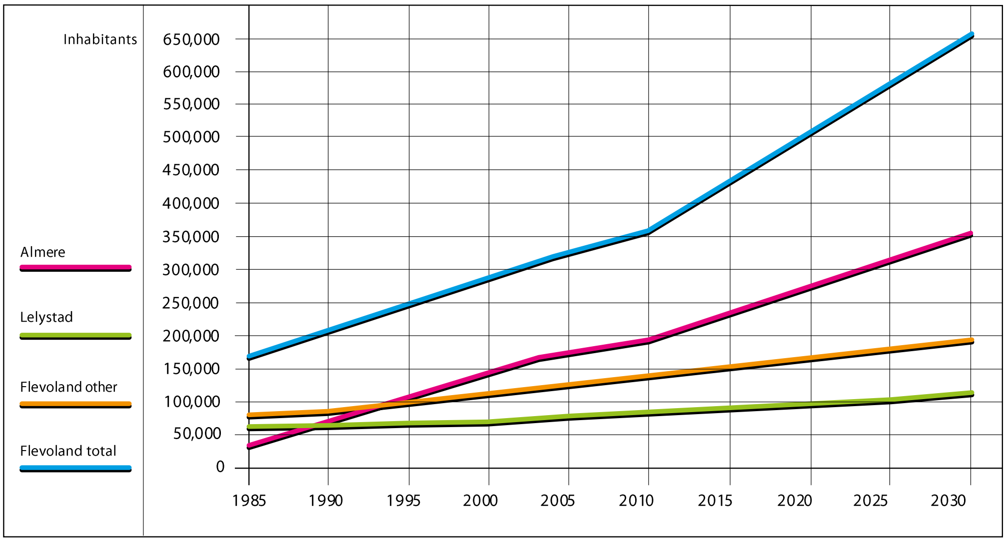
Figure 3.1	Provincial development targets for 2030



Source: Flevoland (2006).

New developments in Almere will be close to or connected with the current developed area. In 2030 Almere will have almost 350,000 inhabitants due to the construction of 70,000 new houses between 2010 and 2030 (Gemeente Almere, 2009). Figure 3.2 shows the demographic development in the major urbanised areas in Flevoland. The blue line indicates the total population in the province, the green line that in Lelystad, the orange line that in Almere and the yellow line that in the rest of the province (Flevoland, 2006).

Figure 3.2	Demographic development in Almere, Lelystad and rest urbanised areas in Flevoland



Source: Flevoland (2006).

Flevoland's workforce is continually growing. Of its current workforce (170,000), one third (63,000) works outside the region. Flevoland's potential workforce (i.e. all people aged between 15 and 65) has grown strongly in the past few years and now totals almost 250,000 people. This total will grow in the coming 15 years (until 2025). A long period of decline will follow this. In 2040, the potential workforce of Flevoland will be 4% bigger than in 2010. The scope for increasing employment depends on the composition of the workforce. The participation rate is higher as the average educational level rises. In Flevoland, 48% of the workforce are workers with a secondary education (ECABO, 2011).

In 2010 in Flevoland there were 140,000 jobs, almost a quarter in business services. Other large sectors are retail (12%), industry (11%), health-care (11%) and wholesale (10%). Service sectors have a large share in Flevoland's economy and that share is becoming more important. This leads to a move away from production work to services. This asks on average for a higher education level (UWV, 2010).

The aim of the province is to get the employment rate to rise to a level of 75% in 2015 and continue this to 90% by 2030 (Meurs et al., 2011). The province wants to improve the business climate for companies in order to facilitate this planned job growth. They plan to create on average 75 ha of business space and 50,000 m^2 of office space per year to realise this plan (Meurs et al., 2011).

3.2.2 Industrial development and service sector

The province wants both Lelystad Airport and the adjoining business space (Larserpoort) to further develop and grow (see the yellow spot in Figure 3.1). The plan is to create more job opportunities by expanding the airport. This will not only strengthen the province's economy but also make Flevoland more accessible. Realising this plan will involve creating a better network of public transport between Lelystad and the airport/business space and the creation of a new 4-lane motorway around the airport.

The province maintains the concentration of horticulture in the areas near Almere, Luttelgeest and Ens, but only in Luttelgeest and Ens is the expansion of area possible. The provincial government wants to see north Flevoland (Noordoostpolder area council and Urk area council) growing economically and thus strengthen the whole economic structure. To achieve this, the development of 450 ha of glass horticultural areas (near Luttelgeest, Nieuwland) is needed within 5 years (before 2015) in the Noordoostpolder (Provincie Flevoland, 2009). Each hectare of glasshouse will create 4-5 jobs (Provincie Flevoland, 2009). The Glastuinbouw Luttelgeest / Marknesse plans from Noordoostpolder council include an arrangement for large-scale glasshouse horticultural companies (Oranjewoud, 2010).

To further develop the economy, the province wants to strengthen the innovative capacity of the companies in the area. In order to achieve this, stimulation of innovative technological companies is needed in the Marknesse area, such as Geomatics Business Park (GBP), the National Air and Space Laboratory (NLR), the German-Dutch Windtunnel and the Composites Cluster. The GBP has doubled in size in recent years to 20 companies with more than 120 employees. It is estimated that the GBP could grow to 250 FTE if it is developed into a European Knowledge Centre in Geomatica.

3.2.3 Energy and sustainable development

The goal of Flevoland is to create 60% sustainable energy production by 2013. There has been a rapid growth in the use of wind turbines in the province in the past few years. Wind turbines can be found all over the province. The province wants to make its rural area cleaner and more efficient by removing almost half of the existing wind turbines and replacing them with newer, higher capacity versions. Wind turbines should be more clustered in a few areas. For the time being, two large areas have been allocated for wind turbines: the Noordoostpolder alongside the IJsselmeer dyke, and at the Zuidlob. The small, solitary turbines will eventually disappear from the landscape. With this approach the province wants to restore and improve its landscape where possible (Flevoland, 2008).

A lot of farmers are now involved in the realisation of wind energy. Farmers initiated and were involved in the development of the current wind turbine parks in Flevoland. The current power capacity of the wind turbines of all the farmers in Flevoland amounts for 290 MW. That is equal to 54% of the total power of the wind turbines in the whole of Flevoland in 2006. The largest part of the agricultural wind energy in Flevoland is stationed at arable farmers. They receive a subsidy for sustainable energy production. The use of wind energy is mainly undertaken by large companies because of the costs involved in setting up such a venture. It is mostly forward-thinking and successful agricultural companies that invest in wind energy for their businesses. In other words these companies are innovative whether or not they use wind energy. It is mostly forward-thinking businessmen who are interested in getting involved in new technologies in order to become successful. Wind energy is a constant and sure way of earning a regular income and therefore crucial in times when the agricultural product prices are low and companies are relying on benefits and subsidies in order to pay their bills etc. (Terbijhe et al., 2009).

The new wind energy policy of Flevoland forbids installing just one wind turbine on a farm. This implies that large wind turbines projects will become the new reality, which will be quite costly in terms of investments to be covered by one farmer. Farmers are thus motivated to cooperate with each other, as well as with energy companies such as Nuon or Eneco. Besides income from delivering wind energy, farmers are entitled to an annual compensation from the energy company for the presence of wind turbines on their arable land.

3.2.4 Agricultural development

In 2005, 968 agricultural companies were registered with a total land area of 51,901 ha in the south and east of Flevoland (Flevopolders). That is an average of 54 ha per company. South and east Flevoland will experience a reduction in the number of agricultural companies up until 2020. These numbers will reduce from 968 in 2005 to 600-700 as a result of the current owners retiring without available successors in family farms. Furthermore, there will be more companies merging their own businesses in order to create larger companies. Land will also be developed for other uses (function change) leading to the area of land being used solely for agriculture structurally falling by 5%. Along with this, the majority of the land will be taken over by the growing agricultural companies when some of the other agricultural companies decide to stop (Flevoland, 2007).

The province has introduced four regulations to implement the spatial planning (Flevoland, 2006). The reason for that is to create more space for developments in Flevoland. One of the regulations serves as a guideline; it is titled 'Small-scale developments in the rural area 2007'. This regulation replaces the former 'Non-agricultural activities in the rural area' and offers more space to small-scale non-agricultural or agricultural activities in the rural area of Flevoland, under the condition that they form no obstacles to existing activities and functions, do not lead to urbanisation of the rural area of Flevoland, and must be well integrated into the landscape and the traffic. This regulation also has several limitations concerning the expansion of the area under agricultural buildings (stables, sheds, etc.).

3.3.5 Nature and landscape development

The urbanisation of especially the south of Flevoland will continue in the coming decades. Flevoland province wants to offer the inhabitants a good lifestyle. To achieve this, the province creates more nature and recreational areas. In the Area Plan Flevoland 2006, the province presents plans to create an ecological connection between Oostvaardersplassen and Horsterwold (two core areas from the EHS) by means of Oostvaarderswold (see the blue-green spot in Figure 3.2). This plan involves using 1,800 ha of agricultural land and creating a nature and recreation area for the inhabitants of Almere, Lelystad and Zeewolde. With the creation of Oostvaarderswold, Flevoland will have a continuous nature area of circa 15,000 ha. In the coalition accord from the new government 2011-2015, the province has given approval for the creation of the new Oostvaarderswold against the policy of the state government in which it is stated that the new area would not be created. This plan should be realised by 2018 (Flevoland, 2010).

The area in which Oostvaarderswold is located is mainly used for agricultural purposes. About 30 agricultural companies are situated in the area. Due to the creation of Oostvaarderswold, these companies must relocate. There will be a large area of agricultural land taken up by nature and recreational use.

The boundaries of the new area will also cut right through the current allotment. Agricultural companies may indeed stop or will have to find new areas in which to continue. Agricultural companies outside the boundaries of the new plans will be able to continue as normal and the new area will create no legislative barriers. They can continue with their strategies for expansion and multifunctional farming. Research has also shown that this plan will not affect the prices of the products from the land. Issues such as seepage, drainage, etc. will have no damaging effects.

On the basis of the Nature Management Plan Flevoland, approximately 800 ha of new nature have been allocated. Farmers can sell their agricultural land to the national government via the Dienst Landelijk Gebied on a voluntary basis. New nature areas will then be created on this land by nature protection organisations like Natuurmonumenten, Stichting Flevolandschap and Staatsbosbeheer. The areas border on existing nature areas. They are mainly new nature areas near the Kuinderbos (123 ha, from forest to open area), Ettelandsweg/Steenwijkertocht (38 ha, wet grassland), Voorster/Kadoelerbos (130 ha, wet grassland, new forest, stream), Zwarte Hoek (76 ha, marshland), Urkerbos (80 ha, meadow/grassland) and the Friese Hoek (Oranjewoud, 2011). The nature development in the eastern part of the Noordoostpolder (expansion of nature area joining Kuinderbos) can create an instance whereby it is no longer possible for livestock farmers to expand (LTO, 2010).

Flevoland has an annual nature management subsidy for only 500 ha of agricultural land. That is low in comparison to other provinces. The province would like to see this amount doubled to 1,000 ha (Flevoland, 2011).

In the Structuurvisie 2011 plan drawn up by the Noordoostpolder council (Oranjewoud, 2011a and 2011b), livestock farmers were given fewer opportunities to expand than other parts of the sector. There were actual plans to develop nature, recreation areas, etc. at the expense of agricultural land. The council also wants to turn a number of agricultural areas into reservoirs (LTO, 2010). Four farmers in Flevoland had to give up 45 ha of land for the development of the Burchttocht, which was one of Flevoland's first water storage projects. It began as a small area but is now 200 m wide and almost 3 km long. It can hold up to 260m litres of water if there is too much water in the polder after heavy rains. Apart from this reservoir the area is also a nature and recreational area. A similar facility is planned for a location near Dronten-West. The Noordoostpolder council would also like to combine the nature area around Schokland with a reservoir. The fact that Schokland is on the World Heritage list also has negative effects for agriculture in the area of the island, as there are many more rules and regulations in relation to nature areas etc. (van 't Westeinde, 2006).

3.4 Economic developments in agriculture in Flevoland

Agriculture is strongly represented in Dronten and Noordoostpolder. In Urk there is also a strong representation especially in the fish industry. With the introduction of new and modern techniques, agriculture in Flevoland has lost many jobs. Between 2006 and 2010 the number of jobs in agriculture and the fish industry in Flevoland fell by 5%. It is expected that a further 60 jobs will be lost in the period 2011-2015. On the other hand, the service sector and the health-care sector will see an extra 1,560 and 1,240 new jobs, respectively, created in the period 2011-2015 (Meurs et al., 2011).

3.5 Conclusion

The plans and projects mentioned in this section will have an effect on agriculture in Flevoland until 2030. Urbanisation will increase in the province. The cities/towns of Almere, Lelystad, Dronten and Emmeloord will continue to grow and expand. Because of this the inhabitants will require more space for nature and recreation, which will lead to agricultural land being required for this purpose. Another effect is due to the agricultural policy and succession problems creating a fall in the number of agricultural companies in the south and east of Flevoland up until 2020. The introduction of new methods and techniques will also see a drop in the number of jobs in agriculture in Flevoland. A further reason is due to the demands for land for nature expansion, recreation and reservoirs.

However, the development of Lelystad airport and the neighbouring Larserpoort and the new companies planned for Marknesse will not have a dramatic effect on agriculture in the area. The glasshouses will stay in a central location and currently further development is allowed only at two existing locations in the Noordoostpolder.

With the introduction of the new wind turbines there will be more power centralised at a few locations in Flevoland, which will help to tidy up the area. Taking part in these schemes is a way for farmers to guarantee themselves a decent income. Farmers, however, can no longer install new turbines on their property.

It will be possible for farmers to develop their land for small-scale expansion. Finally, there will be more possibilities for agricultural and nature conservation.

4 Adaptation to agri-environmental schemes

4.1 Introduction

Some economically and market-oriented environmental policies have emerged in recent decades. In Europe, there is a trend towards the development of agri-environmental schemes (AESs), which are 'payments (including implicit transfer such as tax and interest concessions) to farmers and other landholders to address environmental problems and/or promote the provision of environmental amenities' (Westerink et al., 2008).

The concept of Green and Blue Services (GBS) was first introduced into Dutch national policy in the 'structuurschema Groene Ruimte' in 2002 (the National Structure scheme on the Green Environment). GBS is defined as 'the provision of supra-legal public achievements aimed at the realisation of public demands concerning nature, landscape, water management and recreational use (accessibility), for which a cost-recovering compensation is given' (Westerink et al. 2008).

According to the study by Oostindie and van Broekhuizens (2010), AESs are a particular form of GBS. AES is a purely public system of payment for GBS. However, these two concepts do not completely overlap. GBS include possibilities for private funding and also include services that are not paid for.

GBS is important not only for the landscape but also for the economy. The landscape has significant value; for tourism and employment. In recent years, payment for GBS has become an important issue. Farmers can deliver GBS but at the same time profit from the services provided by surrounding ecosystems. Examples of these benefits are clean water, soil conservation, wind breaking and moderation of temperature.

This section discusses two specific services - water retention (blue services) and field margins (green services) - from the catalogue of GBS.

4.2 Water retention (blue services)

4.2.1 Water retention

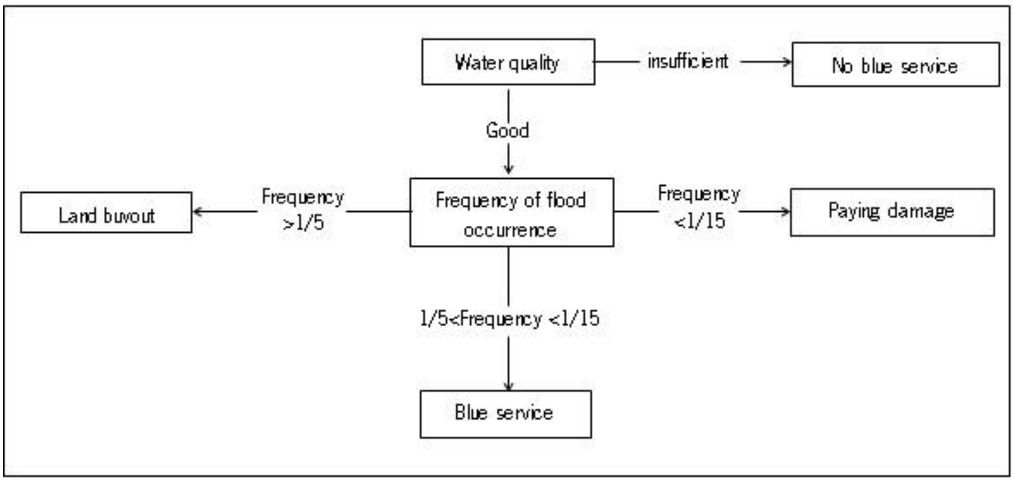
As mentioned in Section 2, water retention on agricultural land refers to the storage of excess water due to the peak discharge of rivers to prevent flooding elsewhere (De Groot et al., 2006). Water retention is one of the blue services provided by the agricultural sector. Blue services are defined as voluntary contributions of private parties to legal assignments of water boards for compensations in conformance with the market (De Groot et al., 2006).

If the water quality is sufficient, water retention on farmland could be considered. The frequency of flood occurrence could be used as an indicator for the decision to implement blue service (see Figure 4.1). As indicated in Figure 4.1, when the frequency of flood occurrence is higher than once per 5 years, a non-recurring buyout of the land should be decided; when the frequency of flood occurrence is less than once per 15 years, compensation for flood damages could be considered. When the frequency of flood occurrence is between once per 5 years and once per 15 years, the blue services provided by agricultural land could be considered.

According to De Groot and colleagues (2006), the costs of blue services comprise the costs incurred by a farm for offering the blue services plus compensation to the farm for providing the blue services. The costs incurred by a farm for offering the service to store water could be expressed in the loss of labour profit. The compensation to the farm for providing the blue service consists of an annual compensation for damage to crops and a single benefit for the decrease of the value of the inundated land. Both types of costs depend on the probability of inundation.

In practice, only cattle farmers provide blue services. This is because the inundation damage to grassland is much less than that to arable land. For example, there will be a total yield loss for arable crops when inundated for two days, while grassland could stand water for a much longer period. Opportunities to create emergency retention areas on farmland along the main rivers include the possibility to develop these areas for recreation, nature development and management (De Groot et al., 2006).

Figure 4.1 The relation between flood occurrence and the decision of blue services



Source: Adapted from Bommel et al. (2009).

Farmlands in the western part of the Netherlands suffer from several interrelated problems: subsidence, water shortage during the dry summer period, excess water during wet periods and salinisation related to sea level rise. Groundwater levels are kept low in agricultural land and high in natural areas. This has created a scattered pattern of groundwater levels and gradients from natural areas to polders.

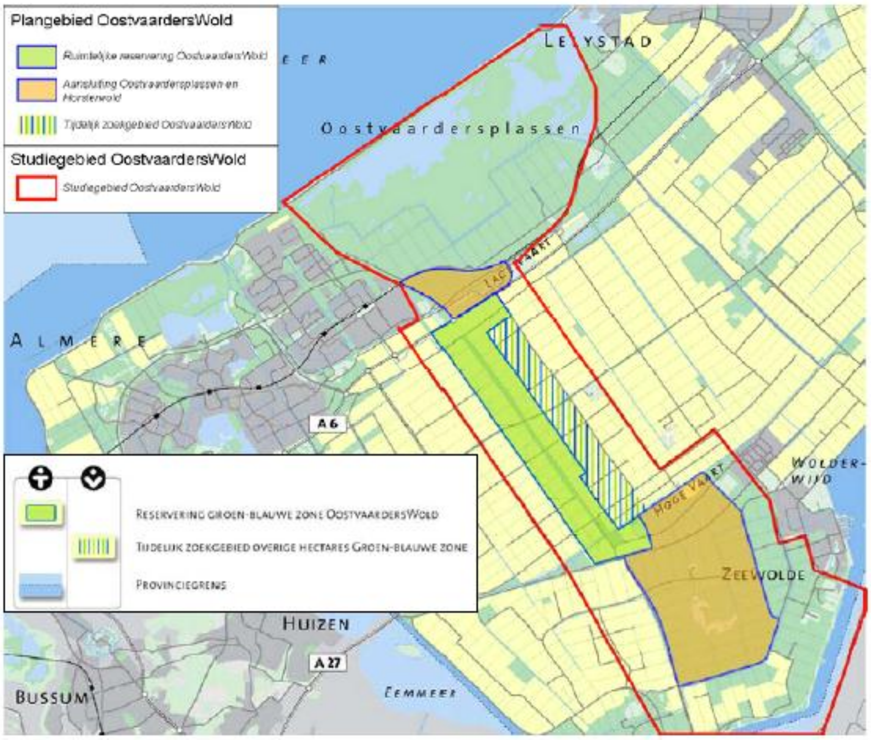
Water level management involves increasing ditch and groundwater levels. This is often referred to as 'wetting of farmland'. According to De Groot and colleagues (2006), several benefits could be related to the wetting of farmland: (1) peak water discharges could be captured; (2) high groundwater levels can be maintained in adjacent nature areas; (3) a groundwater stock can be maintained at the start of the dry summer period; and (4) soil subsidence due to the oxidation of peat is reduced.

4.2.2 Water retention in Flevoland

The Oostvaarderswold green-blue zone in Flevoland, where various natural, water and recreational functions are combined (see Figure 4.2), was mentioned in Section 3. The objectives of this zone are (1) to contribute to water storage in southern and eastern Flevoland; (2) to provide a habitat for large herbivores; (3) to create best quality nature; and (4) to experience a unique selling point (USP) in the field of nature-oriented recreation.

Oostvaarderswold connects Oostvaardersplassen - a young nature reserve covering approximately 5,600 ha - to Horsterwold, the biggest forest in the Netherlands. Oostvaarderswold, Oostvaardersplassen and Horsterwold are together called Oostvaardersland, a new 15,000-hectare nature reserve and recreational area in the province of Flevoland.

Figure 4.2 **Map of Oostvaardersland in Flevoland**



Source: ARCADIS, 2009.

Oostvaardersland will expand the sustainable water system by 4m m^3. The creation of Oostvaardersland will contribute to water retention in the province. This is important because southern Flevoland is one of the lowest regions in the Netherlands and without adequate measures is subject to a considerable risk of flood.

It is planned that 1,950 hectares of agricultural land in Oostvaarderswold will have a significant change of land use from traditional agricultural use to more multifunctional land use forms, such as nature, recreation and water retention. This zone will provide not only a foraging area for various species of harrier but also capacity for water retention. Water retention in Oostvaarderswold includes wetting the green-blue zone and water storage in the green-blue zone.

Wetting the green-blue zone

Wetting in the green-blue zone will take place on lands for which the land use function has been changed. The wetting may have negative impacts on the neighbour agricultural areas (the so-called wet damage). By wetting the green-blue zone, nutrient seepage into the agricultural area may be greater, making it unfavourable for water quality and the achievement of objectives of the European Water Framework. Extra measures to assure water quality may be needed in the agricultural area.

If the water level in the green-blue zone is increased while the current drainage remains the same in the surrounding agricultural area, the subsidence of land in the green-blue zone will be reduced but the problem will remain for the agricultural area. Based on the current ground level variations and subsidence, it is not clearly indicated whether the differences in surface position will increase or decrease (DLG, 2007).

Costs associated with wetting the farmland include costs of productivity loss in the case of structural wetting and the costs of a blue service in the case of periodic wetting. Based on calculation methods provided by LNV (2002), the costs of structural wetting of the farmland in Flevoland were calculated for this section. It was assumed that:

(a) Once per 2 years inundation lasts two continuous weeks somewhere between February and November;
(b) Once per 10 years inundation lasts two continuous weeks somewhere between February and November;
(c) Once per 25 years inundation lasts two continuous weeks somewhere between February and November.

The calculation steps were:

1. Percentage losses or the increase in the production area that is needed to achieve the same production. This percentage was taken from the Waterinstrumentarium report (LNV, 2002).
2. Required additional labour and machine costs per year, compared to costs in the reference situation. These additional labour and machine costs are calculated based on the number of labour (hours/ha) needed according to the most recent KWIN data. The additional labour and machine costs are proportional to the increase of the production area and are estimated at €68 per hour, which is equivalent to the average wage of contracting work.
3. Capitalising compensation costs per hectare. These costs consist of costs for land purchasing (needed increase in production area) and the capitalised costs (factor 10) for extra labour and machine costs.
4. Capitalising income loss per hectare. Here the capitalisation factor 10 was used to convert the annual recurring loss to a one-time compensation.

Table 4.1 Important indicators that are needed for the calculation

Sector	Balance (€/ha per % yield)	Labour (hour/ha)	Average firm size (ha)	Average land price (€/ha)
Arable farm in Flevoland	34	26 (per hour labour costs €68)	44.7	57,754

Here we show the details of calculating the costs of inundation once per 2 years:

1. According to the Waterinstrumentarium report (LNV, 2002), the inundation of once per 2 years on the arable land leads to 66% yield loss, which could be compensated by 66% increase in farm size.
2. 66% increase in farm size indicates an increase of 66% in labour and machine costs per hectare per year:
3. 66% * 26 hour/ha * €68/hour = €1,166.88/ha
4. Capitalising the additional labour and machine costs: €1,166.88/ha * 10 = €11,668.8/ha.
5. Costs of land purchasing due to an increase in the farm size: 66% * €57,754/ha = €38,117.64/ha.
6. The total compensation costs per hectare are: €11,668.8/ha + €38,117.64/ha = €49,786.44/ha.
7. Capitalising income loss per hectare: 66% * €34 per % * 10= €22,440.

The above calculation shows that the compensation for income loss is in this case much cheaper than the compensation for wetting damage.

The same calculation steps apply for the case of inundation once per 10 years and inundation once per 25 years (see Table 4.2).

Table 4.2	**Compensation costs for structural wetting in Flevoland**
Inundation once per 2 years	1. 66% yield loss 2. Additional labour and machine costs due to 66% increase in farm size: 66% * 26 * 68 = €1,166.88/ha 3. Capitalising the additional labour and machine costs: €1,166.88 * 10 = €11,668.8/ha Costs of land purchasing: 66%*57,754 = €38,117.64/ha Total compensation costs: 11,668.8 + 38,117.64 = €49,786.44/ha 4. Capitalising the income loss: 66% * €34 per % * 10 = €22,440
Inundation once per 10 years	1. 13% yield loss 2. Additional labour and machine costs due to 13% increase in farm size: 13% * 26 * 68 = €229.84/ha 3. Capitalising the additional labour and machine costs: €229.84 * 10 = €2,298.4/ha Costs of land purchasing: 13% * 57,754 = €7,508.02/ha Total compensation costs: €2,298.4 + €7,508.02 = €9806.42/ha 4. Capitalising the income loss: 13% * €34 per % * 10 = €4,420
Inundation once per 25 years	1. 5% yield loss 2. Additional labour and machine costs due to 5% increase in farm size: 5% * 26 * 68 = €88.4/ha 3. Capitalising the additional labour and machine costs: €88.4 * 10 = €884/ha Costs of land purchasing: 5% * €5,7754 = €2,887.7/ha Total compensation costs: €884 + €2887.7 = €3,771.7/ha 4. Capitalising the income loss: 5% * €34 per % * 10 = €1,700

Table 4.2 shows that for all the incidences, compensating for income loss is much cheaper than compensating for wetting damage. Costs for inundation decrease significantly when the frequency of inundation decreases. This finding confirms the decisions made in Figure 4.1: when the frequency of inundation is greater than once in 5 years, buying out the agricultural land might be a better choice than compensating for damage or income loss.

Water storage in the green-blue zone

The designation of selected areas of land for the retention and storage of surplus freshwater could also be targeted at building up reserves of stored freshwater that could be used during periods of prolonged drought. In this way, the establishment of the green-blue zone may have positive or negative effects on the water issue for the surrounding agricultural area. Specific analysis should be conducted to find out what these effects are. Within the green-blue zone, the peak storage is integrated into the surrounding area. This is beneficial to the agricultural sector in this region because no additional area is needed for water storage.

One way to achieve an increase in the water storage capacity of the land is to disconnect the drainage ditches from the main surrounding reservoir systems.

The major economic costs of water storage on agricultural land are the sum of the losses of production for future generations, which could be equal to the sum of the initial investment and the costs of management and maintenance. The costs of the initial investment comprise the costs of lowering the water table (thus creating room for storage) and of installing the necessary water works. The costs of management and maintenance include the use of the water works, the implementation of inline users by means of radar images, and the production and application of decision support systems. These costs may amount to as much as €250,000/ha. Enhancing the storage capacity of polder areas by enhancing the number of ditches and disconnecting these from the main receiving reservoirs would cost €300-700 million (De Groot et al., 2006).

In addition to the major costs are the costs of the loss of surface area that leads to the loss of production and a potential threat to certain types of nature that are vulnerable either to inundations or to contact with water of foreign origins.

4.3 Coping with pests and diseases (green services)

4.3.1 Field margins

Green services are focused on the management of the landscape, paths (such as hedgerows and willows) and field margins. Benefits of green services are: the strengthening of the biodiversity, decreasing the dependency on and the use of pesticides, a sustainable agriculture, clean water and an attractive landscape.

Field margins are 3, 6 or 9 m wide strips with flowers or plants that surround a field. The width of the margins is derived from the effective width of the agricultural machinery and the right size for a natural setting. Field margins provide habitats and refuge networks for various flora and fauna that can now survive in previously uninhabitable areas. This allows species (such as insects, butterflies, ladybirds and wasps) to become established in an area, some of which will be the natural enemies of crop pests, and thus might reduce the amount of pesticide used.

Natural enemies of crop pests make use of the landscape. Field margins thus occupy a certain amount of a farm's arable land. According to van Wingerden and colleagues (2004), when the field margins are more equal and intricately located in an area, pests are better suppressed. Moreover, the field margins should occupy at least 5% (7.5% if possible) of a field surface in order to suppress natural pests signifycantly.

Natural enemies rest in field margins and fly over a large area. In this way, field margins provide hibernation opportunities for benevolent parasites. According to Van Alebeek and colleagues (2008), the field margins should be placed every 100-150 m apart.

Field margins in Flevoland

The Flevoland Field Margins Project (Akkerranden Flevoland) runs from 2009 to 2013. This project is an initiative of the province of Flevoland, Zuiderzeeland Water Board, Flevoland Landscape (Landschapsbeheer Flevoland) and LTO-Noord. This project is built upon a pilot project that was carried out in 2006-2008. The number of participants has increased from 26 to 50 farmers since 2009. The aim of the project is to build a 160 km network of field margins in the project area (see www.akkerrandenflevoland.nl).

The goals of this project are to reduce the use of chemical pesticides and to improve the quality of the surface water. Three types of field margins are developed in this project: annual field margins, perennial field margins and mixed field margins. Annual field margins are adapted to the crop next to where the field margin is located. The flowers and herbs are specially selected to attract insects in order to control pests and diseases that are common in the crop. Perennial field margins are suitable places for insects to hibernate. This indicates that the useful insects could stay in the grass through the winter and be active in the early spring. This is important for the crops that suffer from pests already in early spring. Mixed field margins are a mixture of annual and perennial field margins; for example, a combination of 3 m wide annual field margins (mainly flowers) and 3 m wide perennial field margins (mainly grass).

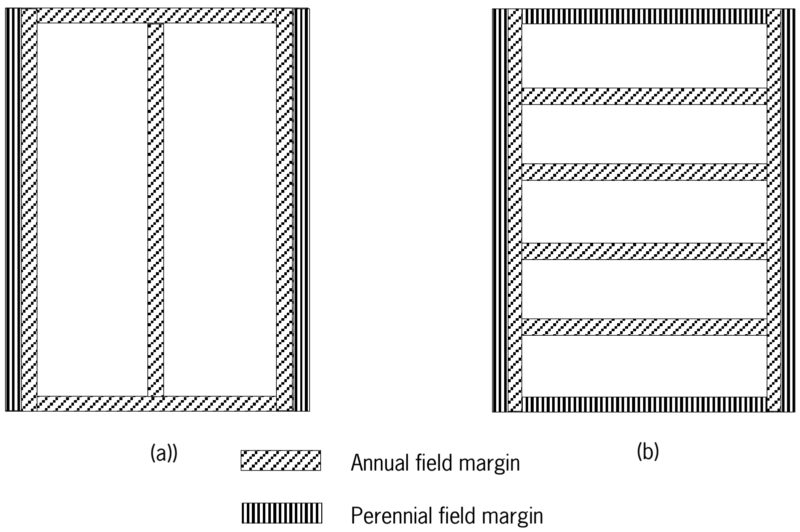
The project participants (farmers) receive seeds for the field margins. After consulting with experts, farmers decide the location of the field margins. Crop inspection is carried out throughout the project. Based on the results of the crop inspection, farmers can decide whether pesticides are needed. Farmers are expected to maintain (mainly mow) the field margins, especially the perennial field margins.

According to Metselaar and colleagues (2011) in 2010 the project reached:

1. 12.6 ha annual field margins by 26 farmers (compensation €2,613/ha);
2. 8 ha perennial field margins by 15 farmers (compensation €2,662/ha);
3. 1.9 ha mixed field margins by 4 farmers (compensation €2,698/ha).

According to Van Alebeek and colleagues (2008), the average size of a plot in Flevoland is 300 x 800 m (= 24 ha). In this section, we assume two different cases to build field margins and calculate the compensation per case could receive (see Figure 4.3).

Figure 4.3 **Two different designs of field margins**



In plot (a), we assume that field margins are planned along the length of the plot. On this plot, mixed field margins are planted along the long edges and annual field margins are planted along the short edges. Since the distance between field margins should not be greater than 150 m, an extra annual field margin is planted in the middle of the plot parallel to the long edge. Table 4.3 presents the areas of different types of field margins on plot (a) and their associated compensation costs. The field margins on plot (a) occupy 5.7% of the plot area and cost €3,661 per year.

Table 4.3 **Areas of the field margins and the associated compensation costs of plot (a)**

Field margin	Area (ha)	Compensation (€/ha)	Total
Annual	0.41	2,613	(0.41 * 2,613) €1,071
Mixed	0.96	2,698	(0.96 * 2,698) €2,590
Sum	1.37		€3,661

In plot (b) in Figure 4.3, we assume that field margins are planned along the width of the plot. On this plot, mixed field margins are planted along the long edges and perennial field margins are planted along the short edges. Four extra annual field margins are planted in the middle of the plot parallel to the short edge. Table 4.4 presents the areas of different types of field margins on plot (b) and their associated compensation costs. The field margins on plot (b) occupy 6.2% of the plot area and cost €3,958 per year.

Table 4.4	Areas of the field margins and the associated compensation costs of plot (b)		
Field margin	**Area (ha)**	**Compensation (€/ha)**	**Total**
Annual	0.35	2,613	(0.35 * 2,613) €915
Perennial	0.17	2,662	(0.17 * 2,662) €453
Combination	0.96	2,698	(0.96 * 2,698) €2,590
Sum	1.48		€3,958

Comparing the two plots, plot (b) has higher costs but provides more habitats for natural enemies. These two designs are suitable for different types of farms in terms of farm size (measured by NGE) and intensity (measured by NGE/ha).

The compensation costs calculated above are received by farmers. However, other costs that are also involved in the project - such as costs of monitoring the pests on the field, costs of the seeds for the field margins, and labour costs spent by farmers to mow the field margins, etc. - were not taken into account.

4.4 Conclusions

This section discussed two specific types of green and blue services that could be found in Flevoland, namely water retention and field margins. The Oostvaarderswold green-blue zone in Flevoland contributes not only to water storage but also to nature conservation and recreation. Compensation costs for structural wetting that are associated with various frequencies of flooding were calculated. It is concluded that if the frequency of inundation is greater than once in 5 years, buying out the agricultural land might be a better option than compensating for inundation damage or income loss. The field margins project in Flevoland runs from 2009 to 2013. Based on the compensation paid to project participants (farmers), compensation costs of two different designs for field margins were calculated. The associated compensation costs provide some insights into the costs related to this type of green services. However, other costs such as costs for crop inspection were not taken into account.

5 Conclusions

This memorandum outlined climate change adaptation options at the farm level in the province of Flevoland, which is the regional focus of the AgriAdapt project. In Flevoland arable farming is the most dominant land use. Adaptation options related to water and to pests and diseases were studied using a literature review. To deal with the described effects of climate change on agriculture in Flevoland, the following adaptation options are considered. First, water storage in times of water surplus might be an effective measure, while in addition the stored water can be used in times of extreme and prolonged droughts. Second, a redesign of the rural landscape to include patches of natural vegetation - such as small wooded parcels and field margins along large arable fields - may suppress future pests and diseases by providing a habitat for the natural enemies of those pests. Third, due to the salinisation of groundwater, breeding crops that are tolerant to salt water is considered an adaptation option.

Moreover, long- and medium-term spatial plans applicable to the case study region were studied and reviewed with regard to external effects on arable farming. The plans and projects mentioned in Section 3 of the report will have an effect on agriculture in Flevoland until 2030. Urbanisation will increase in the province. The cities/towns of Almere, Lelystad, Dronten and Emmeloord will continue to grow and expand. Because of this, the inhabitants will require more space for nature and recreation, which will lead to agricultural land being required for this purpose. Another effect is due to the agricultural policy and succession problems creating a fall in the number of agricultural companies in the south and east of Flevoland up until 2020. The introduction of new methods and techniques will also see a drop in the number of jobs in agriculture in Flevoland. A further reason is due to the demands for land for nature expansion, recreation and reservoirs.

However, the development of Lelystad airport and the neighbouring Larserpoort and the new companies planned for Marknesse will not have a dramatic effect on agriculture in the area. The glasshouses will stay in a central location and currently further development is allowed only at two existing locations in the Noordoostpolder.

With the introduction of the new wind turbines there will be more power centralised at a few locations in Flevoland, which will help to tidy up the area. Taking part in these schemes is a way for farmers to guarantee themselves a decent income. Farmers, however, can no longer install new turbines on their property.

It will be possible for farmers to develop their land for small-scale expansion. Finally, there will be more possibilities for agricultural and nature conservation.

Section 4 discussed two specific types of green and blue services that are found in Flevoland, namely water retention and field margins. The Oostvaarderswold green-blue zone contributes not only to water storage but also to nature conservation and recreation. Compensation costs for structural wetting that are associated with various frequencies of flooding were calculated. It is concluded that if the frequency of inundation is greater than once every 5 years, buying out the agricultural land might be a better option than compensating for inundation damage or income loss. A field margins project in Flevoland runs from 2009 to 2013. Based on the compensation paid to project participants (farmers), the compensation costs of two designs for field margins were calculated. The associated compensation costs provide some insights into the costs related to this type of green services. However, other costs - such as costs for crop inspection - were not taken into account.

Literature and websites

Alebeek, F.A.N. van, R. van den Broek and J.H. Kamstra, *Gebiedsplan FAB Flevoland. Groen-blauwe dooradering in het landschap ten dienste van natuurlijke plaagonderdrukking*. Praktijkonderzoek Plant & Omgeving B.V., Wageningen UR, 2008.

Alebeek, F.A.N. van, A. Visser and R. van den Broek, 'Akkerranden als (winter)schuilplaats voor natuurlijke vijanden.' In: *Entomologische berichten* 67 (2007), 6, pp. 223-225.

ARCADIS, *PlanMER groenblauwe zone OostvaardersWold*. Province Flevoland, 2009.

Binternet, *Het Bedrijven-Informatienet van het LEI (LEI's Farm Accountancy Data Network),* 2011. <www.lei.wur.nl/UK/statistics/Binternet/>

Bommel, K. van., K. Oltmer and E. ten Pierick, *European Blues: Blue services in a European perspective.* LEI, part of Wageningen UR, The Hague, 2009.

Belder, E. den, J. Elderson, G. Schelling and J.A. Guldemondet, 'Het functionele landschap: de invloed van landschap en bedrijfsvoering op natuurlijke plaagonderdrukking in spruitkool.' In: *Entomologische berichten* 67 (2007) 6, pp. 209-212.

CBS, *Crop protection in agriculture and horticulture 2004* (in Dutch). Netherlands Statistics, Voorburg/Heerlen, 2005.

CBS, *Environmental accounts of the Netherlands 2009*. Statistics the Netherlands, The Hague/Heerlen, 2010.

CBS, *Gebruik van gewasbeschermingsmiddelen in de landbouw per actieve stof, 1995-2008 (indicator 0560, versie 01, 16 juli 2010)*. CBS, Den Haag; Planbureau voor de Leefomgeving, Den Haag/Bilthoven and Wageningen UR, Wageningen, 2011.

CBS, *Statline. Bodemgebruik*. Den Haag/Heerlen, 2011.

CBS, *Watergebruik in de land- en tuinbouw, 2001-2008 (indicator 0014, versie 07, 10 september 2010).* CBS, Den Haag; Planbureau voor de Leefomgeving, Den Haag/Bilthoven en Wageningen UR, Wageningen, 2011.

CBS, *Waterwinning en waterverbruik in Nederland, 1976-2008 (indicator 0057, versie 08, 11 februari 2011).* CBS, Den Haag; Planbureau voor de Leefomgeving, Den Haag/Bilthoven and Wageningen UR, Wageningen, 2011.

Commissie Waterbeheer, *Basisrapport bij het advies van de Commissie Waterbeheer 21e eeuw*. 2000a.

Commissie Waterbeheer, *Waterbeleid voor de 21e eeuw, geef water ruimte en de aandacht die het verdient*. Advies van de Commissie Waterbeheer 21e eeuw, 2000b.

DLG, *Verkenning effecten GroenBlauwe Zone OostvaardersWold op omliggende Landbouw en vice versa*. Dienst Landelijk Gebied, regio West in opdracht van Projectorganisatie OostvaardersWold, provincie Flevoland, 2007.

Drunen, M. van, *Naar een klimaatbestending Nederland*; Samenvatting routeplanner, KvR rapport 006/2006, Delft.

ECABO, *Regioscheet Arbeidsmarktregio Flevoland 2011*. 2011.

Eerdt, M. van, A. van der Linden, C. de Lauwere and H. van Zeijts, *Interim evaluation of the Dutch crop protection policy.* XIII Symposium Pesticide Chemistry - Environmental Fate and Ecological Effects, Pavia, Italy, p. 908-916., 2000.

Flevoland, *Omgevingsplan Flevoland 2006*. Provincie Flevoland, Lelystad, 2006.

Flevoland, *Landbouw na 2013 in Zuidelijk en Oostelijk Flevoland. Een landbouwstudie voor de groenblauwe zone Oostvaarderswold*. 12 december 2007. Dienst Landelijk Gebied Regio West, Utrecht, 2007.

Flevoland, *Beleidsregels Windmolens 2008*. Provincie Flevoland, Lelystad, 2008.

Flevoland, *Het Noorden in de lift.* Provincie Flevoland, Lelystad, 2009.

Flevoland, *Uitvoeringsprogramma Economie Flevoland 2008-2012*. Provincie Flevoland, Lelystad, 2009.

Flevoland, Oostvaarderswold. Folder. Provincie Flevoland, Lelystad, 2010.

Flevoland, *Natuurbeheerplan Flevoland 2011*. Provincie Flevoland, Lelystad, 2011.

Groot, R.S. de, E.C. van Ierland, P.J. Kuikman, E.E.M. Nilesen, M. Platteeuw, V.C. Tassone, A.J.A. Verhagen and S. Verzandvoort-van Dijck, *Climate adaptation in the Netherlands*. The Netherlands programme on Scientific Assessment and Policy Analysis Climate Change, Wageningen UR, 2006.

Geertsema, W., E. Steingröver, W. van Wingerden, F. van Alebeek and J. Rovers, *Groenblauwe dooradering in de Hoeksche Waard. Een schets van de gewenste situatie voor natuurlijke plaagonderdrukking*. Alterra, Green world research, Wageningen, 2004.

Gemeente Almere, *Concept Structuurvisie Almere 2.0*. Gemeente Almere en MVRDV, Almere, 2009.

Hoekstra, J.R. and L. Bos, Planologische consequenties en planschade bij waterberging in het landelijk gebied. CLM;583 - 2003: CLM, Utrecht.

Hoogeveen, M.W., K.H.M. van Bommel and G. Cotteleer, *Beregening in land- en tuinbouw; Rapport voor de Droogtestudie Nederland* p. 64., 2003.

Ierland, E.C. van, K. de Bruin and A. Ruijs, *Routeplanner naar een klimaatbestendig Nederland Adaptatiestrategieën* (a qualitative assessment of climate adaptation options and some estimates of adaptation costs). Netherlands Policy programme ARK as Routeplanner projects 3,4 &5, Environmental economics and natural resources, Wageningen UR, Wageningen, 2007.

IPCC, *Third assessment report*. Working Group I., Cambridge University Press, Cambridge, 2001.

Kabat, P., W. van Vierssen, J. Veraart, P. Vellinga and J. Aerts, 'Climate proofing the Netherlands.' In: *Nature* 438 (2005), p. 283-284.

KNMI, *Monthly climate data*. Royal Netherlands Meteorological Institute, 2011. <www.knmi.nl/klimatologie/maand_en_seizoensoverzichten/index.html#jaar>

Lemmen, D.S. and F. J. Warren, 'Climate Change Impacts and Adaptation: A Canadian perspective. In: *Climate Change Impacts and Adaptation Directorate.* Ottawa, ON, 2004.

Linden, A.M.A. van der, P. van Beelen, G.A. van den Berg, M. de Boer, D.J. van der Gaag, J.G. Groenwold, J.F.M. Huijsmans, D.F Kalf, D.F., S.A.M. de Kool, R. Kruijne, R., S.R.M. Merkelbach, R.A.N. Vijftigschild, M.G. Vijver en A.J. van der Wal, *Midterm evaluation of the plant protection policy of the Netherlands environment* (in Dutch, English summary). National Institute of Public Health and the Environment (RIVM), Bilthoven, 2006.

LNV, *LNV-Waterinstrumentarium*. Expertisecentrum, Ministerie van Landbouw, Natuurbeheer en Visserij, Ede/Wageningen, 2002.

LTO, *Brief met zienswijze. LTO Noord op structuurvisie Noordoostpolder*. LTO Noord. Afdeling Noordoostpolder, Zwolle, 2010.

Meerburg, B. and R. Geerts, 'Functionele agrobiodiversiteit: gebruik natuurlijke vijanden om plagen de baas te worden.' In: *Gewasbescherming* 41 (2010) 1, pp. 2-4.

Meerburg, B.G., J. Elderson, E. den Belder and F.A.N. van Alebeek, *Het beperken van insectenplagen in gewassen door het aanleggen van barrières rond of in het perceel: een literatuurstudie*. Functionele Agro Biodiversiteit, 2009.

Metselaar, J., A. Visser, E. van der Wal and A. Zwijnenburg, *Actief Randenbeheer Flevoland 2010. Tussenrapportage over de resultaten uit de gewasinspecties en monitoring*. CLM onderzoek en Advies BV & Agrarische Unie, Culemborg, 2011.

Meurs, M., R. Eselink and M. Stijnenbosch, *Economie en arbeidsmarkt 2010-2011 Flevoland*. Provincie Flevoland, Kamer van Koophandel Gooi-, Eem- en Flevoland en Provinciaal Platform Arbeidsmarkt Flevoland, 2011.

Oranjewoud, 2010. *Bestemmingsplan Glastuinbouw Luttelgeest/Marknesse*. 2010.

Oranjewoud, *Structuurvisie en Bestemmingsplan Buitengebied gemeente Noordoostpolder*. Versie 05. 19 januari, 2011a.

Oranjewoud, *Structuurvisie Noordoostpolder. Behoud door ruimte voor ontwikkeling*. Revisie ontwerp. 2 februari, 2011b.

Oostindie, H. and R. van Broekhuizen, *RDP and agriculture's provision of green and blue services (GBS) in the Netherlands. Assessing the impact of rural development policies (incl. LEADER)*. Case-study report. Wageningen UR, 2010.

Schouten, A., *Beregeningskaarten 2001-2008*. 2011. <www.lei.wur.nl/NL/onderzoek/werkvelden/Regionale+Economie+en+Ruimtegebruik/Beregeningskaarten+2001-2008/>

Terbijhe, A., K. Oltmer and M. van der Voort, *Spin-off Windenergie. Een onderzoek naar de economische, duurzaamheids- en regionale effecten van windenergie*. ACRRES, Wageningen UR, 2009.

UWV, *Regionale arbeidsmarktschets Flevoland, juni 2010*. Amsterdam, 2010.

Veen, H. van der, C. Daatselaar and M. Dolman, *Watergebruik in de agrarische sector 2001-2008, naar stroomgebied.* LEI, Den Haag, p. 27. 2010.

Verhagen, A., M. Blom-Zandstra, P.J. Kuikman, E. den Belder, W. Brandenburg, J. Elderson, C.M.L. Hermans, B. Schaap, J.J.H. van den Akker, P. Vellinga and C. Waalwijk, *Naar een klimaatbestendiger landbouw in Nederland. Quickscan en agendering van onderzoek*. Plant Research International, Alterra, ASG veehouderij, Wageningen, 2009.

Vos, J. A. de and I. E. Hoving, *Verkenning van bedrijfsvarianten en milieukundige gevolgen bij piekwaterberging op landbouwgrond in Salland.* Alterra, Wageningen, 2005.

Vos, J. A. de and I. E. Hoving, 2005. *Verkenning van bedrijfsvarianten en milieukundige gevolgen bij piekwaterberging op landbouwgrond in Salland*. Alterra, Wageningen, 2005.

Vosman, B.B., E. den Belder, J. Bloem, C.J.H. Booij, G.A.J.M. Jagers op Akkerhuis,J. Lahr, J. Postma, J. Verloop and J.H. Faber, *Agrobiodiversiteit, kansen voor een duurzame landbouw*. Plant Research International, Wageningen, 2007.

Vijn, B., *Bestemmingsplan Lelystad - Larserknoop*. Gemeente Lelystad, 2010.

Waterschap Brabantse Delta, *Beleidsnota waterberging en schade*. Waterschap Brabantse Delta, 2007.

Westeinde, J. van't and C. Pool, *Toekomstplan Schokland*. Christelijke Agrarische Hogeschool, Dronten, 2006.

Westerink, J., M. Buizer and J.S. Ramos, *European lessons for Green and Blue Services in the Netherlands*. Working paper Peri-urban Land use RELationships project (PLUREL), 2008.

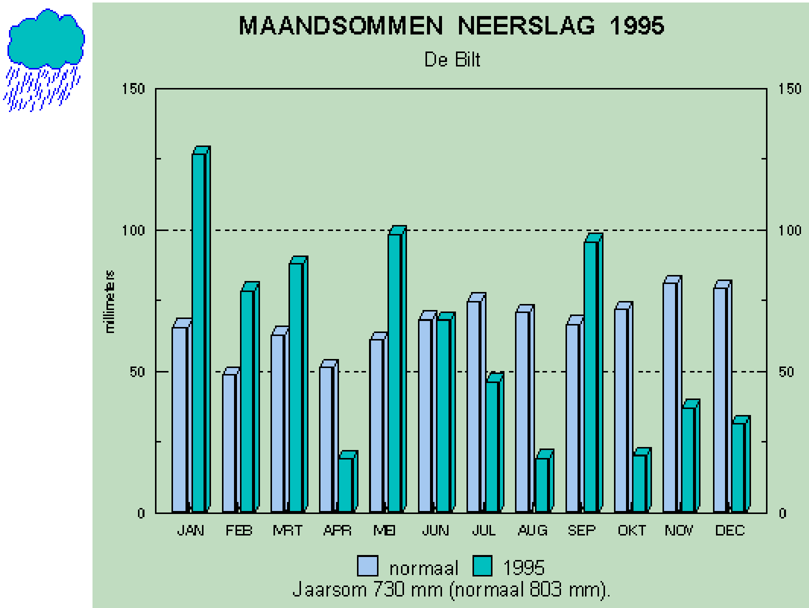
Wingerden, W. van, C. Booij, L. Moraal, J. Elderson, F. Bianchi, E. den Belder and H. Meeuwsen, *Groen en Groente. Kansen en risico's van groen-blauwe dooradering voor de vollegrondsgroenteteelt*. Alterra, Wageningen, 2004.

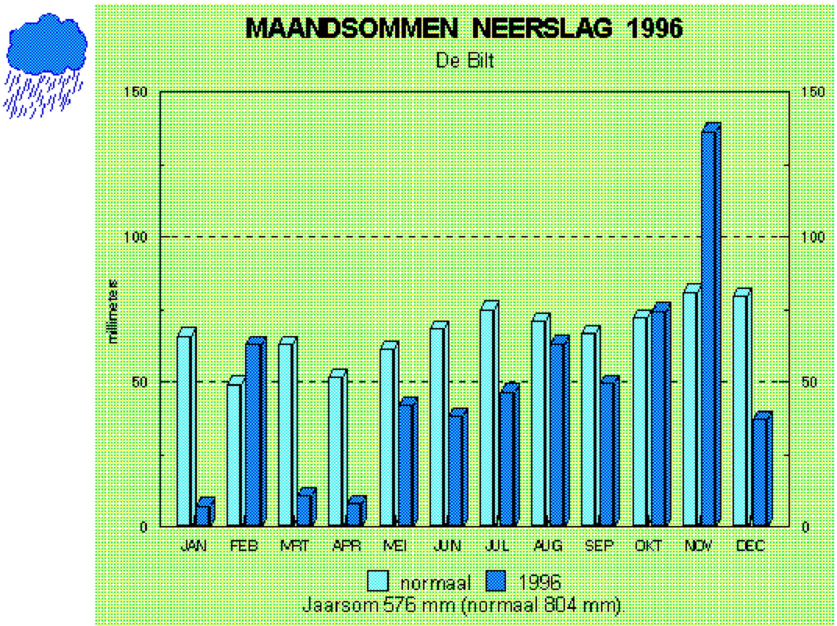
Wolf, J., M. Mandryk, A. Kanellopoulos, P. van Oort, B. Schaap, P. Reidsma and M. v. Ittersum, *Methodologies for analyzing future farming systems and climate change impacts in Flevoland as applied within the AgriAdapt project*. AgriAdapt project report no. 1, Wageningen UR, 2010.

Appendix

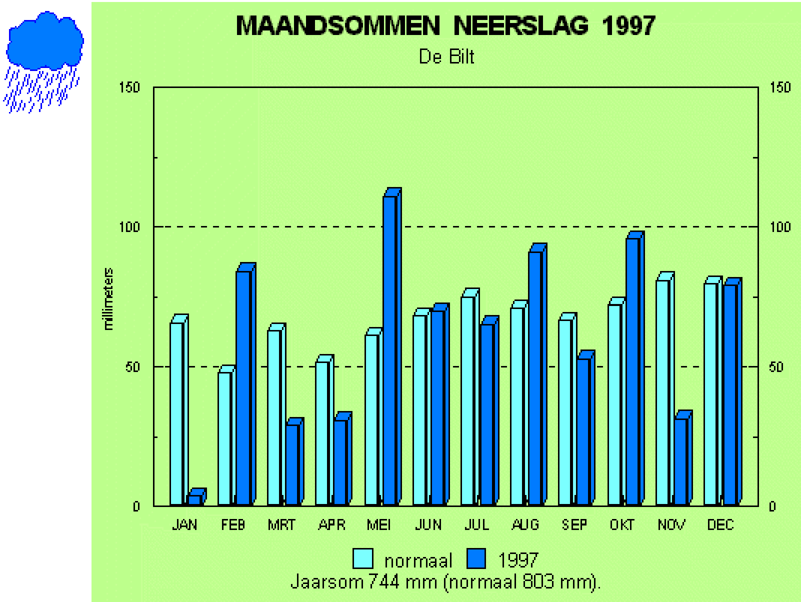
Monthly climate data

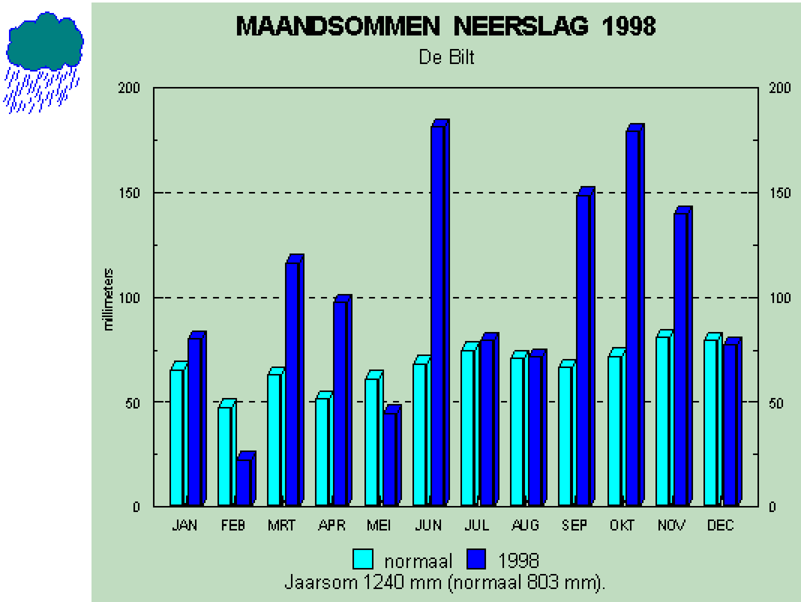
All figures below are taken from the Royal Netherlands Meteorological Institute (KNMI, 2011).



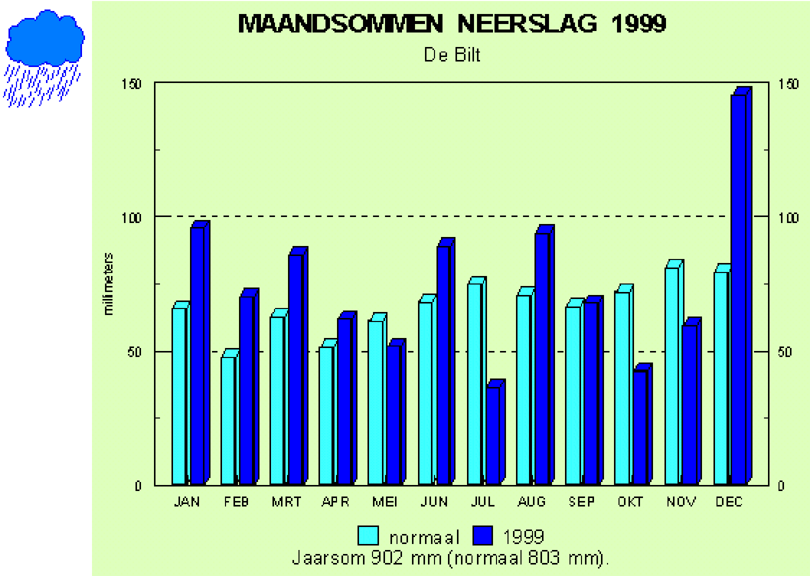


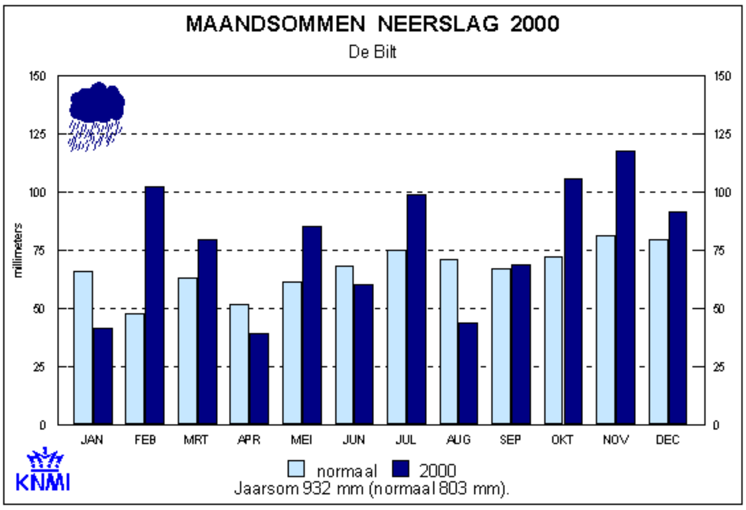
Maandsommen neerlsag = Montly precipitation
Normaal = Montly normal
Jaarsom = Annual factual
(normaal) = (Annual normal)





Maandsommen neerlsag = Montly precipitation
Normaal = Montly normal
Jaarsom = Annual factual
(normaal) = (Annual normal)





Maandsommen neerlsag = Montly precipitation

Normaal = Montly normal

Jaarsom = Annual factual

(normaal) = (Annual normal)

Table A.1	Monthly precipitation in the Netherlands in 2001-2010, mm									
	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
January	70	78	77	123	53	15	104	96	54	41
February	90	139	29	79	73	59	58	39	55	77
March	74	33	24	42	50	104	85	92	48	55
April	87	49	46	33	63	40	0	34	20	31
May	29	35	92	31	54	90	138	33	65	66
June	54	85	35	69	52	18	90	40	54	18
July	87	97	30	122	159	15	161	127	107	77
August	116	112	9	127	96	181	42	114	47	155
September	211	32	52	62	63	9	97	100	34	90
October	41	91	84	48	56	109	32	92	90	88
November	85	83	40	76	98	93	58	91	120	83
December	94	89	96	46	56	75	77	24	84	42
Annual factual	1038	923	614	858	873	808	942	882	778	823
Annual normal	793	793	793	793	793	793	793	793	793	793

Source: KNMI (2011).

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