Nitrogen deposition and ammonia concentrations in the Dwingelderveld as affected by surrounding dairy farms

Evaluation of the OPS-model

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Preface

This research focuses on nitrogen deposition and ammonia concentrations in the Dwingelderveld, an area where the existence of five dairy farmers was threatened. Data was obtained by actual measurement of field conditions and modeled by the OPS-model. This report is prepared as partial fulfillment of the Master's degree in Organic Agriculture and was performed at Organic Farming Systems (OFS) group of Wageningen University (WUR), the Netherlands.

With immense pleasure I would express my sincere appreciation and profound gratitude to Dr. Ir. E.A. Lantinga, Farming Systems Ecology group, Wageningen University, for his thoughtful and rational advice, careful supervision, professional judgment, constant guidance and encouragements throughout the study period. I admire his deep insight in the research problem, free exchange of ideas, practical approach, thoughtful instructions and sharing of responsibility which enriched my experience and made this study worthwhile.

This study would not have been completed without the help of Staatsbosbeheer "Drents-Friese Wold" and the five farmers located near the Dwingelderveld where I was able to do my field research. Without their hospitality and cooperation regarding the needed information this study would not have been possible.

My profound gratitude and heartfelt respect to my parents, sister and friends for their support, inspiration and affection to proceed with my academic career.

Janklaas Santing
Ravenswoud

Summary | EN |

In this thesis the impact of dairy farms located near the Natura 2000 site, the Dwingelderveld, was measured in terms of nitrogen deposition and ammonia dispersion. A published report by Alterra Wageningen recommended that these farms that share the border with the Dwingelderveld terminate their business on the basis of excessive nitrogen emission. The main objective of this thesis was to gain insight into the actual NH_3 concentration, the actual N deposition and farm characteristics in and around the Dwingelderveld in order to be able to evaluate the OPS-model used in the Alterra study. For this research five farmers who are located on the North side of the Dwingelderveld participated. Four of these dairy farmers had around one hundred cows per farm on average and the other dairy farmer had around five hundred cows. The formulated objective was obtained by measuring the ammonia concentrations with passive samplers at fifteen locations in and around the North side of the Dwingelderveld for a period of one year (Feb. 2011 – Feb. 2012). In addition, for a period of 85 days in the spring of 2011 the wet and dry nitrogen deposition was measured with the bioindicator spring barley *(Hordeum vulgare L)* grown in pots (triplicate) at 26 locations in the Dwingelderveld. A control group with 22 pots was located at the meteorological field "Veenkampen" in Wageningen.

The main results that were found showed that around the four farms on the North side of the Dwingelderveld with on average about 90 Livstock Units (LU), only at a distance of up to 50 meters from the farms, detectable nitrogen deposition was measured. The other dairy farm with more than 600 LU which are kept inside throughout the whole year, had detectable nitrogen deposition up to a distance of 400 meters on the South side of the farm. The prevailing wind direction was North-Northwest during the exposure period of spring barley. The crop compensation point is the critical concentration of ammonia, below which there is no uptake of ammonia through the stomata of the plants. In the Dwingelderveld it was found that crop compensation point for the low input spring barley plants was at a concentration around 14.5 microgram per m^3. 75 Per cent of the measured ammonia concentrations were below this critical concentration. Such high ammonia concentrations are rarely found in Natura 2000 sites. The OPS-model is not applicable for the simulation of nitrogen deposition on the local scale due to the overestimation of the dry deposition velocity at a relatively low atmospheric ammonia concentration as it does not implement the crop compensation point correctly. Also other models that assume a critical deposition load for vulnerable vegetation have never monitored the vulnerable species with actual measurements, using bioindicators.

For the continuation of this research it would be recommendable to investigate the role of mosses, which, in contrast to spring barley, is not a vascular plant, and although it does not negatively affect the mosses directly, they react strongly to lower ammonia concentrations. Hopefully this research can lead to a situation where farmers and nature organizations can work together aiming for a higher biodiversity and cohesion of the landscape.

Samenvatting | NL |

In dit onderzoek is de invloed gemeten van melkveebedrijven grenzend aan het Natura 2000 gebied Dwingelderveld op stikstof depositie en de verspreiding van ammoniak. Onderzoekers van Alterra Wageningen adviseerden dat verscheidene bedrijven nabij een natuurgebied in Drenthe gesaneerd moesten worden op basis van een te grote stikstof uitstoot. In dit onderzoek luidde de geformuleerde doelstelling dan ook het inzicht te verkrijgen in de huidige ammoniak concentraties, de stikstof depositie, de bedrijfskenmerken van en rondom deze bedrijven in het Dwingelderveld om hiermee het OPS-model te evalueren. Voor dit onderzoek hebben in totaal vijf melkveebedrijven mee gedaan die aan de noordkant van het Dwingelderveld gelegen zijn. Vier van deze melkveebedrijven hebben gemiddeld honderd koeien en één melkveebedrijf met vijfhonderd koeien. De gegevens werden verkregen door voor een periode van één jaar (Feb. 2011 – Feb. 2012) de ammoniak concentraties te meten met passive samplers in drievoud op 15 verschillende locaties in en rondom de noordkant van het Dwingelderveld. Daarnaast werd voor een periode van 85 dagen in het voorjaar van 2011 de natte en droge depositie gemeten met biomonitoren. Potten in drievoud en ingezaaid met *Hordeum vulgare L.* "zomergerst" werden geplaatst op 26 locaties in het Dwingelderveld en één locatie met 22 potten op het meteoveld Veenkampen in Wageningen als controlepunt.

De belangrijkste resultaten zijn dat rondom de 4 melkveebedrijven aan de noordkant van het Dwingelderveld met gemiddeld 90 GVE tot aan 50 meter meetbare stikstof depositie is gemeten. Bij het melkveebedrijf van meer dan 600 GVE die jaarrond opgestald worden, werd tot 400 meter van de zuid- zuidwestkant van het melkveebedrijf meetbare stikstof depositie gemeten. Rekening houdende met een voornamelijk noord- noordwesten wind tijdens deze meetperiode. Het gewas compensatiepunt, onder deze ammoniak concentratie vindt geen opname meer plaats door de planten, in het Dwingelderveld is gebleken dat de stikstofarme gerstplanten geen ammoniak meer opnamen beneden een omgevingconcentratie van 14.5 microgram ammoniak per m^3. 75 procent van de gemeten ammoniak waarden lagen onder deze kritische concentratie. Daarnaast wordt deze hoge concentratie nauwelijks gemeten in Natura 2000 gebieden. Het OPS-model is ongeschikt gebleken voor het simuleren van stikstof depositie op lokaal niveau door het ontbreken van een gewas compensatiepunt en door overschatting van de droge depositie snelheid bij een lage ammoniak concentratie. Ook andere modellen die werken met een veronderstelde kritische depositie waarden voor kwetsbare vegetaties hebben dit nooit gemonitord met daadwerkelijke metingen als biomonitoren.

Bij eventuele voortzetting van dit onderzoek zal men dus goed moeten kijken naar bijvoorbeeld veenmossen wat in tegenstelling tot zomergerst geen vaatplant is en wel sterk kan reageren bij lagere ammoniak concentraties. Alhoewel dit niet gelijk leidt tot negatieve effecten bij de mossen. Hopelijk heeft dit onderzoek geleid tot een eerste stap in een overeenkomst waarbij zowel veehouderijbedrijven als natuurorganisaties beter met elkaar kunnen samenwerken met als doel een vergroting van de biodiversiteit en samenhang van het landschap.

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1 GENERAL INTRODUCTION – HOW IT ALL STARTED

In June 2010, an article was published by Alterra Wageningen which highlighted the situation that dairy farms were being forced to stop their business in the Dwingelderveld (De Beste Boer, 2010). These farms were not able to comply with the requirements of Natura 2000 to keep the nitrogen deposition within limits. According to the article these specific farms were identified as high emitters of nitrogen. High emitters are defined as farm businesses which have an ammonia deposition of above 50 per cent of the critical deposition value on the edge of a Natura 2000 site. Researchers at Alterra Wageningen recommended either termination of these farm businesses or a reduction of the critical deposition value to 40 per cent as solutions to the problem.

The report of Alterra Wageningen (Hessel *et al.*, 2010) distinguished between eleven Natura 2000 sites in the province of Drenthe coinciding with the actual nitrogen (N) deposition on the eleven types of habitats present in this area. The total N-deposition is 1.895 mol ha^{-1} yr^{-1} in Dwingelderveld with two types of habitats. The active raised bogs and restored active bogs have a critical deposition value of 400 mol ha^{-1} yr^{-1}. The most important inputs of deposition in Dwingelderveld originated for 50 per cent of background deposition and for 29 per cent of nitrogen oxides (NO_x) deposition. The sources of NO_x emissions originated from traffic and industries in the Netherlands and the neighboring countries. Only 20 per cent of the total deposition was caused by farms located within the 5 km zones of the Drentse Natura 2000 site. The remaining 80 per cent of the deposition was caused by sources outside the 5 km zone in Dwingelderveld.

Based on a scenario done by PBL, the prognosis of the total deposition is 1.872 mol ha^{-1} yr^{-1} in 2020, meaning a reduction of only 1 per cent compared to 2007. Reduction of the deposition in the Dwingelderveld to 2020 is dependent on autonomous development, introduction of measures limiting emission and general policies. Autonomous development will reduce the emission by 95 mol ha^{-1} yr^{-1}, air washers by 12 mol ha^{-1} yr^{-1}, management changes by 55 mol ha^{-1} yr^{-1} and low emission floors by 36 mol ha^{-1} yr^{-1}. The termination of the high emitters, which are at a greater distance, will reduce in a reduction of only 9 mol ha^{-1} yr^{-1} (Hessel et al., 2010).

In total there are twenty-two farms contributing more than 50 mol ha^{-1} yr^{-1}, and five of these farms contributed more than 400 mol ha^{-1} yr^{-1} each. Termination of these five farms will result in a greater reduction of the deposition than all other possible measures together, and was mentioned as an the most appropriate solution. For the farms it is feasible to strive for the objective of 1.550 mol ha^{-1} yr^{-1} deposition in 2028, however the critical deposition value of 400 mol ha^{-1} yr^{-1} is beyond their reach. In the future, continuation of stringent reduction policy is necessary to realize further decreases. Farm management measures should include the whole farm, for example cow diets containing less easily degradable protein to prevent the risk of nitrogen losses.

For Alterra Wageningen it is necessary to consider the impact on the existence of individual farms before publishing such conclusions. Neither Alterra Wageningen, nor other institutions connected with this study involved the farmers actively in their research. Without any cooperation of farmers, the individual farms were branded as high emitters by Alterra Wageningen.

1.1 LOCATION

For this thesis research was conducted on the North side of the Natura 2000 site "Dwingelderveld". Dwingelderveld covers 3.823 hectares and belonging to the Natura 2000 landscape 'Hogere zandgronden'; high sandy soils, an ancient historical Drentse 'esdorpen landschap' (A village build on high sand ridge) with extensive heath land (Sonneveld *et al.*, 2009). This wet heath land is the largest in Western-Europe. This landscape includes many different types of habitats with active and recovering fens. In Figure 1, the locations of the farms that are participating in this research are indicated with red circles. The farms; I, II, III, IV and V are located on the border of the natural reserve at the North side of the Dwingelderveld. The border of the natural reserve "Dwingelderveld" is shown with orange dots in Figure 1. Around 2011 and 2012 this area was subjected to a redesign. In the blue part the water retention was recovered. In the future, other things will be reconstructed; roads, the development of a noise barrier along the highway and two existing areas within the Dwingelderveld.

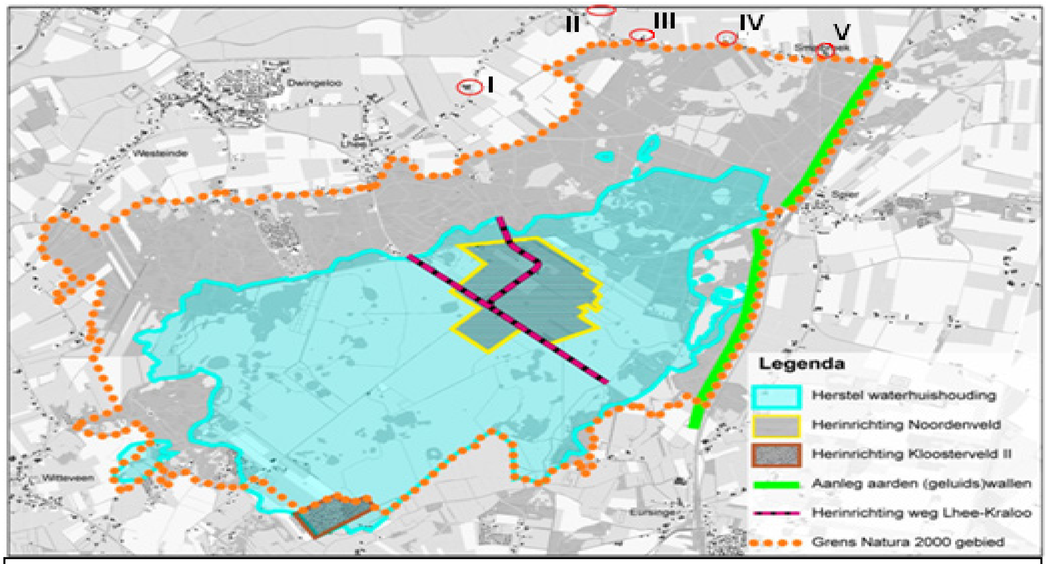

FIGURE 1 LOCATIONS OF THE SELECTED FARMS ON THE BORDER OF THE NATURA 2000 SITE "DWINGELDERVELD"

In consultation with regional managers from "Staatsbosbeheer" a suitable site had to be located to conduct both researches. An open terrain was a prerequisite to avoid the influence of N deposition by high vegetation and to guarantee representative measurements of the surrounded area. In addition, this location had to be close to a site with vegetation of a low critical deposition load. Due to their suggestions to avoid further damage of the ecosystem a location was appointed on the North side of the Dwingelderveld.

The allocation measurement sites at the farm sites were dependent on the following factors; the farmers should not be hampered during their fieldwork (e.g. driving with tractor, mowing, grazing of animals), preferably the site should be located between the farm and the Dwingelderveld, and excluding the presence of high vegetation in order to collect a representative sample of the surrounding area.

1.2 PARTICIPATING FARMS

The identified farmers with high emission (Hessel *et al*., 2010), especially the farms presented in the article of De Beste Boer in 2010 were approached. Eventually, five farmers were willing to participate in this research. Four of them are located on the North side of the Dwingelderveld. One of the farms, Mts. Duiven (I) is located on the North-West side of the Dwingelderveld. Farm IV and farm V were grazing there herd. The characteristics of the participating farms are presented in Table 1.

TABLE 1 OVERVIEW CHARACTERISTICS OF PARTICIPATING FARMS

	I	II	III	IV	V
Data / Name	**Mts. Duiven**	**B. van Unen**	**P. Daatselaar**	**M. ter Wal**	**A. Oostra**
Nr. Dairy cows	500	100	75	85	110
Milk production kg^{-1} cow^{-1} yr^{-1}	9000	9000	8800	7000	9000
Replacement rate (%)	30	25	30	25	25
Milk % fat	4,12	4,55	4,6	4,6	4,6
Milk % protein	3,56	3,58	3,45	3,6	3,71
Milk urea content (mg 100 g^{-1})	24	20	< 20	23	22
Total area (ha)*	253*	52*	45*	55*	52*
Grassland	177	37	33	42	46
Grazing (1) Non grazing (2)	2	2	2	1	1
* Derogation = 250 kg N ha^{-1}					

What can be observed from these farms is that they apply derogation on their farms of 250 kg N ha^{-1}. Which implies that 70 per cent of their surface area is grassland, the other remaining area is mainly maize. There is a high fluctuation in the management of nitrogen per farm. Urea, which is present in the milk is a very good indicator of how much nitrogen is fed to the cows. Most of these farmers add a surplus of protein to the diet of the cows, or do not feed enough energy to obtain a high efficiency of nitrogen. These losses do not promote the maintenance of N-deposition and ammonia concentrations at a lower level.

1.3 ORGANIZATION OF THE REPORT

This report is divided into two different studies. Research 1 is focused on the N deposition with biomonitors and research 2 addresses the ammonia emissions in the surrounding of dairy farms. Every research starts with an introduction, material and methods, results and will finish with a discussion and an overall conclusion according the main research question will be given.

1.4 OBJECTIVES

Derived from the introduction there is a lack of local field information causing uncertainties about local conditions. This is because most of the data was obtained by modeling. The question arose if agricultural data can be validated with modeled data without comparing and correcting them for the actual data and without the integration of local conditions; e.g. border of trees, 70 per cent grassland by derogation[1], farm characteristics like the urea content in milk.

The objective that can be concluded:

- Gain insight into actual NH_3 concentration, the actual N deposition and farm characteristics in and around the Dwingelderveld in order to be able to evaluate the OPS-model.

1.5 RESEARCH QUESTIONS

The main question:

Is the Dwingelderveld really as negatively affected by the N-deposition as calculated by the OPS model “Alterra”?

The sub questions are:

1. To what extent does the farm management influence the concentration of NH_3 and N deposition around every farm (within a few km)?
2. To what extent will the specific conditions like (70 per cent) grassland area, wind direction and location of trees around the Dwingelderveld influence the NH_3 concentration and N deposition on the vulnerable habitats?

1.6 HYPOTHESIS

- The specific conditions like; wind direction, 70 per cent of grassland area per farm and trees decrease the NH_3 deposition at these vulnerable habitat.
- The standard version of the OPS-model, with the standardized inputs, overestimate the NH_3 deposition at this location.

[1] Derogation: Exception for farmers with at least 70 per cent grassland are allowed to put 250 kg N ha^{-1} instead of 170 kg N ha^{-1} under specific conditions

2 Research 1 Introduction Biomonitors

The total deposition is the sum of dry and wet deposition[2] and contributions from sources within the Netherlands and from abroad. In 2010, Dutch agriculture contributed about 40 per cent of the total average of nitrogen (N) deposition in the Netherlands as depicted in Figure 2 (Velders *et al*., 2010). Nearly 60 per cent of the deposition comes from Dutch sources (RIVM, 2011a). Unfortunately this has never been checked and is not true. As stated in this report; 20 per cent is deposited around the emission point only and 80 per cent is exported.

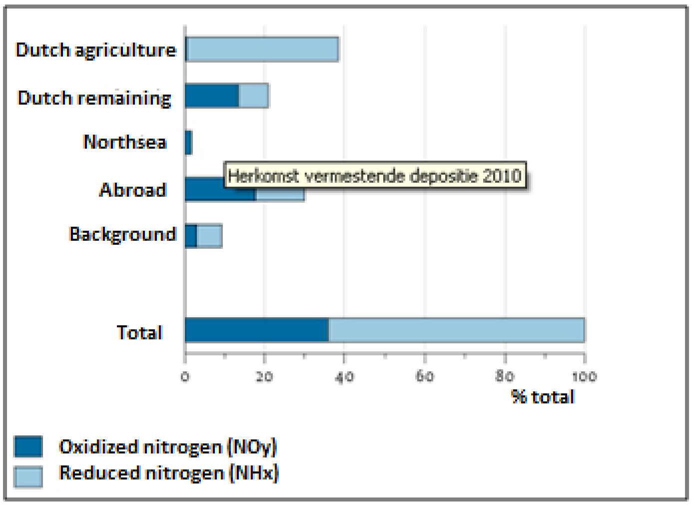

FIGURE 2 ORIGIN NITROGEN DEPOSITION 2010
(Source: RIVM, 2011a)

Nitrogen deposition can be harmful for the natural or semi natural ecosystems. Most of these natural ecosystems are called "Natura 2000 sites" in the Netherlands and they suffer from the abundant presence of nitrogen deposition. In total there are 162 Natura 2000 sites in the Netherlands (Trojan, C., 2008). Nitrogen deposition consists of ammonia (NH_x) and nitrogen oxides (NO_y). From the ambient air it is deposited in the form of acid on the ground, on vegetation and dissolved in water. This can result in acidification, eutrophication and over fertilization, which can lead to a reduction or deterioration of condition of vulnerable species. Natural or semi-natural ecosystems designated as being worthy of protection are classified according to their critical deposition load. The critical deposition loads of nitrogen indicate the boundary of the risk that the quality of the habitat affected by the influence of acidification and fertilization of atmospheric nitrogen deposition can be excluded.

[2] Deposition: deposition of substances on the surfaces from the atmosphere and can be applied as wet (rain, snow, hail, fog) for around 10 per cent – and dry for around 90 per cent of the time.

After the Second World War the average nitrogen deposition was around 500 mol ha^{-1} yr^{-1} in the Netherlands (Trojan, C., 2008). Thereafter it increased dramatically up to 2.500 – 3.000 mol ha^{-1} yr^{-1} in the early nineties. Since 1994, a gradual decline to the current level as showed in Figure 3 (RIVM, 2011b). The nitrogen deposition shows local differences, especially in areas with intensive livestock, depositions are higher than when compared to areas with extensive livestock. Only part of the nitrogen load can be attributed to emissions in the immediate vicinity of nitrogen sources. The other part is the so-called background deposition. Additionally, the potential average acidifying deposition was about 2.480 mol acid ha^{-1} in 2010, having reduced by half since 1981. Especially, oxidized sulfur (SO_2) which is present during the wet deposition of ammonia was reduced with more than 75 per cent during the same period (RIVM, 2011c).

The Natura 2000 site of interest in this study is the Dwingelderveld with a total nitrogen deposition of 1.895 mol ha^{-1} yr^{-1} (= 26,53 kg N ha^{-1} yr^{-1}) and a critical deposition load of 400 mol ha^{-1} yr^{-1} (= 5,6 kg N ha^{-1} yr^{-1}) (Hessel *et al.,* 2010). The average deposition for this site is almost five times the critical deposition. In another report of Velders *et al.,* (2010) the contribution of the N deposition to the Dwingelderveld was 1.530 mol ha^{-1} yr^{-1} (= 21,42 kg N ha^{-1} yr^{-1}) after closing the ammonia gap[3] by 20 per cent. For 2015 it was calculated at 1.430 mol ha^{-1} yr^{-1} (= 20 kg N ha^{-1} yr^{-1})

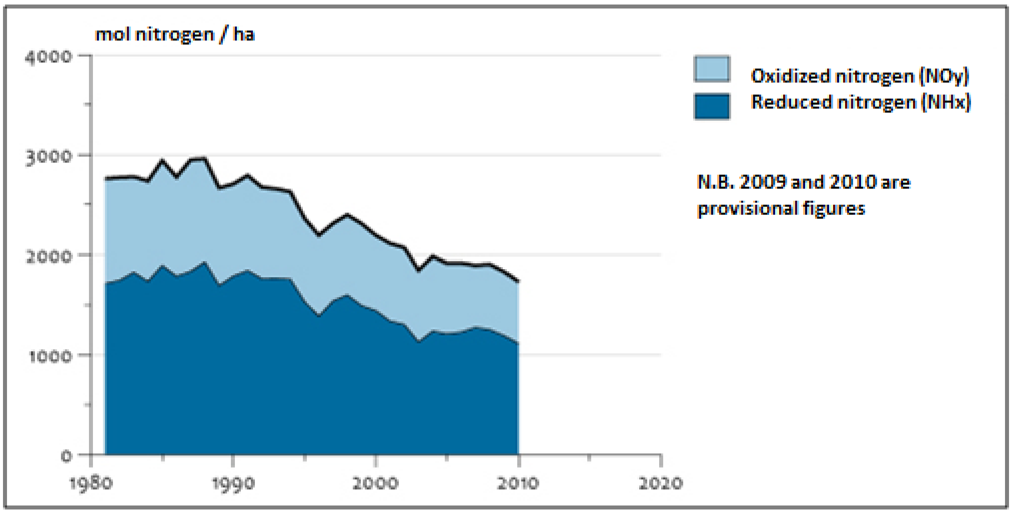

FIGURE 3 NATIONAL AVERAGE NITROGEN DEPOSITION 1981 - 2010
(Source: RIVM, 2011b)

In ecosystems vulnerable to N in the Netherlands a 5 km zone is introduced where livestock producers are not permitted to increase their NH_3 emissions when changing their production systems. This means that 46 per cent of all the agricultural businesses are within 5 kilometers and 29 per cent within 3 kilometers from the N-vulnerable ecosystems in the Netherlands.

[3] Ammonia gap: the difference between the measured and modeled ammonia concentrations; about 30 per cent.

The majority of dairy farms are situated within 3 kilometers (32 to 38 per cent) and up to 50 to 60 per cent within 5 kilometers (Trojan, C., 2008). These farmers who wish to change or increase their livestock production have to comply with strict rules and emission thresholds. The risk of high local deposition from livestock operations is regulated by national legislation.

The WAV[4] is a law that covers the additional, area orientated ammonia emission spore. To ensure together with the generic policy "Degree ammonia emission housing livestock" in the Netherlands) a reduction in ammonia (NH_3) by or from livestock farms (Provinciale Staten Drenthe, 2011). The law "WAV" specifies that the Province is responsible for the identification of vulnerable areas. The law itself sets limits for livestock businesses within a 250 meter zone of the vulnerable area. Within the 250 meter zone, the province Drenthe makes a distinction between farms with less than 50 Nge[5] and more than 50 Nge. The livestock farms with less than 50 Nge are too small to be hampered by the WAV. In the province Drenthe, there are 54 livestock farms that exceed 50 Nge. Modification of the WAV in 2007 gave these specific dairy farmers the opportunity to extend their farms to correspond with an emission of 2.446 kg ammonia per year. This translates to a herd of 200 dairy cows and 144 young stock – 240 Nge.

Local governments, like municipalities and provinces make use of the Aagro-Stacks model to compose an ammonia scan. Recently, an article was published (V-Focus, 2011). This journal is mainly focused on research and development in livestock and policy in the Netherlands and abroad and showed that the Aagro-Stacks model is not trustworthy. Aagro-Stacks has an error rate of 70% (V-Focus, 2011). This model determines the authorization of the Nature Protection Act 1998. Recently, a preliminary calculation model, AERIUS, was developed to support the license process as part of Natura 2000 as part of the PAS (Programmatic Approach to Nitrogen) This presents a nitrogen analysis per Natura 2000 site, to determine remedial actions and to substantiate development space (EL&I, 2011). With AERIUS, elaboration of different scenarios is possible as well as calculating the effect of measures. The general aim of PAS is to decline the nitrogen deposition on Natura 2000 sites.

Certainly there is a need for precise and accurate models to assess how much livestock production will affect N (dry and wet) deposition in nearby natural ecosystems, but the determination of nitrogen deposition is very costly and labor intensive. An alternative could be standardized grass plants or biomonitors to evaluate the impact of nitrogen on a range of habitats, bringing the advantage of on scale of nitrogen measurements at a specific site within a relatively short time period.

[4] WAV: Law ammonia and livestock "area oriented" www.provincie.drenthe.nl
[5] Nge: Dutch livestock units (Nederlandse Grootvee eenheden)

Already in 1988, S.G. Sommer exposed barley (*Hordeum vulgare var. Harry*) plants as a bioindicator of NH_3 deposition along a 0 – 300 meter transect from a dairy farm for 1 month. The tissue N content increased closer to the farm reflecting the increased nitrogen deposition of ammonia (Sommer, 1988). Leith *et al*. (2009) evaluated the effect of the NH_3 concentration / nitrogen deposition on plant root systems. Sommer and Jenson (1991) found that much of the additional nitrogen deposition went to the roots in standardized Rye grass (Leith *et al*., 2009). In this short term pilot *Lolium multiflorum* was selected as a suitable biomonitor. The tissue N content (% dry weight) showed a strong linear correlation in both below and above ground tissue with log NH_3 concentrations. Although N in above ground tissue appeared to be more sensitive to enhanced NH_3 concentrations (Leith *et al*., 2009). But these fast growing plants were not suitable for long term studies nor to be biomonitors of wet nitrogen deposition in upland areas. With *Deschampsia flexuosa (L.) Trin*., a slow growing plant, Leith *et al*. (2009) tested the suitability of this grass specie as a standardized grass bioindicator for a range of habitats and atmospheric nitrogen pollutants inputs. To detect potential nitrogen impact a longer exposure period was required (6-12 months) for bioindicators such as *D. flexuosa*. Without defined point sources, most of the standardized grasses for biodindicators are less effective.

3 Materials and methods

To explore the objectives, the methodology according to Sommer (1988) was used, to calculate the deposition of nitrogen by exposing barley in pots (biomonitors).

3.1 Location

All the farms and the Natura 2000 site "Dwingelderveld" were involved in this part of the research. The location of Mts. Duiven (I) was especially suitable for this situation. This farm is completely surrounded by grassland. Pots were easily placed at different distances and in different wind directions from the farm. At each farm at least one set of pots was placed near the farm building to obtain differences in farming systems. Most of the biomonitors installed, corresponded to the study with the absorbers at the other four farms to find a relation between the ammonia concentration and N deposition. The concentrations were measured at a height of 1,5 meter in triplicate and examined twice a month in regular intervals. To assess the impact of the tree borders, biomonitors were also located on three locations behind the tree border near the vulnerable habit and on one location in the Natura 2000 site. Figure 4 gives an overview of absorbers.

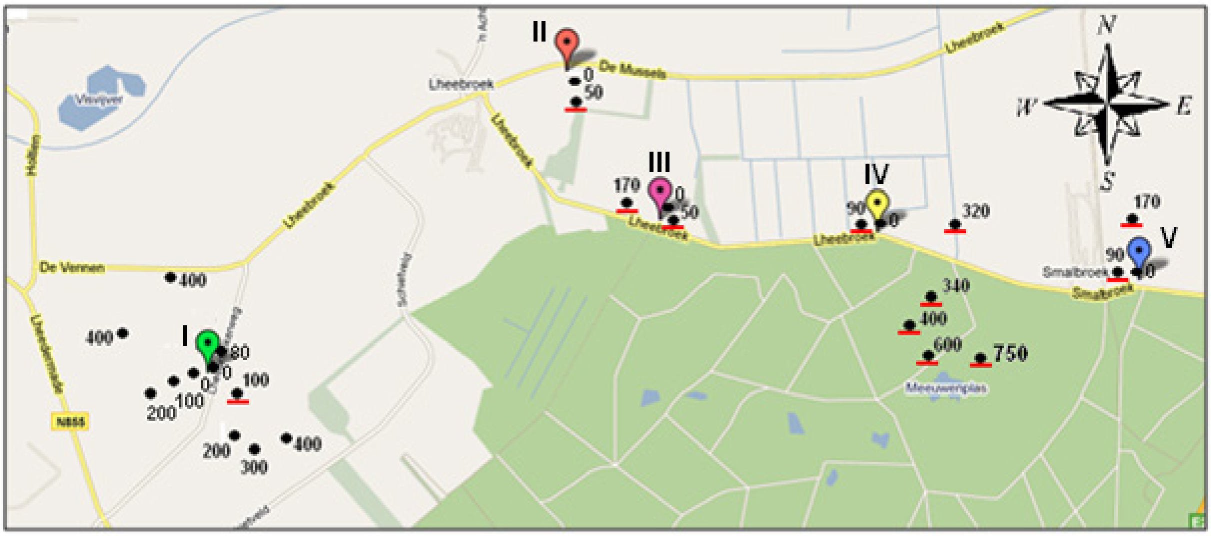

FIGURE 4 ALLOCATION OF BIOMONITORS AND ABSORBERS

The farms (source of emission) are indicated with the balloons and Roman letters. The black dots show the position of the biomonitors in triplicate, including the distance to the source. Black dots underlined in red show the location of biomonitors plus absorbers which were placed in triplicate.

3.2 DETERMINATION OF N DEPOSITION

3.2.1 *THE MATERIALS*

To execute this study 100 pots (570 cm^2 = Ø 26,94 cm) were filled with nitrogen free rockwool to measure N increase in both plants as well as in the rockwool. The rockwool and nutrient solution used for this experiment was provided by Unifarm[6]. The label, Agra Vermiculture from company Pull in Rhenen provided high quality substrates. This particular rockwool, also called granules is particular used for hydroponic plant cultures. Nutrients were supplied in a solution for watering the plants as described in Table 2. A Maximum of 800 mg N were applied to the pots, after that N had to be excluded from the nutrient solution.

TABLE 2 COMPOSITION OF NUTRIENT SOLUTION

Element	mg/l	Element	mg/l
K	78.2	Fe	2
Ca	60.12	Mn	1.5
Mg	12.15	B	0.2
S	16	Cu	0.2
P	31	Zn	0.2
N	110	Mo	0.02

Source: Sommer, S.G., 1988

The experiment started on Wednesday 6th of April. Therefore, 100 pots with a volume of 10 liters, 1200 l rockwool, 2500 *Hordeum vulgare L.* seeds, foil to cover the pots and nutrient solution (first order was 400 l N-free and 100 l of 800 mg l N) were required. The N-solution was provided twice with 0,5 l (400 mg l N) each time with 13 days in between. In appendix I (A, B, C) a description of the seeds used, irrigation scheme and notes during the application can be found. At the beginning of the experiment each pot contained 12 l rockwool and 3,5 l of N-free nutrient solution. Twenty-five *Hordeum vulgare L.* seeds were sown per pot at the depth of 2 cm. The N content of the seeds was measured.

3.2.2 *THE FIELD EXPERIMENT*

3.2.2.1 Preparation of the plant pots

The seeds were germinated at the Unifarm farm, indoors in an open greenhouse where only the roof was covered with plastic to prevent the pots from wet deposition. After the preparation pots were put in this specific greenhouse and covered with foil to protect them from dehydration. 7 days after preparation the foil was removed when plants were in their first growing stadium. During the exposure time in the greenhouse at Unifarm farm the uptake of N by dry deposition was negligible due to the

[6] Unifarm: part of Wageningen UR; facilitator and supervison of cultivated plants and crop research

small growing stage. At growing stage 3 – 4 on the Feekes scale (Miller T.D., 1992) pots were exposed to field conditions. These stages are between tillers formed (stage 3) and beginning of erect growth (stage 4).

3.2.2.2 Placing the pots in the field

The exposure time was started for this experiment at the 20th of April until 30th of June. This was at growing stage 10.5.1. the beginning of flowering on the Feekes scale (Miller T.D., 1992). In total the plants were exposed for 85 days, 71 days in the Dwingelderveld. The pots were put in triplicate at the locations as presented in Figure 4. This makes a total of 26 sites, including 12 sites in combination with absorbers. The control group consisting of 22 pots was placed at meteorological field "Veenkampen" in Wageningen. The white pots had to be buried so that they were just above the soil surface. Around the pots the vegetation was kept below the top of the pot to avoid an effect of the uptake of N by surrounded vegetation. Pots were protected from wildlife with nets 1 meter height attached to bamboo sticks.

3.2.2.3 Harvest

At harvest the plants were cut to the level of the rockwool surface and the above ground biomass was put into paper bags. The plants were oven-dried at 70°C (48 hours) and the weight of the dry biomass was determined. Initially the rockwool included with the roots was also oven-dried at 70 °C but warm air was not able to dry the rockwool. In a second attempt the white pots were emptied and the content was cut into smaller units. These were placed on steel containers and dried again for 6 days at 105°C. The weight of the paper bags, steel containers, white pots, dry biomass of the plants and the dry biomass of the rockwool with roots were determined and noted.

3.2.3 THE ANALYSIS

3.2.3.1 Sample preparation

The increase in rockwool N content was estimated by measuring total N in the rockwool before the experiment and in the rockwool including roots after the experiment. The (1) dry plant material, (2) rockwool including the roots, (3) seeds and some unused rockwool (4) were ground in a mill to a size of 1 mm. From this a homogeneous sample was collected and put into small tube. These samples were analysed by Hennie Halm of the Organic Farming Systems Group at Wageningen University.

3.2.3.2 N analysis

The sampling procedure to analyze the total N is as described in Houba et al.,(1989). The N deposition is calculated using the following equation (Sommer, 1988):

$$\Delta N = (\mathrm{N_{harvested}} + \Delta \mathrm{N_{rockwool}}) - (N_{fertilizer} + N_{seed})$$

ΔN is gain of N to the pot system (= deposition), $N_{harvested}$ is the total N in the plants, $\Delta N_{rockwool}$ is the gain in N content in the rockwool, $N_{fertilizer}$ is the N supplied in the nutrient solution, and N_{seed} is the N content in the seeds. Finally, the average N deposition can be calculated per location in relation to the ambient ammonia concentration.

3.3 IRRIGATION OF BIOMONITORS

To meet the water requirements of the biomonitors, a nutrient solution was applied. The production of 1 kg dry matter requires 250 l of water. A daily growing rate of 225 to 250 kg dry matter per ha^{-1} day^{-1} was assumed. The majority of the water uptake was required for evaporation. Every week the spring barley had to be irrigated with at least 2 l of water, obtained from the nutrient solution and rainfall. Due to this high water requirement the nutrient solution was prepared in a barrel of 1000 l and transported to a location in the province Friesland. Water limitation of the spring barley had to be prevented, because drought limits the N uptake and indirectly slows down the growth rate. Dehydration also causes limited stomata opening, which reduces photosynthesis and hence the uptake of assimilates (Timmer, R.D., 1999).

3.4 METEOROLOGICAL DATA

The dispersion of ammonia strongly depends on local weather conditions, like; wind direction, rainfall and temperature for the re-emission of nitrogen. To obtain regional, hourly and daily data of meteorological parameters, the website of the KNMI[7] was used. From this website, all parameters were selected and copied into an Excel file. Individual weather stations were selected. As there was no weather installation at the experimental field, the two closest weather stations were chosen (KNMI, 2012); Hoogeveen (South of Dwingelderveld) and Eelde (North of Dwingelderveld). From these two weather stations the following parameters were selected and copied into an Excel file and re-calculated for the duration of the experiment; hourly wind direction (1), hourly rainfall (2) and hourly temperature (3). Because this experiment was conducted at two experimental sites (Dwingelderveld and Veenkampen, Wageningen), the data from Veenkampen (WAQ, 2011) was used. This data was obtained from the Meteorology and Air quality group at the WUR in Wageningen and the results were noted in the same Excel file.

[7] KNMI: Royal Netherlands Meteorological Institute www.knmi.nl

4 RESULTS BIOMONITOR

4.1 TOTAL N

The total amount of N that was obtained from the biomonitors is shown in appendix IV, which is the total sum of the above ground plant material and underground particles of rockwool and roots after analyzing for N. The above ground plant material in Dwingelderveld had a mean contribution of 0.40 gram N per pot with a st.dev of 0.10 versus a mean contribution of 0.41 gram N per pot with a st.dev of 0.07 in Wageningen. The underground material like rockwool and roots in Dwingelderveld had a mean contribution of 0.30 gram per pot with a st.dev of 0.04 versus a mean contribution of 0.26 gram per pot with a st.dev of 0.06 in Wageningen. The largest contribution of N was thus provided by the above ground plant material at both research sites. The total N outcomes per pot were averaged per location which resulted in an average nitrogen contribution per location, depicted in Figure 5a. In Figure 5b the same map is presented with only the highest outcomes per pot which resulted in the highest nitrogen contribution per location. These figure clearly shows a tendency in source obtained N and the decrease in N of biomonitor locations that were allocated further away from the source.

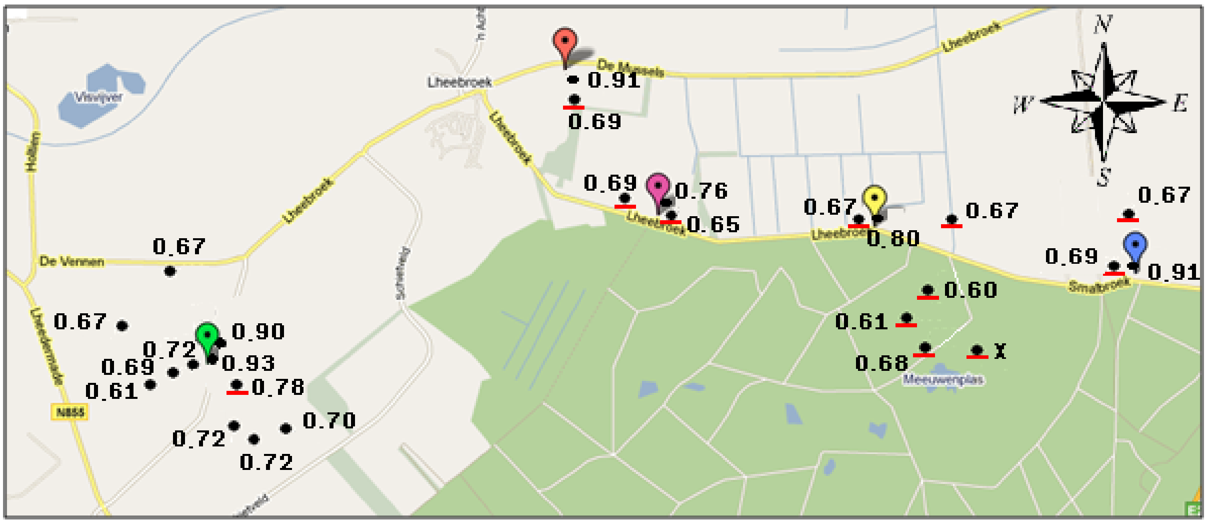

FIGURE 5A ABSOLUTE N PER LOCATION IN DWINGELDERVELD

The contribution of N is expressed in gram/ mean of 3 pots/ location. Location 12 (Dwingelderveld) is marked with an X, because no data was obtained here. Wet pots that had a negative effect on the total N per location were not included.

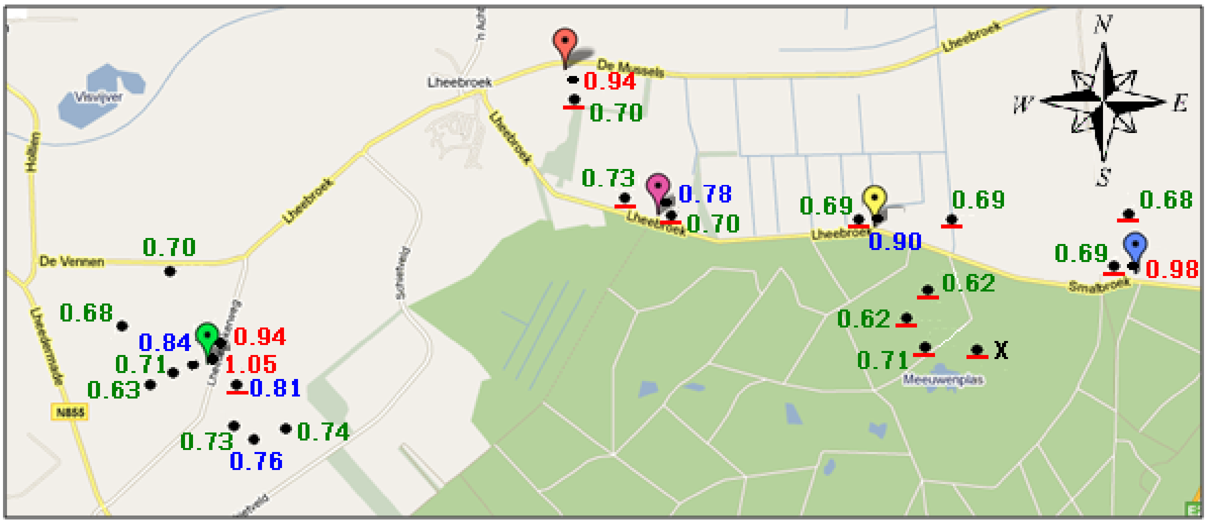

FIGURE 5B HIGHEST OBTAINED ABSOLUTE N PER LOCATION IN DWINGELDERVELD

The highest number of N is expressed in gram N / location and categorized in three subcategories: green < 0.75; blue 0.75 – 0.90; red > 0.90. Location 12 (Dwingelderveld) is marked with an X, because no data was obtained here.

4.2 Dry and wet N deposition

The result of the dry and wet N deposition cannot be obtained from this study. In appendix VI the total input of 0.854 gram of N from the rockwool (0.045 g^{-1} N), seeds (0.008 g^{-1} N) and nutrient solution (0.8 g^{-1} N) is shown. Which would indicate that after subtracting this amount from the total N there is only dry and wet N deposition on the farms of Mts. Duiven (I), Fam. Van Unen (II) and Fam. Oostra (V) and also only for a very short distance from the source. A higher generation of N in the top plant or roots of about 20 per cent would have lead to a better implementation of the results.

4.3 Ammonia dispersion

Measurements 5 till 9 of the ammonia concentrations from both research sites were used as part of the ammonia concentration study. The total average concentrations per location were calculated for the total period that the biomonitor was exposed at both research sites. Dwingelderveld had an average NH_3 concentration of 12 µg m^3 while the Veenkampen in Wageningen had an average NH_3 concentration of 13 µg m^3 during this period. The dispersion of NH_3 in Dwingelderveld is shown in Figure 6. The lowest NH_3 concentrations were obtained at the locations closest to the natural site Dwingelderveld. The highest NH_3 concentrations were found on the farm of Mts. Duiven (I) based on only one measuring point. That single NH_3 concentration point cannot be applied to the other locations of Mts. Duiven (I) where most of the biomonitors were located.

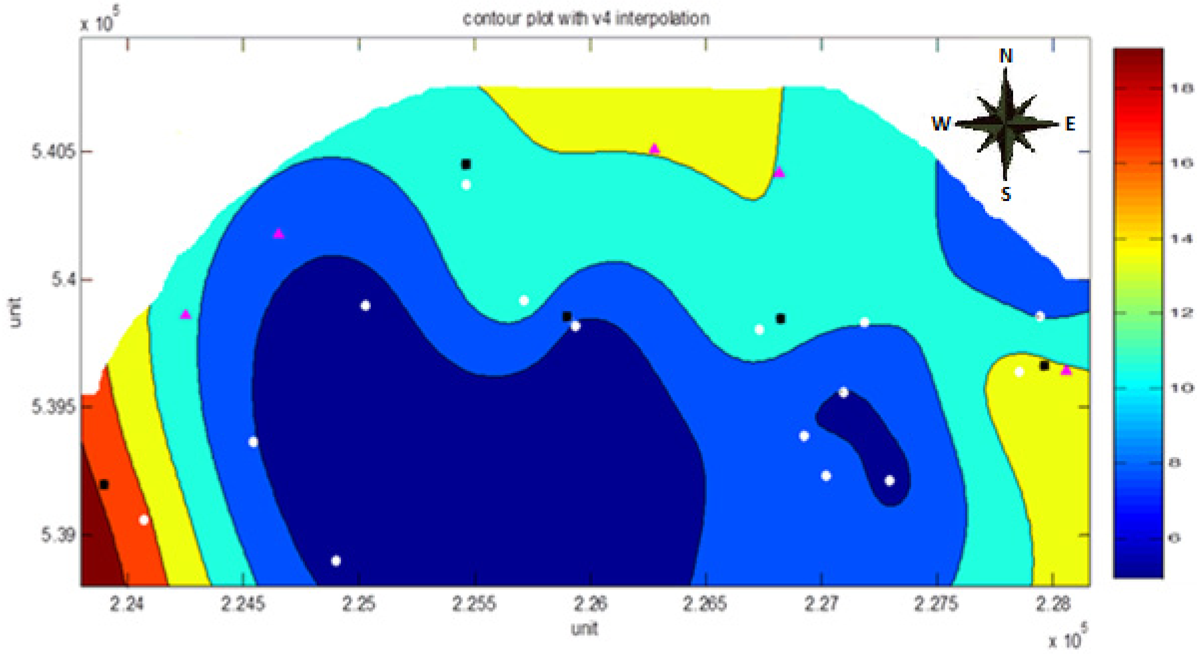

FIGURE 6 DISPERSION OF AMMONIA IN DWINGELDERVELD

Black squares indicate the location of the participating farms. The pinkish triangles show the farms located in the neighborhood which were not involved in this research. White spots indicate the receptors where the NH_3 concentrations were measured. The colors scale (legend) is expressed in NH_3 [µg m^3]. The units are based on the X and Y coordinates of every location. Obtained by MATLAB R2009a

4.4 DRY N DEPOSITION

From both researches a relation can be derived to predict the level of absolute N from a biomonitor under a certain level of NH_3 concentrations obtained from the experimental sites. In Figure 7 these two variables were plotted in a graph. Unfortunately the NH_3 concentrations were not measured at every location which would have led to a better prediction of absolute N per gram. Additionally the measurements at Daatselaar 50 meter, Ter Wal 340 & 400 meter had to be taken out of this function due to a low absolute N output and irregularities caused by frost damage during the growing season of these plants.

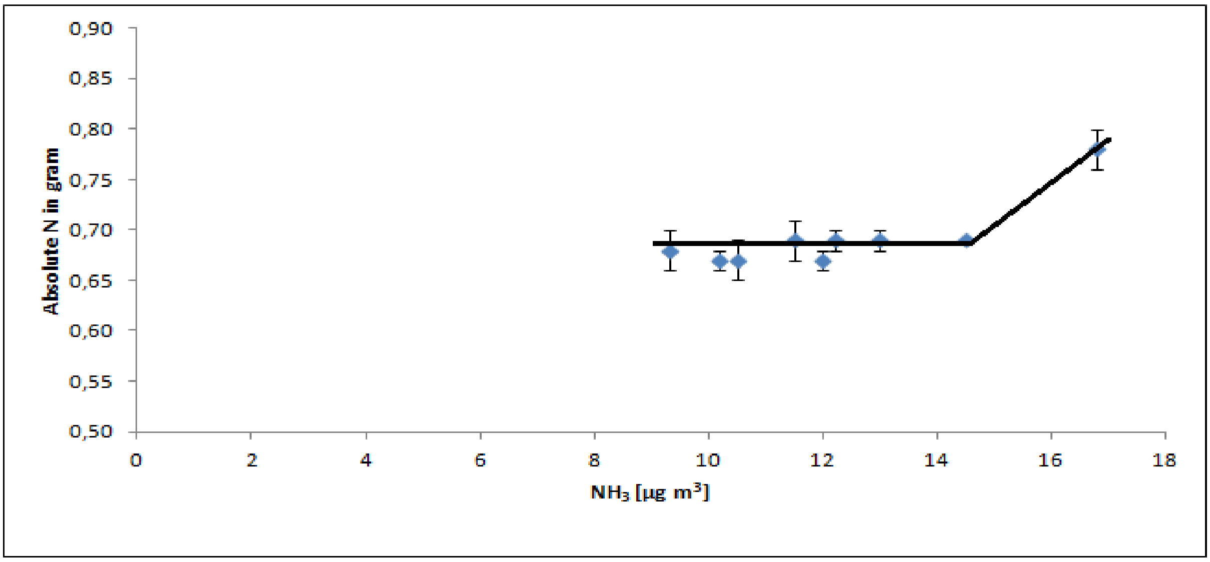

FIGURE 7 THE FUNCTION BETWEEN ABSOLUTE N OBTAINED FROM ABOVE AND BELOW GROUND N PER POT (GRAM N) FOR *HORDEUM VULGARE L.* AND THE AMMONIA CONCENTRATIONS AT DWINGELDERVELD AND THE VEENKAMPEN.

It can be concluded from Figure 7 that below the ammonia concentration around 14.5 µg m^3 no uptake of N deposition occurs (compensation point). Which equals to a level of 0,69 gram N pot^{-1} 85 d^{-1}. This would indicate that on the farms of Van Unen (II); 38,6 kg N ha 85 d^{-1} [166 kg N yr^{-1}], Daatselaar (III); 12,3 kg N/ha 85 d^{-1} [53 kg N yr^{-1}], Ter Wal (IV); 19,3 kg N ha 85 d^{-1} [83 kg N yr^{-1}] and Oostra (V); 38,6 kg N/ha 85 d^{-1} [166 kg N yr^{-1}] was deposited to a distance of 50 meter from the source. On the location of Mts. Duiven (I) the pattern of N deposition around the farm is depicted in Figure 8. At the East side of the farm (I) 180 kg N yr^{-1} was deposited on average.

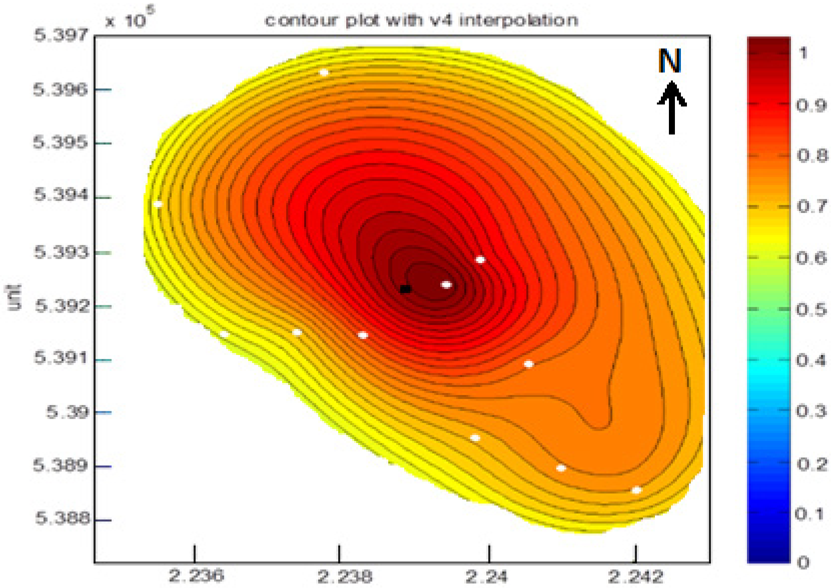

FIGURE 8 N DEPOSTION AT THE LOCATION OF MTS.DUIVEN

This figure represented the highest results of N that were found in one of the pots per location. The black square indicates the location of the farm buildings. The white spots show the location of the biomonitors in triplicate. The colors scale (legend) is expressed in the gram/ pot/ location. The units are based on the X and Y coordinates of every location. Obtained by MATLAB R2009a

This pattern of N deposition is clarified in Figure 9. On the location of Mts. Duiven (I) N deposition occurs to a distance of 400 meters South-East of the farm. At the West side N deposition still occurs to 80 meters of the farm as shown in Figure 8.

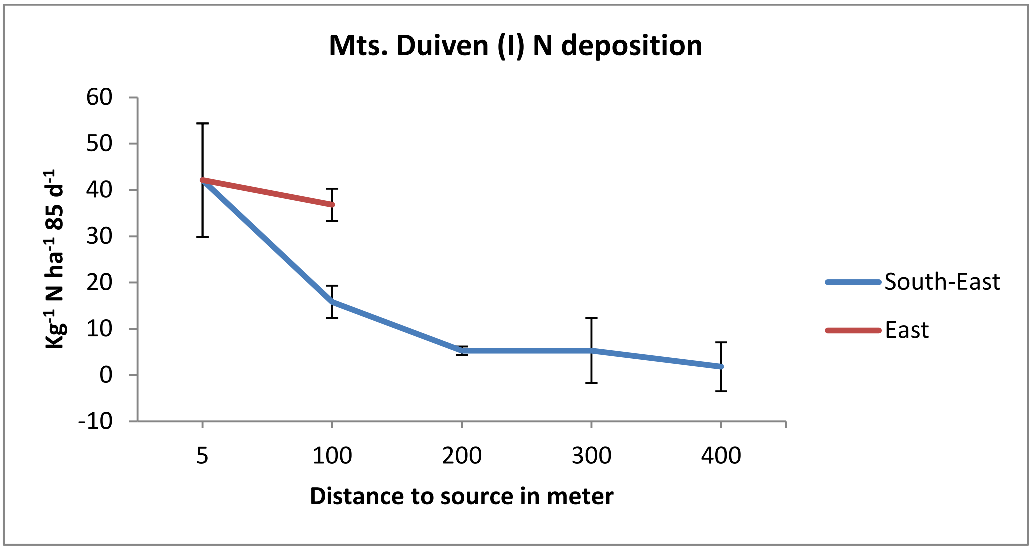

FIGURE 9 MTS. DUIVEN N DEPOSITION
The figure represent the N deposition pattern along the transect of biomonitoren to 400 meter on the South-East side and on 80 meters to the East side of the farm buildings of Mts. Duiven (I).

4.5 IRRIGATION OF BIOMONITORS

An overview of the amount of nutrient solution that was added to the biomonitors can be found in appendix IV. Each graph contain a legend with five variables; (1) the rainfall per weather station for that specific month in 2011, (2) the climatology rainfall per month* period 1971 – 2000, (3) the nutrient solution that was added in mm per pot, (4) the total amount of liquid per pot: 1 + 3 and (5) the evaporation of the assumed 5 mm per day (25 days April, 31 days May, 20 days June). Thus each graph show the relation between the evaporation and total input of liquid

** For April is the expected amount of rainfall re-calculated for the last 10 days that the biomonitor was exposed in the field at this experimental site.*

Dwingelderveld "Eelde"

In the beginning a surplus of nutrient solution was added to the pots. This was done as the root system wasn't developed at that moment and thus it prevented the rockwool from blowing away. In April there was no rainfall during the exposure time of the biomonitor. In May and June there was as much as rainfall as expected. At the end of April nutrient solution was added to the biomonitors, so that the gap between evaporation and added solution in May is lifted. As there was less than expected rainfall in the beginning of June, nutrition solution was still provided. Unfortunately, most of the rainfall occurred at the end of June when the spring barley was at the ripening stage and when less water was needed. This caused problems with the pots which were spoiled by the excess water and this led to a negative effect on the total nitrogen.

Dwingelderveld "Hoogeveen"

The only difference between Hoogeveen and Eelde was the amount of rainfall, which is significantly higher in June in Hoogeveen as compared to Eelde. This enlarged the problems of excess water per pot. Less oxygen leads to denitrification of nitrogen.

Meteorological field Veenkampen Wageningen

At this experimental site the difference between the actual and expected rainfall was much larger. Nevertheless, in June the actual rainfall was more evenly distributed over the whole month. During May there was hardly any rainfall at all. Especially during May the water shortage could have led to water stress which reduces the uptake of N. Nevertheless, the heavy rainfall in June didn't cause flooding in the pots.

4.6 METEOROLOGICAL ANALYSIS

An overview of the weather conditions, rainfall, temperature and wind direction for the months April, May and June 2011 can be found in appendix IV & V. Comparisons are made between the actual weather conditions in 2011 and the climatology data between the years 1971 – 2000. April includes only the last ten days which can give a distorted overview during the comparison. To avoid this, the total value of the entire month of April is given.

Rainfall

In the Dwingelderveld rainfall was not equally distributed over time particularly in April when there was almost no rainfall. Throughout April only 5 mm of rain fell. In May (44 mm) and in June (57 mm)the expected amount was reached but unfortunately most of the rainfall in June was at the end of month when rainfall for the biomonitor research wasn't needed anymore.

For the meteorological field "Veenkampen" located in Wageningen, April and May didn't meet the expected amount of rainfall at all. Normally in April 17 mm and May 55 mm of rain are expected. However, in June the amount of rainfall (109 mm) was almost double the expected (69 mm) amount and more equally distributed over that specific month.

Temperature

The temperature graphs of Dwingelderveld show a tremendous gap for the average temperature in April. Between 14,8 - 15,4 °C against the average of 7,5 °C in April. It must be noted that the 14,8 °C was the average of the last 10 days in April, the average temperature was between 13 – 13,6 °C for the whole month April. During May and June the average temperature increased by 1,2 – 1,7 °C in 2011. The average minimum and maximum temperature also increased. There was a large difference in the minimum temperature at 8,2 °C compared to 2,7 °C. For the maximum temperature at 21,4 °C compared to 12,2 °C in April. For 2011 the average minimum and maximum temperature is 5,9 °C and 17,6 °C in April. May and June were quite similar to the reference period, with a range of between 0,4 °C and 1,2 °C higher.

The temperature graphs of meteorological field "Veenkampen" indicate the same differences. In April the difference for the average temperature is bigger; 16,3 °C against 8,4 °C. Throughout April the average temperature was 13 °C. Differences between the actual and reference period temperature was higher in May (1,7 °C) and June (1,1 °C). Also large differences for the minimum temperature 8,5 °C against 3,3 °C and for the maximum temperature 22,2 °C against 13 °C in April. For 2011 the average minimum and maximum temperature is 6,1 °C and 19,2 °C in April. May and June were also more similar to the reference period, but the range is greater 0,9 °C and 2 °C higher. During 4 and 5 May the minimum temperature was below 0 °C at both experimental sites. The minimum temperature was as low as -2 °C.

Wind direction

To clarify the numbers that are addressed to a certain wind directions they are pointed out here: East = 90; South = 180; West = 270 and North = 360.

Over time the graphs of Dwingelderveld show that the average wind direction is between 270 and 320, also named as North-West. The last ten days of April were in the range of 83 – 94, named as East wind. In both May and June, the average wind direction was between 192 – 199, named as South-West. The result is that the prevailing wind direction was headed away from the Natura 2000 site. However normally during this period the wind is in the direction of the Natura 2000 site. Meteorological field "Veenkampen" also show that normally; April (305), May (292) and June (286) the prevailing wind direction for this period is from the North-West. However, as in Dwingelderveld, the wind direction was coming from the East (85) during April. In both May and June the average wind direction was between 193 – 208; South-West.

5 DISCUSSION BIOMONITORS

For the calculation of the dry and wet N deposition, the obtained N results from the plant tops and plant roots, after subtracting the total input of N (0,854 g N pot) was inefficient. The same amount of unmeasured N of about 20 per cent was also found (21 per cent) in Sommer and Jensen (1991). The loss of N was attributed to N that was left in the sand or lost when roots where washed free of sand. Another explanation is that some of the N taken up may have been lost as NH_3 from the plant tops (Sommer and Jensen, 1991). It was mentioned by Sommer (1991) that it was unlikely that denitrification occurred in the sandy soil containing no organic material. The latter conclusion is doubtful, because the proportion between rainfall, the input of supplied nutrient solution and oxygen cannot be controlled with tight pots as is shown in this research as well by the irrigation scheme of the biomonitors. In hindsight there was an over estimation of the total liquid supplied compared to the total evaporation of the biomontors per month which could have lead to an environment with less oxygen inside the pots. Another article named "Oxygen in the root environment" showed that due to less oxygen in substrates the level of denitrification can be up to 40 per cent due to oxygen poor conditions. Therefore, it would be almost impossible to prevent losses from N by denitrification in substrates and N-free sand. In the research of Leith *et al.,* 2005 *Deschampia flexuosa* was evaluated as a standardized grass N bioindicator. The method of propagation was done in 1.1 liter square black pots containing a peat: loam: grit compost (ratio 4:1:1) where no negative effect were found related to N-losses.

The dispersion of ammonia concentrations that were found during the measuring period of the biomonitor were higher compared to the seasons autumn and winter. Comparative measurements were found in the thesis of Kruit, (2010) with measurements for summer of 13,3 µg m^3 and for autumn of 6,4 µg m^3. This indicates that there are more emission events in the summer than in autumn. The average canopy compensation point that was found in this research was 7.0 ± 5.1 µg m^3 and is strongly temperature dependent whereby high temperatures will cause a high internal leaf ammonia concentration (Kruit,., 2011). The compensation point obtained by Kruit (2010) was indicated to be quite high for non-fertilized conditions which was probably caused by high nitrogen in the past. This is remarkable considering the many intensified farming systems in the Netherlands who inject slurry on the surrounding fields near the indicated research site "Veenkampen". In another study when *Lolium multiflorum* was evaluated as a standardized grass bioindicator for gaseous ammonia, a crop compensation point of 20 µg m^3 was derived, but at a height of 0.5 m above the vegetation along the 60 meter NH_3 transect (Leith *et al,* 2005).

Results of the calculated N deposition along the different NH_3 transects at the participating farms were found similar compared to the research of Sommer,. (1988). Levels of annual N deposition of 50

kg N ha^{-1} were found up to 100 – 200 East in the plume of the farm. Because most of the participating farms are more intensive, an increase in the contribution of N deposition can be expected.
There are similar findings in a study by Cape, *et al.,* (2008) where along a transect of 60 meter from the source, marginal dry deposition was found over a period of 4 years. Calculated dry deposition of NH_3 between 75 – 125 kg N ha^{-1} yr^{-1} were found in a fumigated ombrotrophic bog (Whim bog nitrogen manipulation experiment). Sommer and Jensen (1991) were using biomonitors with Italian ryegrass (*Lolium multiflorum Lam.*) along a NH_3 transect up to 130 meter from a dairy farm dung yard. The deposition of N was 3.0 g N m^2 and 0.7 g N m^2 at average concentrations of 89 and 6 µg NH_3 m^3, respectively (Sommer *et al*., 1991). In another article of Sommer *et al*., (2008) the deposition from and in the neighborhood of a chicken farm was measured along a NH_3 transect up to 320 meters. The calculated N deposition 320 meters away from the chicken farm was only marginally affected by the NH_3 emission from the farm (Sommer *et al*., 2008). These results were mainly found in Scotland and Denmark with simplified biomonitors. Similar dry deposition measurements are not available in the Netherlands. Dry deposition research is seen as labor intensive and costly which results in the simulation of N deposition models, assessment models with allocated reference points in combination with the setting of critical deposition loads to protected ecosystems. As can be thus concluded, most of the N deposition is deposited in the surrounded area of a point source. Further away from the source, the ammonia concentration equals the background concentrations and no N deposition occurs. The remaining nitrogen is taken up by the atmosphere as ammonium (NH_4) aerosols (Sommer *et al.,* 2009), transported over long distances and mainly deposited in the Atlantic Ocean by wet deposition. Changes in ecosystems properties may occur rapidly as N deposition levels begin to rise above background values. This emphasizes the difficulty in setting critical loads to vulnerable species in ecosystems. Particularly in the tissue N content of *R. lanuginosum* (moss) C : N and N : P showed their greatest rates of changes at deposition values < 7 kg N ha^{-1} yr^{-1} (Armitage *et al.,* 2011).

The weather stations that were used for obtaining the specific weather data were not located at the experimental field. The two weather stations that were used are located at a distance of 45 km (Eelde) and 20 km (Hoogeveen) from the research site. Local variation in weather conditions may have occurred during the research period and could have influenced the measurements at the local scale. Obtaining weather data locally would have made the results more accurate, understandable and explicable for some specific locations. Nevertheless, these two weather stations provide reliable information and give a good visibility of the whole region.

6 RECOMMENDATIONS BIOMONITORS

- ✓ In this research the N deposition was executed with spring barley. To elongate the measurement of N deposition throughout the year, other vascular plants can be considered:

  1) *D. flexuosa* could be used effectively as standardized grass species for N biomonitoring, especially at sites with a defined point source (Leith *et al.,* 2005)

  2) *Lolium multiflorum* was found to be a suitable species for use as a standardized grass bioindicator with a defined NH_3 point source under experimental field conditions (Leith *et al.,* 2005)

- ✓ The applied method of tight pots is very sensitive to N losses. Using a wicking system linked to reservoirs of water should improve this. *Cited* (Leith *et al.,* 2005)*: "Two pieces of glass fibre cord (250 mm in length) were placed into each individual pot, with both wick running vertically from just below the soil surface down to the water tray reservoir. The wicks were in constant contact with the rainwater reservoir and therefore, kept the soil moist even during dry periods.* It also requires less management due to the storage of a high volume of water in the reservoir.

- ✓ Installation of a weather station to obtain local weather data from the research site if relationships want to be clarified between the level of individual measurements of ammonia concentrations and any influence from the weather.

7 Research 2 Introduction Ammonia Concentration

The average measured ammonia (NH_3) concentration in the Netherlands was 8,3 µg m^3 in 2010, while the national calculated ammonia concentration was 6,4 µg m^3 in 2010. The calculated concentration was lower, because the whole surface of the Netherlands was taken into account. The lowest ammonia concentrations are found along the coastline (2 µg m^3) and the highest concentrations were found in areas with intensive livestock farms (18 µg m^3) (RIVM, 2011d)

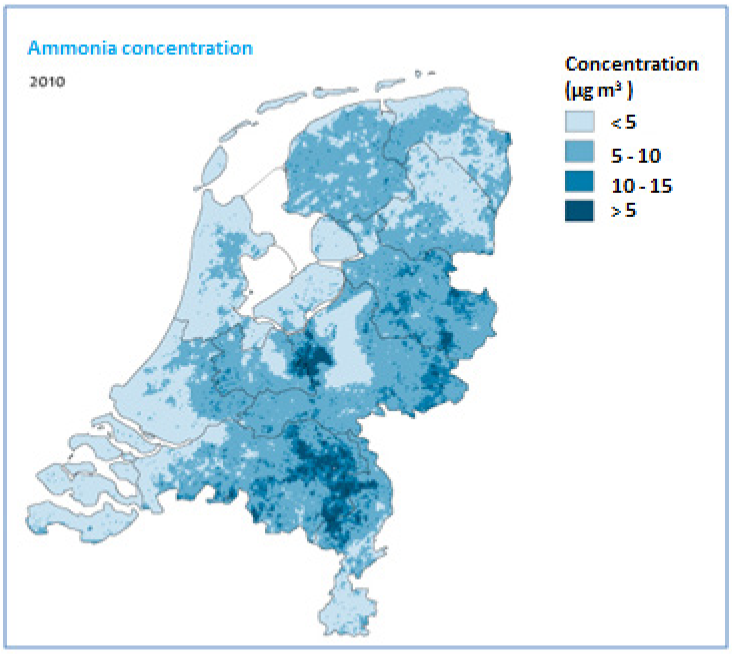

FIGURE 10 AMMONIA CONCENTRATION IN THE NETHERLANDS 2010
(Source: RIVM, 2011d)

Figure 10 shows the dispersion of ammonia concentration in the Netherlands. Especially in the Gelderse Vallei, east of North-Brabant, north of Limburg and in the Achterhoek, high concentrations of more than 15 µg m^3 NH_3 were found. The trend line of ammonia concentrations from 1993 to 2010 initially shows a decrease in the ammonia concentrations. In the last 10 years there were almost no fluctuations in areas with low, middle and high concentrations. There were small fluctuations due to meteorological conditions.

The average ammonia concentrations in natural reserves fluctuated strongly. The distance from the source to the border of the natural reserve highly influences the height of the concentrations. This is the reason why bigger natural reserves have lower ammonia concentrations than smaller areas. Between 2005 and 2007 the ammonia concentrations were measured in several natural reserves including Natura 2000 site Dwingelderveld. In the Dwingelderveld the average ammonia concentration for this period was 3,2 µg m^3 (Stolk *et al.*, 2009). This data was obtained from four measurement points located in the South and middle of the Dwingelderveld area.

There are no standards for ammonia concentrations in the air. Unlike with nitrogen deposition where the government developed policies to reduce these emissions. For ammonia the focus is on resource regulation; emission from stables, manure storage and the application of manure. In 2001 he National Emission Ceilings (NEC) Directive was determined by the European Union (EU). A reduction of the ammonia emission to a level of 128 kton had to be achieved by 2010 in the Netherlands, as is shown in Figure 11. The NEC-directive aims to decrease the emission of substances that lead to eutrofication and acidification. Besides ammonia, the NEC-directive also prescribed maximum national emissions. For the Netherlands the following emissions were determined for sulphur (SO_2) 50 kton, nitric oxide (NO_x) 260 kton and volatile organic compounds (VOC) 185 kton (Beck *et al*., 2003). After 2010 the NEC directives will be revised. In the Netherlands the "Programmatische Aanpak Stikstof" (PAS) will continue to prevent decline in biodiversity and to reduce the nitrogen deposition around and on Natura-2000 areas.

In the Netherlands 90 per cent of the ammonia emission originates from agriculture (Rougoor *et al.,* 2001). Ammonia is released from stables, manure storage, grazing and during the application of manure on the fields. For this reason the Netherlands aims specifically for ammonia reduction in agriculture. In a report, named; "Emissiearm aanwenden geëvalueerd" of the PBL "Netherlands Environmental Assessment Agency" it was mentioned that ammonia emissions declined from 1987 until 2006 by 130 -140 kton. The largest contribution to this decline was due to the application of animal slurry by injecting rather than by surface spreading (80 – 90 kton). This corresponded to a reduction of ammonia emissions by 60 to 70 per cent as shown in Figure 12. These reductions of ammonia emissions where not proven until today. Other important influences were the reduction in animal numbers and remaining factors (40 kton) (De Haan *et al*., 2009).

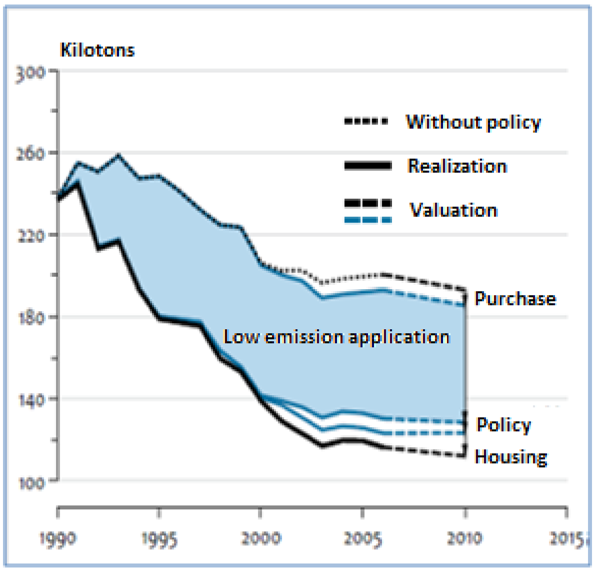

FIGURE 11 AMMONIA EMISSIONS AGRI- AND HORTICULTURE THE NETHERLANDS

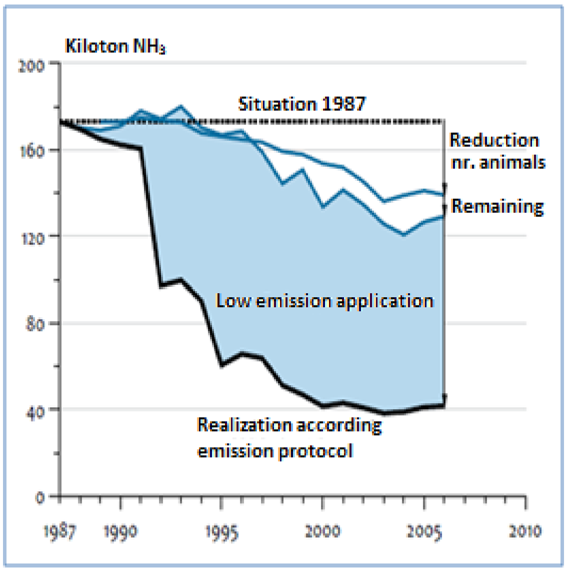

FIGURE 12 AMMONIA EMISSIONS FROM MANURE THE NEDERLANDS

The resulting advice given by PBL is still considered as intrinsic truth by the Dutch government. Nowadays increasing numbers of farmers and scientists disagree with this political statement. Paul Blokker, a dairy farmer and engineer in Dutch agriculture has conducted a desk study about reducing emissions in the application of animal manure on behalf of the association VBBM[8]. VBBM wants to contribute towards the government evaluation of the application of surface spreading of animal manures (VBBM, 2008). According to their view the decline in the production of nitrogen began with a reduction of livestock, from 1994 until 2007 which resulted in a 16 per cent reduction of manure, causing a reduction of 29 per cent in the produced nitrogen in the same time period (from 656 to 464 million kg N). Additionally the manure also contained less nitrogen, a decrease from 7,9 kg N ton in 1994 to 6,7 kg N ton in 2007, a decrease of 15 per cent. Paul Blokker therefore concluded that a decrease in manure production in combination with a decrease in nitrogen content was the most important factor for the decrease in ammonia emission (VBBM, 2008).

Ammonia is a gaseous component and is removed from the atmosphere by dry and wet deposition. In the atmosphere, ammonia is partly converted to a ammonia aerosol, which can also be removed by dry and wet deposition. This aerosol contributes to the fine dust concentrations. Exchange of NH_3 between the atmosphere and vegetation is a two-way process. Ammonia can be taken up or be emitted by the stomatal opening, depending on the stomatal compensation point and the relative magnitude of the atmospheric concentration (David *et al*., 2009). Below this compensation point there is no uptake of ammonia, which is strongly dependent on temperature; thus a higher compensation point indicates a higher temperature (Kruit, 2011). A significant amount of ammonia can be lost from the water on the surface of the vegetation (David *et al*., 2009). This is due to the high solubility of ammonia in water. Especially under wet and cool conditions, the uptake of ammonia takes place. This explains why there are lower concentrations of ammonia in the autumn and winter. However, under dry conditions the dissolved ammonia can evaporate from the surface.

The flower/ ears and green leaves of the plant, which are photosynthesizing are a sink of ammonia. The soil and the litter (senescing attached leaves – dead or decomposing) are a source of ammonia. Changing management practices by for example changing the composition of the sward, directly influences the source / sink relationship at canopy level as well as the interactions with the atmosphere (David *et al.*, 2009). Different types of vegetation have different effects on the deposition velocity of ammonia. Measured deposition velocities very between 0,3 cm sec^{-1} for soil, 1,6 cm sec^{-1} for grass (*Lolium multiflorum)* and 3,6 cm sec^{-1} for coniferous trees (Oosterbaan *et al*., 2006). This implies that trees and forests are very well suited to capture ammonia from the air.

[8] VBBM: Society for the preservation of farmers and the environment www.vbbm.nl

8 MATERIALS AND METHODS

To explore the objectives, the methodology according to the national institution of public health and environment RIVM, MAN-report from 2009 was used. To show the spatial distribution of ammonia concentrations, passive samplers "absorbers" were used in the Dwingelderveld.

8.1 LOCATION

For this project all farms and the Natura 2000 site at "Dwingelderveld" were involved. The contribution of the ammonia deposition of each farm in relation to the "Dwingelderveld" absorbers was measured. The absorbers had to be strategically located and they were thus placed in the direction of the Dwingelderveld as seen from the location of the farm.

Only the fields that were owned by the farmers and those owned by Staatsbosbeheer were used for the placement of the absorbers. Figure 13 shows the locations of the absorbers.

FIGURE 11 LOCATIONS OF ABSORBERS (PASSIVE SAMPLERS)
The location of the farms is indicated by the balloons. Black dots show the position of the absorbers in triplicate. The numbers in red correspond to the positions and represent the name of the position.

8.2 DETERMINATION OF NH_3 CONCENTRATIONS

8.2.1 THE SETUP OF THE EXPERIMENT

Absorbers were installed for a total length of one year to measure the NH_3 concentration in the ambient air around the five farms and the Dwingelderveld. All the seasons and farm management activities, e.g. grazing, application of manure, mowing were included to provide a good insight into ambient ammonia concentrations per location. In total per measurement 47 absorbers were installed in an open space and 1,5 m above the soil surface. Normally, the exposure time of the absorbers was 14 days, for two measurement periods during the winter period it was 21 days. The reason for this lengthened exposure time is that in the winter period there is less fluctuation of ammonia concentrations in the air. During the measurement 4 absorbers were used as controls. Two controls remained at the lab and the other two remained in the bag in which all the passive samplers were transported. These four control absorbers were used to check for contamination and to correct for background ammonia. In total 20 measurement were conducted and approximately 1000 absorbers were used to obtain the ammonia concentrations at these 15 locations as shown in Figure 13. Appendix IV provides an overview of all the measurements that were taken during the year. The absorbers were placed in specially made steel pins which held the absorber under the wooden plank, The pin and plank were connected to a wooden pole as showed in Figure 14. These absorbers were operational within five minutes after installing the treatments and were exposed for the indicated period of 14 days.

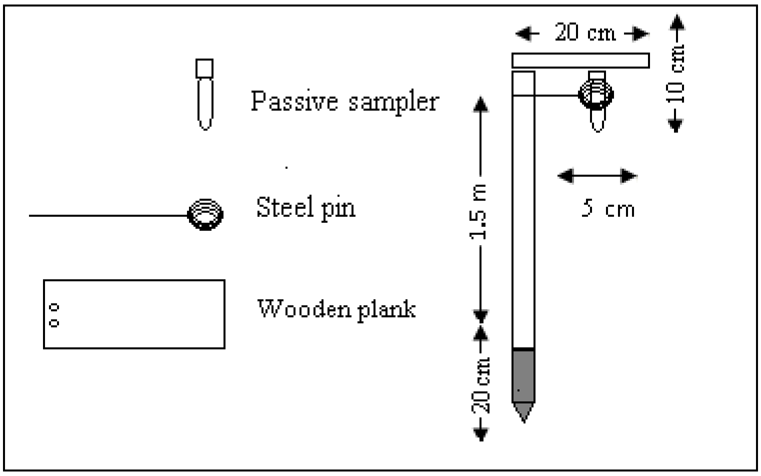

FIGURE 12 DESIGN EXPERIMENT ABSORBER

8.2.2 FUNCTION OF THE ABSORBERS

In the absorbers NH_3 is trapped on steel grids impregnated with sulphuric acid. A diffusion sampler consisted of a palm tube (0.041 m long) fitted to one end with a poly-ethylene cap with rim to contain two stainless steel grids. These grids were coated with 30 µl of 10% w/v sulphuric acid. This amount of acid has a NH_3 binding capacity of 4.55 µg dissolved in 5 ml of water. This quantity of 4.55 µg could capture 81 µg m^3 of ammonia. The ammonia concentrations expected from the measurements was a pattern with high concentrations in the spring and summer (25-30 µg m^3) and lower concentrations in the autumn and winter (10-20 µg m^3) (Smits *et al*., 2005). The front end of the palm tube was fitted to a transparent poly-ethylene cap with a centre hole (10 mm diameter) to contain a Teflon entrance filter of 12 mm diameter and a pore size of 45 µm. This end was closed with a polyethylene cap (14.5 mm diameter) immediately after preparation and field sampling to avoid adsorption of the ambient NH_3. The procedure for preparation involved a pre-wash of tubes, poly-ethylene caps and steel grids with distilled water. Afterwards, only the steel grids were rinsed once with acetone, everything was dried by putting them in an oven at 60°C for 1 hour and the steel grids were coated with sulphuric acid again. After the exposure period, all the installed samplers in the field were removed and immediately transported to the laboratory. Due to the long distance between the laboratory and sampling location passive samplers were kept in a cool box to avoid fluxes in temperature.

8.2.3 THE ANALYSIS

In the laboratory, steel grids were washed with 5 ml distilled water and the solution was analyzed for NH_4-N content according to the procedure described in (Houba *et al*.,1989). With the µg NH_4^+ captured, the NH_3 concentration (µg m^3) in the air above each plot was calculated using the following equation (Shah *et al*., 2010).

$$C = \frac{17}{18} * \frac{Q.\ Z}{D.\ A.\ t}$$

Where, Q is the sampled amount of NH_4^+ (µg), Z is the length of the tube ($4{,}1*10^{-2}$ m), D is the diffusion coefficient ($2.28*10^{-5}$ m^2 s^{-1} at 1013 mBar and 18°C), A is the area of the tube ($0.5 * 0.5 * \pi$ / $10.000 = 7.85 * 10^{-5}$ m^2), t is the sampling time in seconds (s), 17/18 is the conversion factor from NH_4^+ to NH_3, which will result in C; the concentration NH_3 (µg m^3). The outcome is relative and not an absolute outcome even when a blank passive sampler is taken into account.

8.3 VALIDATION PROCEDURE

Before using the obtained measurements of the ammonia concentrations, this data had to be assessed to a validation procedure. The objective of this procedure is to remove false or disturbed samples out of the data range. In this procedure every sample was given a validation code. In case of incorrect measurements the validation code 0 is given. By disapproval or suspicion of a sample a negative validation code is given to that specific sample. All the different validation codes are shown in Table 3 and explained thereafter.

TABLE 3 OVERVIEW RECOGNITION VALIDATION CODES

	Step 1	Step 2	Step 3			
Validation code	Measurement disapproved comments	Measurement disapproved 3 σ	Measurement aberrant and rejected	Measurement aberrant but approved	Different sampling period	Measurement OK
0						x
-1					x	
-2				x		
-3				x	x	
-4			x			
-5			x		x	
-6		x				
-7		x			x	
-8	x					
-9	x				x	

Source: Stolk et al., 2009

The validation procedure can be divided in three steps:

Step 1. **Assessment of comments**

As well as in the field or in the laboratory irregularities can occur. These irregularities, like e.g. damage or contamination by bird dropping can influence the measurements negatively. During the validation procedure all the comments that were indicated are assessed if this could lead to an effect on the result. Secondly, the result will be assessed and decided if the measurement should be disapproved. If this is the case, the result of the measurement is indicated with the validation code -8.

Step 2. **Assessment of outliers**

During step 2 only the approved measurements of step 1 will be included. The test is rejected if an individual measure in the time series is more than three times the standard deviation from the average. Then the measurement is indicated with validation code -6. Measurements will not be rejected if surrounded measurement points also indicate a high or low concentration. When the outlier is disapproved, re-testing takes place on the remaining measurements until there are no more outliers detected.

Step 3. **Assessment based on mutual comparison within one or more areas**

Step 2 was tested if a random measurement fits according the whole range of data at one measurement point. In this case, a measurement does not have to be corrected. So during step 3 every single measurement is assessed by hand. Comparison of a data range within the same area can provide additional information about the existence of aberrant measurements. Also external factors have to be taken into account. The position of ammonia emission sources and the application of slurry in the surrounded area of a measurement point. For every measurement the prevailing wind direction can be obtained from a wind rosette and be used for the explanation.

Based on this evaluation if a measurement inexplicably differs significantly, this single measurement has to be rejected and indicated with validation code -4. Unless, the measurement behaves aberrant regularly, then it might be representative and have to be approved. When the aberrant behavior is less clear, the measurement is approved and will be indicated with validation code -2. To compare measurement within or between areas it's necessary to have data from a similar period. By the composition of a validated data set, measurements that deviate more than 25 per cent with the normal measurement period receive the validation code -1. These validation codes can coincide with other already assigned validation codes. In this case the validation codes have to be added together. The reason of disapproval thus remains traceable. In this report validation code -1 is not used, because there is no similar data available. For this report, only data with a validation code of less than -4 is used.

8.4 METEOROLOGICAL DATA

This section is the same as described in section 4.6 in the biomonitors research, the only difference being that there was no use of the weather station "Veenkampen" located in Wageningen.

8.5 FARM MANAGEMENT

For the five dairy farms in Dwingelderveld the main ammonia sources were housing,
manure storage, manure application and grazing in the pastures. Therefore it was necessary to determine the agricultural situation spatially. The farmers could provide additional data to gain insight in these farms. The data that was needed for this study was the urea content in the milk (mg 100 g^{-1}) over the time period, average herd size, replacement rate, volume and rate of manure and fertilizer applied to the fields in the area surrounding the absorbers. This data was obtained from the farmers while visiting them for the experiment and was noted in an Excel file.

8.6 OPS-MODEL

As mentioned before the OPS-model simulates the spread of pollutants into the air and calculates the deposition on the surface in different units, e.g. mol ha^{-1} yr^{-1}. Specific farm data, e.g. number of cows and young stock, but also GPS-coordinates for the emission and receptors points are needed to run the OPS-model. By using this model it can be considered whether there is a correlation between the measured data and the data simulated by the model. The RIVM and PBL share ownership of this model and it can be downloaded from the following website: http://www.rivm.nl/ops/ | *OPS version 4.3.12* |

9 RESULTS AMMONIA CONCENTRATION

9.1 DATA ANALYSIS

9.1.1 VALIDATION PROCEDURE

For every single measurement a validation code was allocated and the results of the validation are mentioned in Table 4 (left). In total 855 measurements were carried out. Measurement 1 was not taken into consideration due to an error in the preparation or analyze phase and the total number of 17 passive samplers that were measured. Thus the numbers in table 1 refer only to the validation of measurement 2 to 20. For four locations a single measurement was entirely removed.

TABLE 4 ASSIGNED VALIDATION CODES DURING VALIDATION PROCESS

Validation code	Number of allocations	Percentage of allocations
0	584	68,3%
-1	0	
-2	36	4,2%
-4	174	20,3%
-6	32	3,7%
-8	29	3,5%

Validation code	Number of allocations	Percentage of allocations
Approved	584	68,3%
Suspicious	36	4,2%
Rejected	235	27,5%

In the right part of Table 1are the different validations codes divided into three categories; approved, suspicious and rejected. The data that is used in this report includes both the approved and suspicious measurements which concerns 72,5 per cent of the total measurements.

9.1.2 CONTROL BLANK PASSIVE SAMPLERS

In total 76 blank passive samplers were taken into account. Every measurement contained 4 blanks and again measurement 1 was not included. After validation 56 of the blanks were approved and 20 blanks were rejected. Thus 73,7 per cent of the blanks were used because the levels of NH_3 concentrations that were found in these blanks was negligible. The rejection of the remaining 26,3 per cent of the blanks was mainly caused by blank passive samplers that remained in the freezer. Between measurements 7 and 13 large ammonia concentrations were found and these were regarded as outliers.

9.2 AMMONIA CONCENTRATIONS DWINGELDERVELD

9.2.1 DISPERSION OF AMMONIA CONCENTRATIONS ANNUALLY

The dispersion of the ammonia concentrations throughout the year is shown in Figure 15. The white dots represent the receptors. All season and bi- and tri-weekly averaged NH_3 concentrations resulted in one average concentrations for 1 year. Measurement 16 & 17 were measured tri weekly in the period October – November – December. All other measurements were measured bi-weekly.

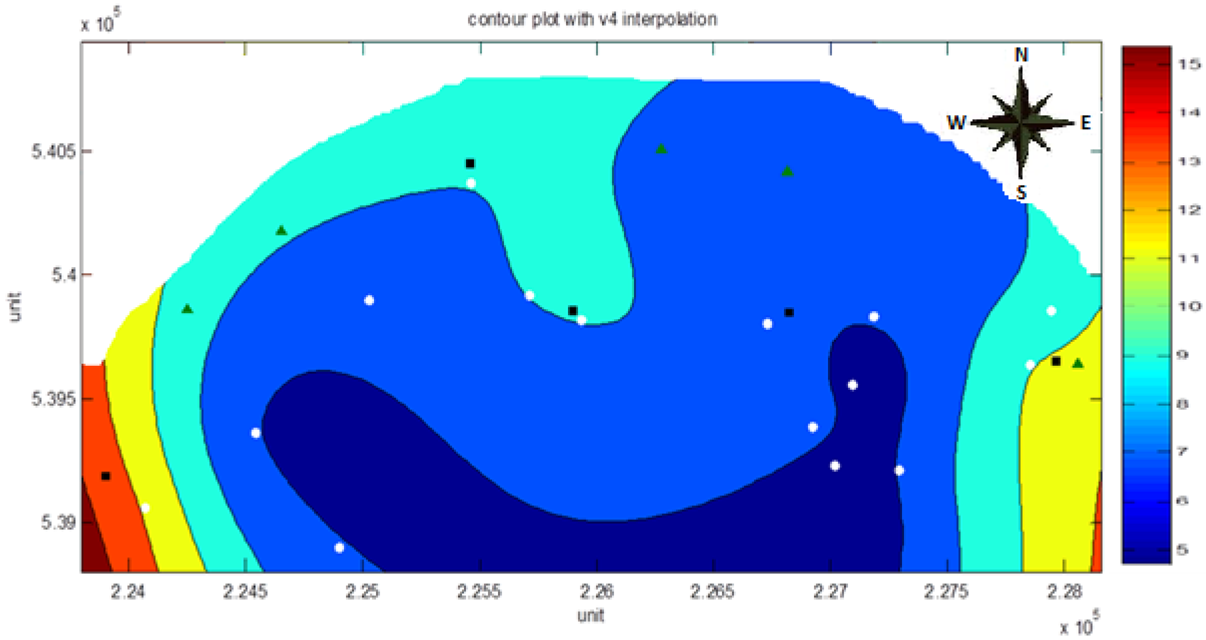

FIGURE 13 DISPERSION OF ANNUAL NH_3 CONCENTRATIONS AT DWINGELDERVELD

Black squares indicate the location of the participating farms. The green triangles show the farms located in the neighborhood which were not involved in this research. White spots indicate the location of the receptors where the NH_3 concentrations were measured. The colors scale (legend) is expressed in NH_3 [µg m^3]. The units are based on the X and Y coordinates of every location. Obtained by MATLAB R2009a

9.2.2 WEEKLY AND SEASONAL NH_3 CONCENTRATIONS

In Figure 16 the seasonal and weekly trends in NH_3 concentration is represented. There was a clear tendency for the seasonal NH_3 concentrations to decrease from 12 µg m^3 in February – March to 4 µg m^3 in December 2011 and January 2012. The largest peak in the bi-weekly NH_3 concentrations was found in June – July & July when large fluctuations in temperature were observed and when manure was applied. Assessing the compensation point that was found for the biomonitors, 75 per cent of the measurement were lower than the critical concentration of 14.5 µg m^3.

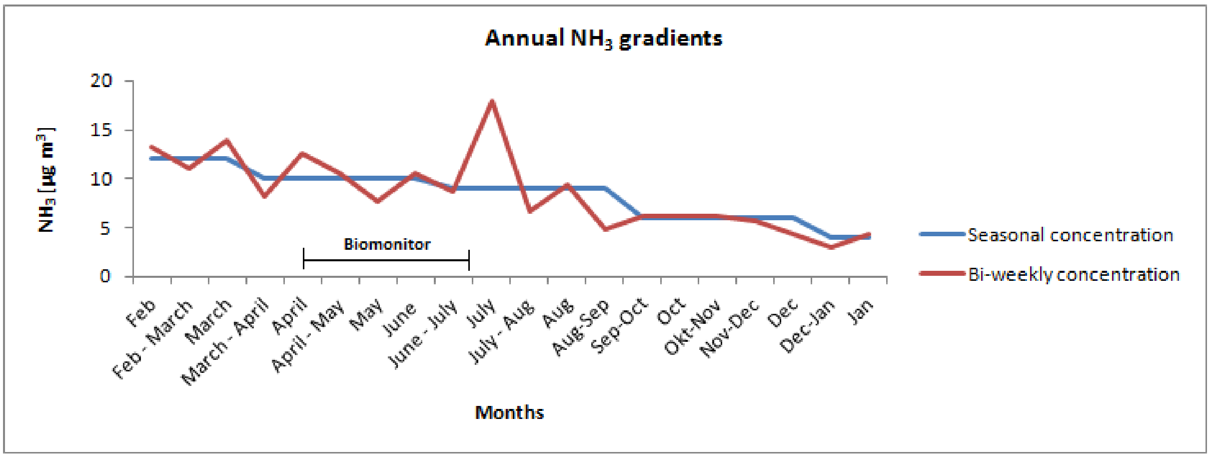

FIGURE 14 SEASONAL AND WEEKLY NH_3 CONCENTRATIONS AT DWINGELDERVELD

9.2.3 *EXPLANATION OF NOTABLE AMMONIA CONCENTRATIONS PER LOCATION*

For each location a graph is shown in appendix XI with the NH_3 concentrations per triplicate including the seasonal average which is expressed using a dotted line. Remarkable values will be highlighted per location. Therefore, appendix XII to XX were used as a guideline for the explanation of the values.

- **Location 1:** In February – March and in May & June there was application of slurry; During June – July there was a change in the wind direction from North to West from the direction of the farm; During October grass was mowed frequently (no uptake of NH_3, left over plant material works like a source of NH_3)
- **Location 2:** There is no actual data about the application of manure, Lilies were grown here by a contractor. The adjacent field was arable land. In November – December NH_3 was influenced by a local source which is located between location 2 and 3 (silo for the storage of manure)
- **Location 3:** In March and December – January the local source (silo) influenced the NH_3 concentrations. In June and in June – July there was a significant drop in temperature.
- **Location 4:** In February – March and in March there was application of slurry; During July the old sward of grass & decline in temperature influenced the NH_3 concentrations. In September – October there was no rainfall and probably a local source influenced the concentrations.
- **Location 5:** During June and June – July grass was mowed and manure was applied twice. In October there was much rainfall (ditch full with water) with fluctuating temperature creating conditions for a rotting process to occur.
- **Location 6:** In March & May there was application of manure. In April slurry was mixed. The wind direction changed to East; In October grass was chopped. In October – November slurry was mixed, wind direction changed to East.

- **Location 7:** In March the application of slurry and artificial nitrogen influenced the ammonia concentration. In July there was an emission flux from the buildings. In August there was application of slurry and in October - November grass was mowed.
- **Location 8:** In February there was application of manure. In June there was hardly any rainfall (begin of June) to retain ammonia. In July there was an emission flux from the buildings. In August manure was applied to an adjacent field.
- **Location 9:** In April no rainfall, strong increase of temperature and very low water level (measuring next to small canal). In September – October grass was cut end of the measurement (no uptake of ammonia).
- **Location 10:** In May there was application of artificial fertilizer.
- **Location 11:** In June to the adjacent field (13) manure was applied in combination with hardly any rainfall. In July there was an application of manure. In September – October grass was mowed. In January there was a link to location 14 of Fam. Oostra (V) in combination with an Easterly wind direction.
- **Location 12:** In April – May a link to location 13 where artificial fertilizer was applied. In July a link to location 11 & 13 where slurry was applied. In August – September a link to location 13 where manure was applied (this increase was not observed at location 13). In January there was a link to location 14.
- **Location 13:** In April – May the application of artificial fertilizer. ; In July the application of slurry. In October grass was cut here.
- **Location 14:** In February there was the application of slurry. In April & April May there was an Eastern wind direction from the farm buildings. In July application of artificial fertilizer. In August heifers grazed here since half of June, fresh manure heaps are located near and under the passive samplers. In January there was an emission flux the farm buildings in combination with an Eastern wind.
- **Location 15:** In March there was an Southern wind from the farm buildings and manure was applied before the start of measurement 3. In July – August & August the milking cows were crossing and waiting at this location before they were able to enter the farm buildings, which have caused accumulated of feces and urine.

Thus it can be concluded that in most cases the application of manure & artificial fertilizer, local sources of NH_3 and weather conditions had the biggest effects on the level of ammonia concentrations.

9.3 METEOROLOGICAL ANALYSIS

An overview of the weather conditions; rainfall, wind direction, temperature gradient and minimum and maximum temperature for the period January 2011 until January 2012 is attached in Appendix XV "Eelde" & Appendix XVIII "Hoogeveen". For every measurement the rainfall, temperature and wind direction are shown separately in different graphs per weather station; appendix XIV & XVI "Eelde" and appendix XVII & XIX "Hoogeveen".

Rainfall

The amount of rainfall in 2011 was 753 mm in Eelde and 785 mm in Hoogeveen against 774 mm on average. Rainfall wasn't regularly distributed over the year. Almost no rain fell in March, April, September and November while there was much rainfall in July, August and December and in January 2012.

Wind direction

The average wind direction in 2011 was both 190 degrees in Eelde as well in Hoogeveen against 240 degrees on average. The prevailing wind direction changed by 50 degrees from 240 degrees (South-West) to 190 degrees (almost South). The wind direction in January 2012 was 213 degrees for both weather stations.

Temperature

The temperature gradient for 2011 was especially high in April, May, June, December and in January 2012 and only lower in June. The average temperature was 0,8 - 1 °C higher in 2011 when compared to the average over the period of 1971 – 2000. The minimum and maximum temperature was respectively 1 °C and 0,7 - 0,8 °C higher at 5,9 °C and 13,7 °C when compared to the average over 1971 – 2000.

9.4 FARM MANAGEMENT

Most of the farm indicators presented in Table 1 did not change during the duration of the experiment. An exception to this is the urea content which fluctuated over the year. These fluctuations are explained in graphs for each farm presented in Appendix XX. Every graph explains the urea gradient during the entire measuring period in mg/ 100 g milk per monthly average over the period November 2010 until January 2012.

The mean and range of urea per farm for the entire period were:

- Mts. Duiven (I) mean 24,2; range 21,2 – 28
- Fam. Van Unen (II) mean 20,6; range 18,1 – 23,8
- Fam. Daatselaar (III) mean 22,2; range 18,5 – 24,8
- Fam. Ter Wal (IV) mean 23,8; range 19,8 – 25,8
- Fam. Oostra (V) mean 22,2; range 19,2 – 24,7

This data shows that there was a large variation in the average urea content per farm. Which indicate that there is a difference in the contribution of ammonia emission of almost 25 per cent between the lowest and highest urea content [10 mg/ 100 g milk * 2,5 per cent (Duinkerken *et al.,* 2004)]. It should be noted that the two farms that graze their cattle (Farm IV & V) had a lower contribution to the release of ammonia in the air due to the excretion of urine and manure in the pasture. Fam. Ter Wal (IV) grazed their cows for 210 days and Fam. Oostra (V) for 150 days.

9.5 OPS-MODEL ELABORATION

The OPS-model consists of 4 different sheets. The first sheet consists of general data; e.g. project name, component (ammonia), year and unit of deposition (mol ha^{-1} yr^{-1}). The second sheet consists of a box where the created file “emission file” can be added. The third sheet consists of box where the created “receptor file” can be added. To create these emission and receptor files the information presented in appendix XXI was used. The fourth sheet consists of meteorological statistics and surface roughness parameters. The most important data that were used for the input of the OPS-model is described in Appendix XXI. During this project an updated version of the OPS-model was generated by the RIVM; version 4.3.15 [Release date: 09 Dec 2011 (local)]. The most important modification noted by Dr. M.C. van Zanten, system modeller by the National Institute of Public Health and the Environment (RIVM) and Center for Environmental Monitoring (CMM) was that the calculated values can be up to 20 per cent higher by the latest version of the OPS-model. The OPS-model in general as well as the difference between the latest and older version will be highlighted in relation to these particular farms.

The output of the OPS-model of all the five farms can be read in Appendix XXII & XXIII.

After running the model for both versions; version 4.3.12 & 4.3.15 it was found that the output of the emissions from the OPS-model were only based on these five farms without the implementation of the **background concentrations**. Relative low ammonia concentrations were found at the emission source and almost no ammonia concentrations at the vulnerable natural areas as can be seen in Figure 15A and 15B. During the input session only these five farms were given as emission sources, so only these emissions will be used for the calculation of the ammonia concentrations and dry deposition. To get an indication about the local contribution of these farms in order to the background, calculations have to be made about the emission strength of the other emission sources in the Netherlands as well from abroad minus the emission of the five farms. These emissions can be obtained from the concentration (GCN) and deposition (GDN) maps, based on a scenario for economic growth and the Dutch and European environmental policies and produced in 2010 (Velders et al., 2011).

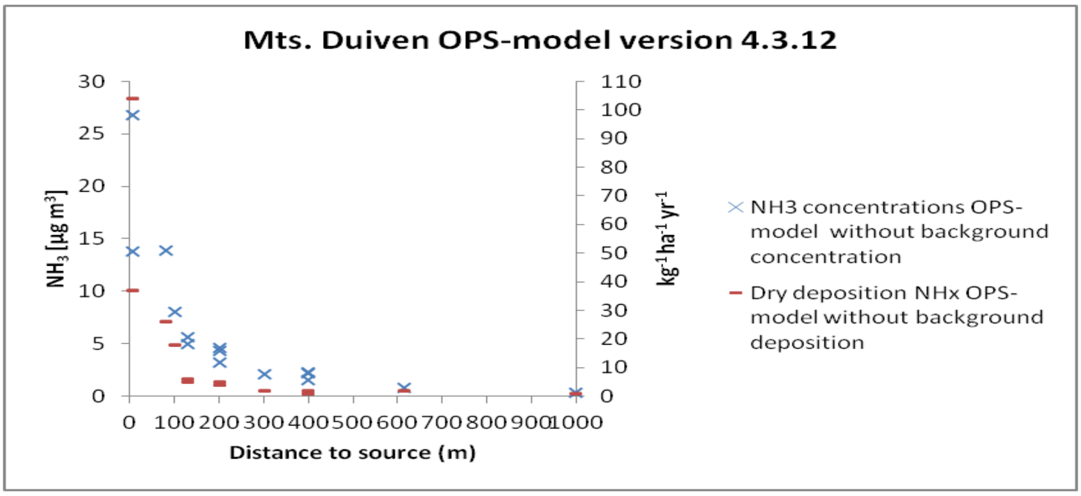

FIGURE 15A MODELED AMMONIA CONCENTRATIONS AND DRY DEPOSITION (NHX) OF THE FARM MTS.DUIVEN

The values in the graph are related to the X and Y coordinates of the biomonitors (Figure 4) and the passive samplers (Figure 12). These results are obtained from the OPS-Model (RIVM), version 4.3.12.

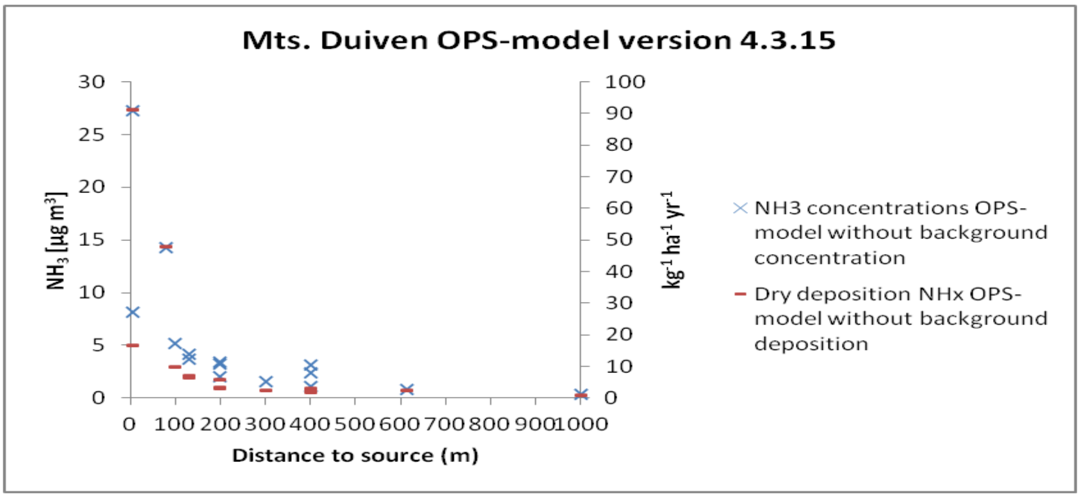

FIGURE 15B MODELED AMMONIA CONCENTRATIONS AND DRY DEPOSITION (NH_X) OF THE FARM MTS.DUIVEN

The values in the graph are related to the X and Y coordinates of the biomonitors (Figure 4) and the passive samplers (Figure 12). These results are obtained from the OPS-Model (RIVM), version 4.3.15.

Without the implementation of the background concentrations also the compensation point seems not be integrated in the output of Figure 15A and 15B. In the description of the model is mentioned that a correction was included for the **compensation point** according to (Kruit, 2010) of 7 µg m^3. Below this concentration no deposition occurs. Otherwise the obtained dry deposition would have been zero with such low ammonia concentrations, below 6 µg m^3 at 100 meter from the emission source.

Besides, the obtained **dry deposition** from this particular farm was even higher in the latest version of the OPS-model with lower ammonia concentration as compared to the older version of the OPS-model. The dry deposition was already in the older version highly overestimated compared to our findings as presented in this report.

Another distinction between the two version is the modification concerning the **wind direction**. Less dry deposition was calculated at the West side of the farm of Mts. Duiven together with a lower ammonia concentration while at the East side of the farm the dry deposition was increased due to the prevailing South-West wind direction.

Also the ammonia concentrations generated by the OPS-model near the emission source as can be seen in Figure 15A and 15B are estimated too low according to our findings and a Spanish report were even an ammonia concentration of 150 µg m^3 was found near a dairy farm (Sanz et al., 2005). Thus, these five farms seems not to have a direct link to the natural area in respect to ammonia concentrations and dry deposition as showed by the OPS-model in Figure 15A and 15B. But when the background concentration is included as can be seen in Figure 16 this farm is exceeding the critical deposition loads of 400 mol ha^{-1} yr^{-1} with 671 mol ha^{-1} yr^{-1}. The background concentration and resulting increasing dry deposition caused by emission sources in the Netherlands and partly abroad ensure that these farms are limited in their development.

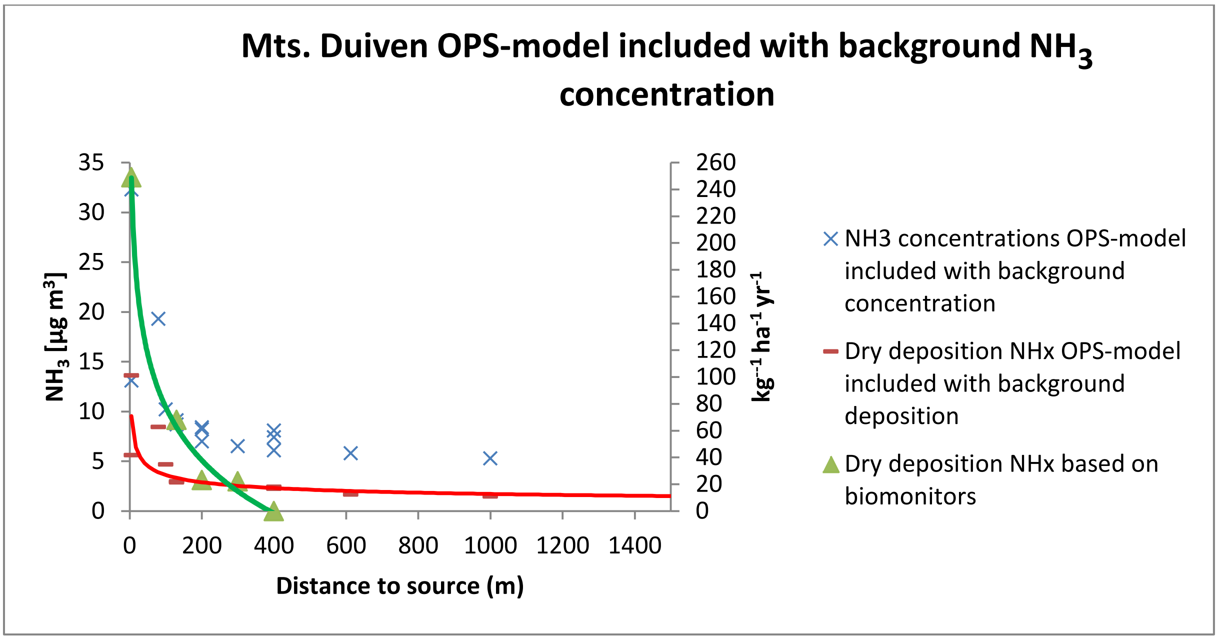

FIGURE 16 DRY DEPOSITION NH_X BASED ON THE LATEST OPS-MODEL COMPARED TO RESULTS BIOMONITOR

The considered background concentration is 5 µg m^3 according to (TNO-report, 2002)

This is resulting in a big disagreement between RIVM and Dr. Ir. Egbert Lantinga from Wageningen University. RIVM stated that 80 per cent of the produced ammonia in the Netherlands will be deposited in the Netherlands, only 20 per cent will be exported. The reasoning of the RIVM is explained by Figure 17 where the total deposition is increasing as the distances to the source increases. According to these statements the OPS-model and the preliminary AERIUS model were build.

FIGURE 17 FRACTION OF THE DEPOSITION NH_X AS A FUNCTION OF THE DISTANCE TO THE SOURCE, AVERAGE OVER ALL WIND DIRECTIONS
(Source: Kooijman et al., 2009 "Kros et al., 2008")

Dr. Ir. Egbert Lantinga stated that 20 per cent of the produced ammonia is deposited as dry deposition in a radius of around 100 meter within the source. Wet deposition gradually increases up till 60 per cent around the earth atmosphere. By other processes disappears the remaining 20 per cent. His statement is based on the findings presented in this report and researches performed in Scotland, Denmark, America and Spain.

Continuation about the research with biomonitors to estimate the nitrogen deposition have to prove and confirm that the latter statement is correct and can be applied for the Netherlands as well.

The information that was generated by this model was thus not applicable for these farms. Based on our findings it can be concluded that no more explanations or conclusions can be related on the basis of ammonia deposition from this OPS-model.

10 DISCUSSION AMMONIA CONCENTRATIONS

The rejected results (27,5 per cent) that were obtained after the validation procedure of the RIVM was disappointing when compared to the results as presented in (Stolk *et al.,* 2009) where only 5,4 per cent was rejected. This can be partly attributed to the area where the ammonia concentrations were measured. In the natural areas where the RIVM conduct their measurements, the passive samplers were hung in the open field which implies that source of the emissions of ammonia was not present in their immediate vicinity. In contrast, the locations in the Dwingelderveld were near sources of ammonia and in front of a forest. The irregular structure of the vegetation causes more wind turbulence whereby the dispersion of ammonia in the atmosphere and the exchange of ammonia between the atmosphere and vegetation will increase (Oosterbaan *et al.,* 2006). This can lead to more fluctuation among the passive samplers in triplicate. In the natural area or as observed at location 10 (totally surrounded by forest) less wind changes occur which lead to a constant flow of air and less fluctuation among the samplers. In addition, the different people that worked with the analysis of the passive samplers also produced different results. Some people generated better results (less outliers) than others. Further to this result, the number of blank passive samplers that were rejected was 26,3 per cent. Most of the rejection occurred during May and September when the average temperature was higher and when the blanks were left in the fridge. This could be an indication of a leak during the analysis of the passive samplers due to the fact that there is no ammonia free chamber available as prescribed in (Houba *et al.,* 1989). The blanks that were left in the fridge contain cold air which shrinks. During the transfer of the steel grid from the blank into the tube with distilled water, the steel grid impregnated with sulphuric acid will be exposed for a few seconds to the ambient air. The cold air can actually pull some of the warmer ambient air downwards into the tube and it expands. In the ambient air, high concentrations of ammonia can be present which can lead to the contamination of ammonia concentrations in the blanks.

The ammonia concentrations found at the fifteen locations in the field; annually, bi-weekly and seasonally were as expected. It was expected that during February – April, when most of the manure that was stored during the winter period was applied to the fields, high ammonia concentrations would be recorded. Another peak in the ammonia concentrations was found during June – July & July. At this time there are large fluctuations in temperature and incidences of high rainfall. At this time most of the fields were cut for grass silage (end of June) and injected with slurry. The young grass is not able to recover all the ammonia in combination with the application of N. In addition, fields that were cut in the beginning of June will, after three weeks, give re-emissions of ammonia (Van Pul *et al.,* 2008). Similar observations with two ammonia peaks were found in Van Pul *et al.* (2008) during the VELD experiment, which explained the gap between calculated and measured ammonia concentrations as represented by the OPS model. At the end of September and in October some of the

locations showed an increase in the ammonia concentrations which could have been caused by re-emissions from grassland (Van Pul *et al.,* 2008).
The lowest annual ammonia concentrations were found in the natural area, at the location behind the border of trees and at location 2 & 3 on the Eastern side of the Dwingelderveld. The other locations were closer to ammonia sources and therefore expected to be higher. This was also proven by earlier studies like Torsten *et al.*,(2008) where ammonia concentrations in summer were measured around 200 µg m^3 at 5 meters from a livestock farm and that these decreased rapidly with increasing distance from the cow shed to 50 µg m^3 at 80 meter. On the farm of Mts. Duiven (I) the highest average ammonia concentrations were found which can be related to the intensity of the farm. Secondly the farm of Fam. Oostra (V) was emitted the highest average ammonia concentrations. On this farm ammonia concentrations were strongly influenced by the local contamination of feces and urine of cows which were deposited in front of location 15. The other farmers were less intensive and this can be observed from their results. Additionally, location 12 indicated as Dwingelderveld was strongly influenced by local application of N fertilizers.

The dairy farms that participated in this research were diverse in terms of land size, herd size, grazing or non-grazing and one of the important variables among the farmers was the milk urea content expressed in mg 100 g^{-1}. This variable is a very good indicator of how much N can be contributed for the emission of each farm. Because there is a linear relationship between nitrogen that is present in the urine and nitrogen present in the milk, it can be shown how much nitrogen is present in the diet of the cows and one can thus predict the ammonia volatilization potential (Burgos *et al.,* 2005). Among the farms there is a huge average variation in urea content, but also on every farm it fluctuates constantly with time. The ammonia emission from natural ventilated stables with slatted floors can increase with 2,5 per cent with an increase of 1 mg 100 g milk at a level of 20 mg urea per 100 g milk. At a level of 30 mg per 100 g milk even a 3,5 per cent increase of ammonia emission per 1 mg of 100 g milk can be expected. The mixing of slurry can cause an increase of 11 per cent and the rise of temperature outdoors with 1 °C an increase of 2,6 per cent ammonia emission (Duinkerken *et al.,* 2004). Because the urea content isn't constant over time it is difficult to relate it directly to the height of the ammonia concentrations or N deposition. Only a relative indication can be drawn from these numbers. On the two farms that grazed their cows for respectively 150 (V) and 210 (IV) days it can be expected that the emission of ammonia was reduced due to the separation of feces and urine. Whereas the feeding strategy was mostly the same among the participating farms, due to the derogation and the growth of maize on the remaining 30 per cent of the total area of the farm. Therefore, 70 per cent of the total area had to be grassland. The report by Oosterbaan *et al.* (2006) showed that in comparison to the uptake of ammonia by different vegetation, under an ammonia concentration of 10 µg m^3, grassland is the greatest receptor of ammonia with 76 per cent. Deciduous forest captured 10 per cent and arable land only 3 per cent. In another report by Galloway *et al.* (2008) it was roughly estimated that improved animal strategies would decrease the reactive nitrogen creation by about 15 Tg n yr^{-1} as a third suggested strategy to reduce Nr use or losses to the environment in the world .

The OPS-model that was used for calculation of the N deposition is integrated with a DEPAC (DEPosition of Acidifying Compounds) module to calculate the dry deposition fluxes. This module is revised, version number 3.11 (Van Zanten *et al.,* 2010) and updated with several major changes including the implementation of the compensation point (Kruit W.J., 2010).

Cited verbatim (Van Zanten *et al,* 2010): "*Due to the update of the DEPAC module, the systematic overestimation of the dry deposition velocity for ammonia above land use class grass has been reduced. This has contributed substantially towards the closure of the ammonia gap (Velders et al., 2010). Proper validation of the updated DEPAC module is hampered by the lack of dry deposition measurements. Up till now most deposition measurements are used to construct the deposition parameterization itself and as such cannot be used for validation. The uncertainty in the local dry deposition velocity is estimated to be a factor two. This is an educated guess and further research is a prerequisite to specify the uncertainty more accurately. Both a validation study as well as an uncertainty analysis is planned for the near future".*

In Velders *et al.* (2010) it was concluded that for the OPS model, updated with the deposition parameterization, the ammonia gap still remains at about 10 per cent, while previously it was about 25 per cent. Having an uncertainty in the ammonia concentrations of 7 per cent, the current difference between the measured and the modeled is no longer significant. The applied correction procedure of the modeled concentrations will remain and future changes of the OPS model will be less sensitive to the calculated concentration of the total deposition. Therefore, it would be almost impossible to simulate local ammonia concentrations spatially by models. This is also due to the fact that ammonia is lighter than air and is very sensitive to local conditions, e.g. vegetation. The deposition module DEPAC uses nine land use classes; (1) grass, (2) arable land, (3) permanent crops, (4) coniferous forest, (5) deciduous forest, (6) water, (7) urban, (8) other, i.e. short grassy area and (9) desert (Van Zanten *et al.,* 2010). The non-vascular plants are not included and as mentioned in the biomonitors section, are very vulnerable to low concentrations of ammonia. Particularly, certain varieties of mosses cannot exist in an environment with high ammonia concentrations. Once the ammonia-adverse mosses have been in contact with high ammonia concentrations they cannot be used as a bioindicator of ammonia reduction anymore during a decrease of the ammonia load. These ammonia adverse species indicate that some developments are irreversible, thus once the damage is caused by ammonia, it cannot be restored (Herk, 2011). There are also varieties of mosses that are well adapted to high ammonia concentrations and have an explosive growth, which indicates that a distinction has to be made among the different varieties of mosses to come up with a relation between the existence of mosses and height of ammonia concentrations. Recently research showed that even with high ammonia concentrations mosses are not negatively affected. The moss growth is limited by a low N:P and N:C ratio, whereby a low carbon rate accelerates the decomposition of moss (Armitage *et al.,* 2012). Another exclusion that this model has is that specific obstacles like windshields, buildings and borders of trees are not integrated. The border of trees predominantly present on the North & North-West side of the Dwingelderveld will act as a kind of barrier to prevent an influx of ammonia to the Natura 2000 site (Verhagen *et al.,* 2006) and it is therefore very important to maintain biodiversity at these adjacent locations.

11 RECOMMENDATIONS AMMONIA CONCENTRATIONS

- ✓ Nitrogen concentrations found in the dry matter of the mosses is a very suitable method to indicate the influence of ammonia concentrations, which is limited by the presence of phosphorus (P) and carbon (C). Continuation of this research should include measurements of N, C, P and vitality checks from mosses (active raised bogs) which are present in the natural site.

- ✓ Four (farms II, III, IV and V) of the participating farms were located near a border of trees, where the other farm (I) was located further away from this boundary. For further research it would be interesting to include a farm that is located on the South side of a natural area, but without these boundaries but rather with an "open area" to show the impact of such wind barriers.

- ✓ It could have been useful to make a calculation of the N-efficiency for the farms that participated in this research to ascertain a more accurate relation between the height of the ammonia concentrations and N deposition.

- ✓ In this research the performed measurements were evaluated with the OPS-model, which included an overestimation of the dry deposition velocity. It could be useful to make use of another model named AERIUS which is the most recent instrument in calculating N deposition. However this model is still under development as part of PAS.

- ✓ Consider the use of N-free chamber for analyzing the passive samplers to reduce the risk of contamination from ambient ammonia in the laboratory.

- ✓ The monitoring network of ammonia measurements (receptors) as it was presented now have to be intensified. The area Kliploo "North-West of Dwingelderveld" should be examined.

12 CONCLUSION | EN |

The results which are represented in this thesis provide an answer to the main and sub-questions which were compiled in the beginning of this report. The Main question is “Is the Dwingelderveld really as negatively affected by the N-deposition as calculated by Alterra?”

The biomonitors show a very clear pattern that most of the nitrogen was deposited near the farms. The level of nitrogen deposition was mainly influenced by the intensity of the farms. The four dairy farms that are located on the North side of the Dwingelderveld had detectable nitrogen deposition within 50 meter from the farms. The other farm of Mts. Duiven (I) had detectable nitrogen deposition up to 400 meter on the South side of the farm. The prevailing wind direction was North- Northwest during the exposure period of the spring barley. There was no nitrogen deposition found in the spring barley in the vulnerable areas and in the locations that which were located further away from the farms.

The spatial pattern of the ammonia concentrations indicate the same trend. Ammonia concentrations were measured on the following farms listed in order from the highest to the lowest; Mts. Duiven (I), Fam. Oostra (V), Fam. Van Unen (II), Fam. Daatselaar (III) and Fam. Ter Wal (IV). These values were influenced by the intensity of the farms, but also by the farm characteristics, such as the urea content of the milk and grazing management of animals. The seasonal pattern of the relative measured ammonia concentrations decreased significantly from 12 µg m^3 in the period February – March 2011 to 4 µg m^3 in December 2011 & January 2012. It was also found that during the measurement with the nitrogen poor spring barley plants, no ammonia was taken up by the stomata of the spring barley beneath the concentrations of 14.5 µg m^3, the so-called compensation point. This concentration was derived from the relative measured ammonia concentrations where the biomonitors were located and the measured nitrogen content in the spring barley plants. Approximately 75 per cent of the relative measured ammonia concentrations were below this critical concentration. The prevailing wind direction was mainly Southerly in 2011.

The OPS-model that was developed by the RIVM and used by Alterra to simulate the nitrogen deposition on the area contains an overestimation of the dry deposition velocity and does not include the implementation of a crop compensation point. These errors result in a seemingly negative impact of the farmers in relation to the adjacent Natura 2000 site. In addition, the study by Alterra did not measure the critical deposition loads which are put on vulnerable vegetation with bioindicators.

Mosses are non-vascular plants and are capable of absorbing ammonia even at low concentrations and therefore these plants should be investigated in the Dwingelderveld. In addition, a closer monitoring network of ammonia receptors should be established to assess the function of border of trees in detail whereas in this research the vicinity of the vulnerable was only highlighted.

A clear answer can be given to the main- and sub questions. The farms that participated in this research on the North side of the Dwingelderveld do not contribute to the nitrogen deposition at the Natura 2000 site, Dwingelderveld. The intensity of the farm businesses has a particularly large influence on the ammonia concentrations around the dairy farms. The remaining ammonia produced is absorbed by the atmosphere and contributes to nitrogen deposition on a global level rather than on a local level. The urea content in the milk is a very useful tool to use as an indicator in order to reduce the emission of ammonia. Observation of these participating farms showed that much progress in the reduction of emissions can be achieved by lowering the input of nitrogen at farm level. Specific influences like 70 per cent of grassland, wind direction and a border of trees had a positive effect on reducing the dispersion of ammonia. Thus the initial hypothesis can be confirmed.

Hopefully this research provides a first step towards an improved connection between farmers and nature organizations which currently act separately. Collaboration would give a win-win situation for both parties.

13 CONCLUSIE | NL |

De resultaten van dit onderzoek geven een antwoord op de hoofd- en deelvragen die in het begin van dit onderzoeksverslag zijn opgesteld. Hoofdvraag: is het Dwingelderveld wel zo negatief beïnvloed door de stikstof depositie als is berekend door Alterra.

De biomonitoren laten een heel duidelijk patroon zien dat naast het melkveebedrijf de meeste stikstof depositie plaats vindt. De grootte van de stikstof deposities voornamelijk beïnvloed door de intensiteit van de bedrijven. Bij de vier melkveebedrijven aan de noordkant van het Dwingelderveld is tot aan 50 meter van de bedrijven stikstof depositie gemeten. Bij het bedrijf van Mts. Duiven. gelegen aan de noordwest kant van het Dwingelderveld, is tot 400 meter van de zuidkant van het melkveebedrijf stikstofdepositie bevonden, rekening houdend met de voornamelijk noord – noordwesten wind tijdens deze periode. Bij de gevoelige gebieden in het Dwingelderveld en op verdere gemeten afstanden van de melkveebedrijven vond geen gemeten stikstofdepositie plaats in de zomergerst die gekenmerkt wordt als vaatplant.

Het ruimtelijke patroon van de ammoniak concentraties geeft hetzelfde beeld aan. Ammoniak concentraties zijn van hoog naar laag gemeten bij: Mts. Duiven (I), Fam. Oostra (V), Fam. Van Unen (II), Fam. Daatselaar (III) en Fam. Ter Wal (IV). Deze ammoniak waarden worden bepaald door intensiteit, maar ook door bedrijfsspecifieke eigenschappen zoals beweiden en het ureum niveau. Het seizoensverloop van de relatief gemeten ammoniak concentraties was sterk aflopend; 12 $\mu g\ m^3$ in het begin van 2011 tot 4 $\mu g\ m^3$ aan het eind van 2011 – begin 2012. Ook is gebleken dat tijdens deze potproef de stikstofarme gerstplanten geen ammoniak meer opnamen beneden een omgevingsconcentratie van 14.5 $\mu g\ m^3$, het zogenaamde compensatiepunt. Het compensatiepunt is afgeleid van de relatief gemeten ammoniak concentraties bij de verschillende locaties van de biomonitors en de gemeten stikstof in de zomergerst. Van de relatief gemeten ammoniak waarden lagen 75 procent onder deze kritische concentratie. De meest voorkomende windrichting was “zuidelijk” met 190 graden over 2011.

Het OPS-model dat is ontwikkeld door het RIVM en vooral gebruikt wordt door Alterra om de omvang van de stikstofdepositie te simuleren in een bepaald gebied bevat een overschatting van de droge depositie snelheid en mist de implementatie van het gewas compensatiepunt. Hierdoor wordt een negatieve invloed van deze bedrijven op aanliggende natuurgebieden ten onrechte gesuggereerd. Daarnaast zijn de kritische depositiewaarden die door het Alterra zijn aangeven op een bepaald gewas nooit nagemeten met behulp van bioindicatoren.

Mossen staan bekend als niet vaatplanten en kunnen ammoniak opnemen bij zelfs lage ammoniak waarden en zullen dus onderzocht moeten worden in het aanliggende natuurgebied. Daarnaast zal er een dichter meetnetwerk opgezet moeten worden om de invloed van de bosrand nader te bekijken. Nu is vooral in de omgeving van de kwetsbare vegetatie gemeten aan de rand van het Dwingelderveld.

Op de hoofd en deelvragen kan dus een eenduidig antwoord gegeven worden. Er is geen invloed op het gebied van stikstof depositie door de bedrijven liggend aan de noordkant van het Natura 2000 gebied Dwingelderveld. De omvang van de bedrijven heeft vooral een grote invloed op de ammoniak concentraties rondom het melkveebedrijf. Overige geproduceerde ammoniak wordt opgenomen in de atmosfeer en draagt bij aan de hoeveelheid stikstof op wereldniveau en niet op lokaal niveau. Met het ureum gehalte in de melk hebben de boeren een goed instrument in handen om de emissies van ammoniak te verlagen. Gekeken naar deze deelnemende bedrijven kan hier nog veel voordeel mee behaald worden. Specifieke invloeden zoals de oppervlakte grasland, windrichting en de bomenrij aan de rand van het natuurgebied hebben een positieve invloed op het tegengaan van de verspreiding van ammoniak en daarmee de stikstof depositie.

Hopelijk biedt dit onderzoek een eerste stap naar de verweving van landbouw en natuur die nu toch op afstandelijke voet van elkaar staan. Samenwerking zou voor beide partijen een win-win situatie betekenen.

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Appendix I Biomonitor experiment

Performed by: Dr. Ir. Egbert Lantinga (OFS chair group; supervisor), Geurt Versteeg (Unifarm; nutrient solution), Frans Bakker (Unifarm, executor experiment), Hennie Halm (BFS chair group, chemical analyst) and Janklaas Santing (MSc student, thesis)

Start biomonitor: Wednesday 6 April
Preparation of 100 (10 L) pots with rockwool (12 L/pot) and seeds (25 seeds/pot).
Added: 3,5 L N-free, and 0,5 L (400 mg/L N)
Location: Unifarm greenhouse, only covered roof

I.A. Description of seed used for biomonitor

NAK Netherlands; Certified seed; variety: spring barley *Hordeum vulgare*; breed: NFC TIPPLE; Batch nr: 950875-15; Sealed: 11-2009; Grown in: NL; Rating: |; Disinfected: 95 – 100%; Dkg: 55 g.

I.B. Irrigation scheme

13 April: foil is removed to protect the pots from dehydration.
19 April: 2 L N-free, and remaining 0,5 L (400 mg/L N) is added.
29 April: 2 L N-free was added to these 22 pots. Dwingelderveld: 3 L/ 78 pots N-free.
9 May: 2,5 L/ 78 pots N-free
10 May: 1 L/ 22 pots N-free
18 May: 2 L/ 22 pots N-free
23 May: 2 L/ 78 pots N-free
24 May: 1 L/ 22 pots N-free
3 June: 2 L/ 100 pots N-free
13 June: 3 L/ 78 pots N-free
16 June 1 L/22 pots N-free
Total gift: Dwingelderveld: 18 L N-free & 1 L N (800 mg/L N).
Total gift: Veenkampen: 14,5 L N-free & 1 L N (800 mg/L N).

I.C. Notes during experiment

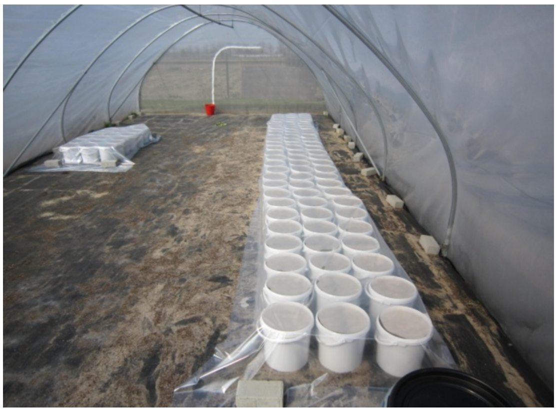
20 April: 78 pots were placed at the location of the 5 farms and natural site, Dwingelderveld.
21 April: Remaining 22 pots were placed outside the greenhouse (fenced with nets). These pots were placed at 29th of April at the location Meteorological field Veenkampen, Wageningen.
4 & 5 May: temperature -0°C; damaging of plants
9 May: Frost damage was clearly seen on part of the 78 plants in Dwingelderveld.
18 May: Egbert Lantinga and J.K. Santing have looked at the condition of the 22 plants at Veenkampen. Some plants were spotted with leaf spot disease, no action.
31 May: Location 12 (Natural reserve Dwingelderveld); a leaf of the spring barley was eaten.
21 June: Egbert Lantinga, Frans Bakker and J.K. Santing together have checked the condition of the 22 plants at Veenkampen. There has been agreed to stop adding nutrient solution.
30 June: All 78 pots were retrieved from Dwingelderveld. Location 12 was destroyed by cows, cannot be used for research anymore.
1 July: All 22 pots were retrieved from Veenkampen, Wageningen.

Appendix II Coordinates Biomonitors

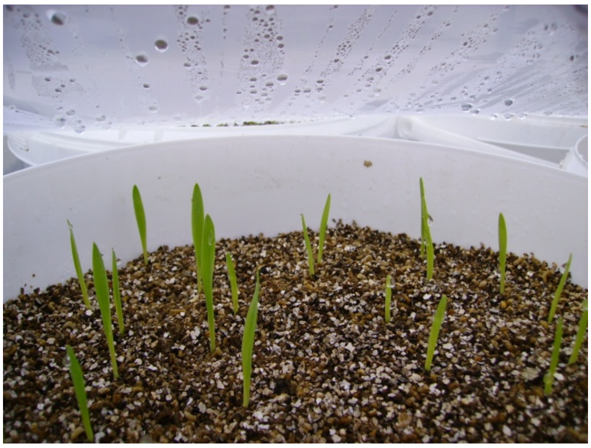
Location/ coordinates	DD.dddddd°	DD°MM.mmm'	DD°MM'SS.s"	X Y
Oostra 0 mtr	52.83899, 6.46968	N 52 50.339, E 6 28.181	N 52 50 20.4, E 6 28 10.8	X 227943 Y 539641
Oostra 90 mtr	52.83906, 6.46840	N 52 50.344, E 6 28.104	N 52 50 20.6, E 6 28 6.2	X 227855 Y 539639
Oostra 190 mtr	52.84129, 6.46984	N 52 50.477, E 6 28.19	N 52 50 28.6, E 6 28 11.4	X 227944 Y 539855
Ter Wal 320 mtr water	52.84097, 6.45860	N 52 50.458, E 6 27.516	N 52 50 27.5, E 6 27 31	X 227186 Y 539833
Ter Wal 340 mtr forest	52.83841, 6.45717	N 52 50.305, E 6 27.43	N 52 50 18.3, E 6 27 25.8	X 227094 Y 539557
Ter Wal 750 mtr nature	52.83580, 6.45936	N 52 50.148, E 6 27.562	N 52 50 8.9, E 6 27 33.7	X 227295 Y 539211
Ter Wal 400 mtr	52.83700, 6.45449	N 52 50.22, E 6 27.269	N 52 50 13.2, E 6 27 16.2	X 226926 Y 539388
Ter Wal 600 mtr	52.83556, 6.45588	N 52 50.134, E 6 27.353	N 52 50 8, E 6 27 21.2	X 227018 Y 539231
Ter Wal 0 mtr	52.84087, 6.45308	N 52 50.452, E 6 27.185	N 52 50 27.1, E 6 27 11.1	X 226816 Y 539826
Ter Wal 90 mtr horse	52.84069, 6.45177	N 52 50.441, E 6 27.106	N 52 50 26.5, E 6 27 6.4	X 226731 Y 539804
Daatselaar 50 mtr	52.84095, 6.44026	N 52 50.457, E 6 26.416	N 52 50 27.4, E 6 26 24.9	X 225938 Y 539820
Daatselaar 0 mtr	52.84166, 6.44008	N 52 50.5, E 6 26.405	N 52 50 30, E 6 26 24.3	X 225928 Y 539905
Daatselaar 170 mtr	52.84190, 6.43679	N 52 50.514, E 6 26.207	N 52 50 30.8, E 6 26 12.4	X 225713 Y 539919
Van Unen 0 mtr	52.84645, 6.43333	N 52 50.787, E 6 26	N 52 50 47.2, E 6 25 60	X 225473 Y 540427
Van Unen 50 mtr	52.84585, 6.43331	N 52 50.751, E 6 25.999	N 52 50 45.1, E 6 25 59.9	X 225462 Y 540372
Duiven 100 mtr South-East	52.83441, 6.41194	N 52 50.065, E 6 24.716	N 52 50 3.9, E 6 24 43	X 224069 Y 539060
Duiven 400 mtr South-East	52.83233, 6.41408	N 52 49.94, E 6 24.845	N 52 49 56.4, E 6 24 50.7	X 224216 Y 538823
Duiven 200 mtr South-East	52.83328, 6.41149	N 52 49.997, E 6 24.689	N 52 49 59.8, E 6 24 41.4	X 223997 Y 538920
Duiven 300 mtr South-East	52.83275, 6.41285	N 52 49.965, E 6 24.771	N 52 49 57.9, E 6 24 46.3	X 224114 Y 538865
Duiven 0 mtr West	52.83491, 6.40898	N 52 50.095, E 6 24.539	N 52 50 5.7, E 6 24 32.3	X 223840 Y 539113
Duiven 100 mtr South-West	52.83490, 6.40743	N 52 50.094, E 6 24.446	N 52 50 5.6, E 6 24 26.7	X 223750 Y 539118
Duiven 200 mtr South-West	52.83488, 6.40603	N 52 50.093, E 6 24.362	N 52 50 5.6, E 6 24 21.7	X 223650 Y 539115
Duiven 400 mtr West	52.83704, 6.40462	N 52 50.222, E 6 24.277	N 52 50 13.3, E 6 24 16.6	X 223561 Y 539357
Duiven 0 mtr East	52.83562, 6.41050	N 52 50.137, E 6 24.63	N 52 50 8.2, E 6 24 37.8	X 223955 Y 539206
Duiven 80 mtr North-East	52.83622, 6.41127	N 52 50.173, E 6 24.676	N 52 50 10.4, E 6 24 40.6	X 224003 Y 539253
Duiven 400 mtr North	52.83925, 6.40685	N 52 50.355, E 6 24.411	N 52 50 21.3, E 6 24 24.7	X 223788 Y 539602
De Veenkampen, Wageningen			N 51 58 53.2, E 5 37 17.6	

Appendix III Pictures of biomonitor experiment 2011

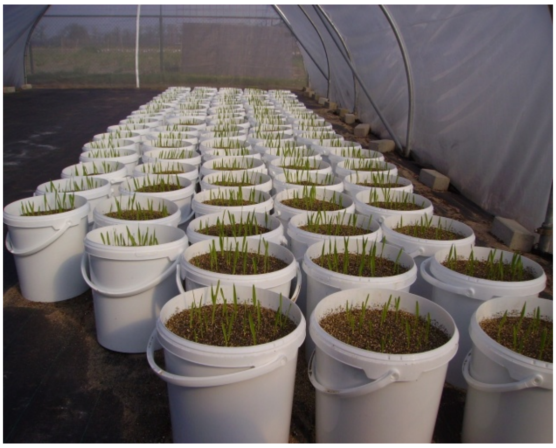
Start 6 of April | Open greenhouse



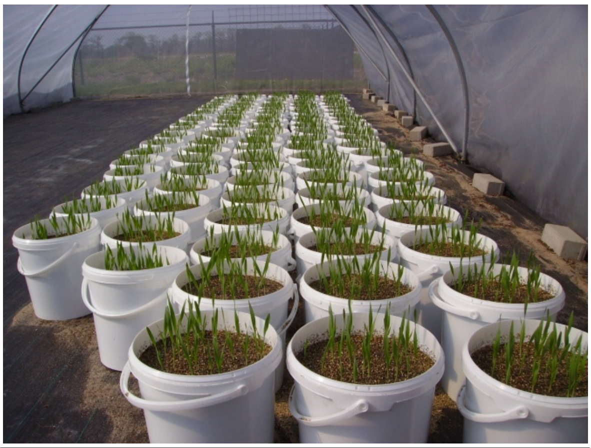
Start: pots prepared, covered with foil



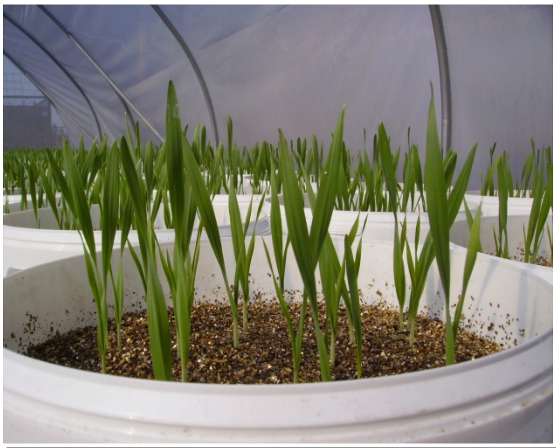
12th of April, 1st growing stage



15th of April



18th of April



18th of April

18th of May Veenkampen, Wageningen

18th of May Leaf spot disease observed

13th of June Fam. P. Daatselaar 0 meter

13th of June Fam. P. Daatselaar 50 mtr.

13th of June Fam. P. Daatselaar 170 meter

13th of June Fam. A. Oostra 0 meter

13th of June Fam. A. Oostra 90 meter

13th of June Fam. A. Oostra 170 meter

13th of June Fam. M. ter Wal 0 meter

13th of June Fam. M. ter Wal 90 meter

13th of June Fam. M. ter Wal 320 meter

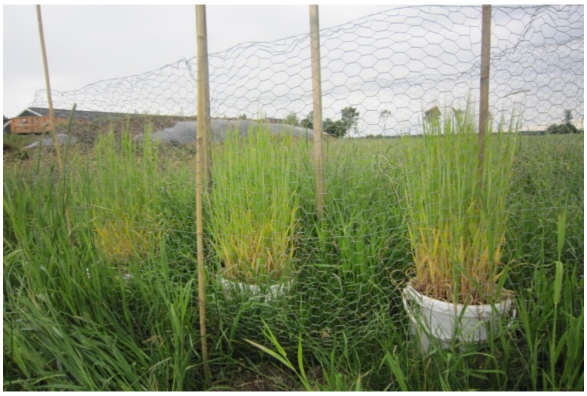
13th of June Fam. M. ter Wal 340 meter

13th of June Fam. M. ter Wal 400 meter

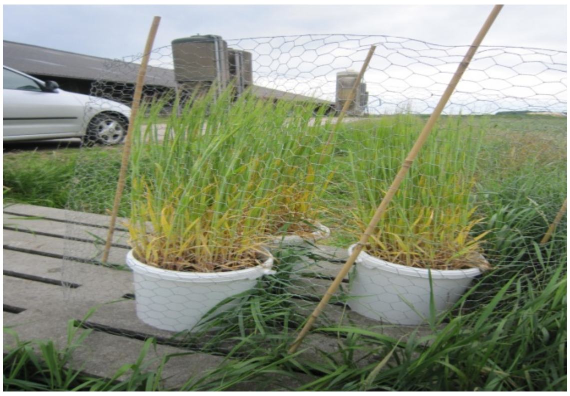
13th of June Fam. M. ter Wal 600 meter

13th of June Dwingelderveld 750 meter

13th of June Fam. B. van Unen 0 meter



13th of June Fam. B. van Unen 50 meter



13th of June Mts Duiven 0 meter East

13th of June Mts Duiven 80 meter East

13th of June Mts Duiven 400 mtr North

13th of June Mts Duiven 100 mtr South

13th of June Mts Duiven 200 mtr South

13th of June Mts Duiven 300 mtr South

13th of June Mts Duiven 400 mtr South

13th of June Mts Duiven 0 meter West

13th of June Mts Duiven 100 meter West

13th of June Mts Duiven 200 meter West

13th of June Mts Duiven 400 mtr North-west

Appendix IV Overview absolute N from biomonitors

Overview absolute N (gram N/pot/location)			
Barn 0 mtr A. Oostra	0,98	200 mtr South side Mts. Duiven	0,72
Barn 0 mtr A. Oostra	0,89	200 mtr South side Mts. Duiven	0,68
Barn 0 mtr A. Oostra	0,86	200 mtr South side Mts. Duiven	0,73
90 mtr A. Oostra	*0,54*	300 mtr South side Mts. Duiven	0,76
90 mtr A. Oostra	*0,55*	300 mtr South side Mts. Duiven	*0,60*
90 mtr A. Oostra	*0,69*	300 mtr South side Mts. Duiven	*0,68*
190 mtr A. Oostra	0,68	Barn 0 mtr West side Mts. Duiven	0,62
190 mtr A. Oostra	0,68	Barn 0 mtr West side Mts. Duiven	*0,84*
190 mtr A. Oostra	0,64	Barn 0 mtr West side Mts. Duiven	0,69
Waterfall 320 mtr M. ter Wal	0,69	100 mtr West side Mts. Duiven	0,71
Waterfall 320 mtr M. ter Wal	0,65	100 mtr West side Mts. Duiven	*0,54*
Waterfall 320 mtr M. ter Wal	0,68	100 mtr West side Mts. Duiven	*0,66*
First nature strip 340 mtr M. ter Wal	0,58	200 mtr West side Mts. Duiven	0,59
First nature strip 340 mtr M. ter Wal	*0,54*	200 mtr West side Mts. Duiven	0,61
First nature strip 340 mtr M. ter Wal	0,62	200 mtr West side Mts. Duiven	*0,63*
Natura 2000 Dwingelderveld *(plant material -*	X	400 mtr North-West Mts. Duiven	0,68
Natura 2000 Dwingelderveld *eaten by cows)*	X	400 mtr North-West Mts. Duiven	0,67
Natura 2000 Dwingelderveld	X	400 mtr North-West Mts. Duiven	0,55
Middle nature strip 400 mtr M. ter Wal	0,42	Stal 0 mtr East side Mts. Duiven	0,91
Middle nature strip 400 mtr M. ter Wal	0,59	Stal 0 mtr East side Mts. Duiven	0,82
Middle nature strip 400 mtr M. ter Wal	0,62	Stal 0 mtr East side Mts. Duiven	1,05
Rear end nature strip 600 mtr M. ter Wal	0,66	80 mtr East side Mts. Duiven	0,94
Rear end nature strip 600 mtr M. ter Wal	0,71	80 mtr East side Mts. Duiven	0,91
Rear end nature strip 600 mtr M. ter Wal	0,66	80 mtr East side Mts. Duiven	0,86
Barn 0 mtr M. ter Wal	0,90	400 mtr North side Mts. Duiven	0,70
Barn 0 mtr M. ter Wal	0,73	400 mtr North side Mts. Duiven	0,65
Barn 0 mtr M. ter Wal	0,78	400 mtr North side Mts. Duiven	0,65
Horse 90 mtr M. ter Wal	0,66	Order of left to right; bottom row - top row	0,69
Horse 90 mtr M. ter Wal	0,69	Meteoveld (Veenkampen Wageningen)	0,59
Horse 90 mtr M. ter Wal	0,66	Meteoveld (Veenkampen Wageningen)	0,73
Sheep 50 mtr P. Daatselaar	0,62	Meteoveld (Veenkampen Wageningen)	0,67
Sheep 50 mtr P. Daatselaar	*0,50*	Meteoveld (Veenkampen Wageningen)	0,61
Sheep 50 mtr P. Daatselaar	X	Meteoveld (Veenkampen Wageningen)	0,70
Barn 0 mtr P. Daatselaar	0,78	Meteoveld (Veenkampen Wageningen)	0,68
Barn 0 mtr P. Daatselaar	0,76	Meteoveld (Veenkampen Wageningen)	0,69
Barn 0 mtr P. Daatselaar	0,75	Meteoveld (Veenkampen Wageningen)	0,66
170 mtr P. Daatselaar	0,66	Meteoveld (Veenkampen Wageningen)	0,68
170 mtr P. Daatselaar	0,68	Meteoveld (Veenkampen Wageningen)	0,64
170 mtr P. Daatselaar	0,73	Meteoveld (Veenkampen Wageningen)	0,69
Barn 0 mtr Fam. Van Unen	0,88	Meteoveld (Veenkampen Wageningen)	0,64
Barn 0 mtr Fam. Van Unen	0,94	Meteoveld (Veenkampen Wageningen)	0,76
Barn 0 mtr Fam. Van Unen	0,90	Meteoveld (Veenkampen Wageningen)	0,78
50 mtr silage heap Fam. Van Unen	0,70	Meteoveld (Veenkampen Wageningen)	0,72
50 mtr silage heap Fam. Van Unen	0,67	Meteoveld (Veenkampen Wageningen)	0,64
50 mtr silage heap Fam. Van Unen	0,70	Meteoveld (Veenkampen Wageningen)	0,77
400 mtr South side Mts. Duiven	0,64	Meteoveld (Veenkampen Wageningen)	0,66
400 mtr South side Mts. Duiven	0,74	Meteoveld (Veenkampen Wageningen)	0,68
400 mtr South side Mts. Duiven	0,71	Meteoveld (Veenkampen Wageningen)	0,69
100 mtr South side Mts. Duiven	0,75	Meteoveld (Veenkampen Wageningen)	0,69
100 mtr South side Mts. Duiven	0,77	** Color yellow: source emission N*	
100 mtr South side Mts. Duiven	0,81	** Color Blue: wet pots*	

Appendix V Input nitrogen of biomonitor

Input N rockwool

Rockwool	Gram	% N	g N/ pot start
12 L	*1274*	0,0046	0,058
12 L	*1262*	0,0026	0,032
Mean	1268	0,0036	**0,045**

Explanation weight of 12 L rockwool in gram			
Bucket (g)	*12 L of rockwool*	*Total (12 L in g - bucket g)*	
531	*1793*		***1262***
Measuring cup	*1 L steenwol*	* 12 L	*Totale 12 L in g*
455	*562*	*106*	***1274***

Input N seeds (*Hordeum vulgare L.)*

Seeds	Gram	% N	g N/ pot start
25 seeds	1,30	0,69	0,009
25 seeds	1,25	0,68	0,009
25 seeds	1,22	0,66	0,008
Mean:	1,26	0,68	**0,008**

Input N nutrient solution

N fertilizer input		**If 40% denitrification*
Mg N/ L/ pot	Gram N/ L/ pot	*Gram N/ L/pot*
800	**0,8**	*0,44*

Total input N in gram per pot

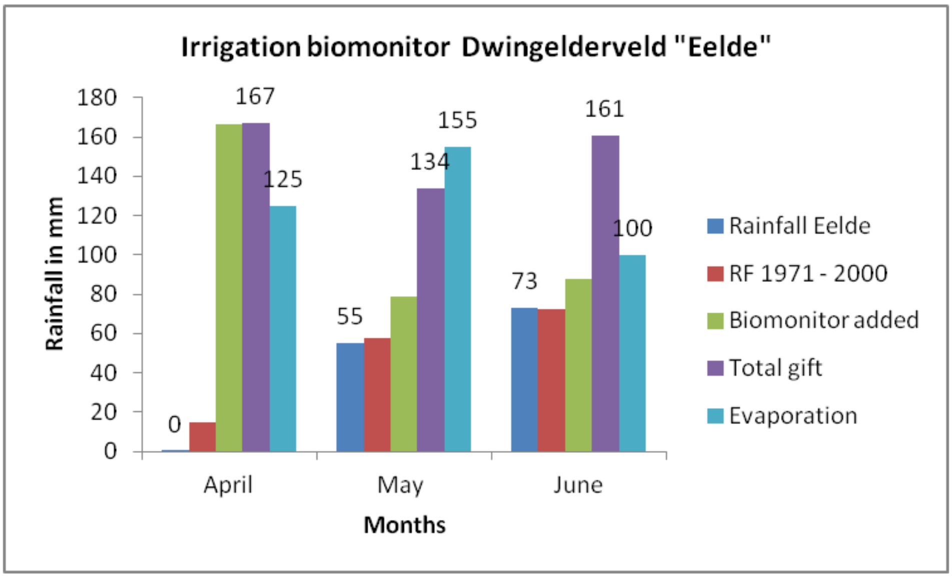
Total input N	g N / pot
Rockwool	0,045
Seeds spring barley	0,008
N fertilizer	0,800
Total N added per pot	**0,854**

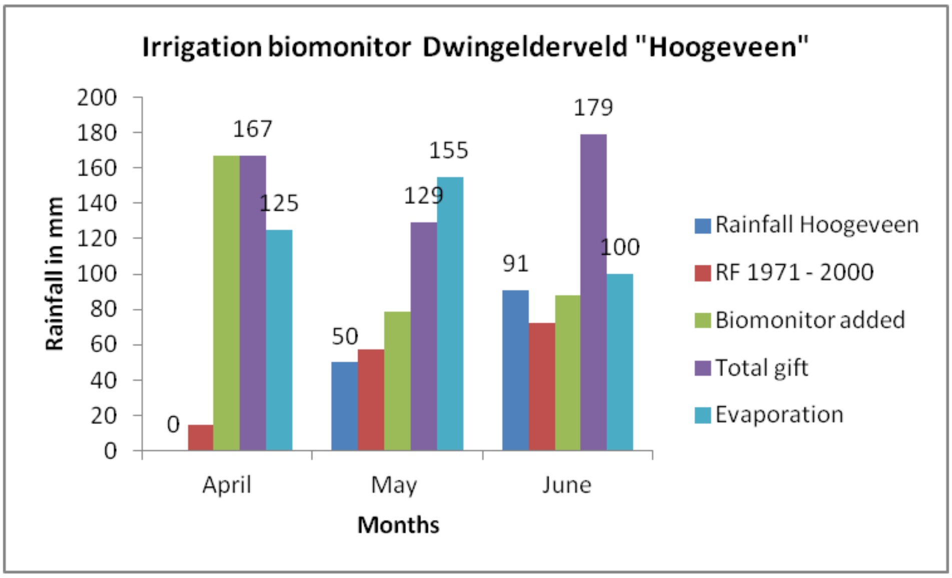
Appendix VI Total N and mean NH_3 concentration per location

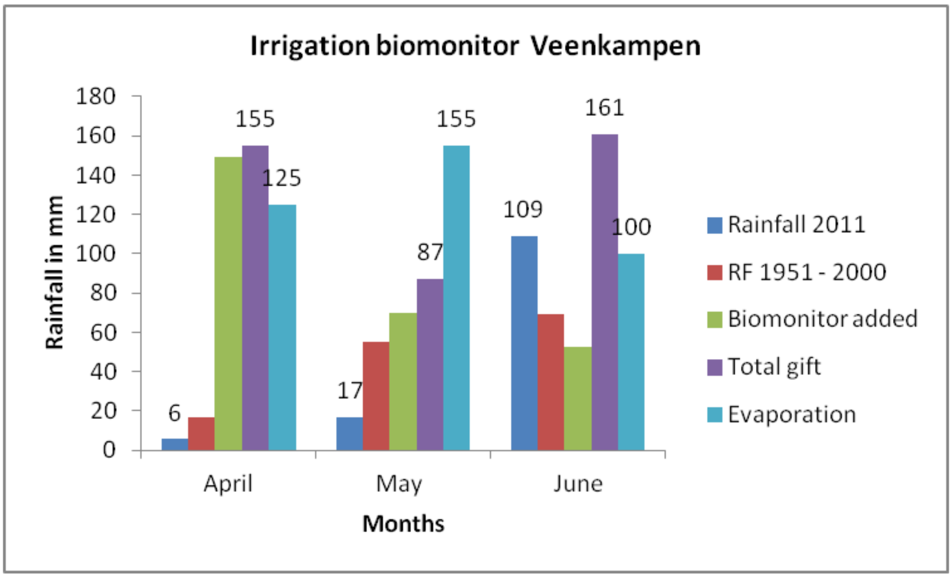
Location	Mean total N	Mean NH3 concentration
Oostra 0 mtr East side	0,91	X
Oostra 90 mtr East side	0,69	15
Oostra 190 mtr North side	0,67	11
Ter Wal 0 mtr West side	0,80	X
Ter Wal 90 mtr West side	0,67	12
Ter Wal 320 mtr East side	0,67	10
Ter Wal 340 mtr South side	0,60	8
Ter Wal 400 mtr South side	0,61	8
Ter Wal 600 mtr South side	0,68	9
Dwingelderveld 750 mtr South	X	7
Daatselaar 0 mtr East side	0,76	X
Daatselaar 50 mtr East side	0,62	8
Daatselaar 170 mtr West side	0,69	12
Van Unen 0 mtr East side	0,91	X
Van Unen 50 mtr South East	0,69	12
Duiven 100 mtr South side	0,78	17
Duiven 200 mtr South side	0,72	X
Duiven 300 mtr South side	0,72	X
Duiven 400 mtr South side	0,70	X
Duiven 0 mtr West side	0,72	X
Duiven 100 mtr West side	0,69	X
Duiven 200 mtr West side	0,61	X
Duiven 400 mtr North West	0,67	X
Duiven 0 mtr East side	0,93	X
Duiven 80 mtr East side	0,90	X
Duiven 400 mtr North side	0,67	X
Veenkampen Wageningen	0,69	13

**X appears if there no values of total N or NH_3 at this location*

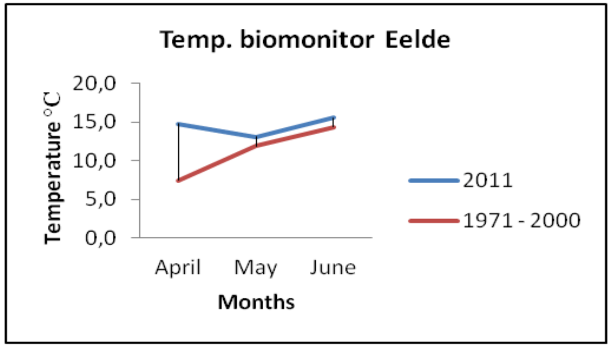
Appendix VII Irrigation of biomonitors

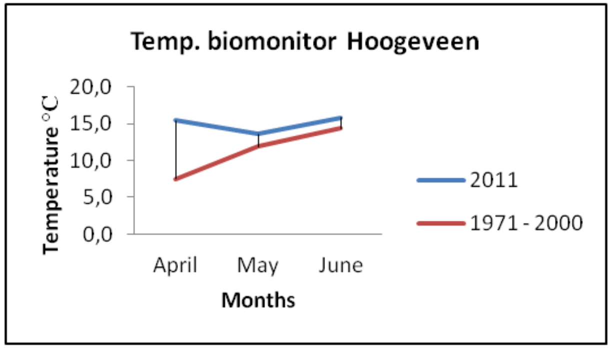


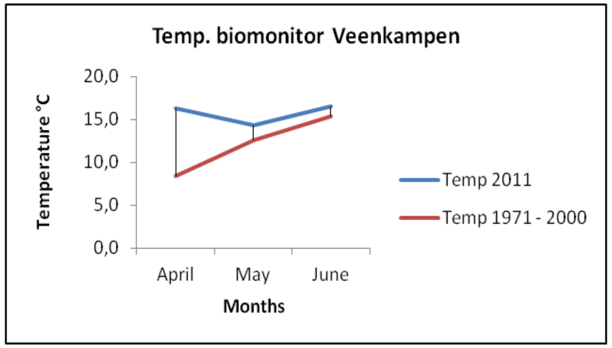


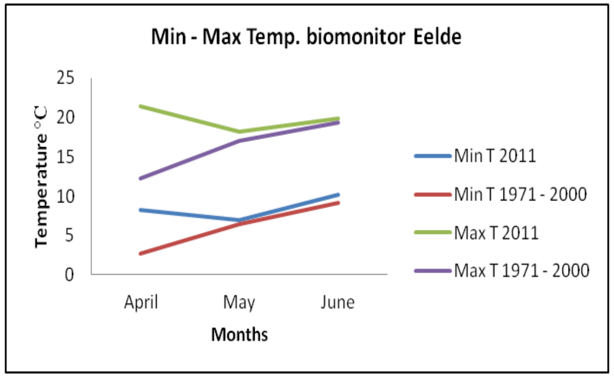


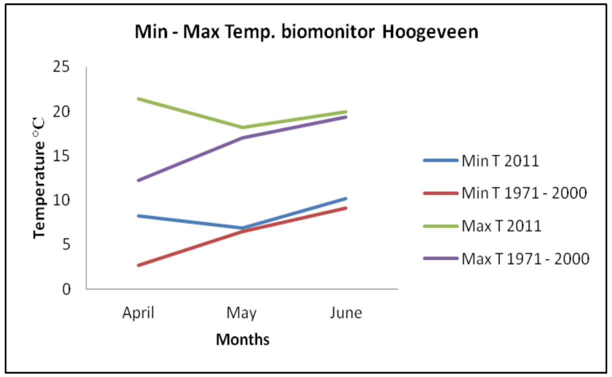
Appendix VIII Meteorological data biomonitor

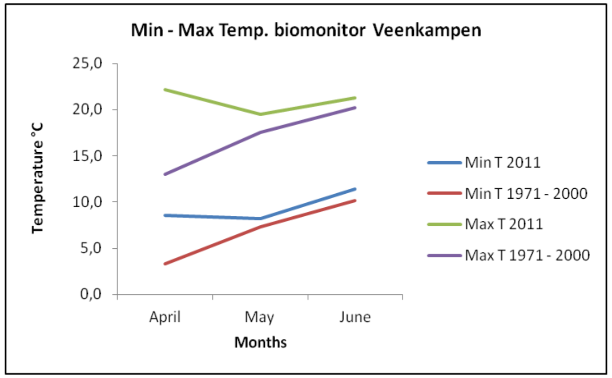


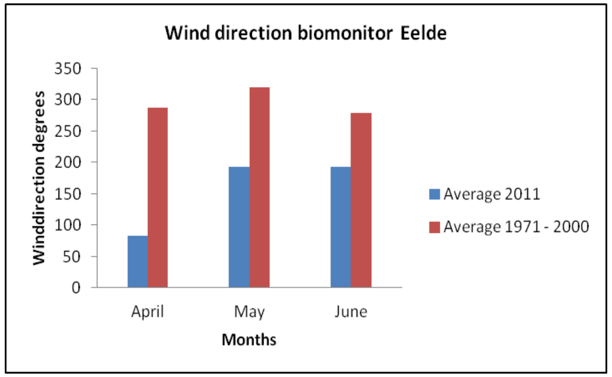


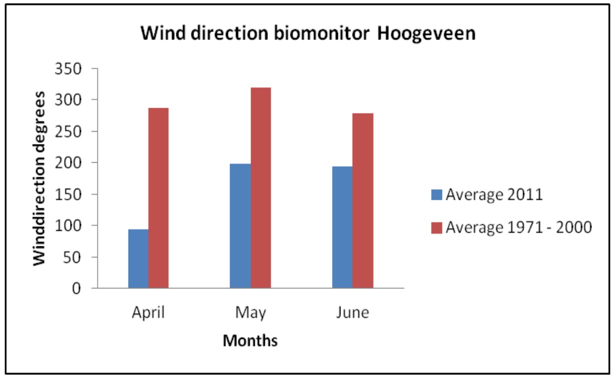


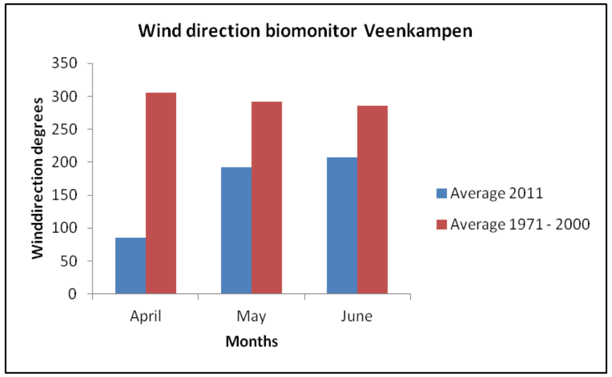












Appendix IX Schedule collecting and measuring absorbers

Measurement	*Month*	*Week*	*Day*	*Notes*
	February	5	1	Start 1st experiment
1	February	7	15	Collecting data
	February	7	16	H. Halm analyze
	February	8	22	Start 2nd exp.
2	March	10	8	Collecting data
	March	10	9	H. Halm analyze
	March	10	10	Start 3rd exp.
3	March	12	24	Collecting data
	March	12	25	H. Halm analyze
	March	13	28	Start 4th exp.
4	April	15	11	Collecting data
	April	15	12	H. Halm analyze
	April	15	13	Start 5th exp.
5	April	17	27	Collecting data
	April	17	28	H. Halm analyze
	April	17	29	Start 6th exp.
6	May	19	13	Collecting data
	May	20	16	H. Halm analyze
	May	20	17	Start 7th exp.
7	May	22	31	Collecting data
	June	22	1	H. Halm analyze
	June	22	3	Start 8th exp.
8	June	24	17	Collecting data
	June	25	20	H. Halm analyze
	June	25	20	Start 9th exp.
9	July	27	4	Collecting data
	July	27	5	H. Halm analyze
	July	27	9	Start 10th experiment
10	July	29	23	Collecting data
	July	30	25	H. Halm analyze
	July	30	27	Start 11th exp.
11	August	32	10	Collecting data
	August	32	11	H. Halm analyze
	August	32	12	Start 12th exp.
12	August	34	26	Collecting data
	August	35	29	H. Halm analyze
	August	35	30	Start 13th experiment
13	September	37	13	Collecting data
	September	37	14	H. Halm analyze

Measurement	***Month***	***Week***	***Day***	***Notes***
	September	37	19	Start 14th exp.
14	October	40	03	Collecting data
	October	40	04	H. Halm analyze
	October	40	05	Start 15th exp.
15	October	42	19	Collecting data
	October	42	20	H. Halm analyze
	October	43	24	Start 16th exp.
16	November	46	14	Collecting data
	November	46	15	H. Halm analyze
	November	46	16	Start 17th exp.
17	December	49	7	Collecting data
	December	49	8	H. Halm analyze
	December	49	9	Start 18th exp.
18	December	51	23	Collecting data
	December	52	28	H.Halm analyze
	December	52	29	Start 19th exp.
19	December	2	12	Collecting data
	December	2	16	H.Halm analyze
	December	3	16	Start 20th exp.
20	December	5	30	Collecting data
	December	5	31	H.Halm analyze

Appendix X Pictures of absorbers per location

24th of Feb. 2011 Mts. Duiven Location **1**

24th of Feb. 2011 Mts Duiven Location **2**

24th of Feb. 2011 Mts Duiven Location **3**

24th of Feb. 2011 Fam. B. van Unen Location **4**

24th of Feb. 2011 Fam. B. van Unen Location **4**

24th of Feb. 2011 Fam. B. van Unen Location **5**

24th of Feb. 2011 Fam. B van Unen Location **5**

24th of Feb. 2011 Fam. B. van Unen Location **5**

24th of Feb. 2011 Fam. P. Daatselaar Location **6**

24th of Feb. 2011 Fam. P. Daatselaar Location **6**

24th of Feb. 2011 Fam. P. Daatselaar Location **7**

24th of Feb. 2011 Fam. P. Daatselaar Location **7**

24th of Feb. 2011 Fam. M. ter Wal Location **8**

24th of Feb. 2011 Fam. M. ter Wal Location **8**

24th of Feb. 2011 Fam. M. ter Wal Location **9**

24th of Feb. 2011 Fam. M. ter Wal Location **9**

24th of Feb. 2011 Fam. M. ter Wal Location **10**

24th of Feb. 2011 Fam. M. ter Wal Location **11**

25th of March 2011 Dwingelderveld Location **12**

25th of March 2011 Dwingelderveld Location **12**

24th of Feb. 2011 Fam. M. ter Wal Location **13**

24th of Feb. 2011 Fam. M. ter Wal Location **13**

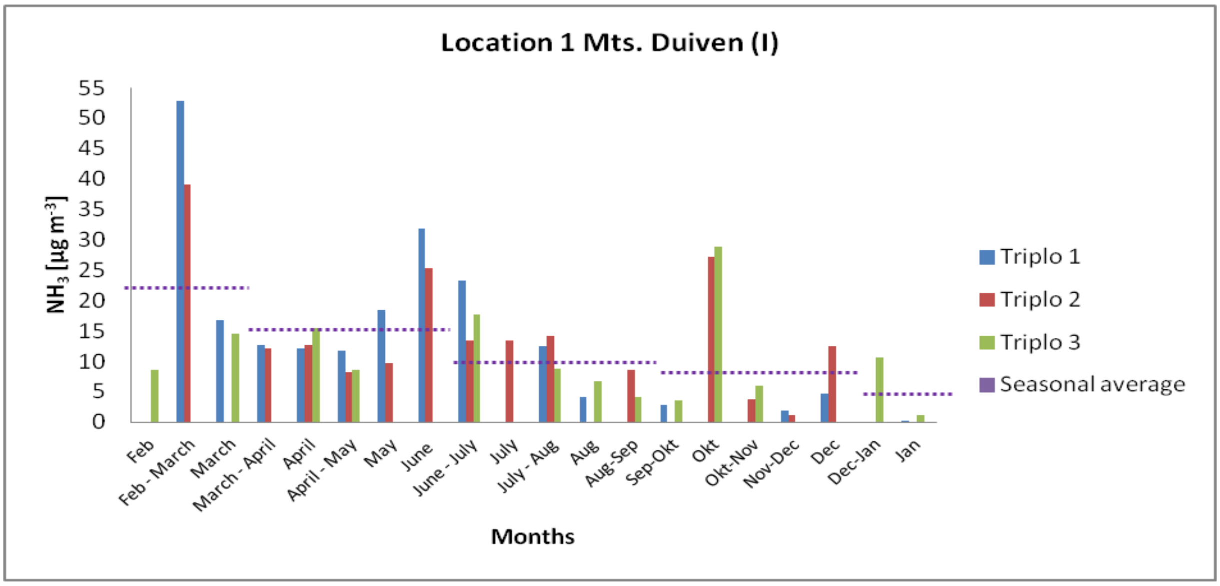
24th of Feb. 2011 Fam. A. Oostra Location **14**

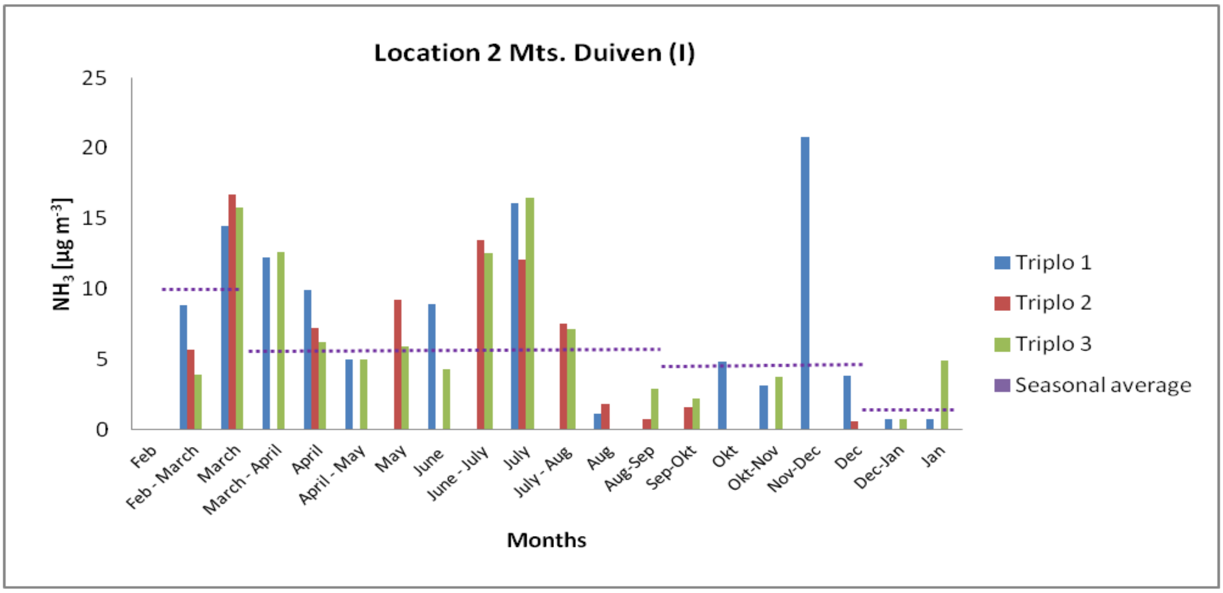
24th of Feb. 2011 Fam. A. Oostra Location **15**

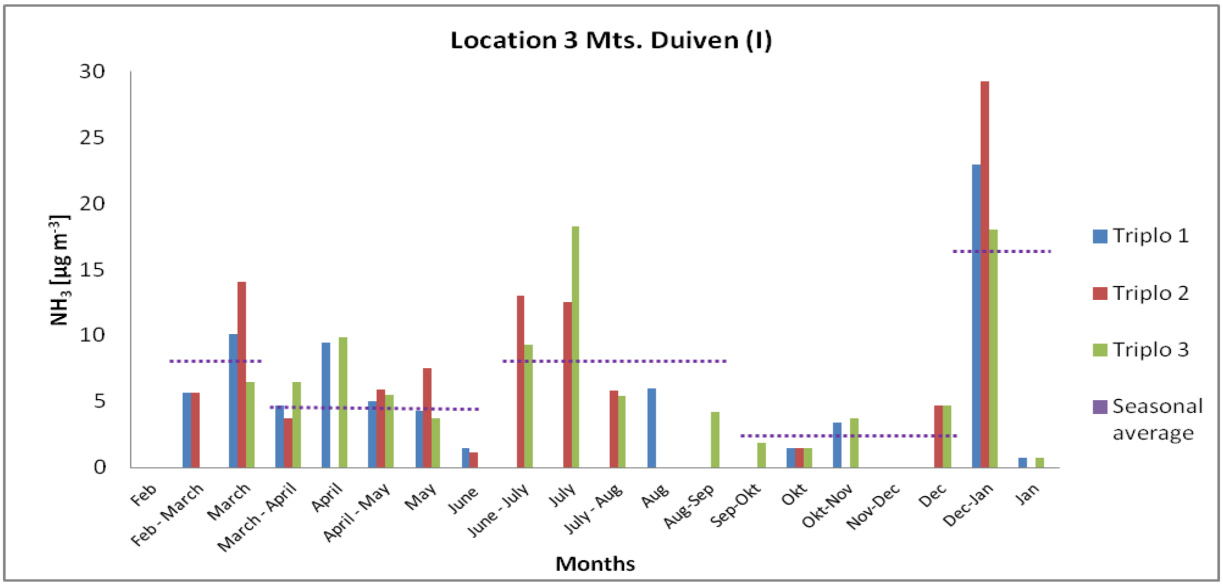
Pictures taken on September 19th

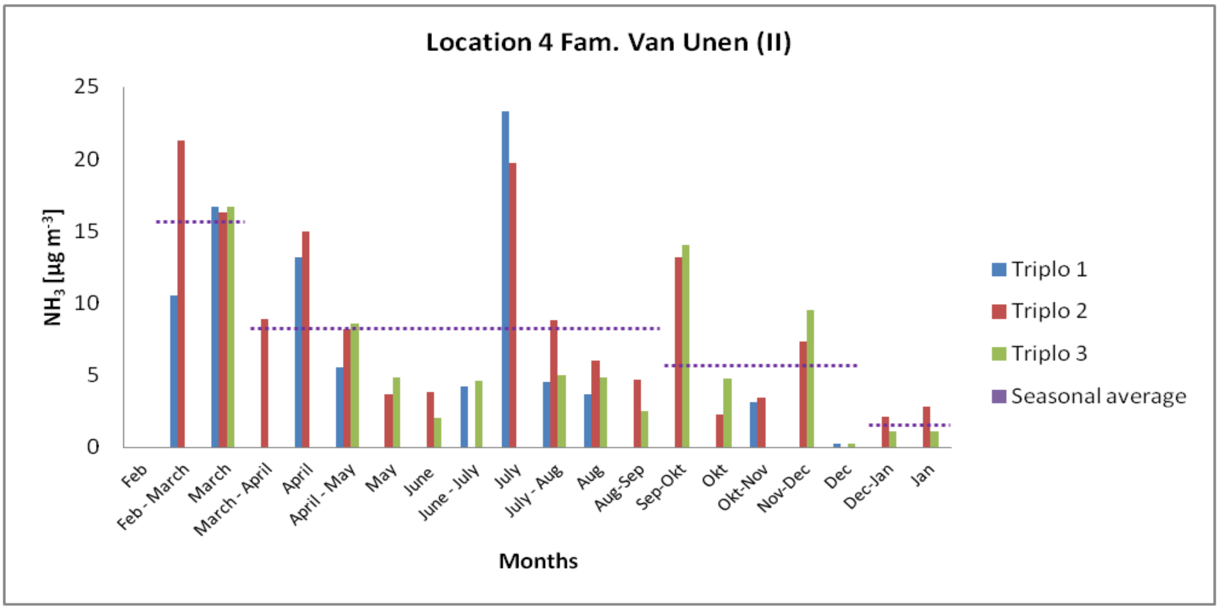
** Numbers in red are indicating the location of the absorbers in triplicate*

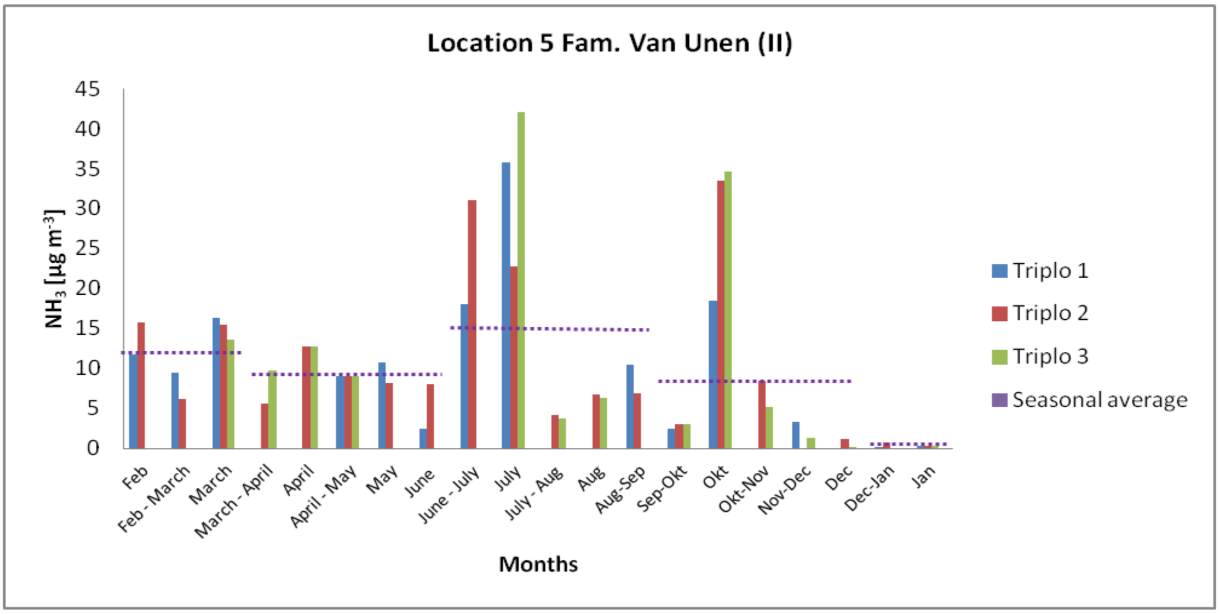
Appendix XI Annual overview of ammonia concentration per location

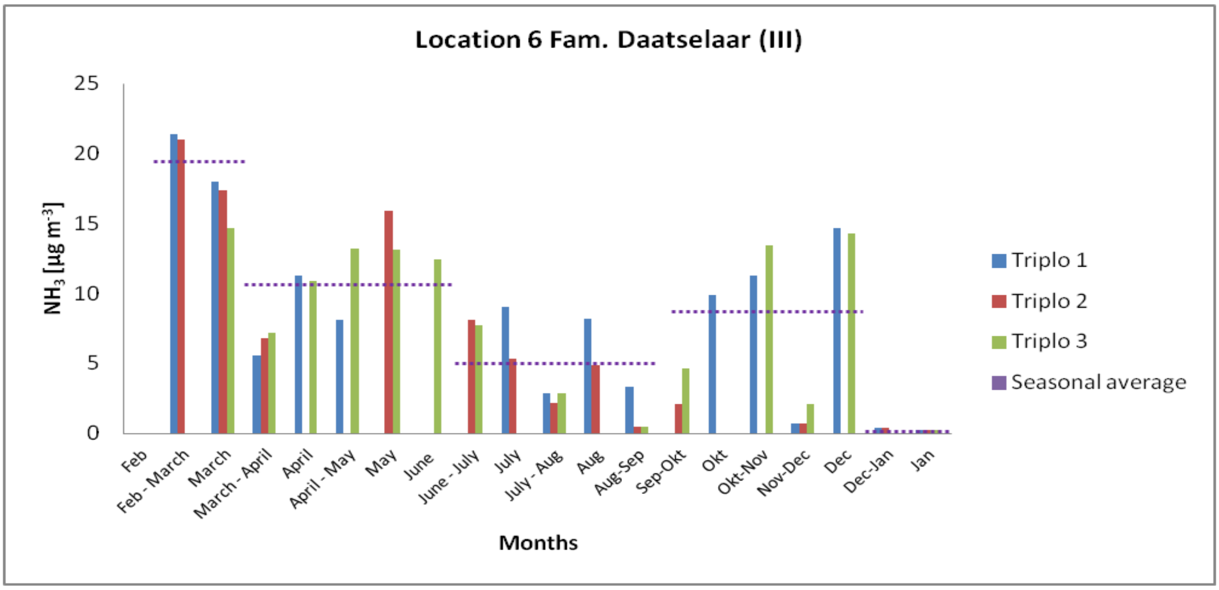


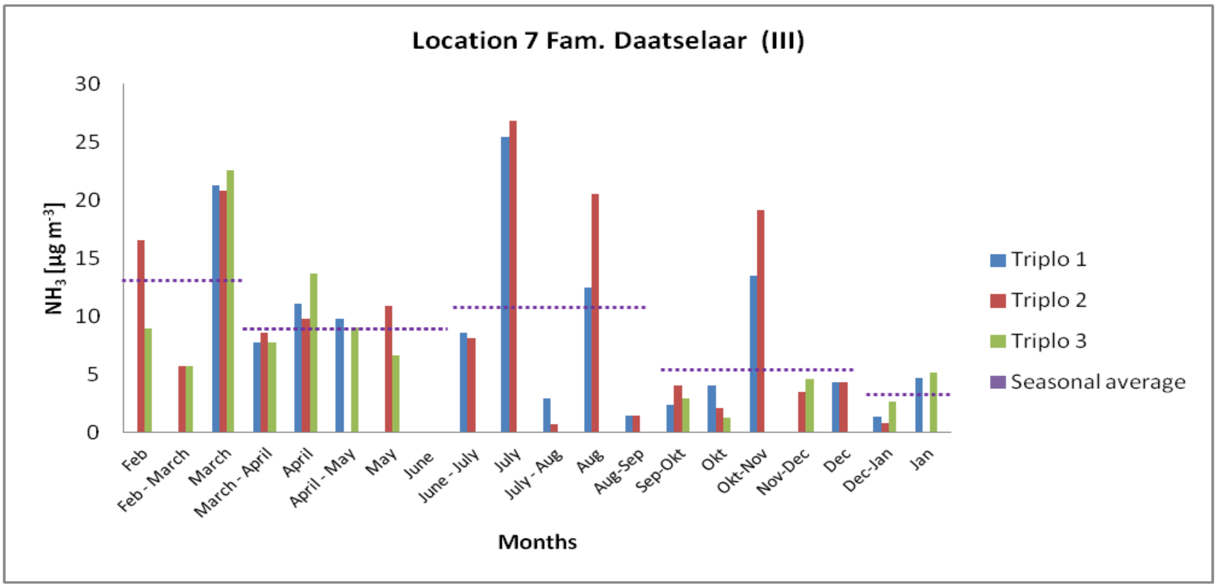


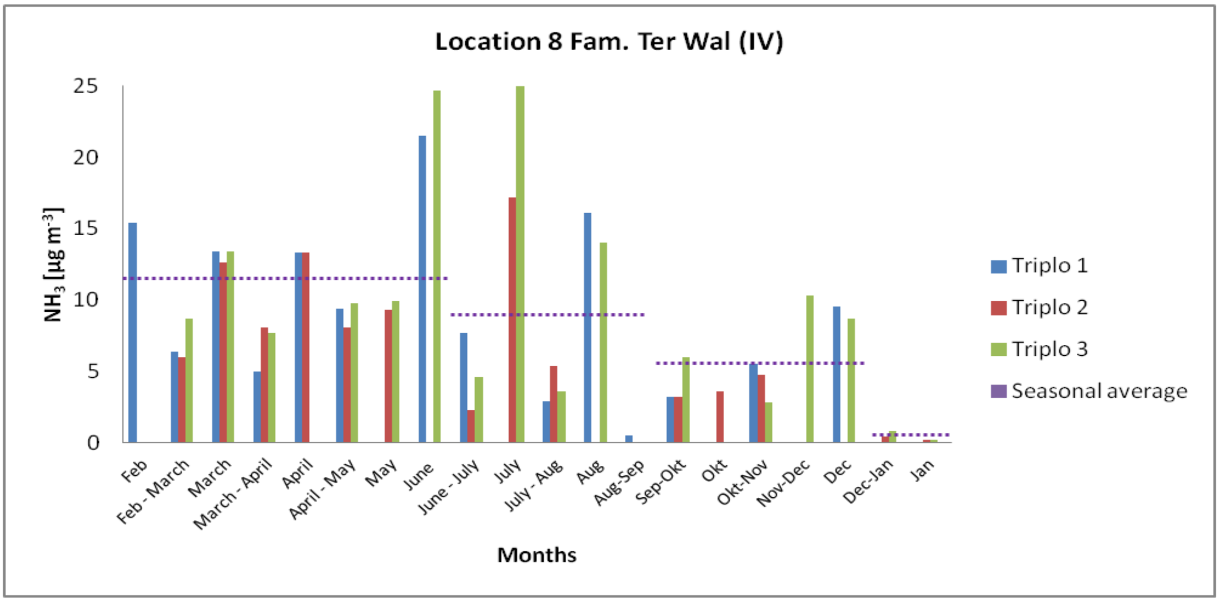


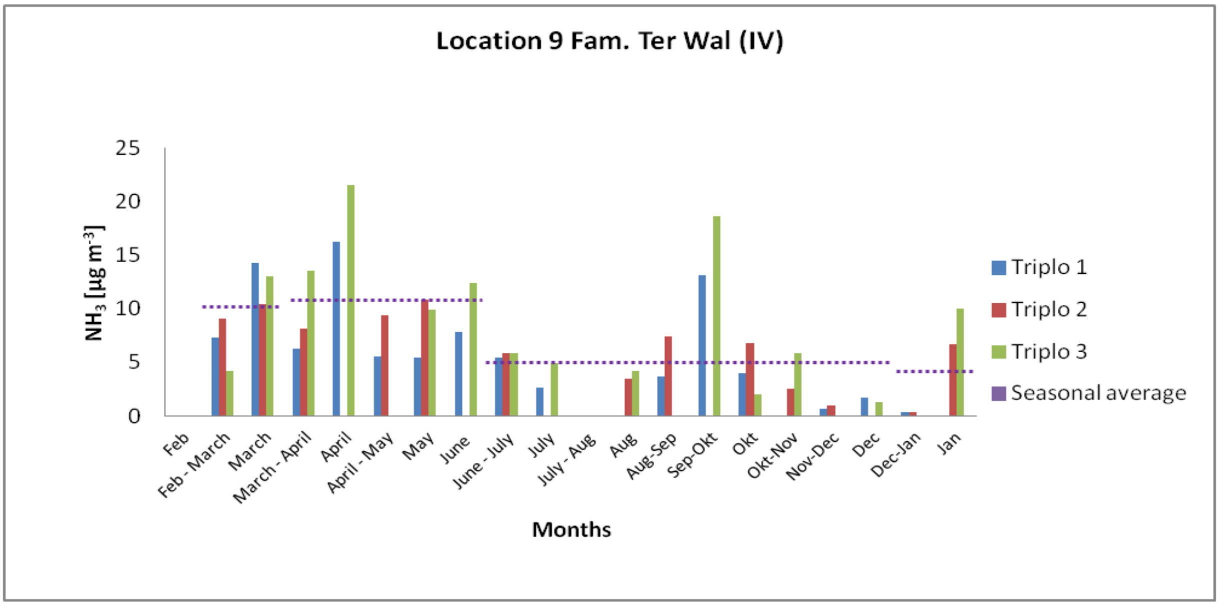

Location 4 Fam. Van Unen (II)
NH3 [µg m-3]
25
20
15
10
5
0
Feb
Feb - March
March
March - April
April
April - May
May
June
June - July
July
July - Aug
Aug
Aug-Sep
Sep-Okt
Okt
Okt-Nov
Nov-Dec
Dec
Dec-Jan
Jan
Months
Triplo 1
Triplo 2
Triplo 3
Seasonal average

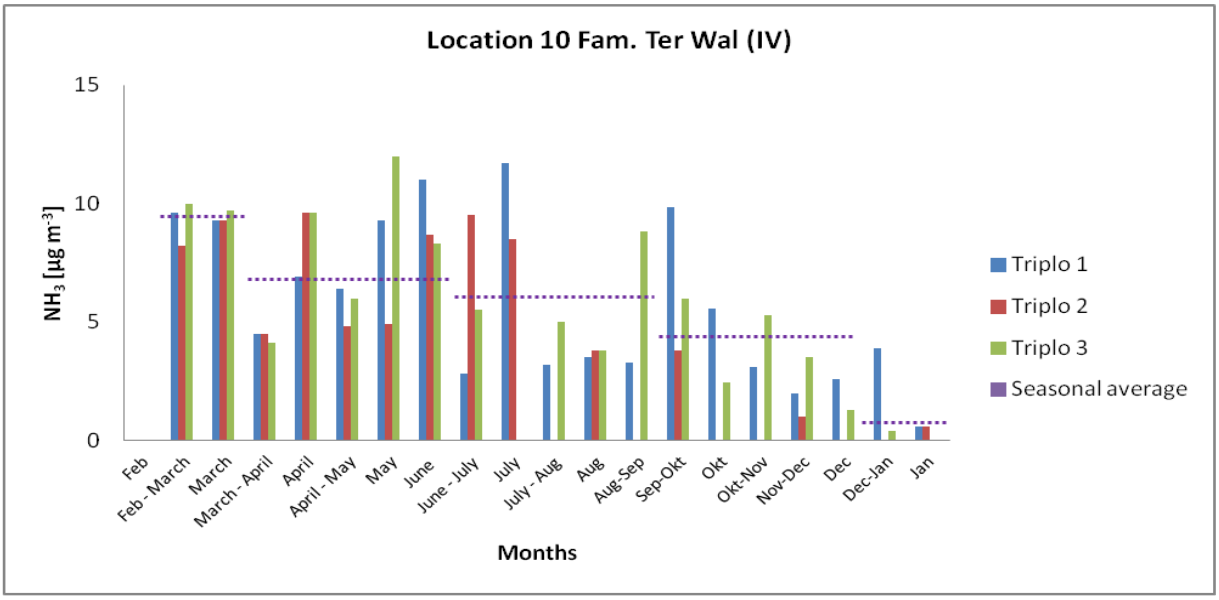

Location 5 Fam. Van Unen (II)
NH3 [µg m-3]
45
40
35
30
25
20
15
10
5
0
Feb
Feb - March
March
March - April
April
April - May
May
June
June - July
July
July - Aug
Aug
Aug-Sep
Sep-Okt
Okt
Okt-Nov
Nov-Dec
Dec
Dec-Jan
Jan
Months
Triplo 1
Triplo 2
Triplo 3
Seasonal average


Location 6 Fam. Daatselaar (III)
NH3 [µg m-3]
25
20
15
10
5
0
Feb
Feb - March
March
March - April
April
April - May
May
June
June - July
July
July - Aug
Aug
Aug-Sep
Sep-Okt
Okt
Okt-Nov
Nov-Dec
Dec
Dec-Jan
Jan
Months
Triplo 1
Triplo 2
Triplo 3
Seasonal average

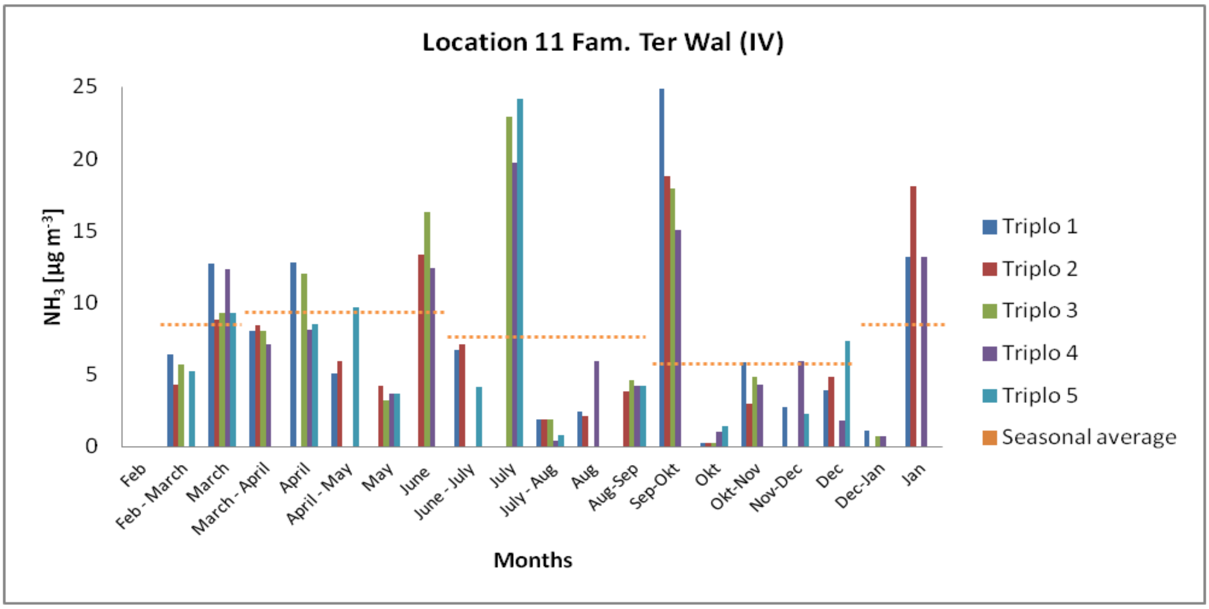

Location 7 Fam. Daatselaar (III)
30
25
20
15
10
5
0
NH_3 [µg m^{-3}]
Feb
Feb - March
March
March - April
April
April - May
May
June
June - July
July
July - Aug
Aug
Aug-Sep
Sep-Okt
Okt
Okt-Nov
Nov-Dec
Dec
Dec-Jan
Jan
Months
Triplo 1
Triplo 2
Triplo 3
Seasonal average


Location 8 Fam. Ter Wal (IV)
25
20
15
10
5
0
NH_3 [µg m^{-3}]
Feb
Feb - March
March
March - April
April
April - May
May
June
June - July
July
July - Aug
Aug
Aug-Sep
Sep-Okt
Okt
Okt-Nov
Nov-Dec
Dec
Dec-Jan
Jan
Months
Triplo 1
Triplo 2
Triplo 3
Seasonal average

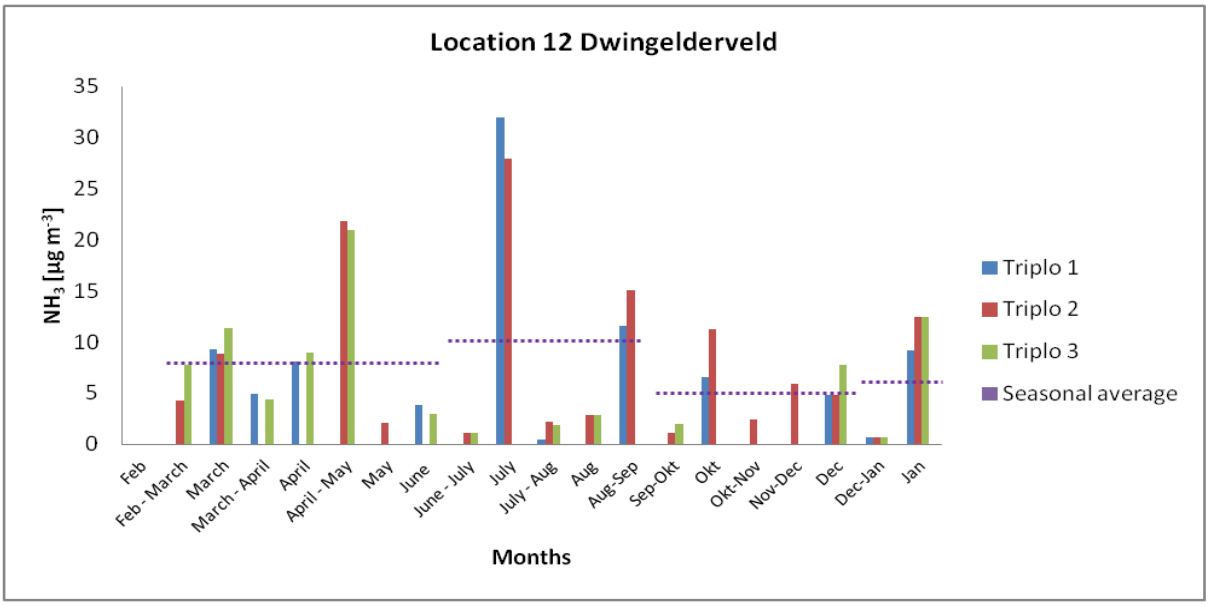

Location 9 Fam. Ter Wal (IV)
25
20
15
10
5
0
NH_3 [µg m^{-3}]
Feb
Feb - March
March
March - April
April
April - May
May
June
June - July
July
July - Aug
Aug
Aug-Sep
Sep-Okt
Okt
Okt-Nov
Nov-Dec
Dec
Dec-Jan
Jan
Months
Triplo 1
Triplo 2
Triplo 3
Seasonal average



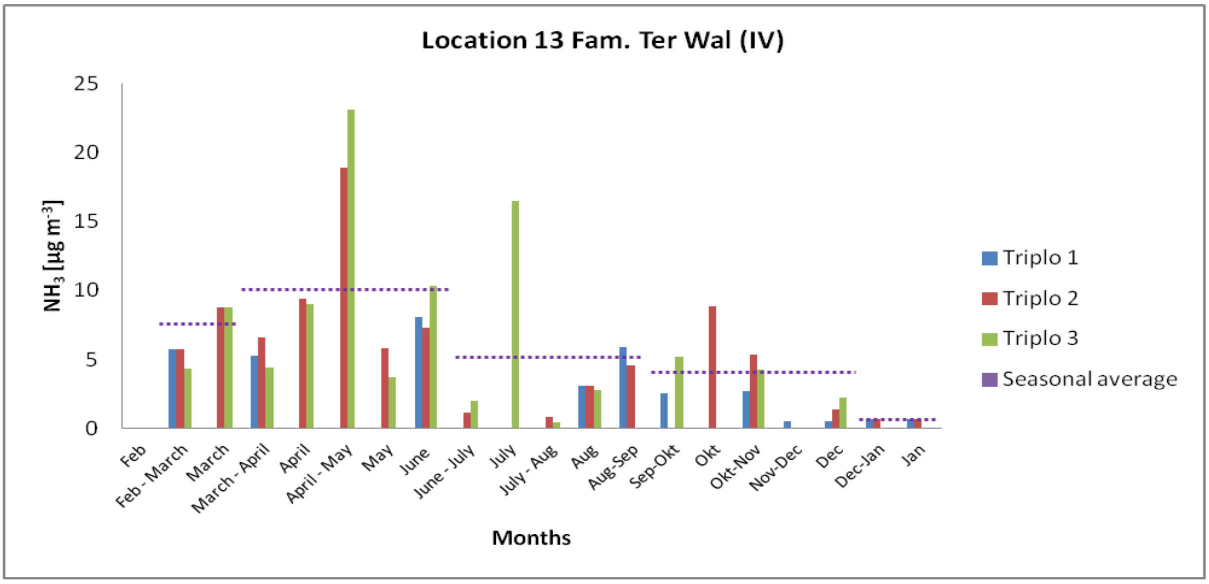
Location 10 Fam. Ter Wal (IV)
15
10
5
0
NH_3 [µg m^{-3}]
Feb
Feb - March
March
March - April
April
April - May
May
June
June - July
July
July - Aug
Aug
Aug-Sep
Sep-Okt
Okt
Okt-Nov
Nov-Dec
Dec
Dec-Jan
Jan
Months
Triplo 1
Triplo 2
Triplo 3
Seasonal average



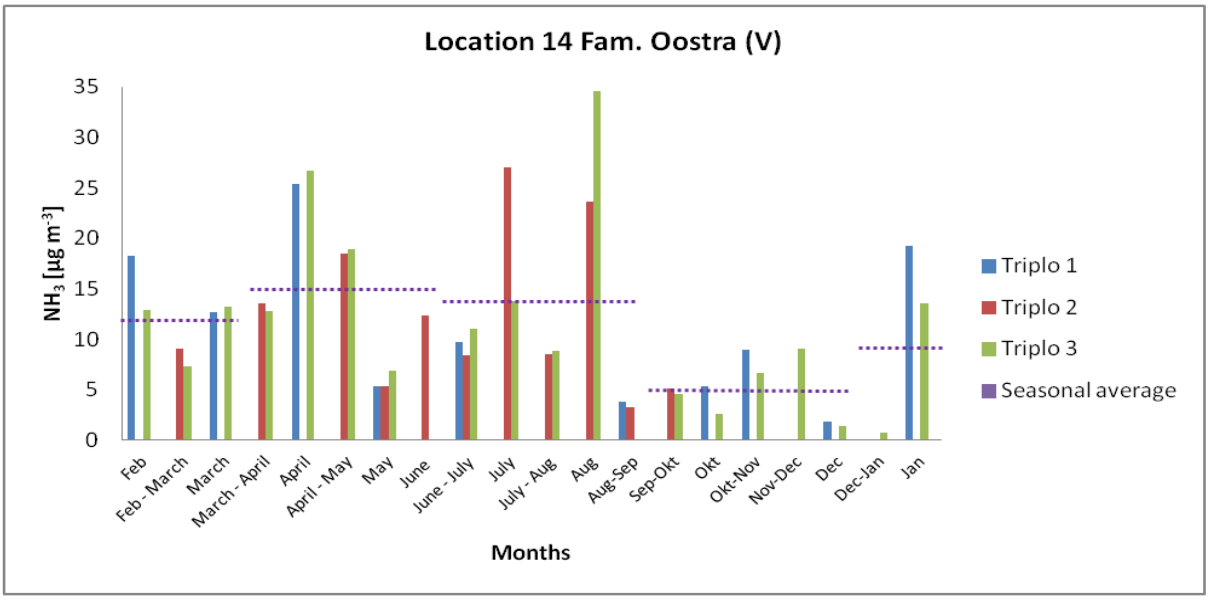
Location 11 Fam. Ter Wal (IV)
25
20
15
10
5
0
NH_3 [µg m^{-3}]
Feb
Feb - March
March
March - April
April
April - May
May
June
June - July
July
July - Aug
Aug
Aug-Sep
Sep-Okt
Okt
Okt-Nov
Nov-Dec
Dec
Dec-Jan
Jan
Months
Triplo 1
Triplo 2
Triplo 3
Triplo 4
Triplo 5
Seasonal average



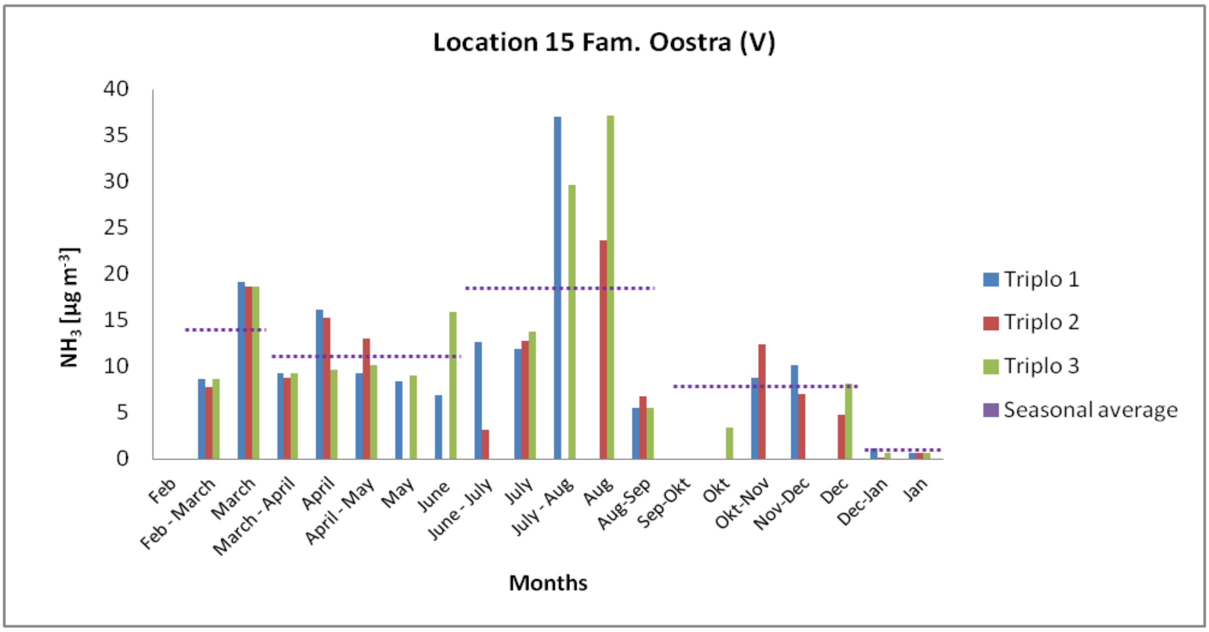
Location 12 Dwingelderveld
35
30
25
20
15
10
5
0
NH_3 [µg m^{-3}]
Feb
Feb - March
March
March - April
April
April - May
May
June
June - July
July
July - Aug
Aug
Aug-Sep
Sep-Okt
Okt
Okt-Nov
Nov-Dec
Dec
Dec-Jan
Jan
Months
Triplo 1
Triplo 2
Triplo 3
Seasonal average



Location 13 Fam. Ter Wal (IV)
NH3 [µg m-3]
25
20
15
10
5
0
Feb
Feb - March
March
March - April
April
April - May
May
June
June - July
July
July - Aug
Aug
Aug-Sep
Sep-Okt
Okt
Okt-Nov
Nov-Dec
Dec
Dec-Jan
Jan
Months
Triplo 1
Triplo 2
Triplo 3
Seasonal average



Location 14 Fam. Oostra (V)
NH3 [µg m-3]
35
30
25
20
15
10
5
0
Feb
Feb - March
March
March - April
April
April - May
May
June
June - July
July
July - Aug
Aug
Aug-Sep
Sep-Okt
Okt
Okt-Nov
Nov-Dec
Dec
Dec-Jan
Jan
Months
Triplo 1
Triplo 2
Triplo 3
Seasonal average



Location 15 Fam. Oostra (V)
NH3 [µg m-3]
40
35
30
25
20
15
10
5
0
Feb
Feb - March
March
March - April
April
April - May
May
June
June - July
July
July - Aug
Aug
Aug-Sep
Sep-Okt
Okt
Okt-Nov
Nov-Dec
Dec
Dec-Jan
Jan
Months
Triplo 1
Triplo 2
Triplo 3
Seasonal average

Appendix XII Manure and artificial fertilizer scheme

Manure and artificial fertilizer scheme of all locations (farms)

Location/ date	Februari		March		April		May		June		July		August		September		October	
Location 1	28	35 m3/ha					16	25 m3/ha	17	15 m3/ha			4	10 m3/ha				
			28	290 kg/ha (25%)			10	140 kg/ha (25%)	16	140 kg/ha (25%)				No KAS				
							5	Mowed	14	Mowed	27	Mowed	30	Mowed	26	Mowed	18	Mowed
Location 2	*Lilies were grown here, harvested 10th of November*																	
Location 3	*Maize, start 27th of April*				15	55 m3/ha											18	chopped
Location 4	17	30 m3/ha											8	30 m3/ha				
			29	320 kg/ha									8	80 kg/ha (25%)				
													1	Mowed	3	Mowed	18	Mowed
Location 5	3	35 m3/ha					25	25 m3/ha			6	20 m3/ha						
			28	320 kg/ha			25	100 kg/ha			23	15 m3/ha						
							23	Mowed	27	Mowed	23	Mowed			26	Mowed		
Location 6			14	30m3/ha			17	15 m3/ha			8	20 m3/ha						
			24	300 kg/ha (26% N)			14	150 kg/ha (26%N)			4	100 kg/ha (26% N)						
							12	Mowed	27	Mowed					3	Mowed	18	Mowed
Location 7			12	30m3/ha			16	15m3/ha	20	20 m3/ha			16	20 m3/ha				
			23	300 kg/ha (26% N)			14	150 kg/ha (26% N)			5	100 kg/ ha (26% N)	8	60 kg/ha (25%N)				
							12	Mowed	17	Mowed	31	Mowed			16	Mowed	18	Mowed
Location 8	14	28 m3/ha					17	17 m3/ha					4	15 m3/ha	1	15 m3/ha*		
			30	300 kg/ha (26% N)			18	100 kg/ha (26%)					23	15 m3/ha *				
							13	Mowed	27	Grazed	23	Grazed	20	Grazed*	26	Mowed*	20	Grazing

Location 9	23	28 m3/ha					14	17 m3/ha					23	15 m3/ha				
			30	300 kg/ha (26% N)			18	100 kg/ha (26%)					25	100 kg/ha (25%)				
							13	Mowed	1	Mowed			10	Mowed	16	Mowed	20	Mowed
Location 10			8	28 m3/ha									4	15 m3/ha				
			30	150 kg/ha (25%)			25	100 kg/ha (26%)			7	150 kg/ha (22%)						
							23	Mowed	27	Mowed	*20*	*Mowed**	*1*	*Chopped**	*3*	*Mowed F*		
Location 11			9	28 m3/ha							9	15 m3/ha	*12*	*15 m3/ha**	*3*	*Mowed**		
			30	150 kg/ha (25%)			25	100 kg/ha (25%)			7	150 kg/ha (22%)	25	100 kg/ha (25%)	*3*	*15m3/ha**		
							23	Mowed	30	Mowed	*10*	*Grazed**	10	Mowed	26	Mowed		
Location 12	*Dwingelderveld*																	
Location 13											7	15 m3/ha			3	15 m3/ha		
			30	150 kg/ha (25%)							7	150 kg/ha (22%)	25	100 kg/ha (25%)				
			24	Re-sown					30	Mowed			10	Mowed	26	Mowed		
Location 14	1	28 m3/ha	8	finish m3			31	25 m3/ha			21	Grazed						
					1	300 kg/ha (25%)	27	150 kg/ha (25%)			20	150 kg/ha (26% N)						
							25	Mowed			11	Mowed	22	Grazed				
Location 15			8	28 m3/ha														
					1	300 kg/ha (25%)	27	150 kg/ha (25%)			20	150 kg/ha (26% N)						
							25	Mowed	3	Grazed	20	Cutted	8	Grazed	10	Grazed		

** There are adjacent field used for agricultural purpose next to this location which can influence the ammonia concentrations. These comments are written in Italic only.*

Appendix XIII Comments & observations measurements absorbers

Farm I Mts. Duiven

Location 1:

- From the beginning of Februari until half of April they were busy with applying manure on grass and arable land.
- 19th of September, location 1 was changed due to extending silage heap (approximately 200 meter from the farm).
- End of September started with chopping maize.
- From the 10th of November sheep were grazing on this field.

Location 2:

- Beginning of March this field was drained
- Middle of March there was put lime on this field
- Start of April lilies were sown here
- End of April there was irrigation on this field
- 10th of November lilies were harvested

Location 3:

- Around 5th of March manure was applied next to this field on arable land
- 27 of April maize was sown here
- 18th of October maize was harvested
- End of October maize adjacent to this field was harvested
- Beginning of December refilling silo
- Beginning of January 2012 smelling of silo

Farm II Fam. B. van Unen

Location 4:

- Around 20th of March, arable land (maize) was injected with manure
- End of October, maize was harvested; adjacent field
- Measurement 18 bird dropping are on top of the wooden plank

Location 5:

- 20th of March, potato field was injected with slurry
- End of October harvesting potatoes
- Start November, every week slurry was mixed
- 7 of December, a lot of water at this location

Farm III Fam. P. Daatselaar

Location 6:

- 11th of April, P. Daatselaar was mixing slurry for arable land
- 10th of October fields were chopped
- 28th of October slurry was mixed

Location 7:

- 25th of January 2012 slurry was mixed
- Same comments as location 6

Farm IV Fam. M. ter Wal

Location 8:

- 1st of February slurry was mixed
- 11th of April slurry was mixed

- 20th of April cows outside behind the barn
- Beginning of November, cows were grazing on this field
- Till the end of November heifers were grazing here, exit end of December

Location 9:

- 26 of April, maize was sown on the other side of ditch
- 10th of August absorbers were stolen

Location 10:

- 30th of June heifers were grazing front parcel (road), 27th of June rear parcel was mowed
- 18th until 23 of July rear field was mowed
- 1th of August front parcel was chopped and only here manure was applied
- 11th of August heifers are grazing on rear field
- 3th of September front parcel was mowed, afterwards heifers came in
- Middle of September heifers were walking on both fields
- Beginning of October heifers were gone, only some horses were grazing here
- 20th of December horses were exit

Location 11:

- 9th of July manure was applied middle field, not the front field near road
- Heifers grazed here till 10th of August for almost 14 days

Location 13:

- Start: on this field was grown maize before
- 24th of April re-sown with grass and spring barley

Dwingelderveld

Location 12:

- Cows were grazing here randomly

Farm V Fam. A. Oostra

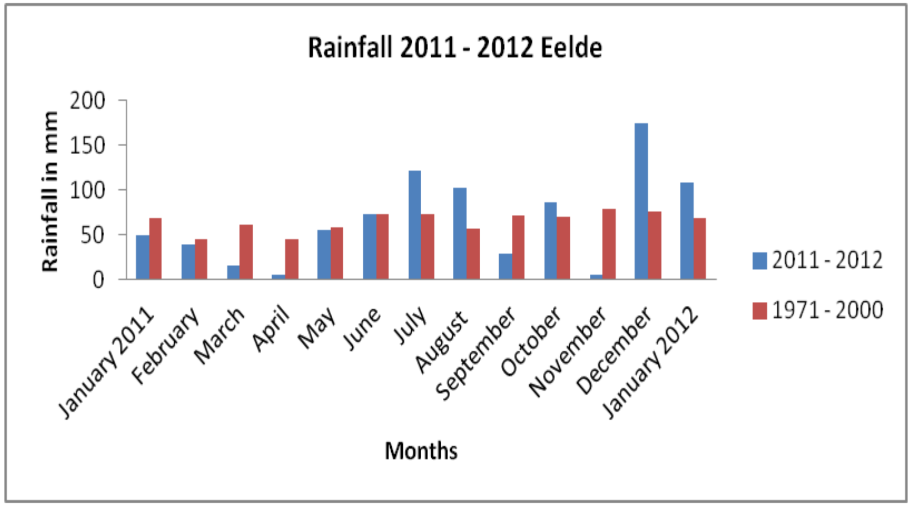
Location 14:

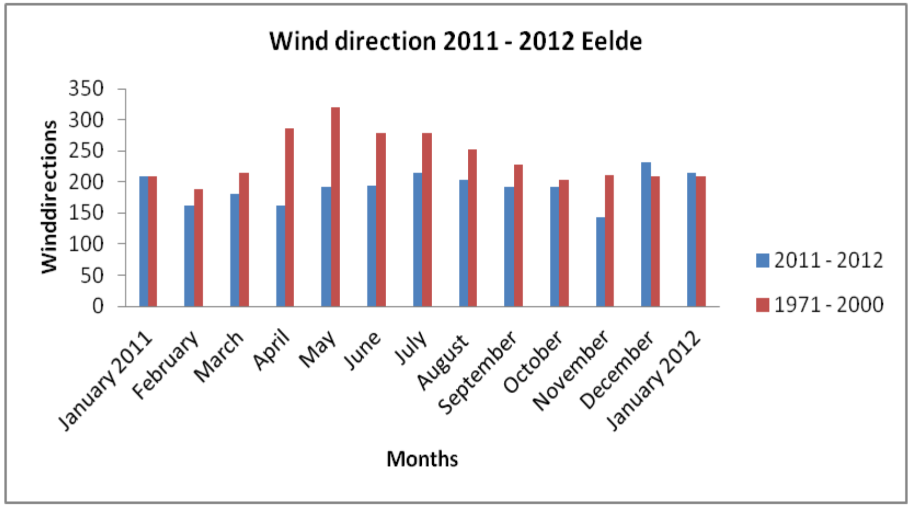
- 15th of June heifers are grazing here front parcel until end of January 2012 (numbers of young stock changed during time, also the field size changed
- 21 of July cows grazed here rear end of this field
- 10th of August slurry was mixed and slurry was brought to field of carrots
- 22 of August cows grazed rear end of this field
- 10 of September heifers grazed on the whole rear end of this field

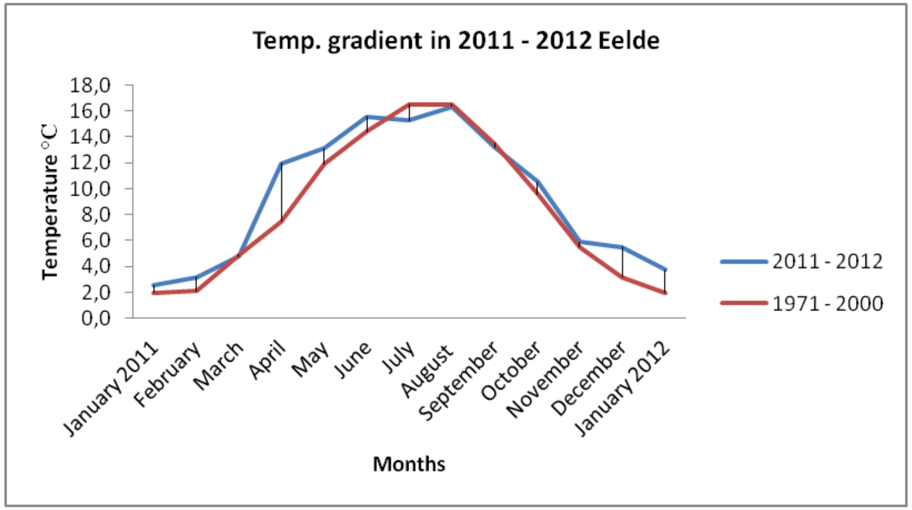
Location 15:

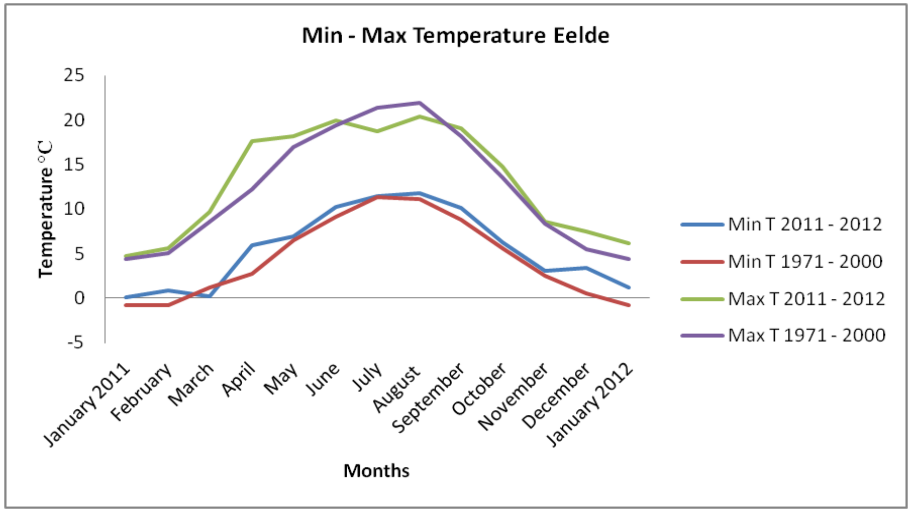
- Cows are outside at the third of June, grazed here
- Till 12 of July cows were grazing here (stripgrazing)
- Then it was chopped and fertilized with artificial fertilizer
- Cows were moved to adjacent field (which was just mowed near bicycle road) (22 of August)
- Till the 8th of August, cows are crossing this location and a lot of manure and feaces were present here
- 10 of September cows were grazing here till 19th of October
- Till December 2011 heifers were able to graze here

Appendix XIV Yearly overview rainfall, temperature (Max. – Min.) and wind direction in Eelde

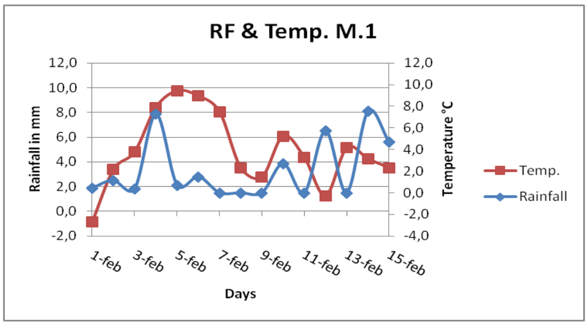


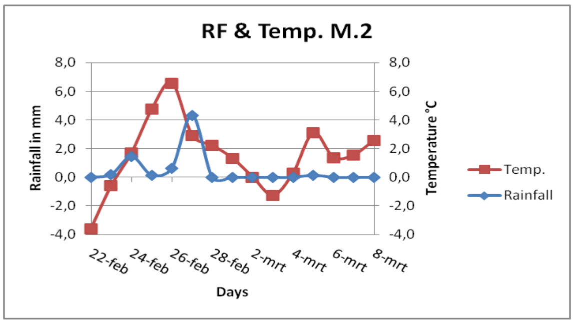


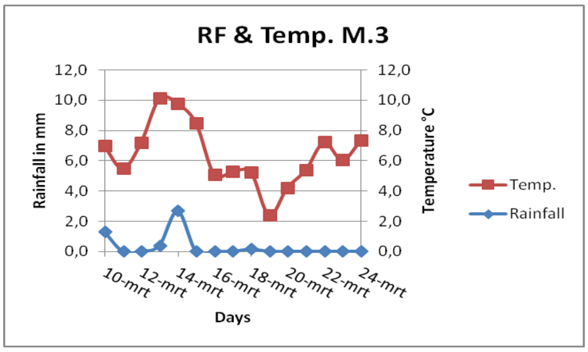


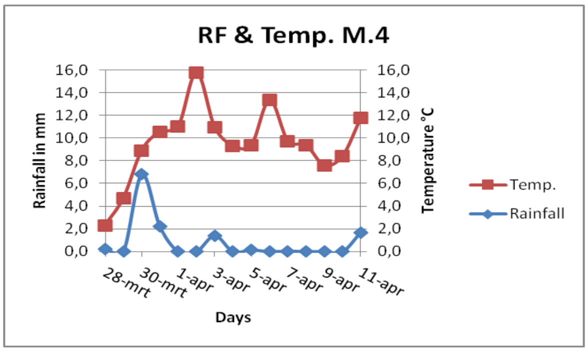


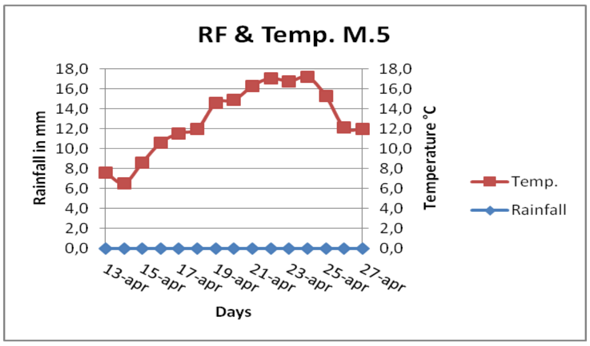
Appendix XV Rainfall & Temperature per measurement in Eelde

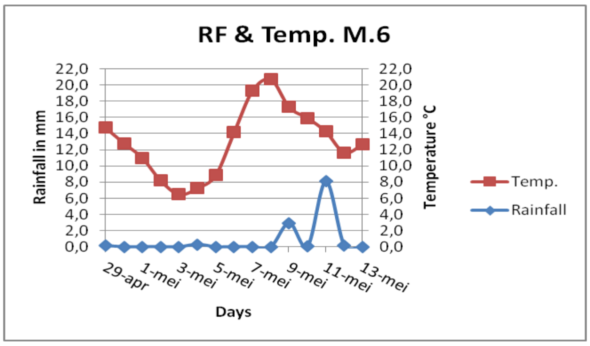


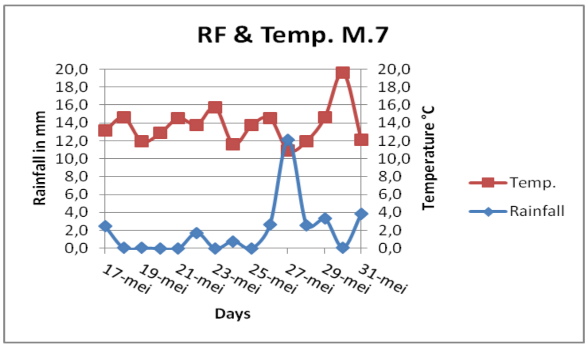


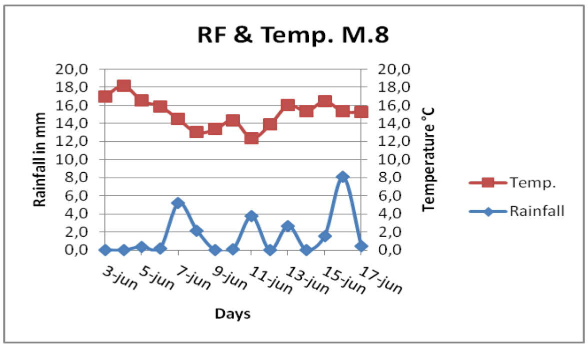


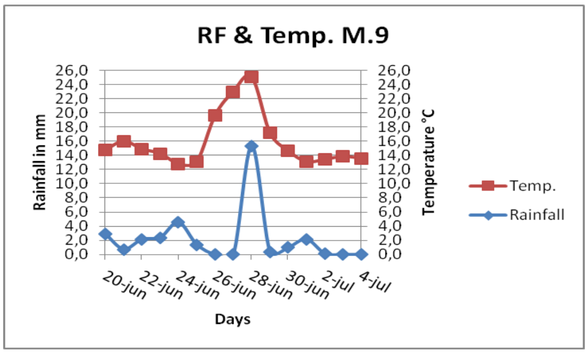


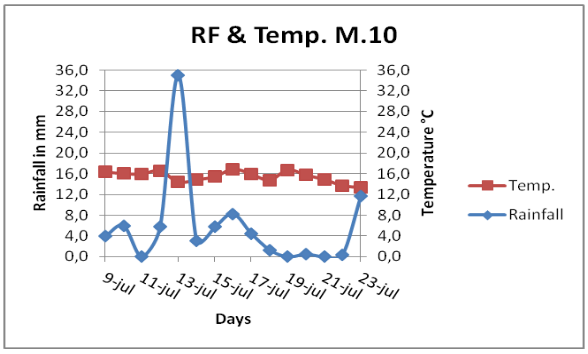


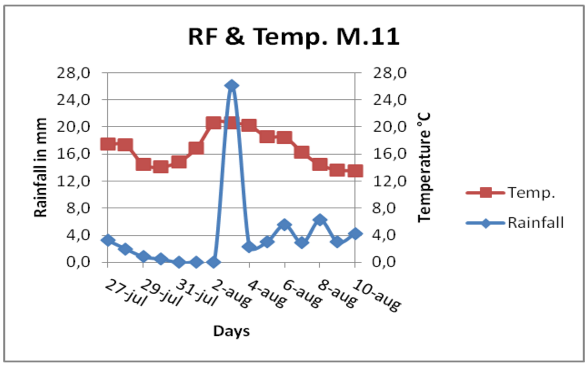


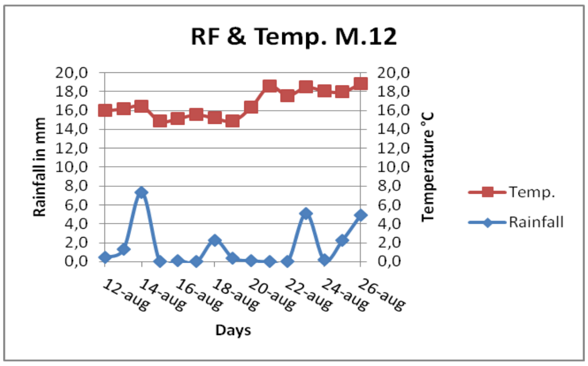


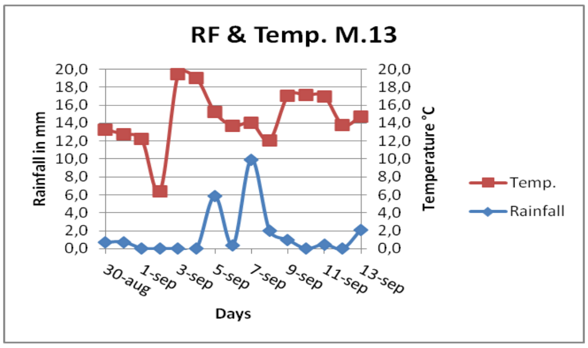


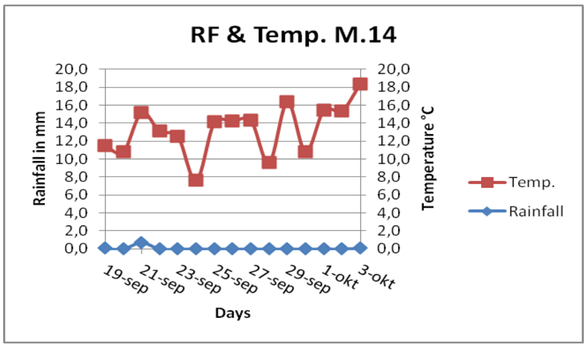


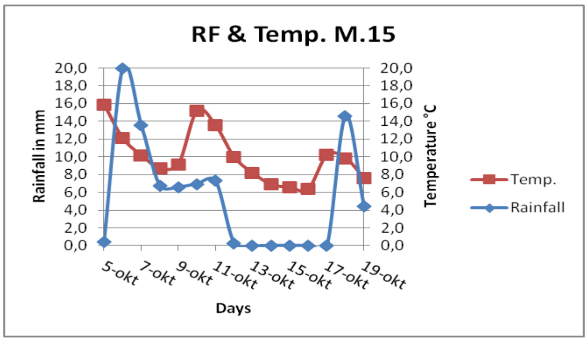


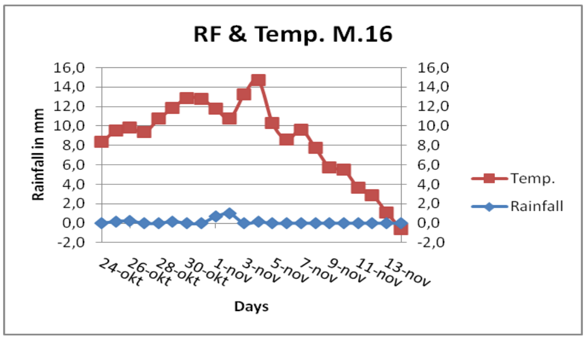

RF & Temp. M.11
Rainfall in mm
Temperature °C
0,0 4,0 8,0 12,0 16,0 20,0 24,0 28,0
27-jul 29-jul 31-jul 2-aug 4-aug 6-aug 8-aug 10-aug
Days
Temp.
Rainfall

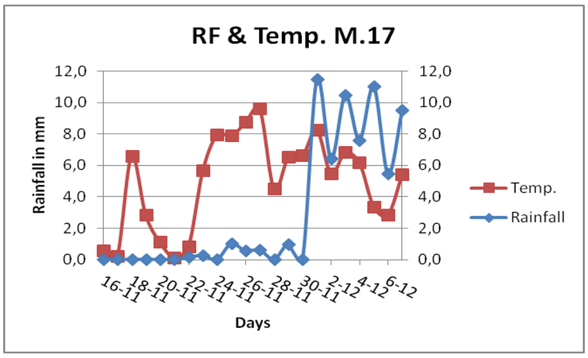

RF & Temp. M.12
Rainfall in mm
Temperature °C
0,0 2,0 4,0 6,0 8,0 10,0 12,0 14,0 16,0 18,0 20,0
12-aug 14-aug 16-aug 18-aug 20-aug 22-aug 24-aug 26-aug
Days
Temp.
Rainfall

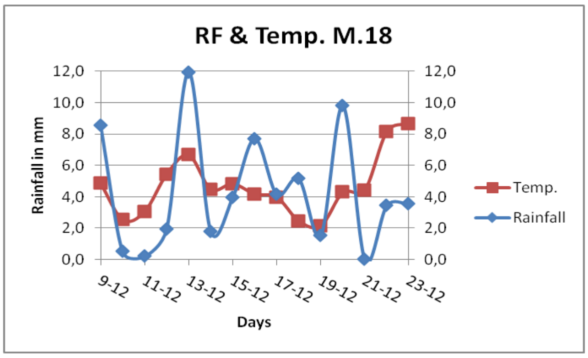

RF & Temp. M.13
Rainfall in mm
Temperature °C
0,0 2,0 4,0 6,0 8,0 10,0 12,0 14,0 16,0 18,0 20,0
30-aug 1-sep 3-sep 5-sep 7-sep 9-sep 11-sep 13-sep
Days
Temp.
Rainfall

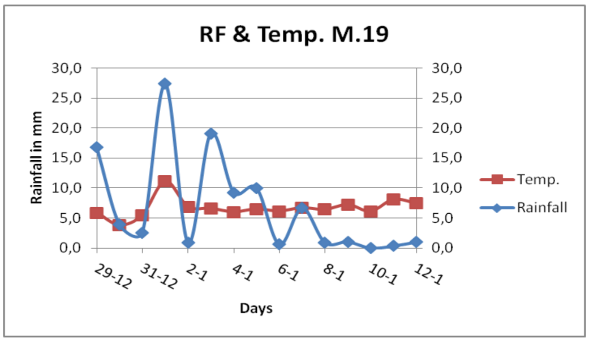

RF & Temp. M.14
Rainfall in mm
Temperature °C
0,0 2,0 4,0 6,0 8,0 10,0 12,0 14,0 16,0 18,0 20,0
19-sep 21-sep 23-sep 25-sep 27-sep 29-sep 1-okt 3-okt
Days
Temp.
Rainfall

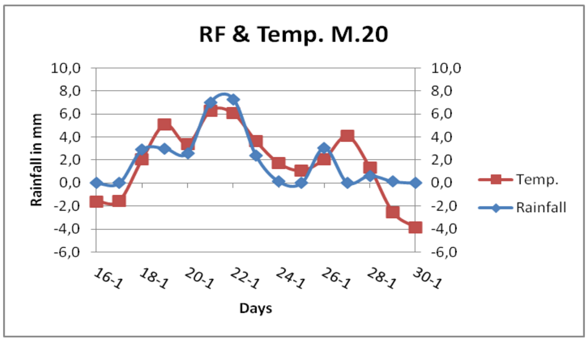

RF & Temp. M.15
Rainfall in mm
Temperature °C
0,0 2,0 4,0 6,0 8,0 10,0 12,0 14,0 16,0 18,0 20,0
5-okt 7-okt 9-okt 11-okt 13-okt 15-okt 17-okt 19-okt
Days
Temp.
Rainfall


RF & Temp. M.16
Rainfall in mm
-2,0 0,0 2,0 4,0 6,0 8,0 10,0 12,0 14,0 16,0
24-okt 26-okt 28-okt 30-okt 1-nov 3-nov 5-nov 7-nov 9-nov 11-nov 13-nov
Days
Temp.
Rainfall

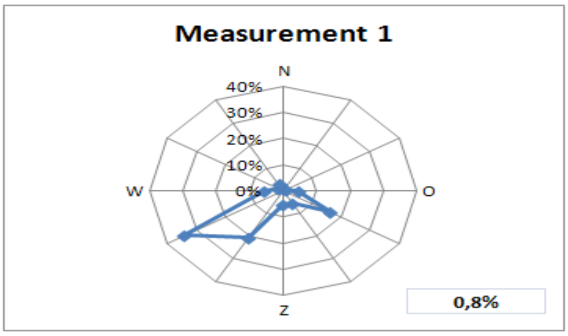

RF & Temp. M.17
Rainfall in mm
0,0 2,0 4,0 6,0 8,0 10,0 12,0
16-11 18-11 20-11 22-11 24-11 26-11 28-11 30-11 2-12 4-12 6-12
Days
Temp.
Rainfall

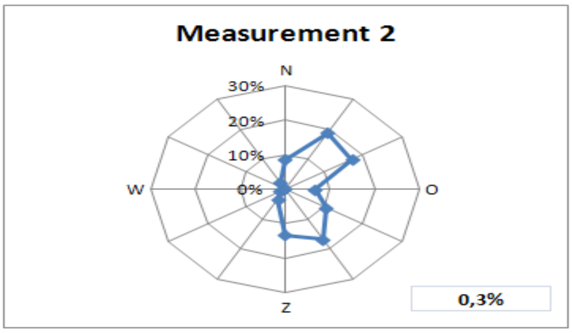

RF & Temp. M.18
Rainfall in mm
0,0 2,0 4,0 6,0 8,0 10,0 12,0
9-12 11-12 13-12 15-12 17-12 19-12 21-12 23-12
Days
Temp.
Rainfall

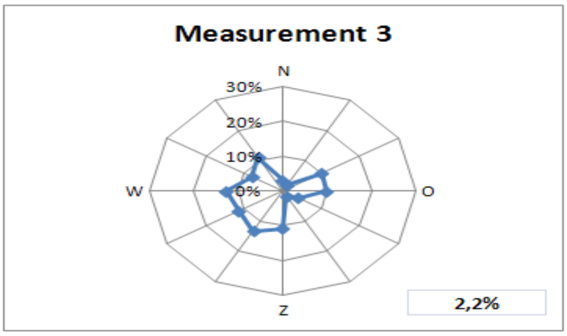

RF & Temp. M.19
Rainfall in mm
0,0 5,0 10,0 15,0 20,0 25,0 30,0
29-12 31-12 2-1 4-1 6-1 8-1 10-1 12-1
Days
Temp.
Rainfall

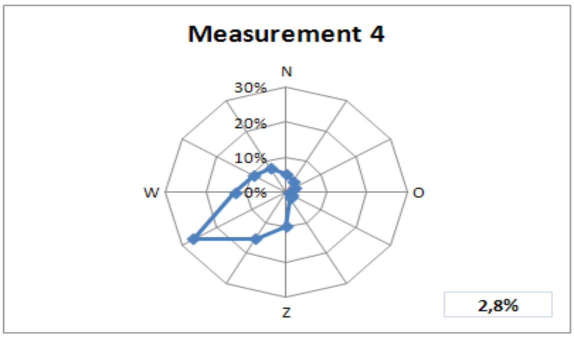

RF & Temp. M.20
Rainfall in mm
-6,0 -4,0 -2,0 0,0 2,0 4,0 6,0 8,0 10,0
16-1 18-1 20-1 22-1 24-1 26-1 28-1 30-1
Days
Temp.
Rainfall

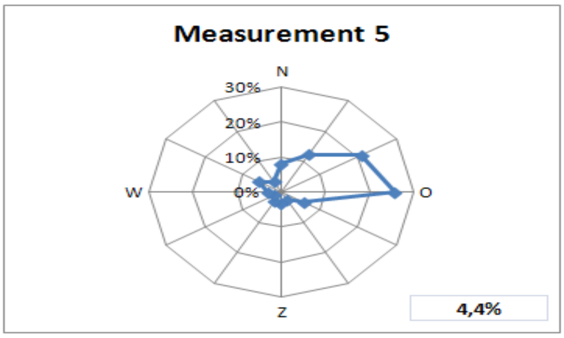
Appendix XVI Wind direction per measurement in Eelde

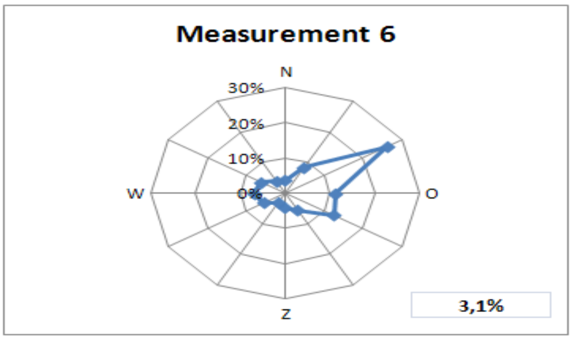


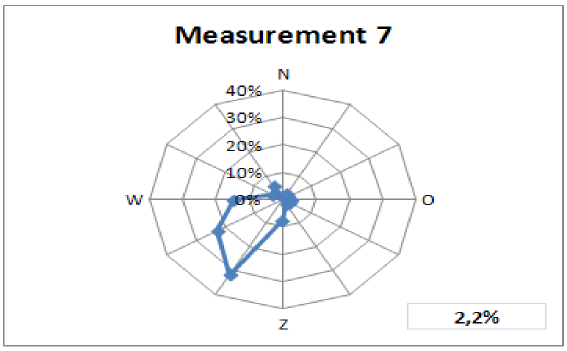


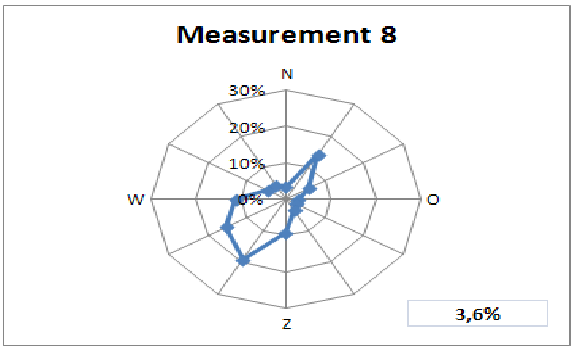


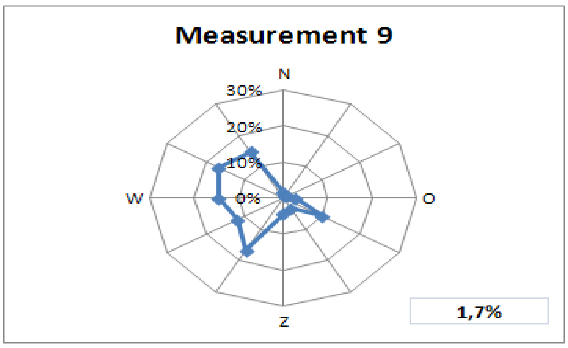


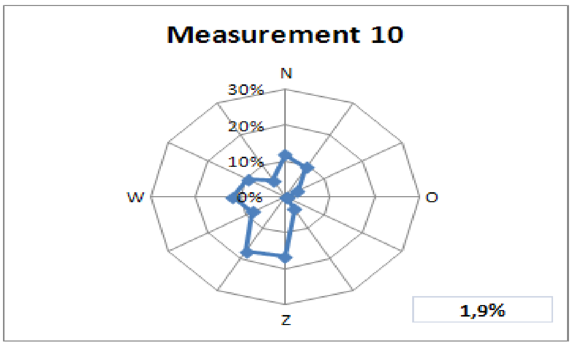


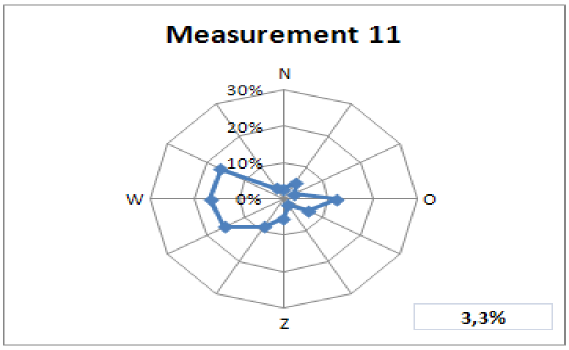


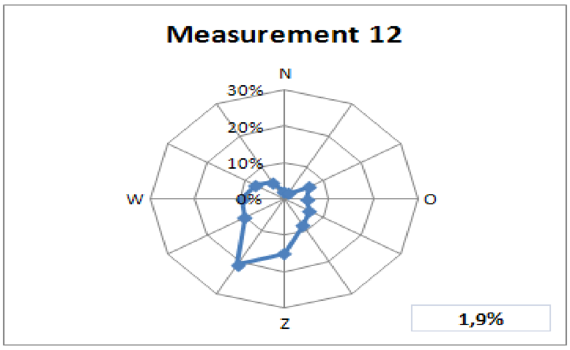


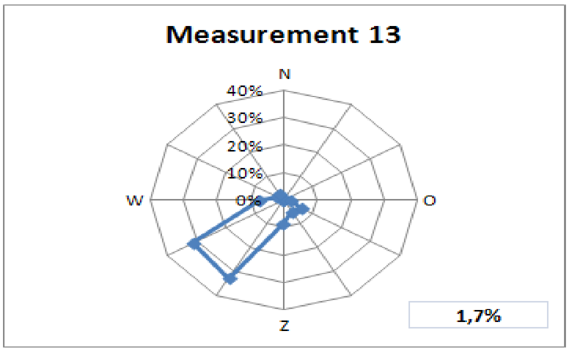


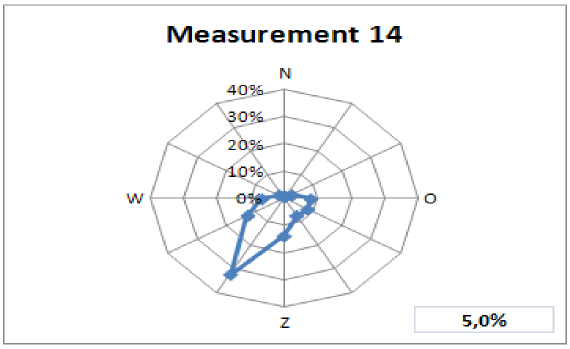


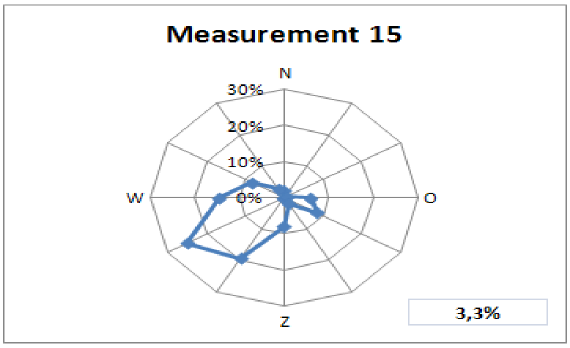


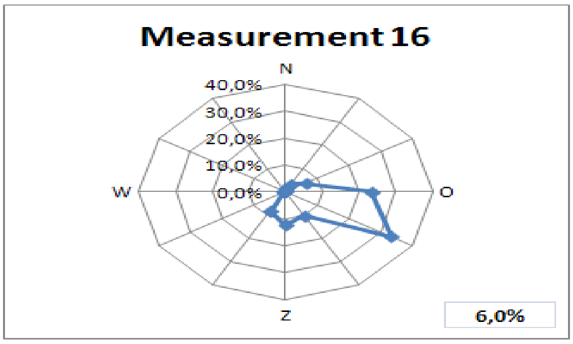


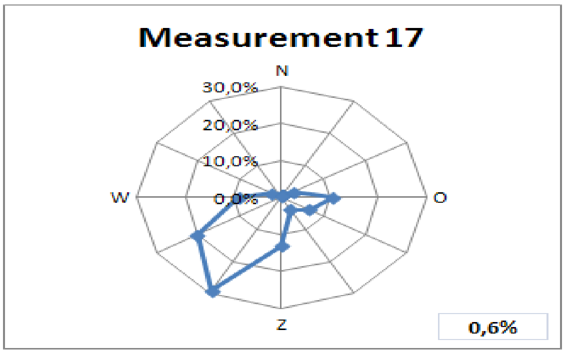


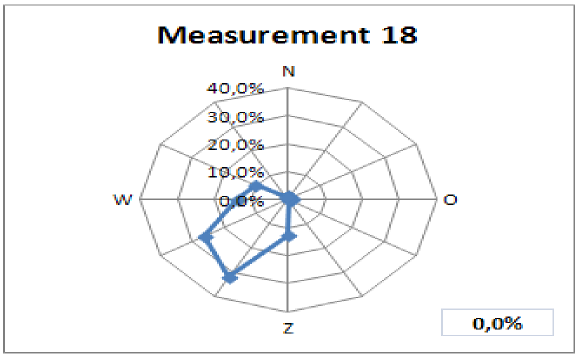


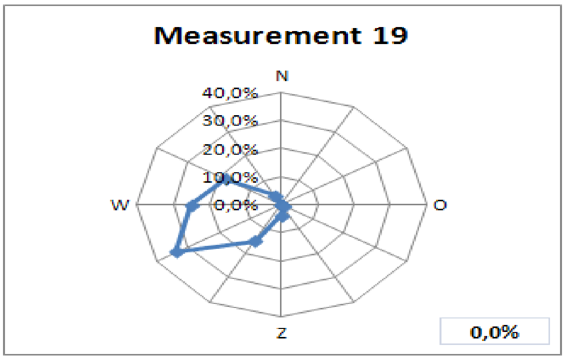


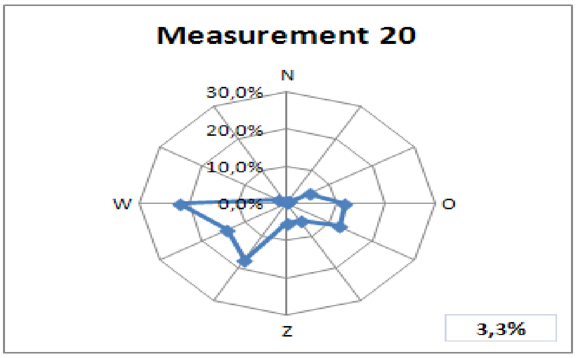






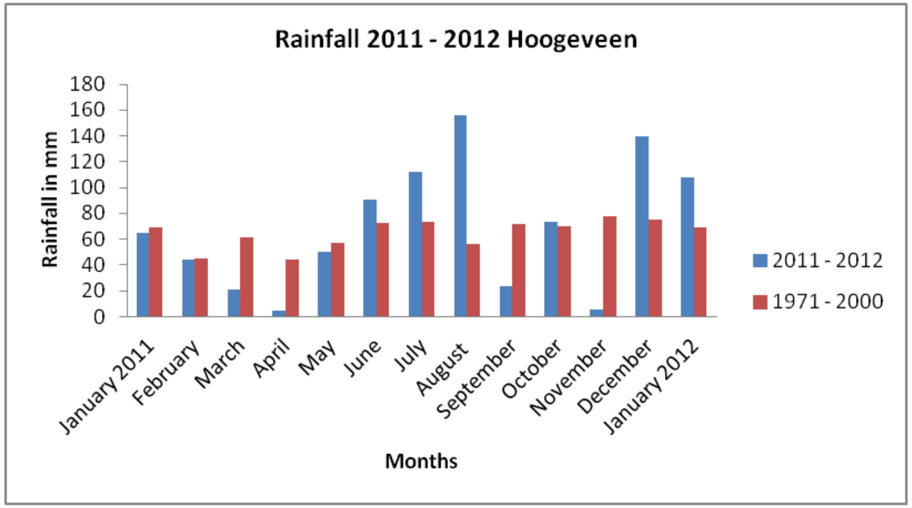


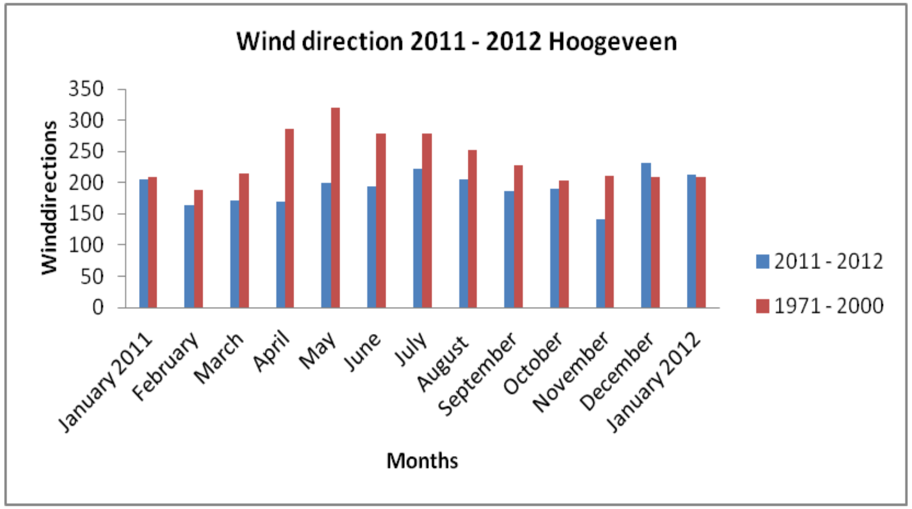


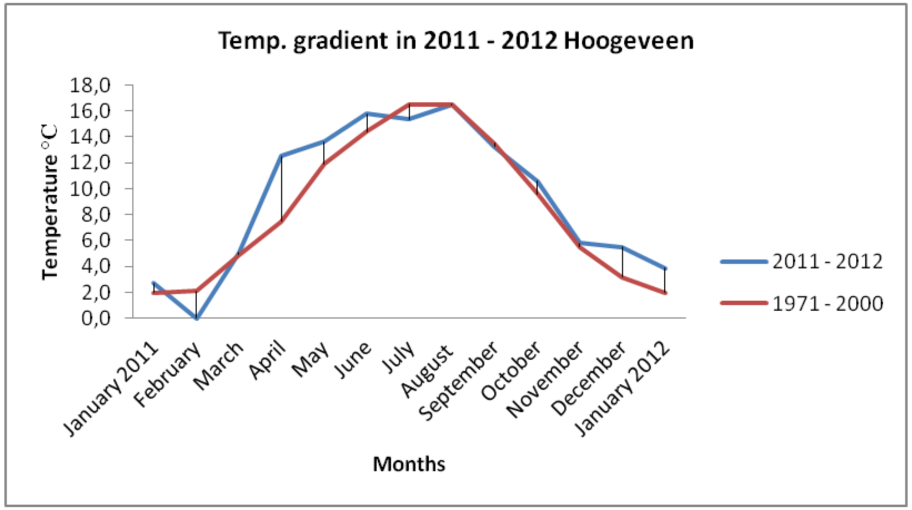


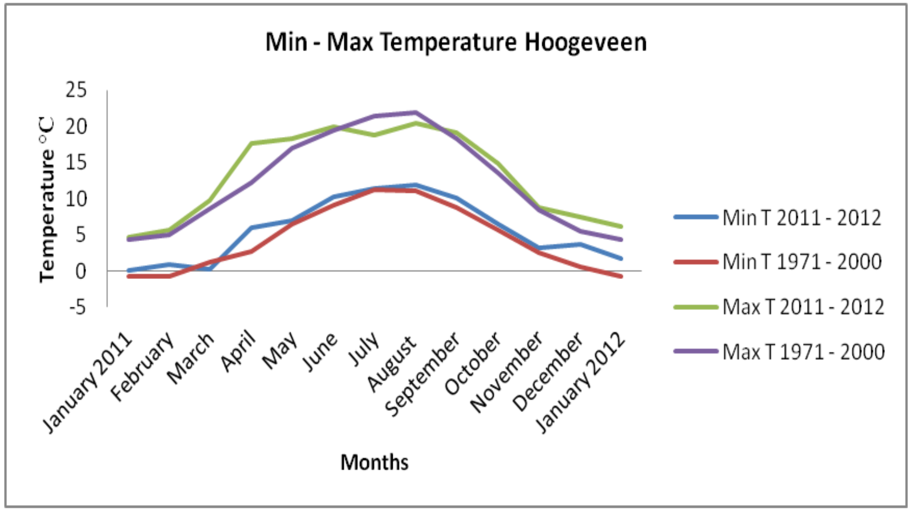
** In the small box (graph) is written the percentage of no- and variable wind of every measurement*

Appendix XVII Yearly overview rainfall, temperature (Max. – Min.) and wind direction in Hoogeveen

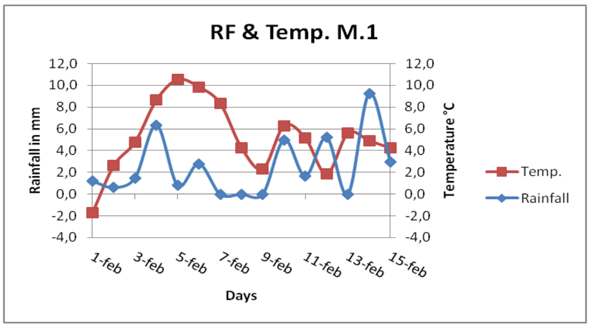


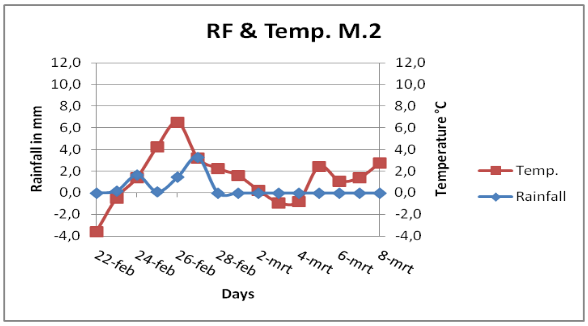


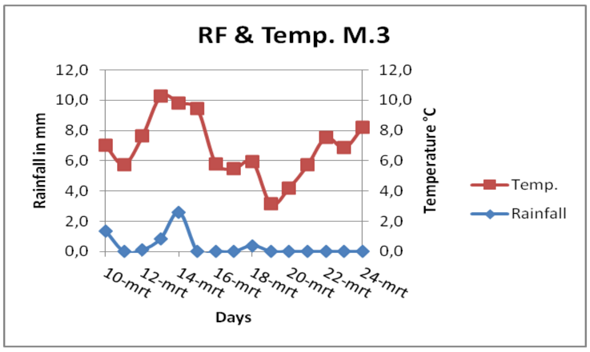


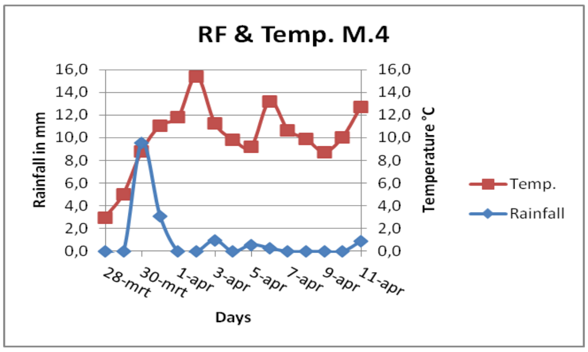


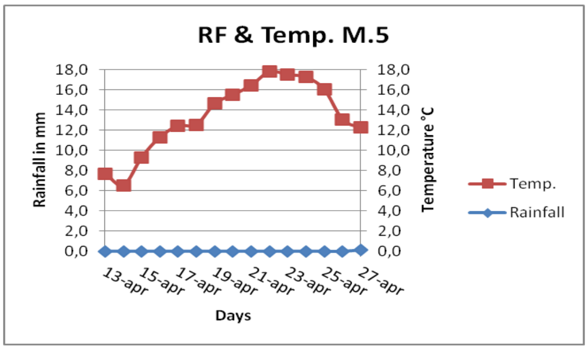
Appendix XVIII Rainfall & Temp. per measurement in Hoogeveen

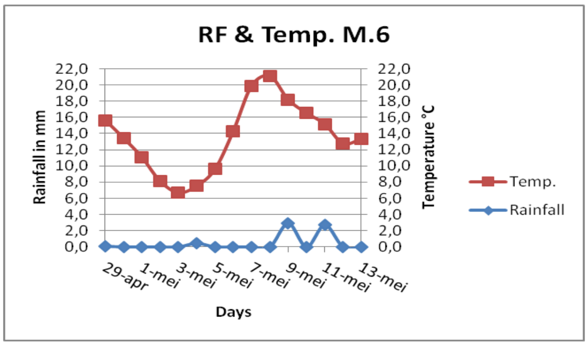


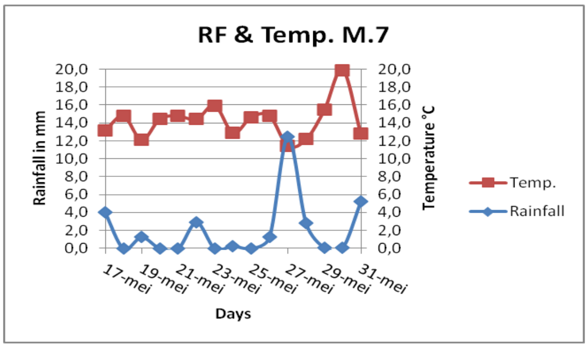


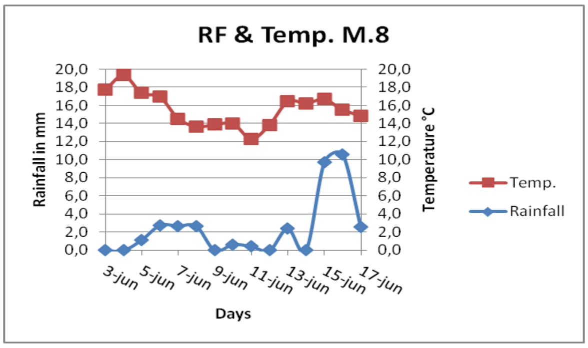


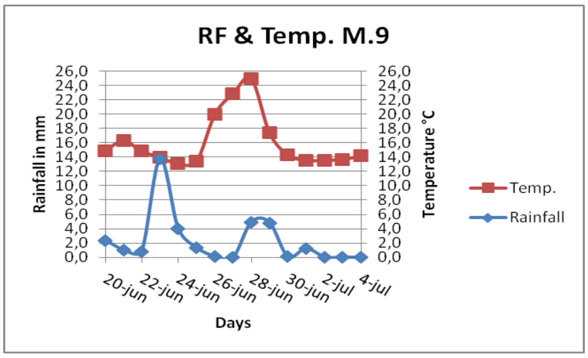


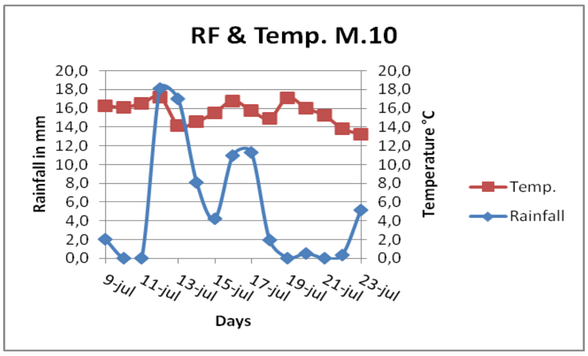


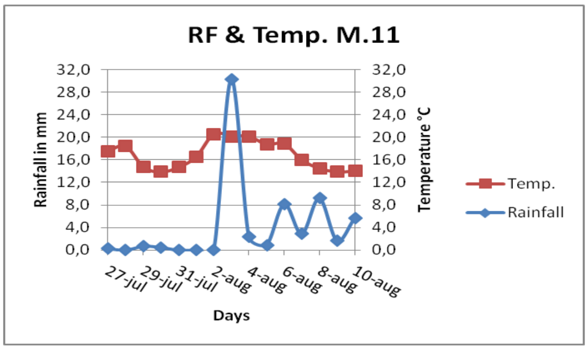


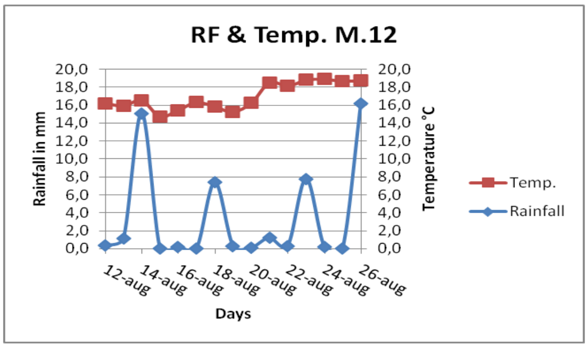


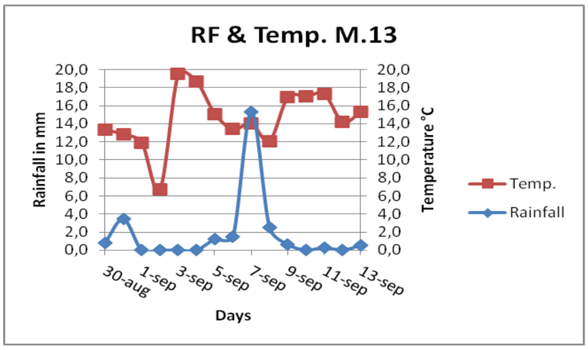


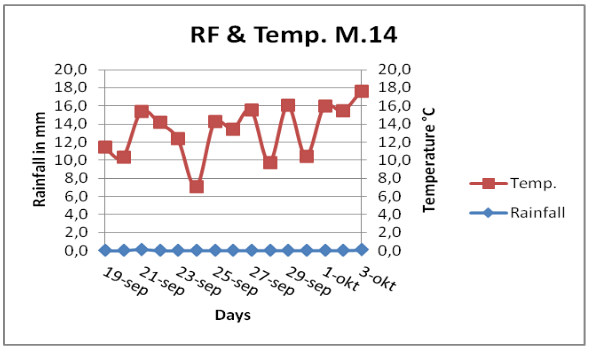


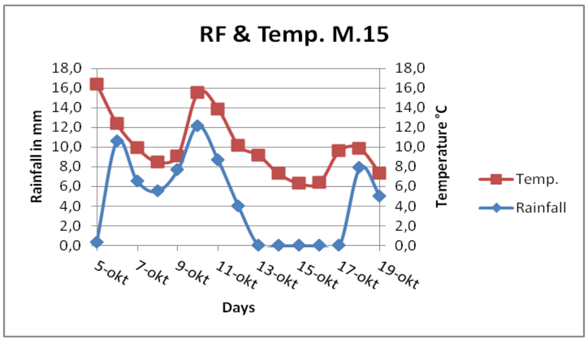


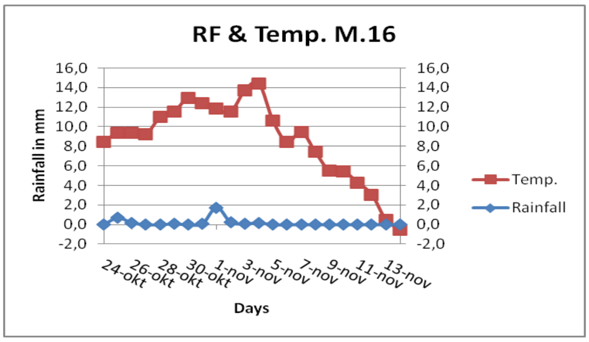

RF & Temp. M.11
Rainfall in mm
Temperature °C
Days
Temp.
Rainfall

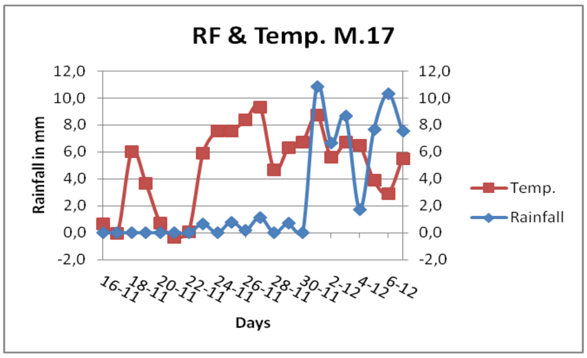

RF & Temp. M.12
Rainfall in mm
Temperature °C
Days
Temp.
Rainfall

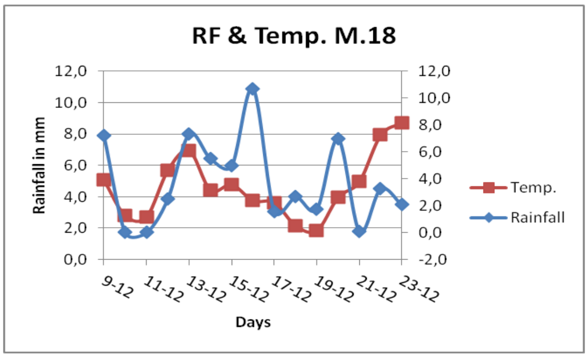

RF & Temp. M.13
Rainfall in mm
Temperature °C
Days
Temp.
Rainfall

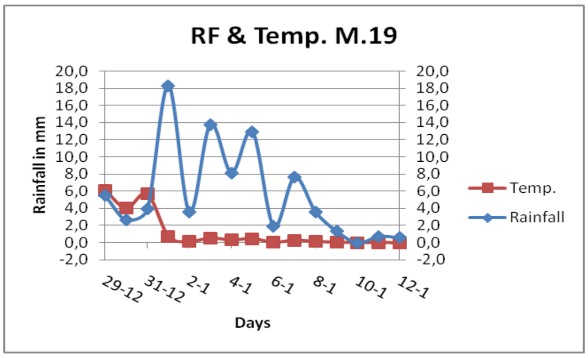

RF & Temp. M.14
Rainfall in mm
Temperature °C
Days
Temp.
Rainfall

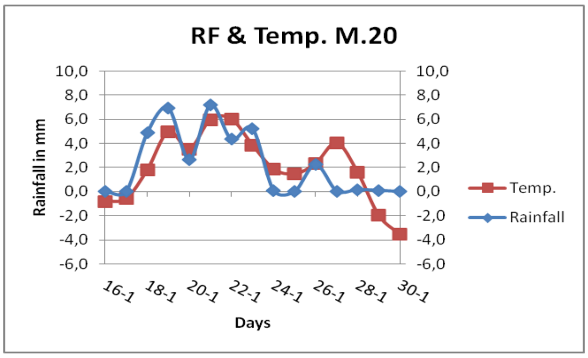

RF & Temp. M.15
Rainfall in mm
Temperature °C
Days
Temp.
Rainfall


RF & Temp. M.16
Rainfall in mm
Days
Temp.
Rainfall

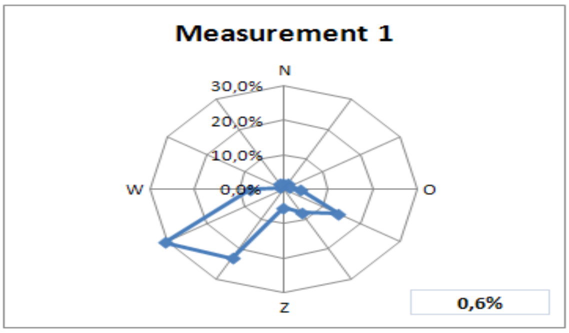

RF & Temp. M.17
Rainfall in mm
Days
Temp.
Rainfall

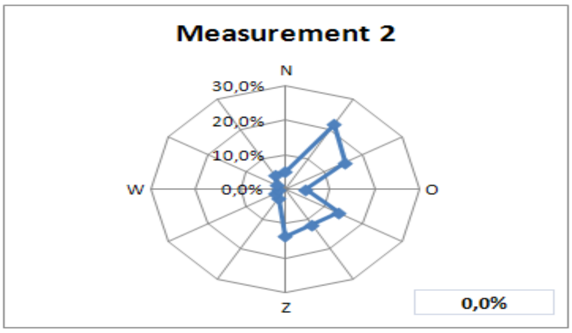

RF & Temp. M.18
Rainfall in mm
Days
Temp.
Rainfall

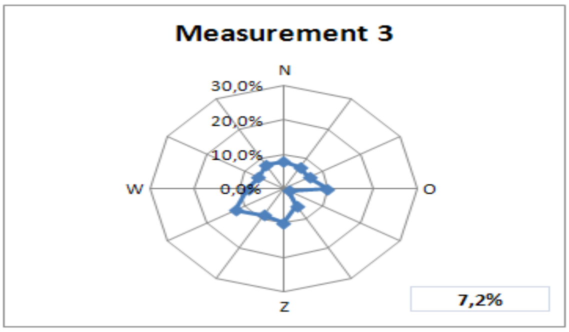

RF & Temp. M.19
Rainfall in mm
Days
Temp.
Rainfall

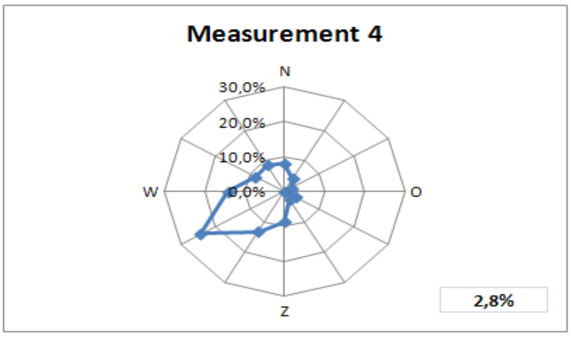

RF & Temp. M.20
Rainfall in mm
Days
Temp.
Rainfall

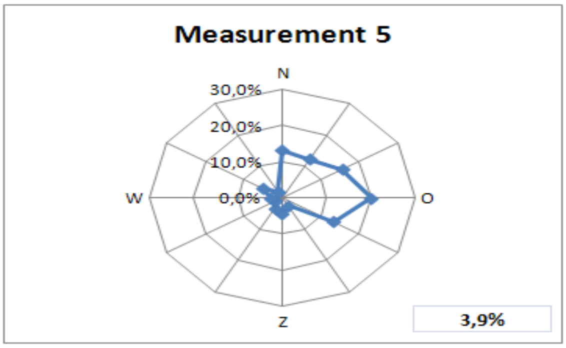
Appendix XIX Wind direction per measurement in Hoogeveen

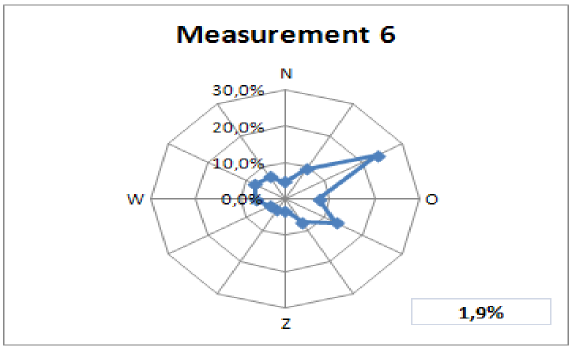


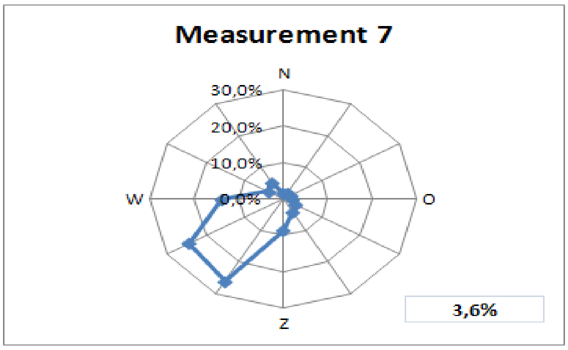


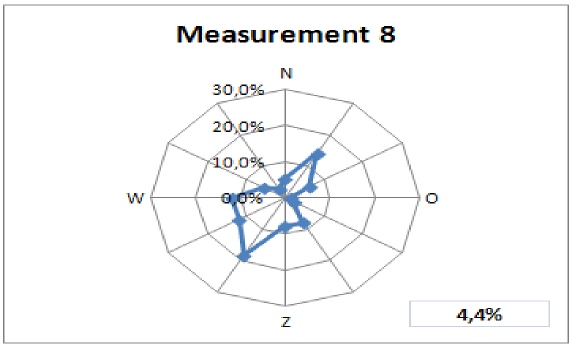


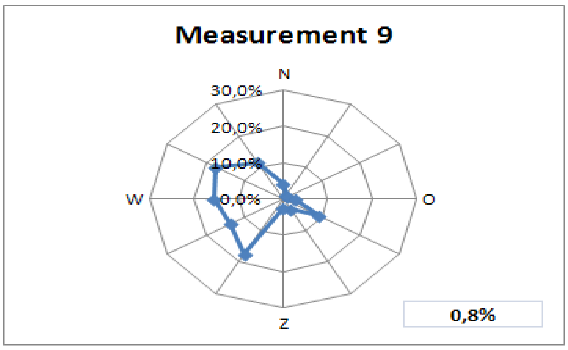


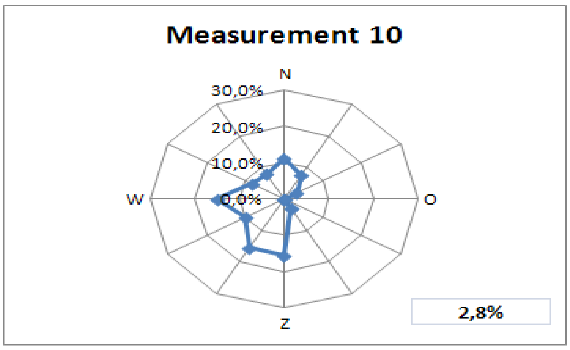


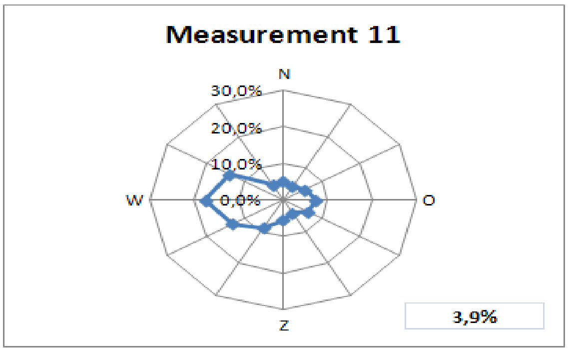


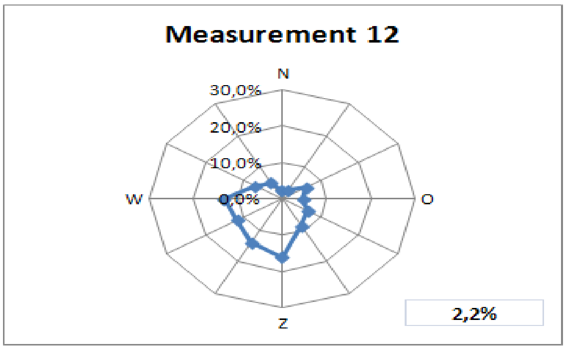


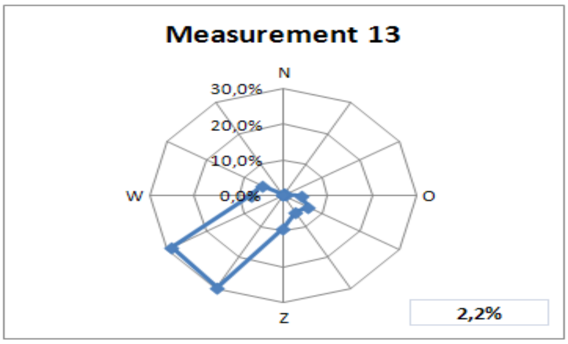


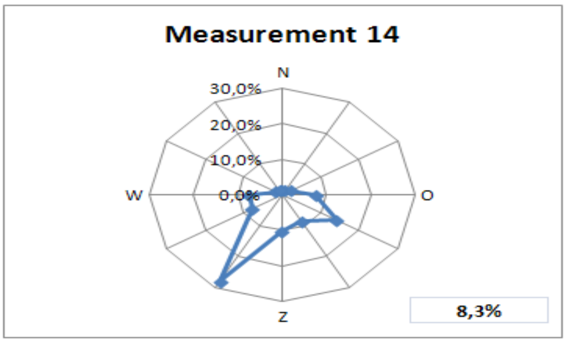


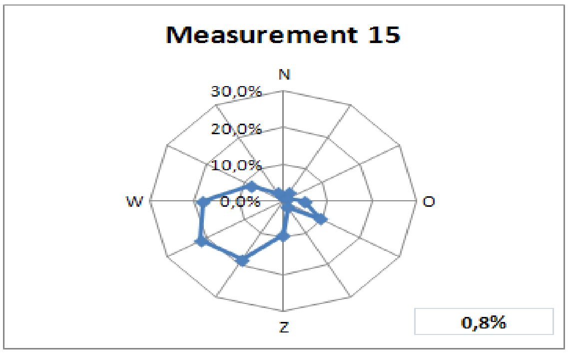


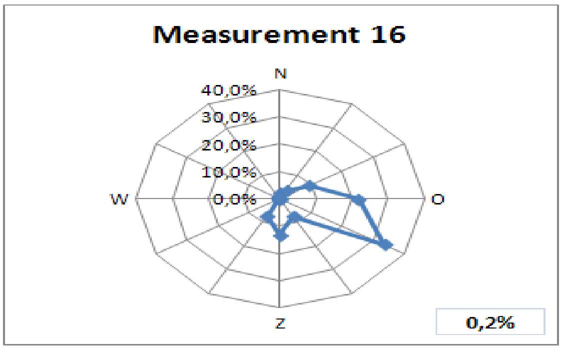


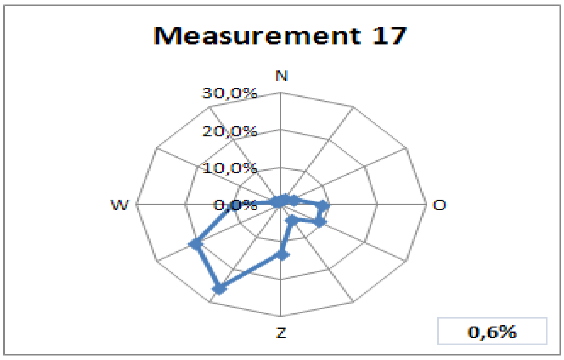


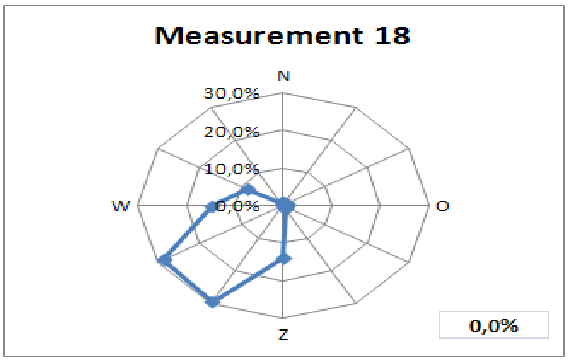


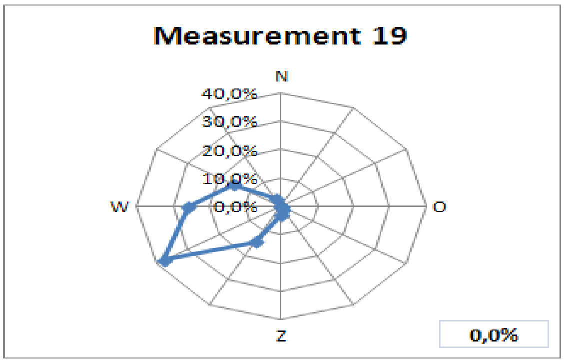


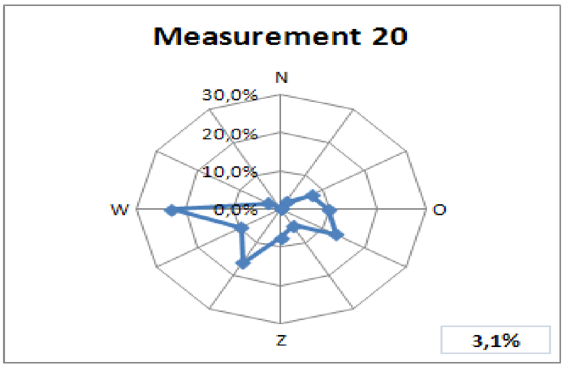






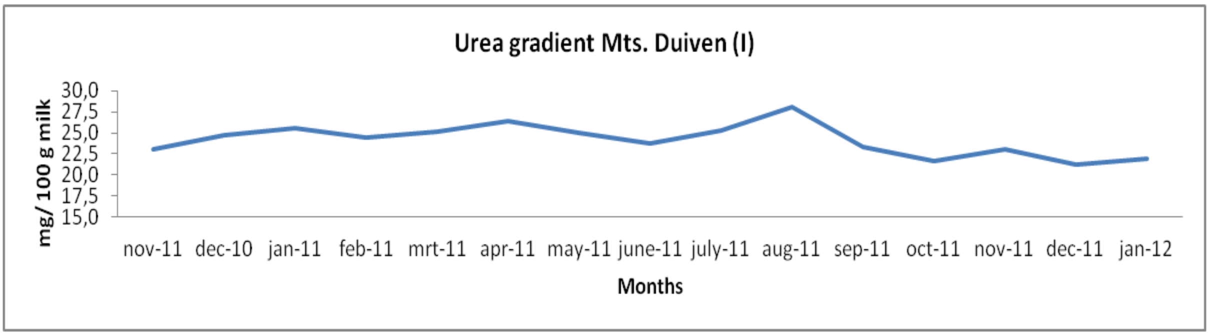


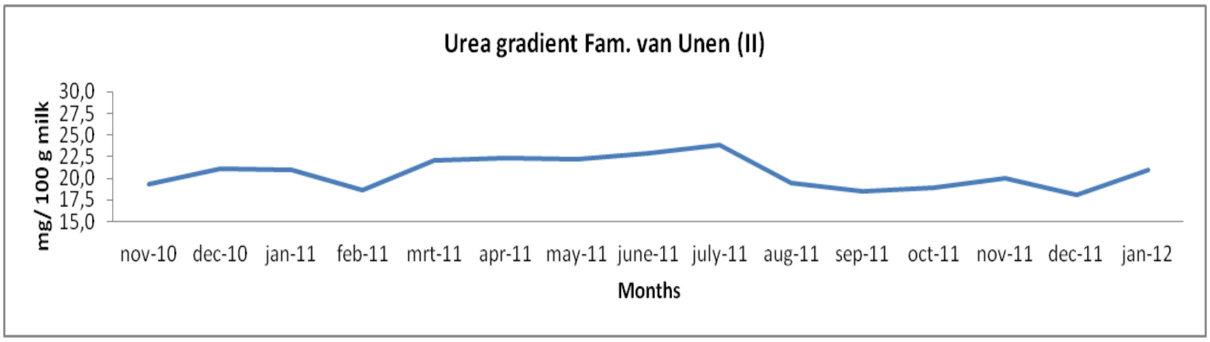


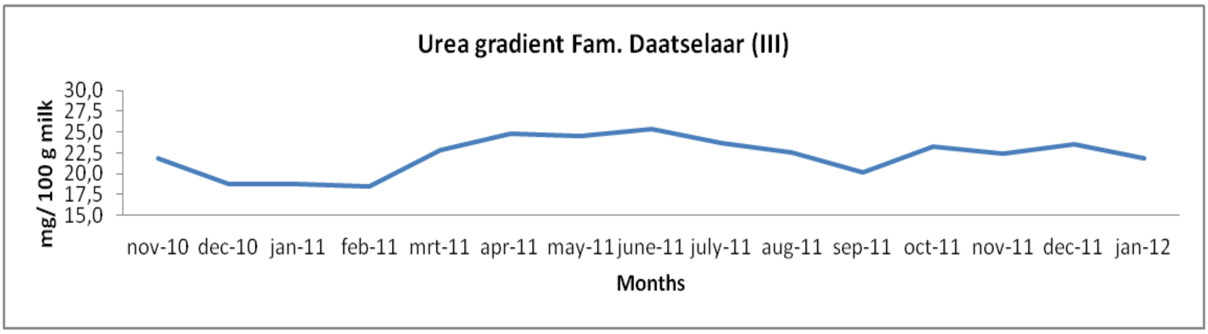


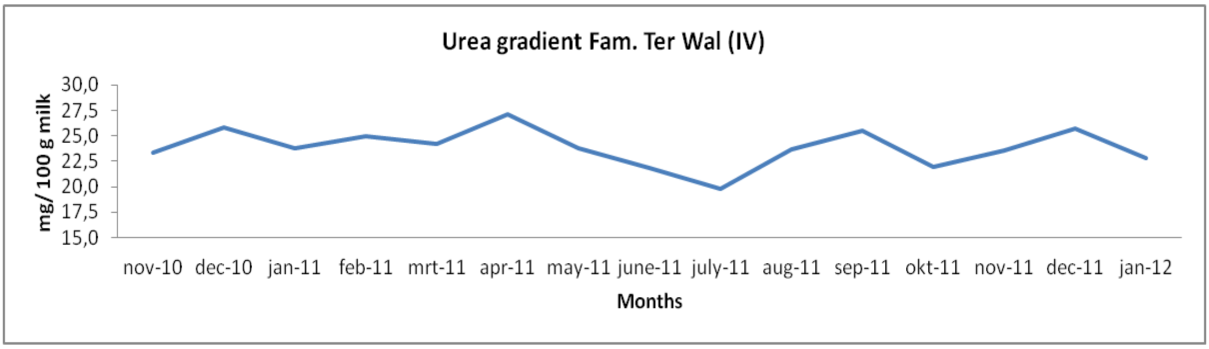
**In the small box (graph) is written the percentage of no- and variable wind of every measurement*

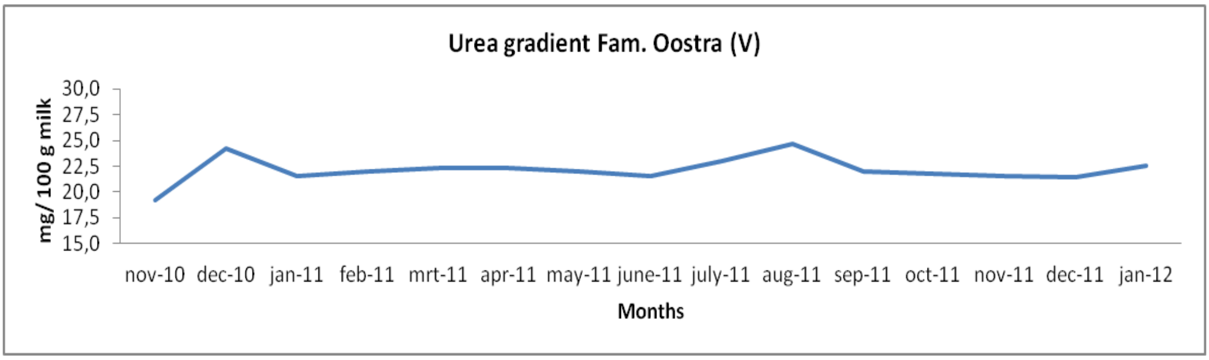
Appendix XX Urea gradient during entire measuring period











Appendix XXI Input OPS-model

Coordinates emission points

Coordinates	Mts. Duiven (I)	Fam. Van Unen (II)	Fam. Daatselaar (III)	Fam. Ter Wal (IV)	Fam. Oostra (V)
X-coordinaat	223900	225460	225902	226821	227956
Y-coordinaat	539200	540446	539850	539845	539662

Calculation of source strength

Farms	Mts. Duiven (I)	Fam. Van Unen (II)	Fam. Daatselaar (III)	Fam. Ter Wal (IV)	Fam. Oostra (V)
Nr of Cows	500	100	75	85	110
GVE (Cow = 1)	500	100	75	85	110
Replacement rate (%)	30	25	30	25	25
Young stock <1	150	25	23	22	28
GVE (Calf = 0,25)	37,5	6,25	5,75	5,5	7
Heifers >1	150	25	22	21	27
GVE (Heifer = 0,5)	75	12,5	11	10,5	13,5
Totaal GVE per bedrijf	613	119	92	101	131
NH_3 per GVE (= 17 kg NH_3)*	10413	2019	1560	1717	2219
*(/365*1000/86400)*					
g NH_3/ s-1	**0,33**	**0,06**	**0,05**	**0,05**	**0,07**

* Hoogeveen *et al.,* 2006

Coordinates of receptors

Location	X Coordinate	Y Coordinate
Punt 1a Measurement 1 - 13	224055	539067
Punt 1b Measurement 13 - 20	224080	539053
Punt 2	224537	539369
Punt 3	224899	538894
Punt 4	225015	539887
Punt 5	225477	540361
Punt 6	225718	539925
Punt 7	225953	539822
Punt 8	226729	539805
Punt 9	227188	539843
Punt 10	227096	539557
Punt 11	226918	539397
Punt 12	227248	539268
Punt 13	227014	539238
Punt 14	227852	539640
Punt 15	227945	539890
New Dwingelderveld (central point)	226680	538906

Appendix XXII Result OPS output all farms & locations; version 4.3.12.

Nr.	Name	X-coord	Y-coord	Pri. conc NH3	Dry dep NHx	Wet dep NHx	Tot. dep NHx	Sec. con. NH4
		(m)	(m)	ug/m-3	kg/ha/yr-1	kg/ha/yr-1	kg/ha/yr-1	ug/m-3
1	Locatie 1a (ps*)	224055	539067	5.6	6	0.2	6.2	0.0096
2	Locatie 1b (ps)	224080	539053	4.6	4.6	0.2	4.8	0.0092
3	Locatie 2 (ps)	224537	539369	0.9	2.2	0.1	2.3	0.0069
4	Locatie 3 (ps)	224899	538894	0.4	0.9	0	0.9	0.0049
5	Locatie 4 (ps)	225015	539887	0.4	0.9	0	1	0.0063
6	Locatie 5 (ps)	225477	540361	3.5	7	0.1	7.1	0.0069
7	Locatie 6 (ps)	225718	539925	1.3	2	0.1	2	0.0064
8	Locatie 7 (ps)	225953	539822	4	9	0.2	9.2	0.0051
9	Locatie 8 (ps)	226729	539805	2.9	3.6	0.1	3.7	0.0051
10	Locatie 9 (ps)	227188	539843	0.5	1	0.1	1.1	0.0042
11	Locatie 10 (ps)	227096	539557	0.4	1	0	1.1	0.0025
12	Locatie 11 (ps)	226918	539397	0.4	0.3	0	0.3	0.0038
13	Locatie 12 (ps)	227248	539268	0.3	0.5	0	0.5	0.0027
14	Locatie 13 (ps)	227014	539238	0.3	0.3	0	0.4	0.0034
15	Locatie 14 (ps)	227852	539640	3.4	8.3	0.1	8.3	0.0054
16	Locatie 15 (ps)	227945	539890	1.5	1	0.1	1	0.007
17	Centralpoint	226680	538906	0.2	0.3	0	0.3	0.0028
18	Oostra 0 mtr (bio**)	227943	539641	9.8	33.6	0.3	33.9	0.0023
19	Oostra 90 mtr (bio)	227855	539639	3.5	8.7	0.1	8.8	0.0054
20	Oostra 190 mtr (bio)	227944	539855	1.9	1.2	0.1	1.3	0.0071
21	Ter Wal 320 mtr (bio)	227186	539833	0.5	1	0.1	1.1	0.0042
22	Ter Wal 340 mtr (bio)	227094	539557	0.4	1	0	1.1	0.0025
23	Ter Wal 400 mtr (bio)	226926	539388	0.4	0.3	0	0.3	0.0038
24	Ter Wal 600 mtr (bio)	227018	539231	0.3	0.3	0	0.4	0.0034
25	Ter Wal 0 mtr (bio)	226816	539826	4.5	9.8	0.2	9.9	0.0035
26	Ter Wal 90 mtr (bio)	226731	539804	3.0	3.7	0.1	3.8	0.0051
27	Daatselaar 0 mtr (bio)	225928	539905	5.5	11.4	0.2	11.6	0.0065
28	Daatselaar 50 mtr (bio)	225938	539820	4.5	10.4	0.2	10.5	0.0049
29	Daatselaar 170 mtr (bio)	225713	539919	1.3	2	0.1	2	0.0064
30	Van Unen 0 mtr (bio)	225473	540427	6.7	16.7	0.4	17	0.0059
31	Van Unen 50 mtr (bio)	225462	540372	3.6	7.4	0.1	7.5	0.0067
32	Duiven 100 mtr Zuid (bio)	224069	539060	5	5.2	0.2	5.3	0.0094
33	Duiven 200 mtr Zuid (bio)	223997	538920	3.3	3.6	0.1	3.7	0.0081
34	Duiven 300 mtr Zuid (bio)	224114	538865	2.2	2.1	0.1	2.2	0.0076
35	Duiven 400 mtr Zuid (bio)	224216	538823	1.5	1.4	0.1	1.5	0.0068
36	Duiven 0 West (bio)	223840	539113	13.8	37.5	0.3	37.8	0.0105
37	Duiven 100 mtr ZW (bio)	223750	539118	8.1	17.8	0.2	17.9	0.0135
38	Duiven 200 mtr ZW (bio)	223650	539115	4.3	3.6	0.1	3.7	0.0118
39	Duiven 400 mtr West (bio)	223561	539357	2.4	2	0.1	2.1	0.0125
40	Duiven 0 mtr Oost (bio)	223955	539206	26.8	103.9	1.2	105.2	0.0087
41	Duiven 80 mtr Oost (bio)	224003	539253	13.9	26	0.6	26.6	0.0121
42	Duiven 400 Noord (bio)	223788	539602	2.2	1.5	0.1	1.6	0.0153

* Location(s) were the ammonia concentrations were measured with passive samplers

** Location(s) were the N depostion was measured with biomonitors

Colours show a linkage between the biomonitors and passive samplers which were placed at the same farm

The centralpoint is an extra receptor point to make a better understanding of the simulation of ammonia

Appendix XXIII Result OPS output all farms & locations; version 4.3.15.

Nr.	Name	X-coord	Y-coord	Pri. conc NH3	Dry dep NHx	Wet dep NHx	Tot. dep NHx	Sec. con. NH4
		(m)	(m)	ug/m-3	kg/ha/yr-1	kg/ha/yr-1	kg/ha/yr-1	ug/m-3
1	Locatie 1a (ps*)	224055	539067	4.1	7.2	0.2	7.3	0.0077
2	Locatie 1b (ps)	224080	539053	3.4	5.8	0.1	5.9	0.0073
3	Locatie 2 (ps)	224537	539369	0.8	2.4	0.1	2.5	0.0060
4	Locatie 3 (ps)	224899	538894	0.3	0.9	0	0.9	0.0050
5	Locatie 4 (ps)	225015	539887	0.4	1	0	1	0.0067
6	Locatie 5 (ps)	225477	540361	2.3	6.1	0.1	6.2	0.0081
7	Locatie 6 (ps)	225718	539925	1.6	2.7	0	2.7	0.0088
8	Locatie 7 (ps)	225953	539822	3.8	12.5	0.1	12.6	0.0059
9	Locatie 8 (ps)	226729	539805	2.1	3.1	0	3.1	0.0060
10	Locatie 9 (ps)	227188	539843	0.5	1.1	0.1	1.2	0.0050
11	Locatie 10 (ps)	227096	539557	0.3	1.2	0	1.3	0.0027
12	Locatie 11 (ps)	226918	539397	0.4	0.4	0	0.4	0.0048
13	Locatie 12 (ps)	227248	539268	0.2	0.6	0	0.6	0.0026
14	Locatie 13 (ps)	227014	539238	0.3	0.4	0	0.4	0.0041
15	Locatie 14 (ps)	227852	539640	3	7.9	0	8	0.0062
16	Locatie 15 (ps)	227945	539890	1.8	1.9	0.1	2	0.0081
17	Centralpoint	226680	538906	0.2	0.3	0	0.3	0.0037
18	Oostra 0 mtr (bio**)	227943	539641	6.1	23.4	0.2	23.6	0.0022
19	Oostra 90 mtr (bio)	227855	539639	3.2	8.3	0	8.4	0.0061
20	Oostra 190 mtr (bio)	227944	539855	2.3	2.5	0.1	2.6	0.0083
21	Ter Wal 320 mtr (bio)	227186	539833	0.6	1.1	0.1	1.2	0.0051
22	Ter Wal 340 mtr (bio)	227094	539557	0.3	1.2	0	1.3	0.0027
23	Ter Wal 400 mtr (bio)	226926	539388	0.4	0.4	0	0.4	0.0047
24	Ter Wal 600 mtr (bio)	227018	539231	0.3	0.4	0	0.4	0.0041
25	Ter Wal 0 mtr (bio)	226816	539826	2.9	7	0.2	7.2	0.0049
26	Ter Wal 90 mtr (bio)	226731	539804	2.1	3.1	0	3.2	0.0060
27	Daatselaar 0 mtr (bio)	225928	539905	6.7	24.8	0.3	25.1	0.0076
28	Daatselaar 50 mtr (bio)	225938	539820	3.9	13.4	0.1	13.5	0.0057
29	Daatselaar 170 mtr (bio)	225713	539919	1.5	2.6	0	2.7	0.0087
30	Van Unen 0 mtr (bio)	225473	540427	5.4	18.7	0.3	18.9	0.0075
31	Van Unen 50 mtr (bio)	225462	540372	2.3	5.9	0.1	6	0.0080
32	Duiven 100 mtr Zuid (bio)	224069	539060	3.7	6.3	0.1	6.5	0.0074
33	Duiven 200 mtr Zuid (bio)	223997	538920	2.1	3.1	0.1	3.2	0.0069
34	Duiven 300 mtr Zuid (bio)	224114	538865	1.6	2.3	0.1	2.3	0.0068
35	Duiven 400 mtr Zuid (bio)	224216	538823	1.1	1.6	0.1	1.7	0.0061
36	Duiven 0 West (bio)	223840	539113	8.1	16.6	0.2	16.8	0.0080
37	Duiven 100 mtr ZW (bio)	223750	539118	5.3	9.9	0	9.9	0.0105
38	Duiven 200 mtr ZW (bio)	223650	539115	3.3	3.4	0	3.4	0.0110
39	Duiven 400 mtr West (bio)	223561	539357	3.1	3	0	3.1	0.0205
40	Duiven 0 mtr Oost (bio)	223955	539206	27.4	91.1	1.3	92.5	0.0088
41	Duiven 80 mtr Oost (bio)	224003	539253	14.3	47.8	0.6	48.5	0.0108
42	Duiven 400 Noord (bio)	223788	539602	2.5	2.5	0.1	2.6	0.0189

* Location(s) were the ammonia concentrations were measured with passive samplers

** Location(s) were the N depostion was measured with biomonitors

Colours show a linkage between the biomonitors and passive samplers which were placed at the same farm

The centralpoint is an extra receptor point to make a better understanding of the simulation of ammonia