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Simulating Future Climate Scenarios: The Effect on Nitrogen Utilization in Organic Fertilizers on Carrot Crops

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ABSTRACT

The agricultural industry's impact on biodiversity loss and greenhouse gas emissions necessitates addressing the use of nitrogen (N) in agroecosystems. This study explores the role of organic fertilizers, such as manure, animal slurry, and food waste, in sustainable agriculture. The model DeNitrification DeComposition (DNDC) was utilized to simulate the effects of future climate conditions on N mineralization and plant growth in carrot crops by considering temperature, precipitation, and CO2 levels forecasted for 2050. The focus was on maximizing crop N uptake and minimizing N losses to the environment. Although the model validation was inconclusive, the results indicate that increased N mineralization in organic fertilizers may not meet the growing plant N demand in a warmer climate. Moreover, higher temperatures and CO2 levels affect plant N uptake and growth patterns, suggesting the need for dynamic fertilizer recommendations. The study also highlights the potential benefits of combining organic fertilizers, such as digestate, with other sources to optimize nutrient availability and waste recycling. However, further field trials are necessary to validate these findings and ensure their practical application. The research underscores the importance of adjusting fertilizer management practices to mitigate the impacts of climate change and enhance N utilization in organic farming systems.

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1. INTRODUCTION

The modern agricultural industry is the leading cause of biodiversity loss (S. Díaz, 2019) and contributes up to one-third of greenhouse gases (GHGs) to the atmosphere (Gilbert, 2012). The production and widespread use of nitrogen (N) in agroecosystems impacts both of these issues (FAO, 2017; Gliessman, 2015, p.260). N is the most frequently limiting nutrient for primary producers as most soils cannot provide sufficient plant available N (Berry et al., 2002; Havlin, 2014, p.117). Although the atmosphere contains 78% diatomic nitrogen (N_2), plants are unable to break the strong triple bond holding the two atoms together (Galloway et al., 2004). To meet plant N requirements in food production, supplemental fertilizers containing the plant available ammonium (NH_4^+) or nitrate (NO_3^-) is needed. Synthetic fertilizer created through the Haber-Bocsh process has helped increase agricultural yields greatly and supported a growing human population since its invention in 1913 (Gruber & Galloway, 2008; Lassaletta et al., 2014a; Mueller et al., 2012). However, industrial splitting of the stable N_2 molecule is energy intensive and contributes globally to 1.4% carbon dioxide (CO_2) emissions and consumes 1% of the world's energy (Capdevila-Cortada, 2019). Moreover, the anthropogenic addition of reactive N (Nr) to the biosphere has increased ten-fold in the last century (Galloway et al., 2004; Schlesinger & Bernhardt, 2020), the largest portion coming from synthetic N fertilizers (Havlin, 2014, p. 118), affecting both the N cycle, and indirectly, the carbon (C) cycle (Galloway et al., 2004). From the agriculture sector, over half of the N applied is lost to the environment through leaching or gaseous losses (Berry et al., 2002; Lassaletta et al., 2014b; Mosier et al., 2004). Leaching and run-off from N fertilizers into lakes and oceans causes eutrophication and can lead to algal blooms suffocating fish and other aquatic life forms (USGS, n.d.). On land, both leached N and volatilized ammonia (NH_3), deposited to ecosystems downwind from agricultural operations, have been shown to reduce biodiversity over time (Maskell et al., 2010). Additionally, Nr in the soil contribute to GHGs by denitrifying microorganisms converting NO_3^- to nitrous oxide (N_2O) gas with a warming capacity 300 times that of CO_2 (Havlin, 2014, p. 134). Addressing the problems of increased Nr in the biosphere by limiting the use of industrially produced Nr, utilizing alternative sources of nutrients and managing N fertilizers efficiently is needed for agroecosystems to become more sustainable.

Manure, animal slurry and food waste are organic sources that supply fertilizers while simultaneously recycling materials. Manure and animal slurry contain 1-6% recoverable N depending on the animal feed content, storage and handling of the manure, timing and method of fertilizer application and soil quality (Havlin, 2014, p. 179). Another source of organic fertilizer is food waste. Household and industry food waste can be run through a biogas facility, where anaerobic microorganisms break down organic compounds that creates methane (CH_4^+) used for energy whilst producing a nutrient-dense by-product, digestate, that can be utilized as a N source for crops (Akari & Uchida, 2021; Furukawa & Hasegawa, 2006; Koszel & Lorencowicz, 2015; Øvsthus et al., 2017). During anaerobic digestion, the original feedstock undergoes several changes that affects macro- and micronutrient availability to plants (Möller & Müller, 2012). The organic N is mineralized to NH_4^+ leaving only a small portion of OM in digestate consisting of materials like lignin in cell walls that are resistant to mineralization (Tambone et al., 2009). In contrast to synthetic fertilizers that disguise drops in soil fertility (Gliessman, 2015, p. 261), organic fertilizers contribute to biological activity and maintenance of soil organic matter. Organic Matter (OM) is important in various aspects of soil health including structure, nutrient-holding capacity, and C storage (Havlin, 2014, p. 451). Some evidence suggests that digestate does not add much to the soil structure by OM, nor does it contribute to the biodiversity of microbes as the anaerobic community of microbes dies off in the aerobic soil (Akari & Uchida, 2021). However, digestate behaves similar to industrially produced fertilizers (Furukawa & Hasegawa, 2006; Tambone et al., 2010) making it a valuable addition in organic vegetable crops as a quick release fertilizer, especially in cooler climates with a short growing season (Möller & Müller, 2012). Digestate contains 1-9% N of which 44-81% is in the form of ammonium depending on the source material (Möller & Müller, 2012). Recycling organic waste materials as fertilizers closes the loop on nutrient cycling, but in order to maximize N utilization by the crop and minimize N losses and harm to the environment, we need to know how to utilize this material to maximize crop uptake and minimize losses to the environment.

The N available for plant uptake in organic fertilizers depends on the initial inorganic N content and the release rate from the organic fraction by mineralizing microorganisms in the soil (Cabrera et al., 2005). Heterotrophic microorganisms require C for energy and through their activity they mineralize N by breaking down proteins to amino acids, amines, and urea. Ammonification then breaks down these products to NH_4^+ (Havlin, 2014, p. 137). From here, NH_4^+ can either be taken up by the plant (N uptake), converted to NO_3^- (nitrification), taken up in the biomass of microorganisms (immobilization), fixed in clay minerals (fixation) or converted to gaseous NH_3 (volatilization). N mineralization is dependent on complex interactions between biotic and abiotic factors including organic composition of the residue, soil properties, temperature, and water content (Havlin, 2014, p. 179; Whitmore, 1996). Generally, the rate increases with soil temperature where the optimal temperature for microbial activity is 25-35°C

(Havlin, 2014, p. 138). The actual plant N-uptake depends on the degree of synchrony between N-availability and crop demand (Berry et al., 2002; Cassity-Duffey et al., 2020). Similarly, losses depend on the synchrony between environmental factors that promote loss and the presence of mineralized N. Additionally, N left in the soil after harvest is susceptible to leaching and gaseous losses during events such as drying and rewetting, freezing and thawing (Cabrera et al., 2005; Foereid et al., 2020). The challenge then is to synchronize the mineralization of N with the plant uptake during the growing season and minimize the N left in the soil after harvest to prevent leaching and volatilization over the winter. Understanding the temporal mineralization of N, and how it might differ in various organic fertilizers along with timing of plant N uptake reduces the likelihood of N losses to the environment. This is particularly important in organic farming, where insufficient or poorly synchronized N release compared to crop demand cannot be compensated for by adding mineral fertilizers (Berry et al., 2002).

To improve our understanding of N in agroecosystems, computer simulations offer a useful supplement to field trials. A properly parameterized, validated, and calibrated model can inexpensively and quickly assess the impact of various external factors and agricultural management practices. Conditions that might be difficult to control in a field trial, such as the impact of climate change, can easily be manipulated in models. Many mechanistic computer simulation models exist that focus on carbon and nitrogen biogeochemistry in agricultural ecosystems e.g., DAISY (Hansen et al., 1991), EU-Rotate_N (Rahn et al., 2010) and CENTURY (Parton et al., 1988). In this study, the model DeNitrification DeComposition (DNDC) version 9.5 (Li et al., 1992) was used. DNDC incorporates both empirical equations and laws of physics, chemistry, and biology to calculate a range of outputs.

Although many studies have been done on the mineralization rate and available N in various organic fertilizers, less information is available on how future climate conditions might change the synchrony between N mineralization and crop demand. For Norway, a temperature increase of 2-3°C in the summertime is expected by 2050 along with a 7-23% increase in rain (Hanssen-Bauer et al., 2017; Miljødirektoratet, n.d.) while global atmospheric CO2 is forecasted to reach 685 ppm by 2050 (OECD, 2012). Here, DNDC was used to simulate how an increase in temperature, precipitation and CO_2 forecasted for 2050 will affect plant growth in carrots and N mineralization in three organic fertilizers with varying amounts of OM: digestate, cow slurry and a commercially produced chicken manure. The model was parameterized, calibrated, and validated based on a field trial in southeast Norway on carrots fertilized with various combinations of organic materials.

The objective of this study then was to initialize, calibrate and validate the model to explore (i) how a warmer climate may increase N mineralization in organic fertilizers and if it corresponds to an increased plant N demand (ii) how plant N uptake and growth pattern in carrots are affected by an increase in temperature and atmospheric CO_2 levels (iii) how organic fertilizer management may need adjustments in the future to maximize N utilization and minimize N losses in carrot crops.

2. METHODS

2.1 DESCRIPTION OF THE FIELD TRIAL

Site description and weather conditions

The field trial used to parameterize, calibrate and validate the DNDC model was conducted in the summer of 2017 and 2018 at Apelsvoll operated by the Norwegian Institute of Bioeconomy Research (NIBIO). The trial site consists of flat plots with a humus-rich morainic loam soil and good drainage The location of the research field is at latitude 60°70' N and longitude 10°87' E at an elevation of 262 meters. Weather data for 2015 to 2018 were collected from Agrometeorology Norway (NIBIO, n.d.-c), Apelsvoll station, located in the vicinity of the field trial. The temperature for the growing season of 2017 was according to Aas et al. (2018, p. 9) 2 °C above average while precipitation was 20% above average (all averages refer to the 1961-1990 period). 2017 was the 6th wettest and the 20th warmest year since 1900. Although a wet and warm year, the temperature curve for 2017 throughout the growing season was similar to the average values and was therefore used as the basis for many of the modeled scenarios. 2018 data, used for calibrating the model against measured yield and soil mineral nitrogen, was recorded as the 13th warmest year since 1900 (Aas et al., 2019, p. 11). Precipitation was close to average this year mostly due to a wet winter. However, the rainfall was only 25-50% of average in May and July with both months recording the hottest temperatures since measurements started in 1900. August had temperatures close to normal, but a precipitation of only 50% led to severe droughts in agricultural areas.

Carrot Field experiment

The crop used in the trial was carrots of the variety "Namdal", a mid-season F1 hybrid. Prior to carrots, two years of potato crops had been grown in the same field. Seeds were planted on the 26th of June and harvested on the 21st of October, 2017 and on the 20th of June with a harvest date of 8th of October, 2018. A sprinkler system provided irrigation during periods with low rainfall. Five organic fertilizers were tested on the carrots (cow slurry, digestate and three commercial fertilizers) in eight different combinations (see Table 1) in four replicate field plots. Some combinations consisted of two types of fertilizers applied before sowing (fertilizer 1 and 2), others had a second application when the plant showed 2-4 true leaves at 64 and 61 days after sowing for 2017 and 2018, respectively. Fertilizer 1 and 2 were incorporated into the soil by rotary harrowing to approximately 5cm depth and took place 2-3 weeks prior to sowing. The second application (in four of the eight combinations) was pellets distributed by hand. Carrot yield for both 2017 and 2018 was measured while soil NH_4^+-N and NO_3^- -N was measured to a depth of 20cm on the 16th of October in 2018 only.

TABLE 1: FERTILIZER COMBINATIONS USED IN THE FIELD TRIAL. EACH OF THE EIGHT TREATMENTS TOTALLED 100 KG N HA^{-1} APPLIED TO THE CARROTS.

Applied 2. June 2017 and 30. May, 2018			*Applied 23. August, 2017 and 20. August, 2018*
Treatment number	**Fertilizer 1**	**Fertilizer 2**	**Second application**
1	Animal slurry, 100 kg N ha^{-1}		
2	Animal slurry, 70 kg N ha^{-1}	8K, 30 kg N ha^{-1}	
3	Animal slurry, 70 kg N ha^{-1}		8K, 30 kg N ha^{-1}
4	Animal slurry, 70 kg N ha^{-1}		PHC, 30 kg N ha^{-1}
5	Digestate, 100 kg N ha^{-1}	Polysulfate (K)	
6	Digestate, 70 kg N ha^{-1}	Polysulfate (K)	Eco, 30 kg N ha^{-1}
7	8K, 100 kg N ha^{-1}	Polysulfate (K)	
8	8K, 70 kg N ha^{-1}	Polysulfate (K)	8K, 30 kg N ha^{-1}

Organic fertilizers

The cow slurry was from OWRA cooperative farms in Toten, Norway, collected from both meat and dairy cows. The slurry was treated by a manure separator and stored over the winter at Apelsvoll research facility. Four to five weeks prior to use it was oxygenated to increase temperature and destroy weed seeds. Manure samples were then collected for analysis and stirred a few times prior to application. The digestate was from Mjøsanlegget biogas facility located at Lillehammer, Norway, where food waste from households, restaurants, and industry are treated in an anaerobic digestion process and the waste product used as fertilizer. The three remaining fertilizers were commercially produced in pelletized form. Eco contains composted chicken manure and 8K is a mix of composted chicken manure, bone meal and vinasse, both produced by Grønn Gjødsel in Rakkestad, Norway. PHC is a granulated extract of sugarcane molasses produced by Plant Health Cure BV, Oisterwijk, Nederland distributed in Norway by NORGRO AS. Manure and digestate were analyzed for nutrient content in 2018 and the same types, but different batches, of commercial fertilizers were analyzed in 2021. All analyses were performed by Eurofins Agro Testing, Moss, Norway using their standard methods (Appendix I). In addition to the fertilizers described above, polysulfate (containing nutrients other than N), was used in the field trial as an additive to both digestate and 8K. Fact sheets on nutrient content for the commercially produced fertilizers can be found in Appendix II.

2.2 PARAMETERIZATION, CALIBRATION, AND VALIDATION OF THE MODEL

Model description

DNDC is classified as a "coupled soil-plant dynamic model" that calculates both daily and yearly soil N content, N leaching and GHG emissions along with plant N demand, uptake, and yield (Manzoni & Porporato, 2009) . The model is divided into two main components (Figure 1). The first is driven by climate, soil, vegetation, and anthropogenic activity. It contains three sub-models of soil climate, plant growth and decomposition that predicts the soil environmental factors: temperature, moisture, pH, and redox potential (Eh). This component then combines with the second component driven by soil environmental factors and contains the sub-models: denitrification, nitrification and fermentation that predicts gaseous emissions from the plant-soil system. The model requires detailed inputs of the primary ecological drivers which affect biogeochemical reactions (Li, 2012). Plant inputs including type of crop, sowing and harvest date, physiological and phenological parameters can be defined. Modifications can be done to default values such as maximum yield, biomass partitioning and crop C:N ratio, thermal degree days (TDD), and optimum temperature. Optimal daily crop growth and plant C:N ratio is used for calculating plant N demand, while the actual N uptake during the growing season may be limited by water or N availability (Zhang & Niu, 2016). Plant N uptake is obtained from the available NH_4+ and NO_3^- pools in the soil down to 50 cm depending on root depth.

The decomposition sub-model of DNDC, described in detail by Li (2012), calculates decomposition, nitrification and denitrification of organic fertilizers based on its biochemical properties. The OM contained in manure is divided into four pools: litter, microbes, humads (active humus), and passive humus. The litter pool is subdivided into categories of very labile, labile, and resistant materials while the microbe and humad pools are each divided into labile and resistant pools. The humus is considered a passive humus pool. Each of these pools have specific decomposition rates and are computed independently following the laws of thermodynamics and first-order kinetics. Dynamic aerobic and anaerobic conditions are considered for estimating CO_2, CH_4, NH_3, nitrogen oxides (NO_x) and N_2O emissions.

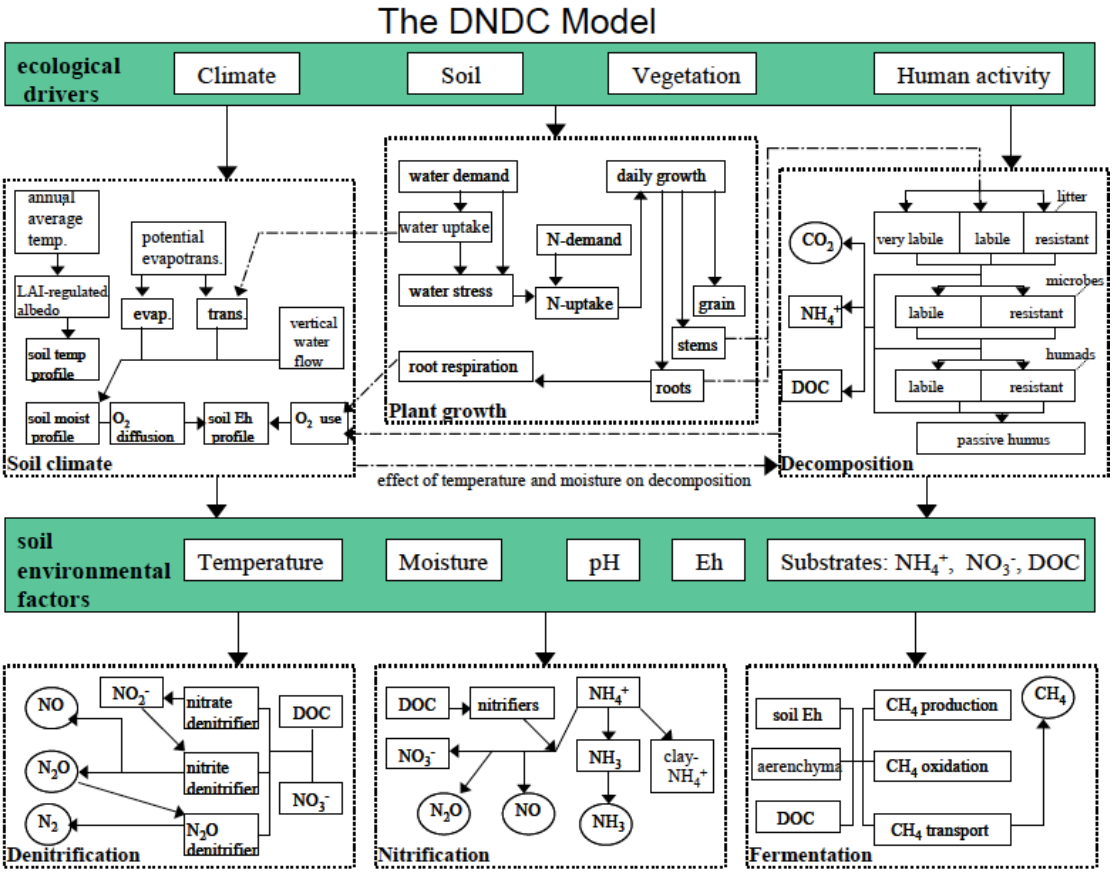

FIGURE 1: DNDC MODEL STRUCTURE (LI, 2012).

Input parameters

The average daily high and low temperature (2m above the ground in °C), precipitation (mm), windspeed (ms^{-1} at 2m), radiation ($MJm^{-2}day^{-1}$) and relative humidity (%) were used as climate input parameters to the model. Climate files from 2015 to 2017 and 2016 to 2018 were used for the field trials and to account for two years of crops preceding the carrot trial in 2017 and 2018, respectively. The carrot storage organ (termed *grain* in the model) *biomass C/N ratio* input parameter was calculated based on analyses from the Apelsvoll field trial, where the average N content was 0.76% of dry matter, giving a C/N ratio of 52.7 using 40% C per dry matter as per DNDC manual. Literature was used to calculate C/N content of leaves giving a N content of 2.23% (Riley & Dragland, 2002). The C/N ratio would then be 17.9 in leaves, the same figure was given to stems. Root C/N ratio was set to match the carrot storage organ. Through reviewing literature and personal correspondence with an expert in the field (Kristian Thorup-Kristensen, personal correspondence, 2021), the default biomass parameters for carrots were deemed representative. To account for additional water input via the sprinkler system, an irrigation index of 1 was used in the model. This automatically delivers water when the model simulates occurrence of water stress in the crop (Li, 2012, p. 30). To equilibrate pools, two years of potato crops were simulated prior to carrots. This crop was also grown on the field prior to the field trial. Here, input parameters were the same as for carrots except the crop was changed to the default potato crop pre-programmed in the model and fertilized with 12 kg N ha^{-1} of animal slurry. Input parameters used in the model along with sources and values are listed in Table 2.

TABLE 2: OVERVIEW OF INPUT PARAMETERS USED IN THE MODEL

Input parameters	**Source**	**Value**
Latitude	LMT (NIBIO, n.d.-a)	60.7
Meteorological data	LMT (NIBIO, n.d.-c)	Downloaded files
N concentration in rainfall 2017 and 2018	NILU 2017 data (Aas et al., 2018)	0.278
	NILU 2018 data (Aas et al., 2019)	0.248
Atmospheric background NH_3 concentration (μg N m^{-3})	NILU 2017 data (Aas et al., 2018)	0.11
	NILU 2018 data (Aas et al., 2019)	0.16
Atmospheric background CO_2 concentration (ppm)	NOAA 2017 numbers (NOAA, 2018)	405
	NOAA 2018 numbers (NOAA, 2019)	407
Annual increase rate of atmospheric CO_2 concentration (ppm yr^{-1})	Not applicable	0
Land use	Thomsen, M., 2021	Upland crop field
Texture	Thomsen, M., 2021	Loam
Bulk density	Eurofins Agro Testing	1.28
Soil pH	Eurofins Agro Testing (average of two analysis)	6.3
Field capacity (wfps)	Thomsen, M., 2021	0.31
Wilting point (wfps)	Thomsen, M., 2021	0.14
Clay fraction	Apelsvoll researcher per Thomsen, M.	0.18
Conductivity	Thomsen, M., 2021 (0.02 – 0.04 m hr^{-1})	0.03
Porosity	Thomsen, M., 2021 (50-55%)	52.5
Depth water retention	DNDC default	9.99
Drainage efficiency	Thomsen, M., 2021	1
SOC at surface soil (0-10cm) (kg C kg^{-1} soil)	DNDC calculation from bulk density	0.0139
Microbial activity index (0-1)	Thomsen, M., 2021	1
Slope	Thomsen, M., 2021	0
Soil salinity index (0-100)	Thomsen, M., 2021	0
Rainwater collection index	DNDC default	1
Nitrate (mg N kg^{-1})	Thomsen, M., 2021	0.45
Ammonium (mg N kg^{-1})	Thomsen, M., 2021	0.97
Planting and harvest time 2017	Thomsen, M., 2021	26 June – 21October
Planting and harvest time 2018	Thomsen, M., 2021	20 June – 8 October
Harvest mode (1: harvested this year)	Not applicable	1
Fraction of leaves and stems left in field after harvest	Not applicable	1
Max. biomass production	DNDC default	2399.8
Biomass fraction	DNDC default: grain, leaf, stem, and root, respectively. Confirmed by Dr. Thorup-Kristensen, April, 2021	0.65, 0.15, 0.15, 0.05
Biomass C/N ratio	Field trial measurements, Thomsen, M., 2021	53, 18,18, 53
Annual N demand, kg N ha^{-1} yr^{-1}	DNDC computation based on max. biomass production	110.296
Thermal degree days for maturity	DNDC default	1400
Water demand, g water g^{-1} DM	DNDC default	500
N fixation index	Not applicable	1
Optimum temperature (degree C)	Thomsen, M., 2021	16
Vascularity	Not applicable	0

Fertilizer parameters

The 'Manure Amendment' input function in DNDC consists of 10 pre-programmed choices of organic fertilizer categories, with an 11th added upon our request to simulate digestate. Differences in the categories are their partitions into discrete sub-pools (Figure 1) where, for instance, a larger portion of manure and animal slurry would be partitioned into labile litter pools while digestate is mostly resistant litter due to its already decomposed nature. Categories used in the model were: *slurry animal waste* for cow manure, *poultry waste manure* for 8K and Eco, *bean cake* for PHC and *digested waste* for digestate. Digestate was parameterized based on incubation trial results from Øvsthus et al. (2021) and the coding was done by Mr. Jia Deng at University of New Hampshire (Deng, personal correspondence). Most of the C in digestate was partitioned into a resistant pool with a slow decomposition rate, where about 10% of the C decomposes to CO2 over 60 days under 15°C and 45% water filled porosity concurrently with a slow mineralization of N. The polysulfate added to digestate and 8K was excluded in simulations due to a lack of N content and no input options in the model.

The model allows for adjustments to the organic C to organic N ratio (C_{org}: N_{org}), NH_4^+ and NO_3^- inputs. In the analysis for animal slurry, digestate and Eco, NO_3^- was not measured. For animal slurry, the DNDC default relationship between Norg, NH_4^+ and NO_3^- was used to calculate the NO_3^- content. The NO_3^- content in digestate was set to zero, a value supported by Øvsthus et al. (2021), and for Eco it was set to match 8K's NO_3^- content near zero. In the field trial, both Eco and PHC was used in only one treatment (Table 1) as 30% of the total N applied. Since C data was missing for Eco, and further samples of the manure were unattainable, the C/N ratio was estimated at 7.5 based on an average of layers and broiler chickens according to Brown (2015) . Both Eco and PHC were used for validation only, not for modeling scenarios. The overview of manure input parameters listed in Table 4 are based on data analyses from Eurofins Agro Testing (Appendix I).

TABLE 3: OVERVIEW OF MANURE INPUT PARAMETERS BASED ON FERTILIZER ANALYSES IN APPENDIX I.

Fertilizer	C_{org}: N_{org} ratio	Organic C in 100kg N ha^{-1}	Organic N in 100kg N ha^{-1}	NH4+ in 100kg N ha^{-1}	NO_3^- in 100kg N ha^{-1}
Animal Slurry	43.71	762	17.43	79.08	3.49
Digestate	216.78	310	1.43	98.57	0
8K	4.47	432	96.62	3.38	0.0035
Eco	7.5*	750	95.79	4.21	0.0035
PHC	4.18	240	57.48	42.5	0.018

* (Brown, 2015)

Calibration and validation of the model

After parameterizing the model by collecting data from various sources (Table 2 and 3), the output values were compared to measured values. As suggested in the DNDC manual (Li, 2012), crop physiological and phenological parameters e.g., maximum biomass production, biomass fraction and C:N ratio, N demand, TDD, and optimum temperature, were adjusted to calibrate the model to better match measured values. The 2018 dataset was chosen to calibrate the model as this was also the only year where soil samples had been collected for mineral N analysis. Finally, updated parameters were used to validate the model by using a separate data set from 2017.

Three datasets were used to evaluate DNDC simulations against observed values: soil temperature, carrot yield, and soil mineral N content after harvest. The soil temperature was collected from the Apelsvoll weather station from 2016 to 2018 and compared with modeled values. Carrot yield from the field trial was converted from g plot^{-1} to kg C ha^{-1} by using a dry weight of 11.88% based on field trials at Apelsvoll and a C content of 40% of the dry matter (as per the DNDC manual (Li, 2012, p. 26)). The measured yield in kg C ha^{-1} was then used to compare with simulated yield. Soil samples to a depth of 20 cm were collected on 16. October 2018 for analysis of soil mineral N content and compared with simulated values. No calibration was done to the fertilizers except changing the ratio of ingredients in 8K.

The agreement between simulated and measured yield was assessed by using a lack of fit F-test as described by Whitmore (1991) along with a linear regression. Once validated, the model was used to simulate the effect of future climate scenarios.

2.3 SIMULATED FUTURE SCENARIOS

To simulate the effect of temperature on mineralization, two weather files were created with a “cool” and a “warm” profile. The cool weather file had a daily high temperature of 20°C, low of 10°C and the warm file had a high temperature of 30°C, low of 20°C. The simulations were done without a crop to be able to understand the effects of temperature on mineralization. Two rain events in the beginning of the growing season were included in both files to explore how precipitation affects N losses.

For the rest of the simulations, 2017 was selected as a baseline (BL) weather file based on a temperature curve similar to the average temperatures from 1961-1990 (Figure 2).

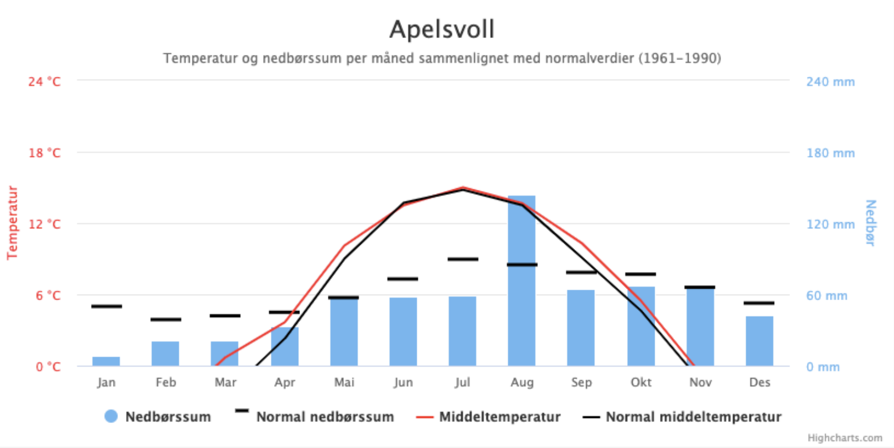

FIGURE 2: TEMPERATURE CURVE FOR 2017 WITH PRECIPITATION AMOUNTS SHOWN IN BLUE COLUMNS. AVERAGE TEMPERATURE (FROM 1961-1990) IS DEPICTED IN BLACK, 2017 AVERAGES ARE DEPICTED IN RED. SOURCE: NIBIO (N.D.-B).

Future weather scenarios were modeled by adding +2 and + 4°C to BL for both the daily high and low temperature for the whole year. In addition, files with 20 % of rain added to each rainfall event was created for each temperature file. To simulate the effects of 2050 CO_2 levels, the input of 405 ppm atmospheric CO_2 in 2017 was compared to 685 ppm in the above weather scenarios (Table 5). Changing the CO_2 input to 326 ppm to simulate 1970 levels in one scenario was also done to explore the influence of CO_2 on crop growth and N uptake. For each of the weather files listed in Table 5, output of yield, N-uptake by the plant and when it becomes limited, N leaching, denitrification and mineralization were collected. To evaluate how the organic fertilizers might behave differently under different climatic conditions, the future weather scenarios were tested using the fertilizers *digestate* (with a low organic N fraction), *animal slurry* (with a medium organic N fraction) and *8K* (with a high organic N fraction) along with split combinations to evaluate how the organic fertilizers might behave differently under varying circumstances. For all simulations a total amount of 100 kg N ha-1 was used.

TABLE 4: OVERVIEW OF WEATHER FILES USED FOR SIMULATING FUTURE CLIMATE SCENARIOS. BASELINE (BL) REFERS TO 2017 WEATHER FILE DOWNLOADED FROM LMT (NIBIO, N.D.-C)

Atmospheric CO2 content	**Weather files used**					
405 ppm (2017 measured)	BL	BL +2°C	BL +4°C	BL + 20 % rain	BL +2°C + 20% rain	BL +4°C + 20% rain
685 ppm (2050 forecast)	BL	BL +2°C	BL +4°C	BL + 20 % rain	BL +2°C + 20% rain	BL +4°C + 20% rain

3. RESULTS AND DISCUSSION

3.1 CALIBRATION AND VALIDATION OF THE MODEL

Soil temperature

Figure 3 shows the soil temperature over three years as simulated by DNDC and measured at Apelsvoll weather station. The soil temperature matched quite well for 0-10 cm depth but became progressively less accurate at deeper levels.

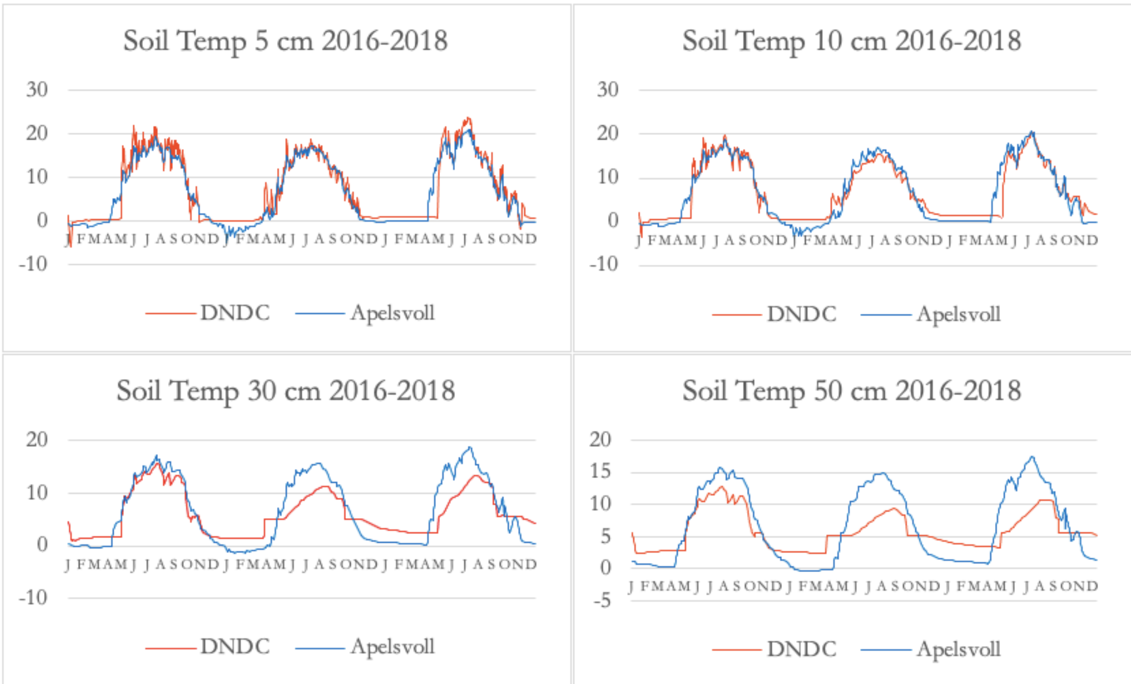

FIGURE 3: SOIL TEMPERATURE IN DEGREES CELSIUS AS SIMULATED BY DNDC (RED) AND MEASURED AT APELSVOLL (BLUE)

Carrot Yield

The model underestimated yield as compared to field trial averages for all treatments except treatment 5 where digestate was the only fertilizer (Figure 4). A lack of fit F-test gave a value of 0.859 for 2018, below the limits of the F distribution table value of 1.641(Dinov, 2020), indicating the difference between measured values were greater than between measured and simulated. Including 2017 values to expand the variables gave a value of 0.893, still below the tabled value of 1.34. A linear regression gave an R^2 value of 0.1849 and 0.0075 for 2017 and 2018, respectively (Figure 5).

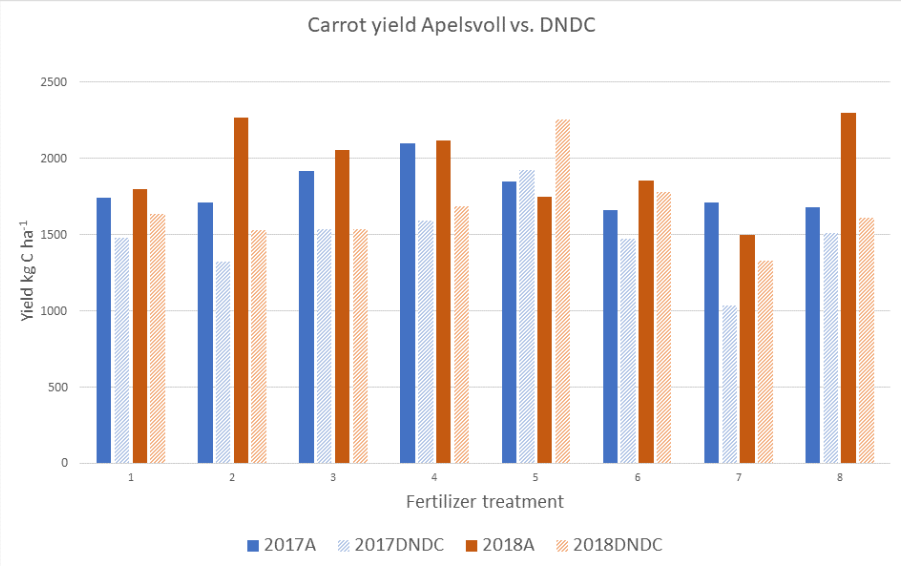

FIGURE 4: MEASURED YIELD (AVERAGE OF FOUR REPLICATES) IN TWO YEARS IN THE FIELD TRIAL AT APELSVOLL (2017A AND 2018A) AND SIMULATED YIELD (2017DNDC AND 2018DNDC) OF CARROTS FERTILIZED WITH TREATMENTS 1-8 LISTED IN TABLE 1.

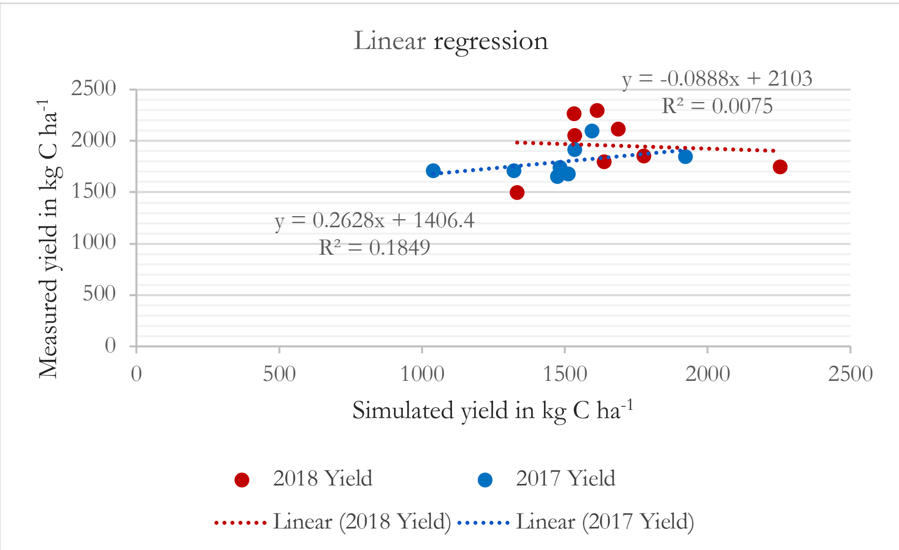

FIGURE 5: LINEAR REGRESSION FOR SIMULATED AND MEASURED YIELD OF CARROTS.

Soil mineral N content

Simulated and measured values for NH_4^+ and NO_3^- are depicted in Figure 5. Neither simulated value fit measured ones, particularly NO_3^- which was close to zero in all model calculations.

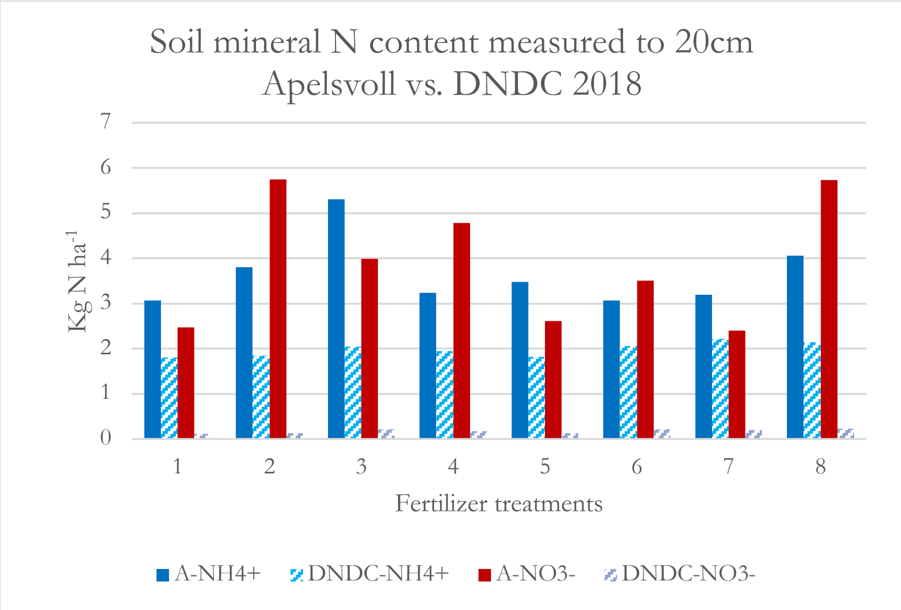

FIGURE 6: A-NH_4^+ AND A-NO_3^- IS MEASURED VALUES AT APELSVOLL. DNDC-NH_4^+ AND DNDC-NO_3^- IS MODELED VALUES. TREATMENT 1-8 IS FERTILIZER COMBINATIONS DESCRIBED IN TABLE 1.

Discussion of simulated vs. measured results

Higher temperature in the soil than modeled in the deeper layers might have led to underestimated mineralization and carrot growth. This could be a contributing factor to the lower simulated yield and soil N content in Figure 4 and 6, respectively. According to simulations, plant N uptake was mostly from the top layers of the soil. However, once deficient, N was also pulled from deeper levels in the late growing season when the carrot root was filling in (not shown). If a lower mineralization rate was simulated due to colder soil temperature, it could likely cause a reduction in the simulated yield.

The difference between simulated and measured values for soil mineral N may indicate an overestimation of simulated plant N uptake or underestimation of N mineralization due to cooler soil temperatures (Figure 3). Simulated NO_3^- leaching may also be overestimated during irrigation and rain events. However, since the simulated soil NO3- was low in all treatments, including digestate with very little organic N, a low modeled mineralization rate is not the likely cause of the discrepancy between modeled and observed. Denitrification was also at low values leaving an overestimated N-uptake from the carrot crop as the likely cause of low simulated soil NO_3^- levels.

Carrot yield values (Figure 4) are based on average yield for each fertilizer treatment in four replicate field plots. The variance among the repetitions exceeded a factor of two in some instances (Appendix III), and no statistically significant difference between the fertilizer treatments was detected, even after excluding several outliers from the analysis. The low R^2 value reflects a poor correlation coefficient between simulated and measured yield (Figure 5).

Calibration and validation

Maximum biomass was initially set to a number that resulted in simulations not matching measured yield. Normal yield in carrots is listed by the agricultural organization Norsk Landbruksrådgivning (NLR) to be 40 000 kg ha^{-1} with a fertilizer rate of 100 kg N ha^{-1} (Solberg & Bysveen, 2016). This yield equals 1901 kg C ha^{-1} but using this figure for maximum biomass caused the model to calculate a N demand below 100 kg N ha^{-1} and simulating larger values than measured. Therefore, the 'Max. biomass production' crop parameter was left at the DNDC default of 2399.8 to reflect a simulated yield closer to measured. TDD for the carrot was calculated to be 919 based on average temperatures from the downloaded weather files and a maturation period of 100 days (obtained by phone conversation with the seed company), but this resulted in a lower simulated yield and a growth pattern that ended half-way through the season. Therefore, the default TDD of 1400 was used to reflect a continuous growth throughout the season. An approximate ratio of the three ingredients in 8K was obtained from its manufacturer (via phone May 12th, 2021) and inputs to the model was therefore initially split between three categories: *poultry waste*, *meat or blood meal* and *bean cake*. However, the difference between simulated and measured yield increased after this was done. Setting the input category for 8K to 100% *poultry waste* resulted in a better prediction of measured values. No calibration was found that changed the low simulated values for NO_3^-. Since the variance in the replicate field plots was considerable and there was no significant difference between fertilizer treatments, no further adjustments were made to crop parameters or fertilizers to calibrate the model. With the low accuracy between replicate field plots, a validation using 2017 input parameters reflected the same poor correlation between simulated and measured yield as 2018 (Figure 4 and 5).

Possible errors in simulations

By running scenarios with a fixed daily high and low temperature, no rain events and only irrigation to meet the plant need, DNDC showed two distinct N uptake periods for carrots (Figure 7). The first uptake started nine days after sowing and remained at a set value for above-ground plant growth then went to zero. A second, slightly larger N uptake started when the carrot storage organ increased in biomass. The second uptake period varied with temperature, TDD and availability of N. The N-uptake during "grain" growth also remained at a fixed value until the soil N in the top 20 cm was depleted after which NO3- from deeper levels were utilized until uptake returned to zero and remained there until harvest date. Simulated data is limited to 50cm depth but carrot root mass may reach depths of 200cm although the majority is in the upper 100cm (Johansen et al., 2015). Westerveld's (Westerveld et al., 2006) found that storage root forms between 13-34 days after seeding which concur with simulations. Further, he found that N demand remains low until 50-60 days after seeding after which the majority of the N uptake occurs and continues until harvest. This does not agree with simulations which show a higher demand period early in the growing season followed by an abrupt end to both the first and second uptake period. This illustrates that the model is not quite able to simulate plant N uptake pattern in a realistic manner.

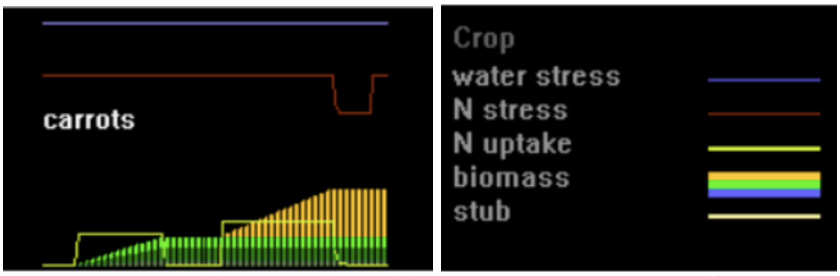

FIGURE 7: SIMULATED PLANT N UPTAKE. YELLOW LINE DEPICTS PLANT N UPTAKE, LIGHT AND DARK GREEN LINES ARE ABOVE-GROUND BIOMASS AND ORANGE LINES INDICATE CARROT STORAGE ORGAN GROWTH. SOURCE: DNDC (INSTITUTE FOR THE STUDY OF EARTH, N.D.).

The following additional factors may contribute to inaccuracies in both simulated and measured values:

- No input parameter option for the physical properties of fertilizers, i.e., liquid or pellets, was provided in the model. Animal slurry and digestate has a high water-content while 8K, Eco and PHC are pelletized. Therefore, no consideration was taken in the model for added water during fertilization.
- DNDC default values of litter pool ratios and mineralization rates in the various fertilizer categories may differ from actual ones. Cassity-Duffey et al. (2020) found organic fertilizer mineralization rates to be highly variable and need to be described individually.
- The pelletized commercial fertilizers containing a higher organic N content and low to no NO_3^- content had the lowest simulated yield, a result not reflected in the field trial. This may indicate a possible slower simulated N mineralization than actual.
- Simulations did not account for diseases like tip rot which was particularly present in digestate treatments in 2018.
- There was no control plot with mineral fertilizers to evaluate organic fertilizers against.

Since no statistically significant differences between treatments were detected due to a high variability in the field trial, the model could not be satisfactorily validated. To evaluate N mineralization in organic fertilizers and plant N uptake, a higher N demanding crop such as e.g., broccoli may be more suitable to evaluate and validate the model. Especially since carrot has in some research been deemed to not need added fertilization (Westerveld et al., 2006). A field trial coupled with simulations along with incubation trials of the organic fertilizers are needed to adequately validate the model. Although the data available from the field trial was inadequate and too variable for proper validation it does not preclude the model from simulating useful tendencies. Therefore, this study preceded with simulated future scenarios with the understanding that results may not be accurate but can be used to indicate possible trends.

3.2 SIMULATED FUTURE SCENARIOS

N-mineralization and Plant N-uptake

Simulating the effect of an average temperature increase of 10°C on N-mineralization in animal slurry during a growing season of 130 days showed a difference of 2-3 kg N ha^{-1} at the end of the season between a "cool" and a "warm" weather file. Figure 8 depicts N-mineralization at three depths through the growing season and N-leaching from two rain events at day 12 and day 17 after fertilizer application.

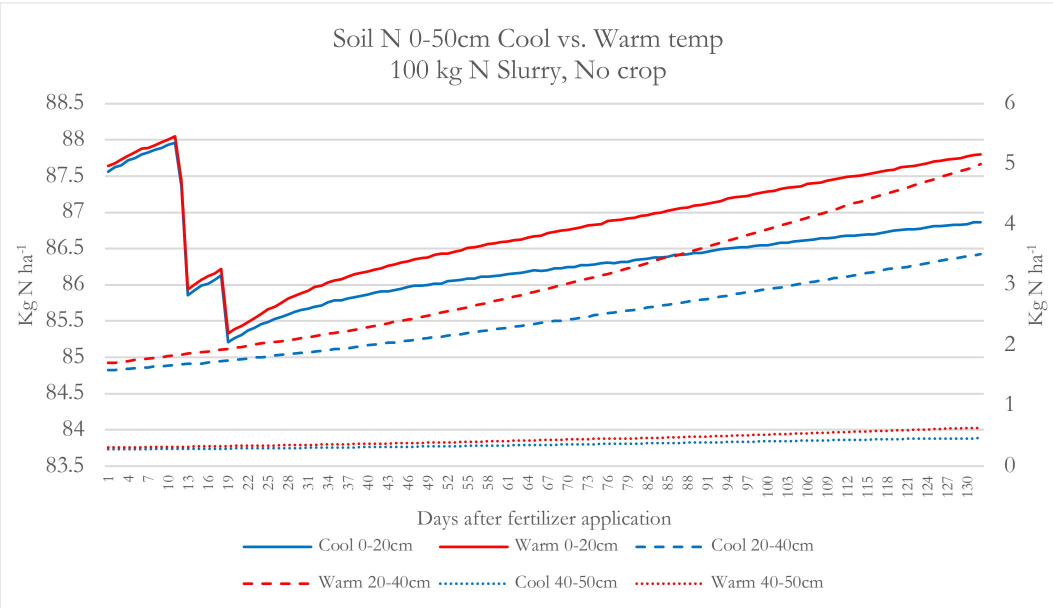

FIGURE 8: MODELED SOIL N CONTENT AT THREE DEPTHS USING ANIMAL SLURRY. TWO WEATHER FILES WITH MANIPULATED TEMPERATURE AND RAIN WERE USED. TWO RAIN EVENTS ON DAY 12 AND DAY 17 ILLUSTRATES THE LOSS OF N. NO RAIN OR IRRIGATION WAS ADDED AFTER THESE EVENTS. EACH DEPTH DEPICTS A TOTAL N CONTENT OF BOTH NH_4^+ AND NO_3^-. SOLID LINES ARE DEPICTED ON THE PRIMARY Y-AXIS (ON THE LEFT), DASHED LINES ON THE SECONDARY Y-AXIS (ON THE RIGHT).

Using BL weather files with a temperature addition of 2 and 4°C yielded a N mineralization increase similar in all three fertilizers (Figure 9). 8K containing the highest organic N content had, as expected, the largest amount of mineralized N at the end of the growing season, digestate the lowest. Mineralized N at the end of 2017 showed a similar pattern with the highest amount of mineralized N for 8K, lowest for digestate (Appendix IV). However, a similar relative rate of increase in N mineralization with increased temperatures in all fertilizers may suggests that the model may not be good at evaluating differences between organic fertilizers. Although an increase in N mineralization was expected at higher temperatures, as the activity of soil microorganism is temperature dependent (Havlin, 2014, p. 138), the increase was anticipated to be less in digestate since it contains a larger portion of organic N in resistant litter pools (Figure 1).

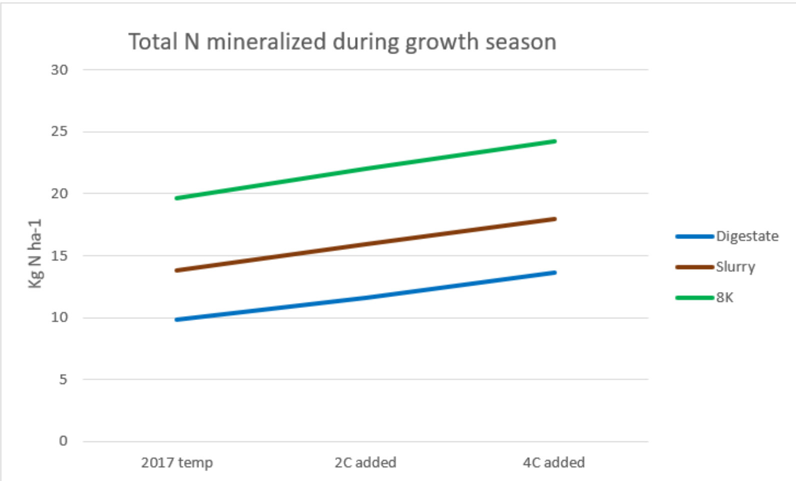

FIGURE 9: TOTAL N-MINERALIZED AT THE END OF THE GROWING SEASON. RESULTS SHOWING DIGESTATE, SLURRY AND 8K AT 405PPM, BASELINE (BL) TEMPERATURES, 2 AND 4°C ADDED.

Comparing N-mineralization in the soil to N-uptake by the carrot (Table 6A and B) suggests the N-demand from carrot is higher than can be met by an increased N-mineralization at warmer temperatures.

TABLE 5: SOIL N-MINERALIZATION (A) AND PLANT NITROGEN UPTAKE (B) IN KG N HA^{-1}. COLUMNS "2C ADDED" AND "4C ADDED" SHOWS THE ADDITIONAL N MINERALIZED OR TAKEN UP COMPARED TO THE BASELINE SCENARIO. 405 IS SIMULATIONS DONE AT AN ATMOSPHERIC CO_2 CONCENTRATION OF 405PPM, 405R IS WITH 20% ADDED RAIN, LIKEWISE FOR 685 AND 685R.

A

Mineralization	Digestate			Slurry			8K		
	Baseline	2C added	4C added	Baseline	2C added	4C added	Baseline	2C added	4C added
405	9.86	1.78	3.75	13.84	2.12	4.10	19.62	2.45	4.66
405R	9.62	1.80	3.54	13.57	1.99	4.18	19.18	2.32	4.39
685	9.84	1.88	3.73	13.91	2.21	4.20	19.83	2.26	4.49
685R	9.63	1.94	3.83	13.67	2.08	4.20	19.5	2.12	4.24

B

N uptake	Digestate			Slurry			8K		
	Baseline	2C added	4C added	Baseline	2C added	4C added	Baseline	2C added	4C added
405	93.93	2.31	4.39	85.18	2.32	4.73	76.52	3.03	5.19
405R	92.17	2.28	4.73	83.44	2.43	4.99	75.28	3.01	5.09
685	96.3	2.46	4.52	87.27	2.98	4.65	78.86	2.74	4.58
685R	94.85	2.83	4.41	85.78	3.23	4.85	77.88	2.86	4.77

Growth pattern and N-uptake periods for the carrots shifted at warmer temperatures. The two crop N-uptake periods mentioned earlier (Figure 7) shortened and the N-uptake per day increased. The periods also shifted to an earlier start and end of N-uptake along with an increased yield. A higher yield at warmer temperatures corresponds with Westerveld et al. (2006) findings of an increase in carrot yield to a maximum between 15-16°C, whereas temperatures beyond this optimal would see decreasing yields. This suggests that in warmer temperatures more N is needed in the beginning of the season.

The effect of CO2 levels on N uptake and carrot growth

Below are three images showing the N uptake pattern and carrot plant growth with a simulated CO_2 level from 1970, 2017 and 2050. 1970 depicts the lowest per-day N uptake over the longest period. The N-uptake period (yellow line) progressively shortens from 1970 to 2050 while per day N uptake increases. At 685 ppm there is a break with no N-uptake between the first and the second uptake period (Figure 10).

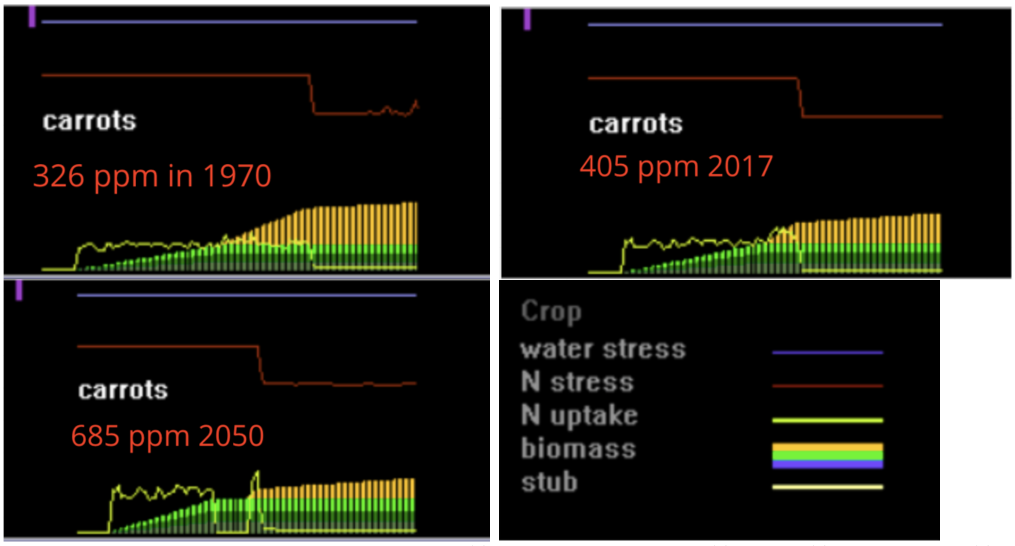

FIGURE 10: COPY OF DNDC VISUAL DEPICTION OF CROP GROWTH, N UPTAKE AND N STRESS. GREEN LINES ARE THE GROWTH OF THE TOPS, ORANGE IS THE CARROT ROOT. YELLOW LINE DEPICTS N-UPTAKE WHILE THE RED LINE ON TOP INDICATES N STRESS. SOURCE: DNDC (INSTITUTE FOR THE STUDY OF EARTH, N.D.).

The simulations calculated a yield reduction as atmospheric CO_2 content increased. No other parameter was changed in this simulation. The weather file, and therefore also the temperature, was the same for all CO_2 levels. Since N is a major component in chlorophyll it appears the increased above-ground biomass depleted N in the soil earlier in the season and therefore reduced the yield portion of the carrot (orange lines in figure 8). This suggests that as CO_2 increases in the atmosphere, the growth pattern for carrots changes and its N requirement increases. In an experiment by Wurr et al. (1998) carrots supplied with non-limiting amounts of nutrients had a maximum dry weight at a CO2 concentration of 650ppm. These findings suggests that there may be a need to update fertilizer recommendations continuously as temperature and CO_2 levels increase in the future.

Future climate change scenarios

A summary of results from simulating the effect of future climate change scenarios for digestate, animal slurry and 8K is listed in Table 6. Detailed results can be found in Appendix V.

TABLE 6: SUMMARY OF SIMULATED FUTURE CLIMATE SCENARIOS.

Effect on:	**Warmer temperature**	**More rain**	**Higher CO_2 ppm**
Yield	Increased	Decreased	Decreased
Plant N-uptake	Increased	Decreased	Increased
N leaching	Decrease	Increase	Decrease
NH3 volatilization	Increase	Little effect	No effect
Denitrification	Increase	Little effect	Little effect
Net CO_2 equivalents	Increase	Little effect	Decrease
Date N became limiting	Earlier	Little effect	Earlier

As expected, yield increased at warmer temperatures. However, a decrease in yield at higher CO_2 levels was likely the result of N being used up early in the growing season as indicated in Figure 10. Plant N uptake increased at warmer temperatures and higher CO_2 levels while it decreased with more rain. Simulations indicated that an increase in rain caused an increase in N leaching and therefore less available N to the carrot. A decrease in N leaching at higher temperatures can be explained by a higher plant N uptake. An increase in NH_3 volatilization may be explained by an increase in evaporation at warmer temperatures, and a higher denitrification may be the results of an increase in microbial activity. As shown in Figure 10, increased CO_2 levels moves the plant uptake pattern earlier, a warmer temperature had similar effects.

Efficient use of organic fertilizers

The overall highest yield with the least amount of N leaching was modeled when the initial fertilizer application was done the day of the first plant N uptake, nine days after sowing, in all scenarios. In all cases the mineral N in the soil was depleted before harvest date and simulations showed a N stress towards the end of the N uptake period. Digestate had the highest yield, followed by slurry and 8K, indicating that the model favors a fertilizer with a high mineral N content or underestimates N mineralization.

A split application simulated the best yield when the initial application amount was less than the second application. This was true for all three fertilizers. Since N uptake is less in the beginning of the growing season, splitting the application 40/60 in contrast to the 70/30 split done in the field trial yielded better results. The amount of N needed at the initial fertilization changed with a change in the carrot growth pattern and N-uptake increase as influenced by temperature and atmospheric CO2 content. These findings correspond with other field trials where split applications have been shown to increase N utilization (Burton et al., 2008; Luis et al., 2012; Rahman et al., 2011).

Simulated results suggest that using a combination of an initial fertilizer such as animal slurry or 8K and a later application of digestate is a good combination that would allow the most time for mineralization of organic N while minimizing losses of mineral N. A larger amount of N mineralized after the growing season for 8K suggests a greater loss of N with this fertilizer. Additionally, effects of remaining mineral N in the soil during drying and rewetting and freezing and thawing events over the winter may lead to larger N2O emissions as shown by Foereid et al. (2021). Furthermore, combining a fertilizer high in OM with digestate can both improve the soil structure in the long-term while also meeting short-term N needs as suggested by Øvsthus et al. (2017). In addition, split applications can be useful in fertilizer management by timing additional applications after rain or warm temperatures as simulations indicated leaching connected to precipitation (Figure 8) and an increase in N uptake during warmer periods.

4. SUMMARY AND CONCLUSION

Although the model could not be satisfactorily validated, several of the results pointed to interesting trends and provided insight into the three research objectives posed in the introduction:

(i) The higher N uptake by the plant suggests that an increase in N mineralization does not keep up with the increased plant N demand in a warmer climate.

(ii) As temperature and atmospheric CO_2 levels increase, plant N uptake and growth pattern changes indicating a need for constantly updating fertilizer recommendations.

(iii) The model suggested that yield in carrot crops may decrease in warmer temperatures and higher CO_2 levels unless more N is applied. Split applications showed a better N utilization in all three fertilizers. Combining digestate with other organic fertilizers may be a good combination to take advantage of the benefits of both a quick release fertilizer and a fertilizer high in OM while at the same time recycling waste materials.

These findings suggests that both the quantity of fertilizers and timing of applications need to change with a changing climate. Therefore, these findings need to be further tested to find if measured values in field trials agree with simulated results.

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APPENDIX I – FERTILIZER ANALYSES

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AR-18-NF-001442-01

EUNOMO4-00013248

Analyseperiode: 27.04.2018-04.05.2018
Referanse:

ANALYSERAPPORT

Prøvenr.:	**542-2018-04270007**	Prøvetakingsdato :	26.04.2018
Prøvetype:		Mottaksdato:	27.04.2018
Prøvemerking:	Husdyrgjødsel Apelsvoll	Rapporteringsdato:	04.05.2018
Dyreslag:	Storfe - melkeku (våtkompos		

	Analyse	Resultat	Enhet	LOQ	MU	Metode
a)*	Tørrstoff (TS)	3.6	g/100 g	0.1		VDLUFA Methodenbuch II, 9.1
a)	Nitrogen (N)	2.39	kg/tonn	0.1		VDLUFA Methodenbuch II.3.5.2.7
a)	Ammonium-Nitrogen (NH4-N)	1.89	kg/tonn	0.01		VDLUFA Methodenbuch II.1 3.2.2
a)	Fosfor (P)	0.3	kg/tonn	0.01		NS EN ISO 11885
a)	Kalium (K)	3.3	kg/tonn	0.01		NS EN ISO 11885
a)*	Svovel (S)	0.28	kg/tonn	0.01		NS EN ISO 11885
a)*	pH	7.6				Konduktometri
a)	Magnesium (Mg)	0.4	kg/tonn	0.01		NS EN ISO 11885
a)	Kalsium (Ca)	0.8	kg/tonn	0.01		NS EN ISO 11885
a)*	Natrium (Na)	0.47	kg/tonn	0.01		NS EN ISO 11885
a)*	C/N forhold	7.62				Kalkulering
a)*	Bor (B)	44	mg/kg TS			NS EN ISO 11885
a)*	Mangan (Mn)	270	mg/kg TS			NS EN ISO 11885
a)*	Jern (Fe)	880	mg/kg TS			NS EN ISO 11885
a)*	Kobber (Cu)	50	mg/kg TS			NS EN ISO 11885
a)	Sink (Zn)	250	mg/kg TS			NS EN ISO 11885

Merknader:
1210022 Dyrkingssystemet

Utførende laboratorium/ Underleverandør:
a)* Eurofins Agraranalytik Deutschland (Jena), Löbstedter Strasse 78, D-07749, JENA
a) Eurofins Agraranalytik Deutschland (Jena), Löbstedter Strasse 78, D-07749, JENA DIN EN ISO/IEC 17025:2005 D-PL-20226-01-00,

Kopi til:
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Moss 04.05.2018

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Maria Soledad Armero Rodriguez
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Tegnforklaring:
* Ikke omfattet av akkrediteringen   LOQ: Kvantifiseringsgrense MU: Måleusikkerhet
<: Mindre enn >: Større enn nd: Ikke påvist. Bakteriologiske resultater angitt som <1,<50 e.l. betyr 'ikke påvist'.

Opplysninger om måleusikkerhet og konfidensintervall fås ved henvendelse til laboratoriet.
Rapporten må ikke gjengis, unntatt i sin helhet, uten laboratoriets skriftlige godkjennelse. Resultatene gjelder kun for de(n) undersøkte prøven(e).

Side 1 av 1

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AR-18-NF-009015-02

EUNOMO4-00018858

Analyseperiode:	25.10.2018-03.12.2018
Referanse:	Faktura ref. 120010.12 Annbjørg Ø. Kristoffersen

Denne analyserapporten erstatter tidligere versjon(er).
Vennligst makuler tidligere tilsendt analyserapport.
AR-18-NF-009015XX

ANALYSERAPPORT

Prøvenr.:	**542-2018-10250179**	Prøvetakingsdato :	
Prøvetype:	Gjødsel	Mottaksdato:	25.10.2018
Prøvemerking:	MJØS 2018	Rapporteringsdato:	03.12.2018

	Analyse	Resultat	Enhet	LOQ	MU	Metode
a)*	Tørrstoff (TS)	2.0	g/100 g	0.1		VDLUFA Methodenbuch II, 9.1
a)	Nitrogen (N)	2.10	kg/tonn	0.1	10	VDLUFA Methodenbuch II.3.5.2.7
a)	Ammonium-Nitrogen (NH4-N)	2.07	kg/tonn	0.01	5	VDLUFA Methodenbuch II.1 3.2.2
a)	Fosfor (P)	0.3	kg/tonn	0.01		NS EN ISO 11885
a)	Kalium (K)	1.0	kg/tonn	0.01		NS EN ISO 11885
a)*	Svovel (S)	0.12	kg/tonn	0.01		NS EN ISO 11885
a)*	pH	7.8				Konduktometri
a)	Magnesium (Mg)	0.1	kg/tonn	0.01		NS EN ISO 11885
a)	Kalsium (Ca)	0.9	kg/tonn	0.01		NS EN ISO 11885
a)*	Natrium (Na)	0.93	kg/tonn	0.01		NS EN ISO 11885
a)*	C/N forhold	3.1				Kalkulering
a)*	Bor (B)	33	mg/kg TS			NS EN ISO 11885
a)*	Mangan (Mn)	260	mg/kg TS			NS EN ISO 11885
a)*	Jern (Fe)	3000	mg/kg TS			NS EN ISO 11885
a)*	Kobber (Cu)	49	mg/kg TS			NS EN ISO 11885
a)	Sink (Zn)	300	mg/kg TS			NS EN ISO 11885
a)	Bly (Pb)	8.1	mg/kg TS			NS EN ISO 11885
a)	Kadmium (Cd)	< 0.35	mg/kg TS			NS EN ISO 11885
a)	Krom (Cr)	12	mg/kg TS			NS EN ISO 11885
a)	Nikkel (Ni)	5.8	mg/kg TS			NS EN ISO 11885
a)	Kvikksølv (Hg)	< 0.2	mg/kg TS			EN 1483: 2007-07
a)	Arsen (As)	< 5.0	mg/kg TS			NS EN ISO 11885

Merknader:
Renalyse av N og NH4-N bekrefter tidligere resultater, innenfor måleussikkerhet.

Utførende laboratorium/ Underleverandør:
a)* Eurofins Agraranalytik Deutschland (Jena), Löbstedter Strasse 78, D-07749, JENA
a) Eurofins Agraranalytik Deutschland (Jena), Löbstedter Strasse 78, D-07749, JENA DIN EN ISO/IEC 17025:2005 D-PL-20226-01-00,

Tegnforklaring:
* Ikke omfattet av akkrediteringen LOQ: Kvantifiseringsgrense MU: Måleusikkerhet
<: Mindre enn >: Større enn nd: Ikke påvist. Bakteriologiske resultater angitt som <1,<50 e.l. betyr 'ikke påvist'.

Opplysninger om måleusikkerhet og konfidensintervall fås ved henvendelse til laboratoriet.

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AR-21-NF-003834-01

EUNOMO4-00046519

Analyseperiode: 11.03.2021-30.03.2021
Referanse: Prosjekt 11337

Prøvenr.:	**542-2021-03110018**	Prøvetakingsdato :	02.03.2021
Prøvetype:	Gjødsel	Mottaksdato:	11.03.2021
Prøvemerking:	102 Grønn Øko K8	Rapporteringsdato:	30.03.2021

	Analyse	Resultat	Enhet	LOQ	MU	Metode
a)*	Tørrstoff	90.5	%	0.1		SFS-EN 13040: 2008
a)	Total nitrogen (mod. Kjeldahl)	72	kg/tonn	0.1	14	EN 13654-1 (mod.), SFS-EN 13342:2000
*	Ammonium-N	2.43	kg/tonn			Kjeldahl
a)	Fosfor (P)	32	kg/tonn		8.1	SFS-EN 13650:2002
a)	Kalium (K)	8.9	kg/tonn		2.2	SFS-EN 13650:2002
a)	Svovel (S)	3.5	kg/tonn			SFS-EN 13650:2002
a)	pH	6.2				SFS-EN 13037:2011

Utførende laboratorium/ Underleverandør:
a)* Eurofins Viljavuuspalvelu (Mikkeli), PL 500, FI-50101, Mikkeli
a) Eurofins Viljavuuspalvelu (Mikkeli), PL 500, FI-50101, Mikkeli SFS EN ISO/IEC 17025:2005 FINAS T096,

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* Ikke omfattet av akkrediteringen LOQ: Kvantifiseringsgrense MU: Måleusikkerhet
<: Mindre enn >: Større enn nd: Ikke påvist. Bakteriologiske resultater angitt som <1,<50 e.l. betyr 'ikke påvist'.

For mikrobiologiske analyser oppgis konfidensintervallet. Ytterligere opplysninger om måleusikkerhet fås ved henvendelse til laboratoriet.
Rapporten må ikke gjengis, unntatt i sin helhet, uten laboratoriets skriftlige godkjennelse. Resultatene gjelder kun for de(n) undersøkte prøven(e).

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AR-21-NF-003833-01

EUNOMO4-00046519

Analyseperiode: 11.03.2021-30.03.2021
Referanse: Prosjekt 11337

Prøvenr.:	**542-2021-03110017**	Prøvetakingsdato :	02.03.2021
Prøvetype:	Gjødsel	Mottaksdato:	11.03.2021
Prøvemerking:	101 Grønn Øko	Rapporteringsdato:	30.03.2021

	Analyse	Resultat	Enhet	LOQ	MU	Metode
a)*	Tørrstoff	89.7	%	0.1		SFS-EN 13040: 2008
a)	Total nitrogen (mod. Kjeldahl)	66	kg/tonn	0.1	13	EN 13654-1 (mod.), SFS-EN 13342:2000
*	Ammonium-N	2.78	kg/tonn			Kjeldahl
a)	Fosfor (P)	25	kg/tonn		6.3	SFS-EN 13650:2002
a)	Kalium (K)	14	kg/tonn		3.4	SFS-EN 13650:2002
a)	Svovel (S)	4.6	kg/tonn			SFS-EN 13650:2002
a)	pH	6.3				SFS-EN 13037:2011

Utførende laboratorium/ Underleverandør:
a)* Eurofins Viljavuuspalvelu (Mikkeli), PL 500, FI-50101, Mikkeli
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Tegnforklaring:
* Ikke omfattet av akkrediteringen LOQ: Kvantifiseringsgrense MU: Måleusikkerhet
<: Mindre enn >: Større enn nd: Ikke påvist. Bakteriologiske resultater angitt som <1,<50 e.l. betyr 'ikke påvist'.

For mikrobiologiske analyser oppgis konfidensintervallet. Ytterligere opplysninger om måleusikkerhet fås ved henvendelse til laboratoriet.
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EUNOMO4-00046519

Analyseperiode: 11.03.2021-30.03.2021
Referanse: Prosjekt 11337

Prøvenr.:	**542-2021-03110019**	Prøvetakingsdato :	02.03.2021
Prøvetype:	Gjødsel	Mottaksdato:	11.03.2021
Prøvemerking:	103 PHC 11-0-5	Rapporteringsdato:	30.03.2021

	Analyse	Resultat	Enhet	LOQ	MU	Metode
a)*	Tørrstoff	98.1	%	0.1		SFS-EN 13040: 2008
a)	Total nitrogen (mod. Kjeldahl)	100	kg/tonn	0.1	21	EN 13654-1 (mod.), SFS-EN 13342:2000
*	Ammonium-N	42.5	kg/tonn			Kjeldahl
a)	Fosfor (P)	1.3	kg/tonn		0.32	SFS-EN 13650:2002
a)	Kalium (K)	38	kg/tonn		9.6	SFS-EN 13650:2002
a)	Svovel (S)	24	kg/tonn			SFS-EN 13650:2002
a)	pH	5.1				SFS-EN 13037:2011

Utførende laboratorium/ Underleverandør:
a)* Eurofins Viljavuuspalvelu (Mikkeli), PL 500, FI-50101, Mikkeli
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Tegnforklaring:
* Ikke omfattet av akkrediteringen LOQ: Kvantifiseringsgrense MU: Måleusikkerhet
<: Mindre enn >: Større enn nd: Ikke påvist. Bakteriologiske resultater angitt som <1,<50 e.l. betyr 'ikke påvist'.

For mikrobiologiske analyser oppgis konfidensintervallet. Ytterligere opplysninger om måleusikkerhet fås ved henvendelse til laboratoriet.
Rapporten må ikke gjengis, unntatt i sin helhet, uten laboratoriets skriftlige godkjennelse. Resultatene gjelder kun for de(n) undersøkte prøven(e).

Eco 8K is a versatile organic fertilizer for grain / legume, pasture and grass. Eco 8 K is made of hygienized chicken dung, minced beef and vinasse, containing 7.3% calcium, 2.9 sulfur and essential plant nutrients. Eco 8 is our best-selling fertilizer.

Efficient: 8-3-5 is based on chicken manure
Homogenized: The ingredients are evenly mixed, like ensures a uniform amount of nutrition in each pellet.
Persistent: The industry is easily accessible with effect through the growing season.
Hygienized and composted: The raw materials are composted at high temperature for a long time. Ensures infectious fertilizer.
Pellets: Pellets in size 4-5 mm. Easily maneuverable for immersion and fertilization.
Fertilizer value: One of the most economical fertilizers available in the market.

From 2020 with an even more soluble nitrogen source

Suitable for deep fertilization

Pasture and grass production: Very suitable for fertilizing established plant stock

Cereals and legumes: For fertilizer, eco 11 (11-3-2) or eco 14 (14-2-1) of established stock is recommended

Period of residence: Do not fertilize after 21 days before harvesting or grazing

Grain and oilseed
50 - 100 kg/daa
For partial fertilization and as needed, mulled down when sowing. 2 times fertilization by stretching grain plants. Dissolves quickly by 2 times fertilization in grass / meadow eg fertilizer after the first mowing.

Grass
50 - 80 kg/daa
For partial fertilization and as needed, mulled down when sowing. 2 times fertilization by stretching grain plants. Dissolves quickly by 2 times fertilization in grass / meadow eg fertilizer after the first mowing.

Vegetables
50 - 100 kg/daa
For partial fertilization and as needed, mulled down when sowing. 2 times fertilization by stretching grain plants. Dissolves quickly by 2 times fertilization in grass / meadow eg fertilizer after the first mowing.

Analysis

Nitrogen (N)	7,5 %
Phosphorus (P)	3 %
Potassium (K)	5 %
Calcium (Ca)	7,3 %
Magnesium (Mg)	0,2 %
Sulfur (S)	2,9 %
Boron (B)	14 ppm
Manganese (Mn)	90 ppm
Iron (Fe)	499 ppm
Copper (Cu)	19 ppm
Zinc (Zn)	120 ppm
Silicon (Si)	135 ppm

Content

Composted and hygienized:

chicken-hen manure
meat and bone meal
vinasse

The fertilizer is chlorine free.
Hectolitre weight: 0.75 kg.

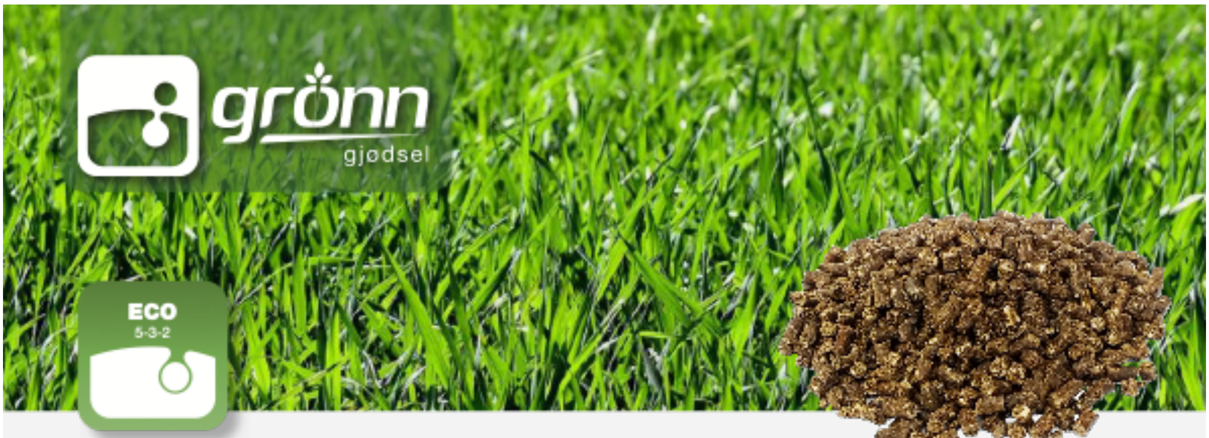
Recommendation

50-100 kg / decare

General fertilizer recommendation, quantity must be adjusted.
Refer to soil and possibly leaf analysis, as well as consult your adviser, plant nutritional needs and crop level.

15 kg/600 kg

www.gronngjodsel.no post@gronngjodsel.no +47 92 48 50 00



Eco is our original organic fertilizer, pelleted and adapted to modern organic farming. Eco is made from hygienized chicken manure and contains 2.7% calcium as well as all the essential plant nutrients. For many organic farmers, Eco has become a standard.

Exclusive: Eco 5-3-2 is produced from "processed" chicken manure which gives it wonderful properties.
Homogenized: The ingredients in Eco are evenly mixed, ensuring equal content in each pellet. It provides smooth distribution of all nutrients.
Hygienized and composted: The raw materials are composted at high temperature for a long time. Ensures infectious fertilizer.
Pelleted: Eco is pelleted in size 4-5 mm.
Easily maneuverable for immersion and fertilization.
Soluble and renewable: Nutrients are easy available with lasting effect. This gives the plants access to nutrients throughout the growing season.

Value: One of the most economical fertilizers available on the market.

Eco (5-3-2) is a versatile organic fertilizer

Eco is made from 100% organic raw materials

Eco contains 0.4% magnesium

Suitable for deep fertilization

Suitable for fertilizing established stock

Grain and oilseed
50 - 100 kg/daa
For partial fertilization and as needed, mulled down when sowing. 2 times fertilization by stretching grain plants. Dissolves quickly by 2 times fertilization in grass / meadow eg fertilizer after the first mowing.

Grass
50 - 80 kg/daa
For partial fertilization and as needed, mulled down when sowing. 2 times fertilization by stretching grain plants. Dissolves quickly by 2 times fertilization in grass / meadow eg fertilizer after the first mowing.

Vegetables
50 - 100 kg/daa
For partial fertilization and as needed, mulled down when sowing. 2 times fertilization by stretching grain plants. Dissolves quickly by 2 times fertilization in grass / meadow eg fertilizer after the first mowing.

Analysis

Nitrogen (N)	5 %
Phosphorus (P)	3 %
Potassium (K)	2 %
Calcium (Ca)	2,7 %
Magnesium (Mg)	0,4 %
Sulfur (S)	0,5 %
Boron (B)	27 ppm
Manganese (Mn)	379 ppm
Iron (Fe)	402 ppm
Copper (Cu)	69 ppm
Zinc (Zn)	341 ppm
Silicon (Si)	291 ppm

Content

Composted and hygienic:
Chicken/hen manure

The fertilizer is chlorine free.
Volume weight: 0.75 kg / liter

Recommendation

50-100 kg / decare

General fertilizer recommendation, quantity must be adjusted.
Refer to soil and possibly leaf analysis, as well as consult your adviser, plant nutritional needs and crop level.

15 kg/600 kg

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PHC Organic Plant Feed Granulat 11-0-5

SOIL ASSOCIATION APPROVED

Vegetabilsk, granulert organisk gjødsel for potteproduksjon, plener, hage- og landbruk.

PHC Organic Plant Feed (OPF) er en 100 % vegetabilsk granulert gjødsel med et høyt nitrogeninnhold.

OPF er rasktvirkende gjødsel som kan brukes både ved breigjødsling og radgjødsling. Kornene oppløses raskt i vann og gir plantene balansert gjødsel i flere uker.
Ca. 50 % av nitrogenet frigis i løpet av de første 30 dagene. De resterende 50 % frigjøres langsomt. Dette er en grov indikasjon og avhenger av værforholdene og mengde mikrobielt jordliv. På grunn av denne gjødselens naturlige opprinnelse, går det tapt mye mindre nitrogen enn ved tradisjonell ureagjødsel.

Forhold mineraler
OPF består av en balansert sammensetning av mineraler i forholdet N 11: P 0: K 5 + mikronæringsstoffer. Fosfatinnholdet er svært lavt fordi det som regel er lagret tilstrekkelig fosfat i jorda. Om nødvendig kan fosfat doseres separat. OPF er biologisk gjødsel. Derfor kan analysene avvike med inntil 15 % per parti.
8 % av nitrogenet i dette produktet kommer fra aminosyrer, 3 % er organisk bundet nitrogen.

Organisk gjødsel må omdannes til anorganiske opptakbare mineraler. For å oppnå godt bakterielt liv i dyrkingsjorda, slik at denne omdanningen blir mulig, anbefales det å bruke Biovin.

PRODUKTFORDELER
- Forbedrer jordstrukturen og det mikrobielle jordlivet.
- Mindre utvasking av næringsstoffer
- Økt motstand mot stress

BRUK
OPF kan brukes til alle avlinger og kan spres med praktisk talt alt utstyr. Sørg for at maskinene er **helt tørre** og bruk OPF kun i oppholdsvær (produktet er hygroskopisk). OPF Granulat må **ikke bli liggende på bladene** pga. fare for forbrenning. OPF Granulat er særlig egnet til gjødsling i rader (sparer nitrogen og penger).

SKJEMA FOR GJØDSLING

Grasmark/plen	22,5-27,5	kg/daa	Breigjødsle på våren
Mais	25-32,5	kg/daa	Breigjødsle ved såing/planting
Korn	25-32,5	kg/daa	Breigjødsle ved tidlig strekningsvekst
Frukttrær	30-45	kg/daa	i omliggende område (helst med Biovin)
Salat	10-20	kg/daa	Radgjødsling ved planting
Poteter	40-50	kg/daa	Radgjødsle rett før eller ved setting
Gulrøtter	15-25	kg/daa	Radgjødsle rett før eller ved såing
Grønnsaker friland	10-25	kg/daa	Radgjødsle ved planting
Veksthusgrønnsaker	5-25	kg/daa	Radgjødsle gjennom vekstperioden
Pottejord	1,5-3	kg/m^3	Blandes inn før såing/potting

Granulert, organisk, vegetabilsk gjødsel for økologisk og konvensjonell produksjon

Ideell til bruk i kombinasjon med andre Plant Health Cure-produkter

PHC Plant Health Cure

Polysulfate is an organic mineral fertilizer of a unique composition, an ideal choice of sulfate to fulfill the potential of a variety of organic crops. Well-suited for potatoes, vegetables and berries that have a higher potassium requirement than those covered with regular fertilizers.

Consists of potassium, magnesium and calcium sulphates, water-soluble and readily absorbable. Grain size 2-4 mm and spreading of up to 36 m with centrifugal spreader. Studies show that the mineral reserves in the soil may decline, however most of the potassium lie in the straw. When it is profitable to sell straw, it is important to increase potassium input. The potassium in Polysulphate complements routine fertilizes.
Magnesium is part of the chlorophyll and crucial for photosynthesis, often only added directly crops and vegetables. It is removed in considerable quantities by harvest, and Polysulfate will provide a useful supply of a nutrient often overlooked.
The fourth component of Polysulfate is calcium. Calcium is responsible for proper plant cell division and for strengthening cell walls. Polysulfate helps maintain essential calcium reserves in the soil. Polysulfate is particularly suitable for crops that prefer low levels of chloride in the soil, such as in fruits, and where higher solids are desirable in potatoes and other vegetables.

Soluble, sulphate form for immediate use
Granular form, which provides flexibility to tailor the use
Concentrated, little storage need and is quick to disperse
A source of potassium, magnesium and calcium - bonus
Low chloride, so suitable for chloride sensitive crops
Environmentally friendly as it is used in its natural state - no processing or waste products, and no acidification

Grain and oilseed
Apply at the beginning of spring, to oilseed rapeseed to optimize the synthesis of yield, protein and oil. For wheat to increase yield and to ensure grain protein quality. On painted barley for yield and quality.

Peas
Apply directly in the seedbed or immediately after germination. Brings readily available sulfur to the crop, and can therefore be picked up by the plant at an early stage to feed the nitrogen fixation, which occurs in the roots and for protein synthesis in the plant.

Grass
Livestock manure and manure is not a safe source of sulphate, and is best regarded as maintaining soil reserves. Polysulfate should be applied in accordance with nitrogen requirements to achieve optimal grass growth throughout the season in proper N: S ratio.

Analysis

Svovel	19,2 %
Kalium	11,6 %
Magnesium	3,6 %
Kalsium	12,2 %
Klorider	5,0 %
Natriumoksid	4,4 %

Content

From polyhalite rock, about 1000 meters off the North Yorkshire coast of the United Kingdom. Founded 260 million years ago, minerals lie in a special niche of natural ash from ancient times.
Contents:
48% SO_3 as sulfate
14% K_2O from potash sulphate
6% MgO as from magnesium sulfate
17% CaO from calcium sulfate

15 kg/1000 kg

Recommendation

Refer to soil and any leaf analysis, as well as consult your advisor, plant nutritional needs and crop level.
Polysulfate can be applied before growth starts in the spring. The goal is often to adapt the sulfur requirements to the crop's nitrogen requirements.
Where the amount of nitrogen is varied, for example in precision fertilizers, the Polysulfate amount can be varied to best match the total nitrogen use.

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APPENDIX III – CARROT YIELD

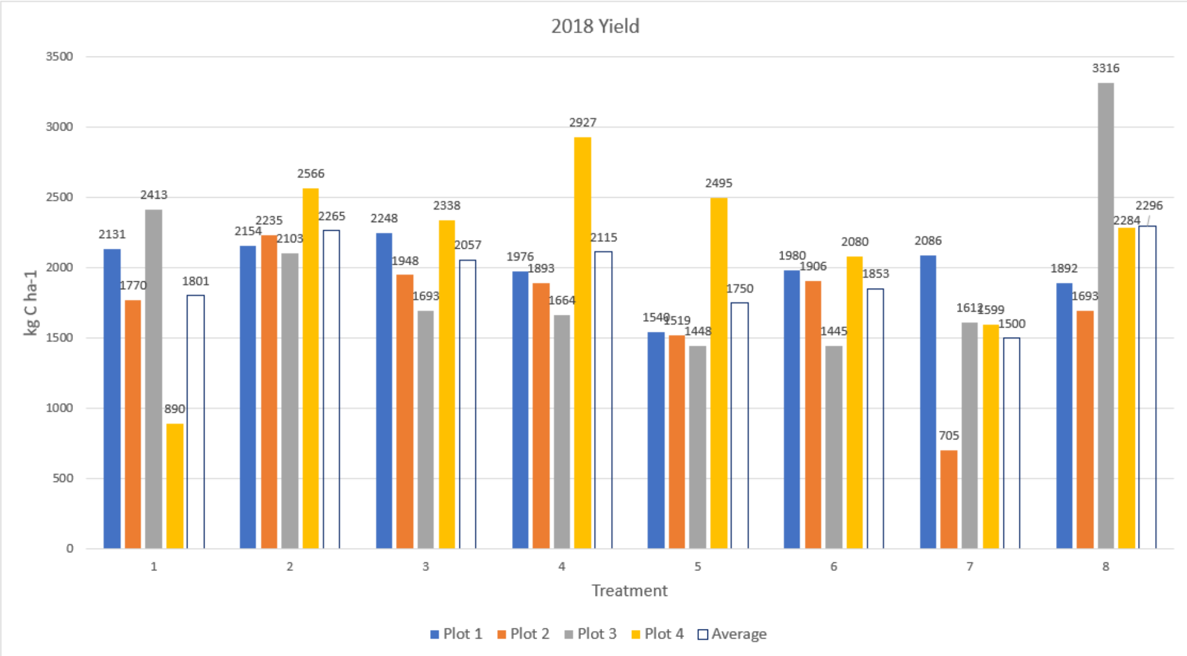

FIGURE A1: YIELD FOR 2018 IN FOUR REPLICATE PLOTS FOR EACH FERTILIZER TREATMENT (TREATMENT 1-8 LISTED IN TABLE 1). AVERAGE COLUMNS ARE USED IN FIGURE 4.

APPENDIX IV – N MINERALIZATION

TABLE A1: TOTAL N MINERALIZATION IN KG N HA-1 AT THE END OF THE GROWING SEASON AT 405PPM (405), 405 PPM AND 20% RAIN ADDED (405R), 685 PPM (685) AND 685 PPM WITH 20% RAIN ADDED (685R).

	Digestate			Slurry			8K		
	Baseline	pluss 2C	pluss 4C	Baseline	pluss 2C	pluss 4C	Baseline	pluss 2C	pluss 4C
405	9.86	11.64	13.61	13.84	15.96	17.94	19.62	22.07	24.28
405R	9.62	11.42	13.16	13.57	15.56	17.75	19.18	21.5	23.57
685	9.84	11.72	13.57	13.91	16.12	18.11	19.83	22.09	24.32
685R	9.63	11.57	13.46	13.67	15.75	17.87	19.5	21.62	23.74

TABLE A2: MINERALIZATION FOR THE WHOLE YEAR.

	405PPM						**685PPM**					
	BL	+2C	+4C	20% Rain	+2C +20%	+4C +20%	BL	+2C	+4C	20% Rain	+2C +20%	+4C +20%
DIGESTATE	15.8	19.86	24.37	15.54	19.63	23.94	15.79	19.97	24.33	15.56	19.81	24.24
SLURRY	21.01	25.61	30.22	20.72	25.2	30.03	21.09	25.8	30.41	20.84	25.43	30.16
8K	29.05	34.17	39.12	28.68	33.64	38.47	29.29	34.21	39.17	29.04	33.79	38.65

APPENDIX V – SIMULATED FUTURE SCENARIOS

TABLE A3: RESULTS FROM FUTURE WEATHER SCENARIOS. BL IS BASELINE WEATHER FILE FROM 2017, R IS RAIN AND ADDED °C ROWS ARE BASELINE WEATHER FILE WITH THE DEPICTED TEMPERATURE ADDED IN THE GROWING SEASON.

Condition	*Yield*	*N-uptake*	*Atmospheric N deposit*	*N-leaching*	*NH3 volatilization*	*Denitrification (N_2O,NO,N_2)*	*Change in Soil N*	*Net GWP*	*J-date N is limited*
	kg C ha-1	kg N ha-1	kg N ha-1	kg N ha-1	kg N ha-1	kg N ha-1	kg N ha-1	kg CO_2 equivalent ha-1	
				Slurry					
				405 ppm					
BL	1482	85.10	0.90	10.30	1.20	0.10	12.90	-1277	244
+2°C	1552	87.60	0.90	10.30	1.40	0.30	10.40	-751	238
+4°C	1612	89.90	1.00	9.80	1.60	0.40	8.30	-242	234
BL + R	1393	83.40	1.10	12.00	1.20	0.10	13.10	-1276	243
+2°C + R	1470	85.90	1.20	11.70	1.50	0.30	10.80	-763	237
+4°C + R	1537	88.40	1.30	11.20	1.70	0.40	8.60	-228	233
				685ppm					
BL	1318	87.30	0.90	8.40	1.20	0.10	13.70	-1491	238
+2°C	1338	90.20	0.90	7.90	1.40	0.30	11.30	-1003	232
+4°C	1474	91.90	1.00	8.10	1.60	0.40	9.00	-429	229
BL + R	1236	85.80	1.1	9.80	1.20	0.10	14.00	-1498	237
+2°C + R	1271	89.00	1.20	8.90	1.40	0.20	11.80	-1017	232
+4°C + R	1404	90.60	1.30	9.30	1.60	0.40	9.30	-428	229
				Digestate					
				405 ppm					
BL	1923	93.90	0.90	12.90	1.30	0.20	1.50	-539	251
+2°C	1999	96.30	0.90	12.60	1.50	0.30	-0.70	-63	243
+4°C	2044	98.30	1.00	12.50	1.60	0.40	-2.80	437	238
BL + R	1834	92.10	1.10	14.60	1.30	0.30	1.70	-540	249
+2°C + R	1908	94.50	1.20	14.30	1.50	0.40	-0.40	-81	242
+4°C + R	1972	96.90	1.30	13.60	1.70	0.40	-2.30	411	237
				685ppm					
BL	1804	96.30	0.90	10.60	1.10	0.20	2.50	-772	242
+2°C	1798	98.70	0.90	10.40	1.30	0.30	0.30	-320	235
+4°C	1956	100.80	1.00	10.10	1.50	0.40	-1.90	224	232
BL + R	1725	94.80	1.10	12.10	1.20	0.20	2.60	-774	242
+2°C + R	1740	97.70	1.20	11.40	1.40	0.40	0.60	-316	235
+4°C + R	1872	99.20	1.30	11.80	1.50	0.40	-1.80	237	231
				8K					
				405 ppm					
BL	1039	76.50	0.90	7.50	2.10	0.10	23.4	-642	238
+2°C	1141	79.50	0.90	7.20	2.40	0.20	20.6	-165	233
+4°C	1190	81.80	1.00	7.00	2.60	0.30	18.4	287	229
BL + R	977	75.30	1.10	8.50	2.10	0.10	23.9	-654	237
+2°C + R	1078	78.30	1.20	8.10	2.40	0.20	21.1	-180	232
+4°C + R	1121	80.40	1.30	7.90	2.70	0.30	19.0	276	229
				685ppm					
BL	862	78.80	0.90	5.30	2.00	0.10	24.4	-854	234
+2°C	865	81.60	0.90	5.20	2.30	0.20	21.8	-429	229
+4°C	1014	83.40	1.00	5.30	2.50	0.10	19.3	88	226
BL + R	810	77.90	1.10	6.20	2.00	0.10	24.7	-862	233
+2°C + R	820	80.70	1.20	5.80	2.30	0.20	22.4	-441	228
+4°C + R	973	82.70	1.30	5.90	2.50	0.30	19.8	82	225

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