Farming Challenges in North Rhein-Westphalia: Is Vertical Farming The Solution?

A.Batson 28067*, D.Larose* 27571*, K.Gauri* 27628 *, L.Skaf* 27826*, R.Jeewon* 26941*, Y.Wang* 27634

Weather and Climate Change In North Rhein-Westphalia (NRW) (Leen Skaf)

Regional climate has a direct impact on farming activities, involving all indicators such as precipitation, temperature and wind patterns. Between 1951 and 2015, NRW showed an increase in average annual temperature of 1.5 °C, caused by anthropogenic spreading practices and their contribution to rising greenhouse gases levels in the atmosphere (EurActiv, 2016). Moreover, warmer air can hold a lot more water vapor than colder air, which flips precipitation patterns and wind circulation systems significantly among regions. This can lead to more frequent heavy rain events, as from 1950 to 2008, the average number of such extreme events in NRW has increased yearly. Hence, the risk of floods from river banks that might leave the soil surface suffering from erosion will get higher. Those soil-free surfaces add to the obstacles faced by local farmers and hinder food production processes. From 1937 to 2007, the erosion resulting from heavy rain in NRW grew by 4% each decade (EurActiv, 2016). A recent example of floods was in Düsseldorf back in February 2021. In a Guardian report on that incident, meteorological scientists have predicted the growing frequency such as floods, droughts, and storms, but their expectations were far-stretched surpassed. Some experts went further and claimed that the trends of rising temperatures and spiraling extremes might be “non-linear” or bumpy due to accumulative effects from drought or ice melt in the Arctic (The Guardian, 2021).

In conclusion, NRW is in danger of losing most of its arable land because of the catastrophic events, removing all the healthy soil. The crazy fluctuation of temperature all year long also harms soil temperature and structure, leading to a narrow range of high-tolerant plant species naturally growing on farmland. Hence, vertical hydroponic farms have a drawing potential to save local crop production in the region because they require no soil, small space, specific liquid nutrients, and other environmental conditions like heating and lighting can be almost completely controlled.

Depreciation In Water Quality (Use Of Fertilizers) (Yongyi Wang)

The water quality in Nordrhein-Westfalen (NRW) has been primarily affected by agriculture due to fertilizers. Fertilizer means "any substance containing a nitrogen compound or nitrogen compounds utilized on land to enhance the growth of vegetation; it may include livestock manure, the residues from fish farms, and sewage sludge". The usage of fertilizers will lead to nitrate, potassium, and phosphates in water and thus depreciated water bodies. Farming is the most important contributor of nitrate inputs in groundwater and surface water (BMU and BMELV 2012). The EU law Council Directive 91/676/EEC was about protecting waters against pollution caused by nitrates from agricultural sources.

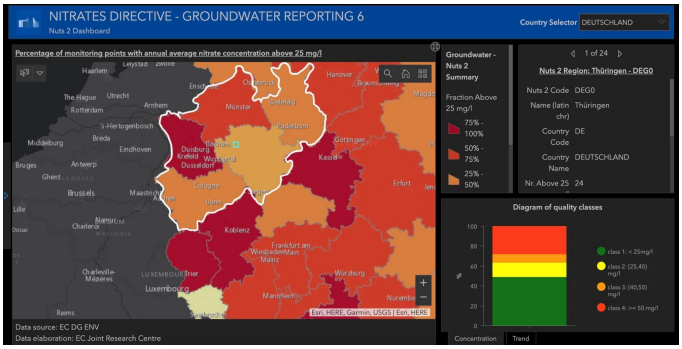

Fig 1*:Nitrates directive in groundwater report*
Source:[*https://water.jrc.ec.europa.eu/portal/apps/opsdashboard/index.html#/8b12fb8f3f544edfb4db52e4bbf7290*](https://water.jrc.ec.europa.eu/portal/apps/opsdashboard/index.html#/8b12fb8f3f544edfb4db52e4bbf7290)

Nitrate is the most severe pollutant for water. The Water Framework Directive (WFD) stated that the threshold value for nitrogen in groundwater should be less than 50 mg/L. Groundwater has nitrate pollution from both soil and surface water. From figure 1, it can be seen that the nitrate concentration in the groundwater of NRW is not reaching the goal of the WFD. Poor water quality will largely affect biodiversity and will lead to health problems for humans. In NRW, only 60% of groundwater and 6% of running water is in good chemical status. In 2015, almost 14% of the 100 groundwater monitoring stations spread throughout the state recorded values that exceeded this value (30% recorded values over 25 milligrams per liter) (2016 Environmental Report NRW)

Therefore, vertical farming in a way would help to prevent nitrogen leaching into groundwater and surface water. As vertical farming does not use fertilizers but nutrient solutions under controlled conditions, this in turn reduces the usage of fertilizers.

Importing Competition For Local Farmers (Kshama Gauri)

Farmers in Germany face a general backlash when it comes to selling to local retailers due to imports.

Regional retailers often stage or sell imported goods given a cheaper cost than foods produced by local producers, as written in the article by *(Wingard and Diehn, 2012)*. This is due to the low labor and production costs that foreign countries bring and local producers find hard to compete with.

According to *(CBI, 2019)* Germany's leading suppliers are the Netherlands, Spain, and Italy.

Mainly citrus fruits are imported from Spain, tomatoes and sweet pepper from the Netherlands, and apples and grapes from Italy. Meanwhile, the more exotic and tropical fruits and vegetables are being imported from countries primarily across the coast. This is illustrated in figure 2.

Therefore, farmers have demanded to put forth a specific regulation for each import or establish a label for the locally produced goods. Hence, consumers are more aware of their choices during purchase. *(Rueter, 2016)*

Though politicians have argued that this will be of little to no help since affordability is not a major concern for most German consumers *(Rueter, 2016)*. Hence, as long as free trade flourishes in the EU, imports will continue to threaten local farmers. As shown in table 1, imports have only grown in 5 years to a great degree.

Nonetheless, having free trade would also mean an increase in the carbon footprint of Germany in the world, especially in developing countries. Whereas locally produced goods are much fresher and have a lesser carbon footprint when it comes to product freight. Moreover, people are becoming product conscious and are starting to opt for a sustainable, laborless farming technique to grow fruits and vegetables. It would help Germany reduce their overall carbon footprint.

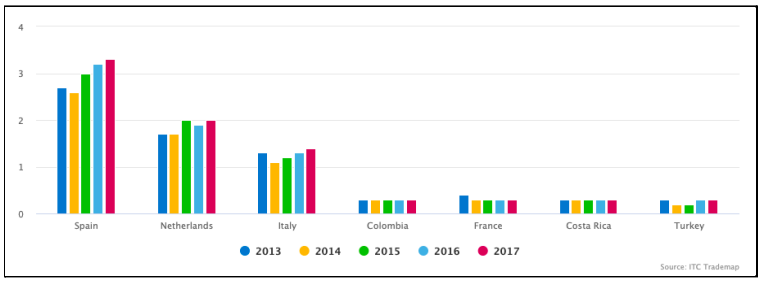

Fig 2: *Countries that export fruits and vegetables to Germany (CBI,2019)*

Table 1: *Main imported products from developing countries in million euros.*

Products from developing countries	Imports 2017 in euros	5-year growth in %
Fresh fruit of species vaccinium myrtillus (berries)	39,458	662
Avocados	102,103	281
Fresh raspberries	32,966	221
Fresh or dried dates	36,772	98
Fresh or dried guavas, mangoes and mangosteens	147,128	70
Fresh melons (excl. watermelons)	45,902	64
Fresh exotic fruit	29,104	59
Fresh cherries (excl. sour cherries)	86,535	50
Fresh table grapes	249,621	45

Source (CBI, 2019)

Main Constellation Work Scheme: Scale Modularity: (Adiel Batson)

Based on our findings, Germany has some specialized and general problems which we believe a combination of multi-floor towers and container set up would solve. We believe these methods, when correctly developed and assembled, succinctly meets the needs of the region.

In NRW, high groundwater nitrate concentration is a significant challenge, mostly brought on by traditional farming and fertilizer use (Wendland, 2020). In tandem with this, growing weather and climate phenomena unstabilize the agricultural prospective by altering the frequency and intensity of rain events, humidity, and increasing the temperature (EurActiv, 2016). Weather catastrophes hinder traditional farming potential and nullify the possibility of remediation of damage caused by traditional farming.

Simultaneously, along with many other countries Germany has set Land-use targets and food security targets to reach while simultaneously industrializing and growing (Siedentop, 2020). Sustainable development is a core factor, which cannot be overlooked in selecting an appropriate hydroponic system.

Why our system*:*

A multi-floor system resolves land use and food security challenges by enabling a dense yield harvest per square meter of space use. Water management systems also control inputs in a looped system, allowing avoidance of soil/ groundwater pollution and opening up the possibility of complete control of climate systems when climate poses a substantial threat to crop growth. The system can potentially avoid soil pollution in its use of water systems.

Secondly, we believe the system should be smart and modular. This not only adds to scalability but simultaneously simplifies the management of the necessary plant parameters. Programmability, monitorability and adaptability of our system is another core strength, quintessential to the success of the project and long term maintenance.

For these reasons, we strongly believe the best solution lies in the combination of multifloor towers and shipping containers.

Aspects Of The Container Vertical farms (Daphne Larose)

The ability to obtain a controlled and monitored environment makes the vertical container farm the best choice. They provide the crops with protection against the outdoor climatic conditions and create an indoor environment with optimum conditions.

One of the key elements needed for the plants' growth is lighting. A lack of proper lighting can affect the plants' growth, development, and metabolism. Wavelengths, known as Photosynthetically Active Radiation (PAR) in the visible light (400 - 700 nm) and the infrared (700 - 800 nm), are the most important for photosynthesis. (Avgoustaki & Xydis, 2020) Light-emitting diodes (LEDs) are used as artificial light sources since they are highly energy-efficient, durable, and have long lives that go up to about 100 000 hours. (Avgoustaki & Xydis, 2020) Red and blue LEDs combined make up the prime conditions to grow plants since blue light is found in the range from 450 to 495 nm and red light between 620 and 750 nm, and the LEDs act as a source when the temperature is too low inside the container.

(Vertical Farming Planet, 2021) Air conditioners, overhead fans, and exhaust fans help in temperature control and removing the water vapor that plants transpire. A lack of proper airflow could lead to improper growth or diseases in the plant.

In case of a temperature rise, the air conditioners turn on and release cold air in one part of the container; usually, the front and with the overhead fan, the air enriched with CO_2 can circulate and create a constant air distribution. The CO_2 levels are required to stay at certain levels, 1000 ppm, during photoperiods. (Avgoustaki & Xydis, 2020) If the CO_2 levels drop, CO_2 tanks release as much as needed, and if the CO_2 concentration is too high, the excess CO_2 is released outside using the exhaust fan. (Freight Farms, Inc, 2020) The containers are equipped with dehumidifiers to keep the appropriate humidity level and avoid mold that could cause harm to the plant. The dehumidifier condenses the moisture to water. This water can then be collected and reused again in the main tanks.

Fig 3: *Lighting inside a container vertical farm*
Source: *https://verticalfarmingplanet.com/purple-led-lights-in-vertical-farming-why-does-light-color-matter/*

Water Consumption For Irrigation (Rajshree Jeewon)

In multi-floor tower farming, the conditions required by the plants are adjusted to provide optimal plant growth, and one of the many key elements is the irrigation system. Closed irrigation systems have been shown to achieve high water use efficiency. Hydroponic is the primary growing system that is used in vertical farming, in which plants are grown in soil-free nutrient solutions (Birkby J., 2016). The nutrient solution is regularly controlled so that the right amount of chemicals for the plant is maintained.

The overall water consumption in an enclosed area for irrigation is estimated to be about 2% of that of a greenhouse. Almost 95 percent of the water vapor transpired from the leaves of plants is condensed to liquid water at the cooling coil panel air conditioners, which are then collected and put back into the nutrient solution after sterilization (Kozai et al.,2019). The nutrient solution that is drained from the culture beds is also returned to the solution tank after sterilization. Therefore, the volume of water added to the tank is nearly equal to the volume of water that is being held in the harvested plants and the amount of water that evaporated through air gaps as water vapor. Likewise, the amount of nutrients added and absorbed by the plants is almost the same. Thus, there is no soil and groundwater pollution. In most cases, the water use efficiency and nutrient use efficiency are over 0.95 and 0.90, respectively (Kozai et al.,2019). Moreover, the vegetables grown in vertical farming do not require the need to be washed before consumption as they are pesticide-free, insect-free, and free from foreign substances. Hence a significant amount of water is saved.

References

1. Avgoustaki, Dafni Despoina, and George Xydis. How energy innovation in indoor vertical farming can improve food security, sustainability, and food safety?. Advances in Food Security and Sustainability vol. 5 (2020): 1–51. doi:10.1016/bs.af2s.2020.08.002
2. Birkby, J. (2016). Vertical farming. *ATTRA sustainable agriculture*, 1-12. Accessed on 19 Oct 2021.
3. Cbi.eu. 2019. *Exporting fresh fruit and vegetables to Germany | CBI*. [online] Available at: <https://www.cbi.eu/market-information/fresh-fruit-vegetables/germany> [Accessed 20 October 2021].
4. Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31991L0676
5. Das Landesportal, "Landwirtschaft 2030: Eine Branche mit Zukunft für Nordrhein-Westfalen" (2020). Accessed on 18 Oct 2021: https://www.land.nrw/de/pressemitteilung/landwirtschaft-2030-eine-branche-mit-zukunft-fuer-nordrhein-westfalen
6. Environmental report, 2016 MKULNV, umwelt.nrw https://www.umwelt.nrw.de/fileadmin/redaktion/Broschueren/umweltbericht_nrw_2016_en.pdf
7. EU News & Policy Debate, 2016, "GERMANY's AGRICULTURAL CHALLENGES", special report, EurActiv, 6 pages. Accessed on 18 Oct 2021: https://www.euractiv.com/section/agriculture-food/special_report/germanys-agricultural-challenges/
8. "EXPLAINED – The Technology Behind Container Farming" (2020) Freight Farms, Inc accessed from https://www.freightfarms.com/blog/container-farming-technology
9. EdenGreen Technology, February 2021, Environmental Impact of Traditional and Vertical Farming- 2021 Report https://www.edengreen.com/blog-collection/environmental-impact-of-traditional-and-vertical-farming-2021-report
10. Johnson, I., 2020. *Germany's food imports leave massive 'footprint' abroad: study | DW | 06.06.2020*. [online] DW.COM. Available at: <https://www.dw.com/en/germanys-food-imports-leave-massive-footprint-abroad-study/a-53708515> [Accessed 20 October 2021].
11. Kozai, T., Niu, G., & Takagaki, M. (Eds.). (2019). *Plant factory: an indoor vertical farming system for efficient quality food production*. Academic press. https://books.google.de/books?hl=en&lr=&id=z-C7DwAAQBAJ&oi=fnd&pg=PP1&dq=irrigation+system+in+vertical+farming&ots=zDniyPkidr&sig=P9techeSwqcpiaJt7AOxJ74b2hE&redir_esc=y#v=onepage&q=irrigation%20system%20in%20vertical%20farming&f=false
12. SRU, MAy 2015,The implementation of the water framework directive in Germany with regard to nitrogen inputs from agriculture. https://www.umweltrat.de/SharedDocs/Downloads/EN/02_Special_Reports/2012_2016/2015_06_part_translation_implementation_water_framework_Directive.pdf?__blob=publicationFile&v=2
13. State Office for Nature, Environment and Consumer Protection

14. North Rhine-Westphalia, 2016, “Effects of the Climate Change in North Rhine-Westphalia”, LANUV-Information 38, 36 pages. Accessed on 18 Oct 2021:
15. https://www.lanuv.nrw.de/fileadmin/lanuvpubl/1_infoblaetter/LANUV-Info_38_englisch.pdf
16. Nuissl H., Siedentop S. (2020) Urbanisation and Land Use Change. In: Weith T., Barkmann T., Gaasch N., Rogga S., Strauß C., Zscheischler J. (eds) Sustainable Land Management in a European Context. Human-Environment Interactions, vol 8. Springer, Cham.
17. Rueter, G., 2016. *Explainer: What are Germany's farmers so angry about? | DW | 18.01.2020*. [online] DW.COM. Available at: <https://www.dw.com/en/explainer-what-are-germanys-farmers-so-angry-about/a-52054387> [Accessed 20 October 2021].
18. The Guardian, 2021, “Climate scientists shocked by scale of floods in Germany”, international edition. Accessed on 18 Oct 2021: https://www.theguardian.com/environment/2021/jul/16/climate-scientists-shocked-by-scale-of-floods-in-germany
19. Vertical Farming Planet, 2021, Purple LED Lights in Vertical Farming: Why Does Light Color Matter? , accessed from https://verticalfarmingplanet.com/purple-led-lights-in-vertical-farming-why-does-light-color-matter/
20. Wingard, J. and Diehn, S., 2012. *Cheap food imports undermine local producers | DW | 13.10.2012*. [online] DW.COM. Available at: <https://www.dw.com/en/cheap-food-imports-undermine-local-producers/a-16299667> [Accessed 20 October 2021].
21. Wendland, Frank u. a. „Model-Based Analysis of Nitrate Concentration in the Leachate—the North Rhine-Westfalia Case Study, Germany". *Water, Vol 12, Iss 2, p 550 (2020* 2020. Web.