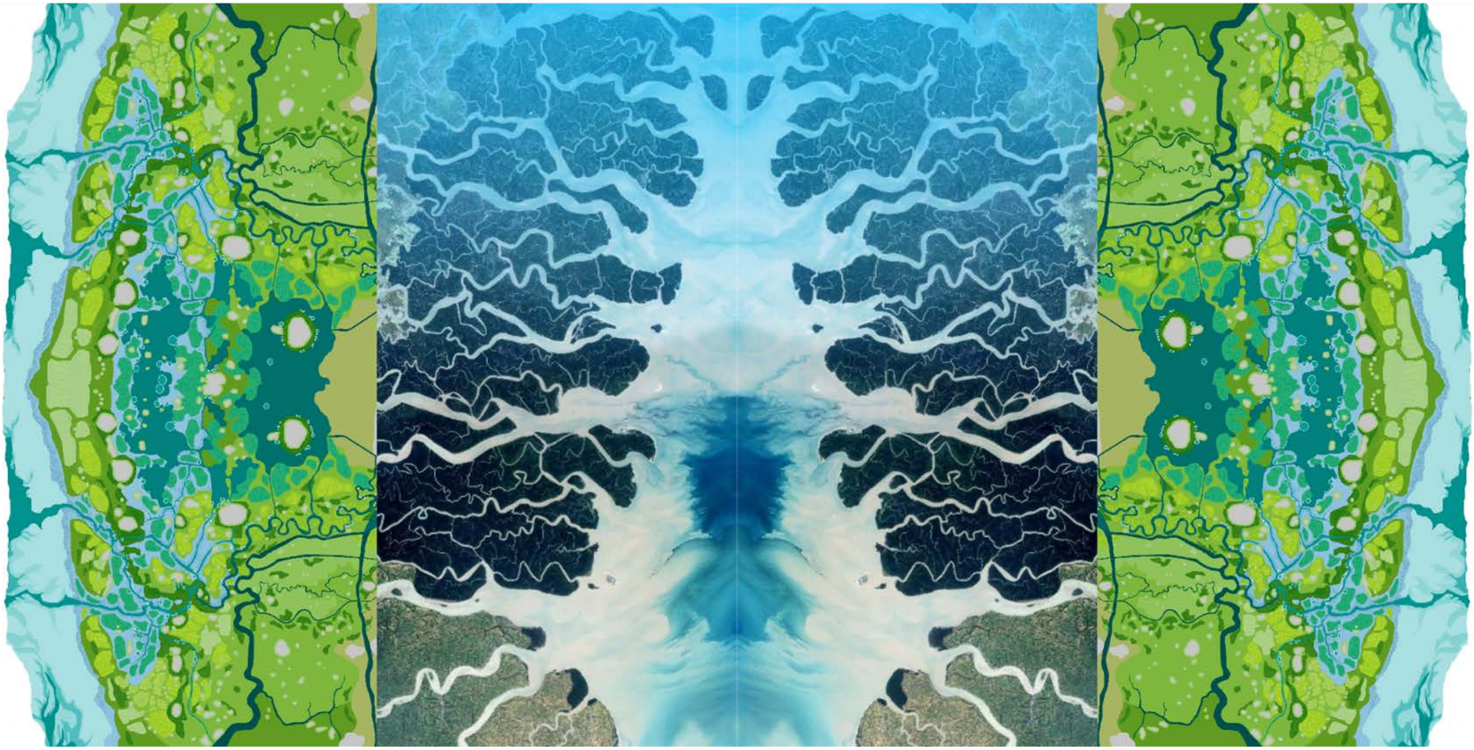
MOEDER ZERNIKE

Embracing a natural future



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Dr. Rob Roggema, Professor of Spatial Transformations, NoorderRuimte, Hanze University of Applied Sciences
Bob Verheijden, Head of Department of Design, Minerva Art Academy, Hanze University of Applied Sciences
Matthijs Hollanders, Landscape Designer, Delft University of Technology
Rachael Tillotson, Architecture Student, Academy of Architecture, Hanze University of Applied Sciences
Louy Fakhr Edin Alsharani, Master Student, Global Water Systems and Agro-economy, Wageningen University

With:
Klaas-Pieter Lindeman, Minerva Art Academy, Hanze University of Applied Sciences
Dr. Nico Tillie, Delft University of Technology
Prof. Greg Keeffe, Queens University Belfast
Dr. James Ehrlich, ReGen Villages and Stanford University
Rob Liebeskind, ReGen Villages
Femke Scholten, Alumni Minerva Art Academy, Hanze University of Applied Sciences
Nine Marije Ligtenberg, Alumni Minerva Art Academy, Hanze University of Applied Sciences
Allard Roest, NoorderRuimte, Hanze University of Applied Sciences
Ozlem Genel Altinkaya, NoorderRuimte, Hanze University of Applied Sciences

Translation: Anouk Roggema, AF Wordsmith, Amsterdam

Hanze University of Applied Sciences Groningen
The Stanford Flourishing Project
ReGen Villages
Queen's University Belfast
TU Delft
Technische Universiteit Delft
Wageningen University & Research

“The rain falls. The rain which feeds and cleanses us, falls in steady streams on the thirsty land. The rain cleanses our soul. The rain brings us back. The journey to the roots of our existence approaches its end. We must say goodbye to the warm, wonderful world of our forefathers and -mothers. At the speed of light, the speed of the laser which scans this CD, we return to the world of the now and to the rushing blood in the framework we call ourselves. And we, we have changed forever. We treasure that task and carry it through to the future. The task given to us by the sun, the moon, and the perpetually silent power: Oh, Cananefates, carry and keep this Earth, be one with the waiting sea, the cheerful wind, the peaceful sand and the raging rain.” (Song lyrics from ‘Epiloog’. On: De fluiten van ver weg. Wim de Bie, 1996)

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This report presents the results of a design study on a long-term climate adaptive future for the Zernike University Campus Groningen, as part of the Climate Manifestation of the Climate Adaptation Week, for the Global Centre on Adaptation, the Province of Groningen, and the City of Groningen.

Hanze University of Applied Sciences Groningen
GLOBAL CENTER ON ADAPTATION
provincie groningen
Gemeente Groningen

Table of content

SUMMARY

The future is uncertain. The campus is eminently the place where new knowledge is developed, and therefore also the best place to experiment with new solutions which may be useful in the future, however that may look.

Climate adaptation on the Zernike campus is primarily focused on dealing with a surplus of rainwater, drought, and rising temperatures. These form the new framework for the functioning of life on campus: new circumstances determine how students, employees, and perhaps in future, residents, can use and live on the campus.

For a sustainable use of the built environment and our landscape, we must not only account for changing consumption patterns, such as for example a different diet, but also for changing ways in which goods and materials are produced. These will have their own impact on how we must arrange our environment and how we can use this to our advantage.

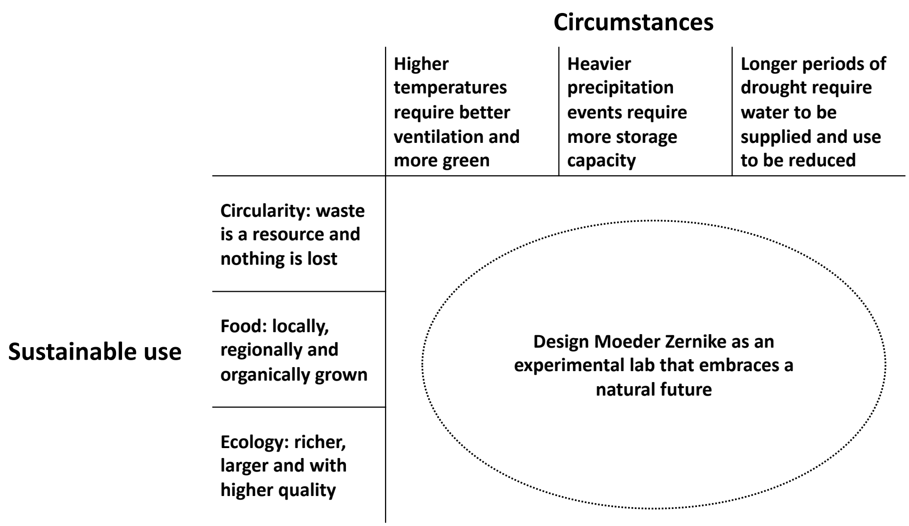


Figure 1. *Link between sustainability of land use and the context of a changing climate*

The continually ‘upscaling’ agriculture finds itself at an intersection: continuing on the path of more and more effective methods, using up all the natural resources and emaciating the landscape, or creating a way in which we can let our crops grow such that the soil quality is enriched, and nature remains healthy? The most secure choice is to start cultivating our food where we need it – close to us. A local-regional food system has the capacity to feed everyone, without dependency on (un)successful harvests elsewhere, without the risk of contamination or diseases as a result of unknown or different quality norms, while also having a smaller impact on the environment.

Can nature still be saved? Since the 70s, two thirds of the biodiversity have been lost. That is a staggeringly high tempo. Furthermore, the knowledge that our life is dependent on the functioning of the natural system implies that we cannot sever this umbilical cord. Instead of trying to protect nature, we should give it more space, start thinking in terms of larger ecosystems, and start seeing ourselves as part of nature as opposed to vice versa.

The use of fossil fuels for our energy supply is passé; the switch to alternative sources of energy is in full swing. Hydrogen as the new carrier, and the sun and wind as suppliers will shape the future. Perhaps even more important, though, is a structural reduction of the need for energy. In homes and offices, existing technologies are available to produce net energy and in doing so, cause these to become the supplier rather than the consumer.

The water is up to our neck, as a result of heavier rains and more impactful storms, caused by the sea levels rising. This can lead to temporary discomfort due to floods, but there is also the possibility of a disaster such as a dike breach. In Groningen, this already almost occurred in 2006. We therefore need to create more space in our urban environments to catch the water and allow the city to function as a sponge. Furthermore, the old adage of building a higher and higher dike when the sea level rises is outdated. The way we think about water safety has progressed, and more and more often makes use of the strengths that nature offers us: self-organisation, resilience, and continual adaptiveness. However, there are also periods in which there is a shortage of water. This scarcity leads to desiccation of the landscape and has major consequences for agricultural crops and nature. Water has now become a commodity, that is traded on Wall Street. The economic fight for access to water has begun.

The task now is to look 100 years into the future – a practically impossible task. Could the people alive in 1921 have known that, in 2021, we would have smartphones, have walked on the moon, or have discovered the Higgs particle? Or that our climate would change drastically, and the landscape would have been mined for everything it had?

If we go a little bit further back in time, we see a northern landscape that could fend for itself. In a dynamic balance, the landscape grew along with the sea level – whether that rose or sank. Nature formed natural systems, which protected the land against large floods, which were a part of the dynamics. Humans lived on small elevations in the landscape; later, these same humans would create artificial elevations, the ‘wierde’. Only when dikes were constructed did the possibility emerge for a breach, and a risk of catastrophic flooding. The bigger the dike, the greater the risk – at least, risk is defined as the chance a disaster will happen x the effect or impact of the disaster. With a higher dike, the chance may decrease, however, the eventual effect is correspondingly large.

How things will be in 2121 is unknown, but it is evident that it will be very different from now, 1991, or 1961. Current plans, visions, or policy plans will be looked upon with a sly smile.

Because of this, the Moeder Zernike plan is focused on connecting our future life with the origins of the Earth. First, by understanding how Mother Earth works and how a sustainable balance can be created. Then, by looking at what the soil, air, and water can offer us, wat they can produce and how generous they can be. We must do this in order to see what is necessary for the Earth to recover, to give it time to replenish resources, and to allow nature to bloom once again. The circle must be completed. Finally, we must learn from the powers of nature, and how we can strengthen these, make them resilient, and allow them to continually recover.

The necessary transformation of the way we grow food, the availability of resources such as water, and how to counteract biodiversity loss is taken as the entrance point for the adaptation of the campus.

Calculations of the amount of food required for everyone that spends time on campus revealed that the space necessary for cultivating our future diet is available. When food is grown inside, on top of and attached to current buildings, a surplus can even be produced. Everyone can eat year-round from the food produced on Zernike grounds. Climate change, however, influences the amount of rainwater available to let the plants grow. Annually, there is not enough water available, and therefore, other sources must be used. The Wadden Sea is nearby and can be the fountainhead providing us with endless water availability. For this reason, a connection between the sea and campus should be established. With our green minds set on a 100-year future, a slow transformation of the landscape allows the seawater to reach the campus, just in time to supply the food system there with sufficient water. It will have some collateral advantages, such as an explosion of diverse new nature and a richer, more saline and economically prosperous agriculture. Additionally, due to incoming sediment, it elevates the land, creating a safer landscape for the inhabitants of Groningen.

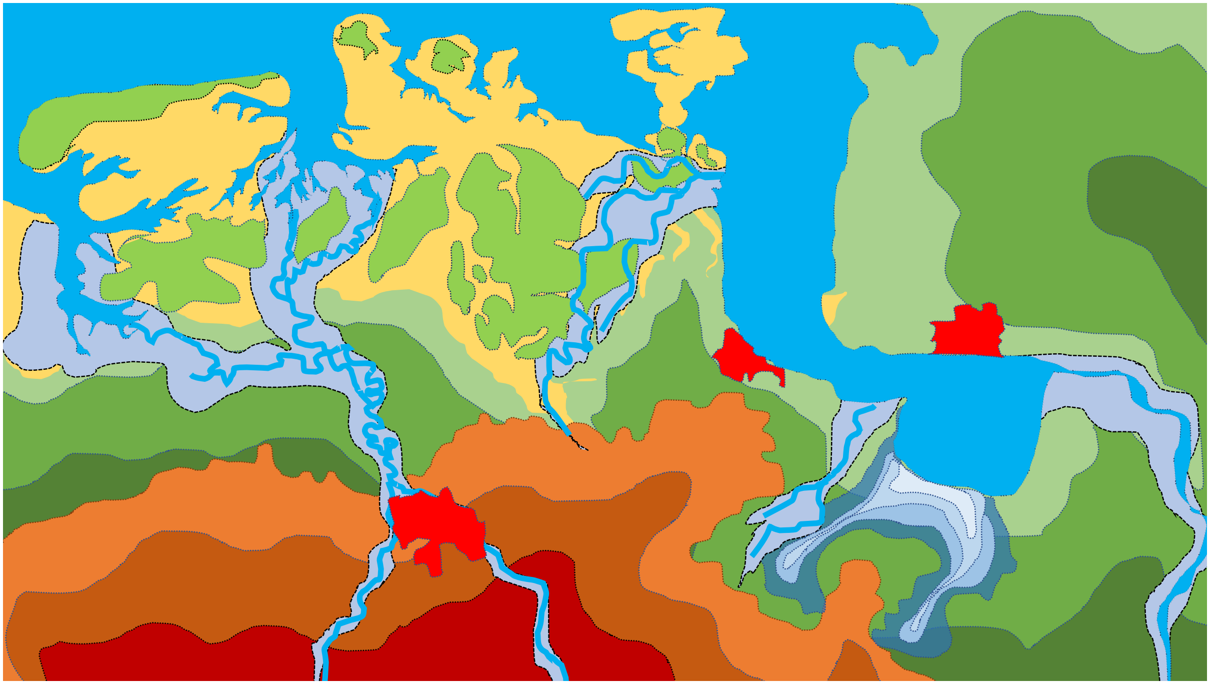
On campus, Moeder Zernike is a spaceship full of experimental new technologies, applications, and adaptations landed in this exciting new environment. It transforms traditional educational buildings into mixed-use spaces which cool themselves down by growing greens and crops. Learning, teaching, eating, living, and working take place in one built environment, and a new community is born out of these futuristic challenges. All rainwater is harvested, wastewater is treated in helophytes, and brackish water is cleansed through sandy dunes, all supplying the crops with water and nutrients to grow. The edge of campus brings together new productive practices, such as lobster and shrimp farming, and is also home to duckweed ponds and high peat bogs. The Van Olst tower reveals itself as a green productive building, with hanging fruit, and crops turning the façade into a living wall.

Time is a constraint, but also on our side. We need to act, the time is now; however, we also have the time to let the landscape transform, experiment in the lab on campus and let peat emerge. The future is uncertain, but what we know for sure is that it will not be like the past. Moeder Zernike is our connection with the land, and nature will guide us on how to self-organise to become more resilient and climate-proof. It only takes the courage of decision-makers to trust the power of nature.

Moeder Zernike thus follows the tradition of Pachamama, and the connection with the land in the way Aboriginal tribes and traditional indigenous peoples experienced it. They knew they were dependent on Mother Earth for their continued existence. In keeping with this idea, Moeder Zernike invests in a regenerative lab where experiments can be conducted which in 2121 will have led to a completely different way of dealing with our surroundings. This environment that will have been created will be capable of producing all the food that its inhabitants consume and will consist of a landscape that moves dynamically along with change and is protected by its own growing strength. In this environment, the sea and the land together determine what the coastal zone will look like. The ecology has increased, and the loss of biodiversity is compensated with new species and richer, larger nature reserves. Learning is not a goal in and of itself, but a means to be able to live in a more resilient and natural environment.

Pachamama
Moeder Aarde
Moeder Zernike

1.
EMBRACING UNCERTAINTY.



In our quest for future wellbeing, unpredictability is, for many, too exciting. We are looking for grip and we find this often in the well-known past. This way, we muddle through and are improving bit by little bit. When the future can be predicted, this is no problem at all. Indeed, in this case the future is a lookalike of the past or can be estimated pretty well. We can continue to build using the means we are already familiar with. However, if the degree of unpredictability is larger, the solutions from the past no longer suffice. At least, it is more likely that they do not work, than that they will help us in times of trouble.

Currently, people often talk about the transition era. This presumes we are moving from the current era towards a new future. It is strange that the transition itself is qualified as an era. This implies we have ample time to implement the necessary changes. It would be better to talk about transitioning from one era to the next. The current era being oriented on profit, individualism, using all raw materials available, that is replaced by an era that returns us to being in equilibrium with our environment, using less resources and becoming reciprocal, and where togetherness comes into place instead of personal gain.

We'd rather call this a transformation, because a transition implies that we adjust current practice while the unpredictability of the future urges us to implement more fundamental changes. Transforming is not simple, is not happening by itself, and touches on our deeper self. Are we as humans really in control of our environment? Or are we part of a bigger system – natural forces if you wish – which determine within which boundaries we operate and stay alive? Given the rise of natural disasters in the world, it seems humans can be a bit more modest about their own influence and leave it to what nature represents: self-organisation, succession towards maturity, biological responsibility, and evolution.

Indeed, major changes are knocking on the door. As a matter of fact, they are already among us. Since the 70s, approximately 68% of species has been lost, land ice is melting at an accelerated rate, and the way we produce our food comes with pandemics. Therefore, we shall have to change course in the way we build our (not yet or unbuilt) environment and change our attitude and approach. First, think about the way nature would solve it, before we decide on how we fit in this context. To speak as Darwin: How can we find our best 'fit' in the ecosystems of the urban landscape?

This requires transformative thinking, decisionmakers and the building sector alike, in three crucial areas: climate, food, and ecology. What could emerge?

1.1 Climate.

In the field of climate change, we first need to recreate the landscape and help it become more resilient. We must do this without throwing our engineering capabilities overboard, but using our intelligence to understand dynamic systems, emergence, and succession. The current landscape of Northern Netherlands for instance, is harnessed in strictly controlled dikes and rules. Though chances are low the dike, of which its strength is calculated in detail, will break, *if* this occurs, the misery will be incalculable. Constructing a dike is building in the risk of a dike breach. Without the dike, this breach would be an impossibility. The alternative is centuries old. The northern coast has been capable of guaranteeing its own safety for millennia. The sea brough sludge, clay particles and sandy sediments, and built its own land whenever sea levels rose. A firm buffer of peat bog completed the protection of the higher grounds in a natural and resilient way. We have expelled this power of nature from the landscape. This ultimately led to an increased flood risk and heightened danger for all. By now, projects such as the MarkerWadden and Sand Engine proved that if we leave our safety to the building capacity of nature, we may be better off. In the northern parts of the Netherlands, it is therefore better to let the water in, let the land raise and introduce new forms of land use, than to undergo ourselves apatically into a vicious circle of dewatering, soil subsidence, and salinification. Moreover, it opens up the way to new forms of living in places that were not possible beforehand, in a landscape in which innovative agriculture, water management, nature, and residential areas could form an idyll.

Not only do we need sea water to let our food grow, we also need all the rainwater we can capture, to grow crops, for our drinking water, and to supply nature. To keep water is to have water; pumping it away is a waste. Keeping the water in the landscape, public spaces, and in our buildings is necessary and beneficial as subsequent drought records have shown we'll need every drop we can get. This will become an economic factor of importance, since scarcity will have its price. If you can create your own resource in your house, office, or city, you'll be safe.

And what about energy? We did have a huge task called the energy transition, didn't we? Is the way forward to allocate solar fields on former fertile soil? And have wind turbines become the new symbol of resistance in society? Or do we start where we can gain the most: by building better buildings? Constructing them in a way they keep warm when it is cold outside and stay cool when a heatwave hits the city? In Germany, for instance, Passiv-Haus or Büro buildings have thick walls, which turn every building into its own little energy plant.

1.2 Food.

Looking at the way we produce our food, we can no longer afford to transport it over long distances. Viruses get the opportunity to travel along and it is polluting air, soil and water. On top of this, local food is way more interesting. Crops from the local area keep the taste of the region intact and offer dishes the uniquity that has been lost in the menu of all hamburger chains. Therefore: own food first!

In every house or office, we can grow and cook our own menu. Along the coast, saline crops and seafood offer the ingredients for high-end cuisine. Such a transformation meets resistance amongst the farming community, but tides can turn when new forms of agriculture could be more profitable than continuing to grow crops that are increasingly more difficult and less viable. Move with the increase of salinity and making use of the changing and growing conditions is as profitable as current practice, but on only 20% of the current land. Calculated differently, if we keep 50% of current land productive, farmers become 2.5 times as rich! A beckoning transformative perspective, isn't it?

1.3 Ecology.

In order to survive as the human species, it is a no-brainer that we should adapt to our environment; this is even more pressing when conditions change rapidly and significantly. Here, we can learn a lot from ecology, which is used to behaving like this all the time, everywhere. No species we can think of will behave against its environmental conditions, as this would mean extinction. Therefore, as humans, we can only benefit if we allow nature to fully develop and grow as it wishes. Moreover, it is demonstrated that if we base farming on ecological principles, it will be more profitable than regular farming. We should therefore transform our land for more than 50% into nature. The essay 'Natuurrijk Nederland' (www.natuurrijknederland.org) illustrates how this can be achieved in a feasible way: we generously buy land off the farmers that are open for sale, create new nature on these lands, and pay for this transformation by allowing sparsely dense paradise-housing. This is not only profitable, it also provides a large number of new jobs, just like the land reclamation in the 19th and early 20th century did.

In urban environments, green takes over stone, ecology takes over concrete. Planting on top of, attached to, and inside buildings is good for its market value and lets these colossi regulate themselves in extreme heat or cool days. Nature thrives and can also be harvested. Examples of this can be vertical grapevines as cooling facades of office buildings of the Amsterdam South-Axis, or Aquaponic fish farming on the roof of the Groninger Forum, the building recently chosen as the building of the year in the Netherlands. Tasteful, healthy, and cooling! To speak as Winy Maas of MVRDV: this way, entire cities may undergo a Green Dip.

As aforementioned, unpredictability leads to uncertainty. Real transformations require imagination. Besides not knowing what the future holds, it also offers a hopeful perspective. We need a courageous administration, which has the guts to transform, and jump ship; one that understands that taking risks is always better than being confronted by the effects of not doing so. Let imagination be the inspiration for people, countries, and the world, so that sadness can be expelled by confidence. For the Netherlands, this means it can be seen as leading the way forward, showing that taking faith in yourself can make a difference in shaping the way of life on the edge between land and sea. As the old saying goes: God created the world, but the Dutch created their own land. Let’s get it done.

2.
RATIONALE.

2.1 Ecological context.

The presence of humans on Earth has long been in balance with their environment. They took from the land what they needed, kept what they needed to survive in barren times and lived in an equilibrium with nature. Many indigenous peoples therefore cherished mother earth, or, as it is called in South America, ‘Pachamama’. In two centuries, humankind has succeeded in overtaking all other species as the single distinctive one that dictates what happens to others. Moreover, we exhaust available resources and cause fundamental change, placing the survival of ourselves, other species, and Mother Earth in danger. In the Groningen province, this process of human superiority has led to a controlled, diked landscape, which subsided as result of gas extractions and which lost biodiversity as result of intensive and large-scale agriculture. Moeder – the Dutch word for mother – Zernike aims to turn the tide: both mentally and physically.

Realising a future which is fully climate resilient requires transformations in many directions and on as many topics. This is not possible by focusing on the individual issues, distinct breakthrough technologies, or by adopting mindful policy plans. A basic mental shift in mindset is needed, which turns the way of thinking upside down. Where most effort, investment, and attention are currently put towards the 'red' side of urban development (hard infrastructural plans and measures) this should be reversed to a 'green' mindset, through which all developments are started with the natural system as the point of departure.

'Nature is not that fun, but we have to do something with it' (Aan de Burgh, 2020). 'Humans want quantity over quality, growth over development, production over protection – usually realised in the most inefficient ways. Natural ecosystems self-organise with an increase of species richness, size and age of organisms, biomass, productivity, efficiency in the recycling of organic matter, three-dimensional structure created by living organisms, and stability, among many other properties. But humans latch on to one idea and blindly focus on it. We turn mature ecosystems into monocultures – cultures of single species – which are the simplest of ecosystems. With our blinders on, we prioritise just one species, selected to grow fast – like cornfields in Iowa or salmon farms in the Chilean fjords – and we focus all our efforts on it to the detriment of any surrounding species. Although these monocultures are intended to feed us, ironically, they are the closest thing to a barren landscape when it comes to ecosystem maturity – the anti-climax. Our built environments are misguided attempts at re-creating the assembly and productivity of natural ecosystems, designed to satisfy our needs. We are abruptly interrupting and most often reversing ecological succession across the biosphere, turning complex ecosystems into simple, homogenous systems with fast turnover rates: That is, we are accelerating and fragmenting the biosphere. Does that mean that we are isolating ourselves from nature?' (Sala, 2020, Pag 61-62). 'For humans, the ancient necrosphere is the key that unlocked the shackles of the present and allowed us to escape the alternating turnover cycle of predator and prey. We cheat: we use energy from the past to subsidise our overexploitation of the present. That energy subsidy allows us to build artificial ecosystems (cities) that consume more energy (including food) than they produce. No other species can do that. Had we continued to use daily solar energy as our main source of energy (via plant biomass and natural food webs), the human population would probably never have reached the current seven and a half billion and growing. The world would be a different place. We use energy from the past to subsidise our looting of the present.' (Sala, 2020 p. 125-126). 'We assume we know what is good for a species, but we forget that our landscape is so changed, so desperately impoverished, we may be recording a species not in its preferred habitat at all, but at the very limit of its range (Tree, 2018; p. 182). This is called the 'Shifting Baseline Syndrome' (Tree, 2018, p.191). Besides this, we have to deal with new scarcity. The supply of water, for example, is running out, and there is no alternative (Santema, 2020). It is becoming clearer and clearer that 'we have all ended up in a systemic labyrinth, and only those who see possibilities in unexpected events will have an impact and determine the future.' (paraphrased from: Alkemade, 2020).

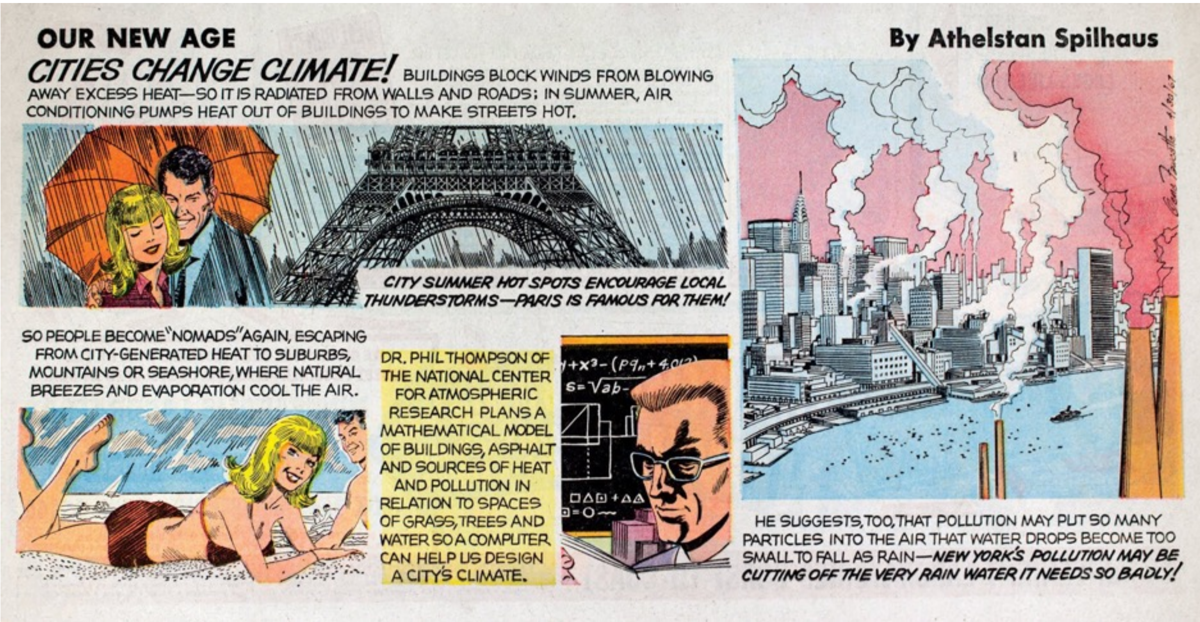


Figure 2. *Athelstan Spilhaus, "Our New Age," 1967, courtesy of "The Experimental City," a documentary*

The objective of the Moeder Zernike project is to design a climate resilient university campus with a time horizon of 100 years. The Groningen University campus is home to two universities, several research institutes, and many enterprises and start-ups. It hosts approximately 30,000 people, students, and staff on a daily basis and is located just to the north of the City of Groningen, in a transition zone between the urban and rural landscape. In order to increase resilience and maintain a long-term focus, the landscape dynamics are taken as the point of departure for the design process. It unites aspects such as flood mitigation, local food production, biodiversity enhancement, the energy transition, mixed use urbanity, and freshwater preservation.

2.2 From Red to Green.

In Moeder Zernike, we ask decision-makers (being politicians, owners of enterprises, farms or companies, or the knowledge brokers of academic and educational institutions) to consider whether they should continue on the pathway of prioritising their own interests, economic values, and investment strategies, or if an emphasis may be put on the life of Mother Earth first, establishing an environment that is self-sustaining for both humans and all other organisms? This implies that landscape, ecology, and local food is positioned at the core of development. For Moeder Zernike, this culminates in a joint agreement in which all stakeholders endorse the willingness and necessity to make this shift.

This does mean that the red spectacles must be taken off, and that the landscape, ecology, and local food is positioned at the core of development. It also implies we have to learn to decide for the landscape first, which places the ecological and the water systems, the topography and the soil at the start of any deliberation. This requires a novel way of looking at the business case; the value of non-monetary commodities should be taken as the context without which traditional economic laws will not survive. Instead of trying to capitalise and quantify the economics of ecological, social, or contemplative aspects of life, these should be an a priori and be planned for before even considering urban development.

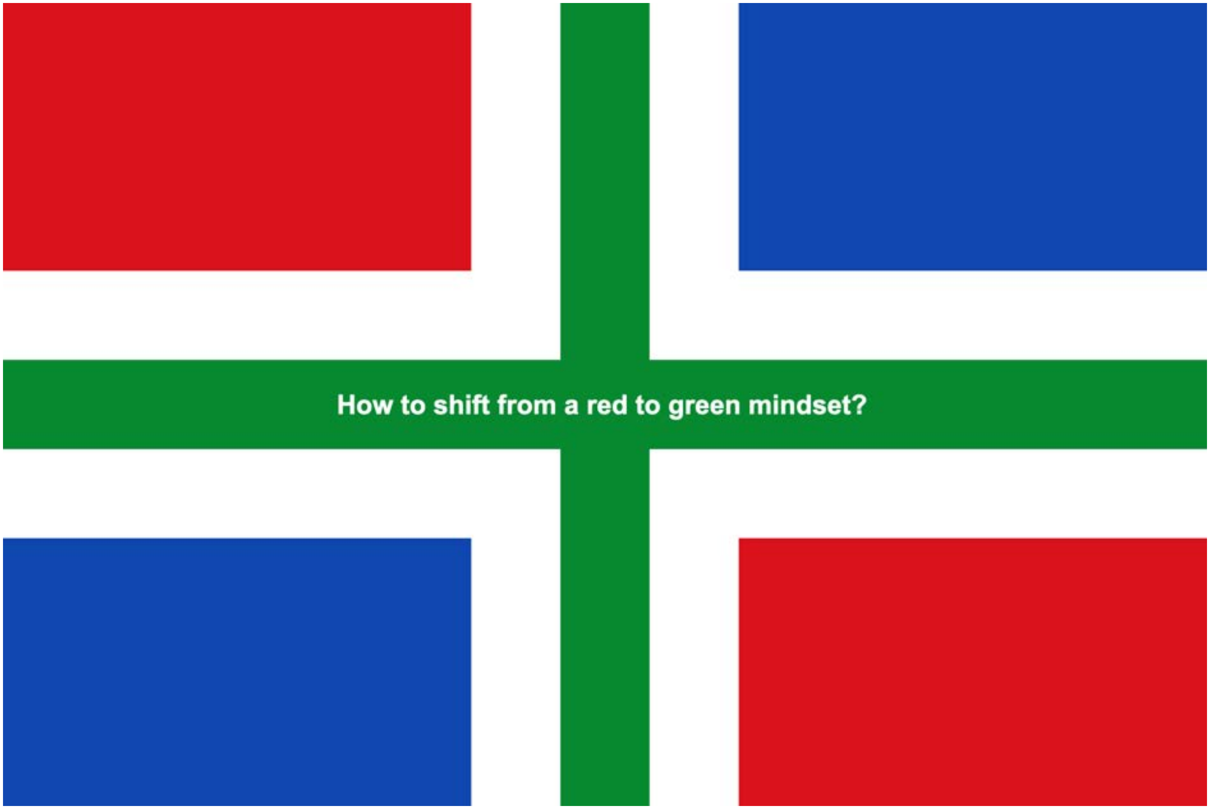


Figure 3. *A red-to-green shift in mentality*

2.3 An organism's perspective.

The mental shift is not only human-oriented, but even more so in the interest of non-human organisms. Normally, humans take responsibility to decide what is good for other organisms, meaning they will think about what an acceptable environment for the other organisms to live in would be. Often, this leads to suboptimal living conditions for these organisms as, in the end, human interests prevail. The shift in mindset here is not to think for other organisms but instead becoming one, or more. When people try to look at the environment through the eyes of a plant, tree, bird or animal, the lives of these creatures are placed at the basis, i.e., the way they use or want to use the landscape, find and build their homes, build up ecosystems, forage, and whatever needs they have to lead a fruitful life. The development is no longer nature-based, but nature-driven. This novel way of looking at ecology emphasises a humble role for humans as guests in their environment and as part of global ecosystems.

Figure 4. *Smelt and bee (drawings credit: Bob Verheijden)*

Table 1. *Building Zernike Ecologies, three examples*

	Pond Bat	Little Owl	Smelt
Climate: what is your optimal climate? What are the risks (when would you not survive)?	I need a moderate climate. I am dependent on water, I could not survive in drought stricken areas where the water has dried up, or in freezing climates where water surfaces are frozen for most of the year.	Moderate climate. I am a threatened species on the Dutch red list. This is caused by the changes that have occurred in the countryside, such as urban developments and the upscaling of agriculture. Besides this, the nest possibilities have reduced due to decline of old barns and orchards. Hedges have decreased and traffic causes casualties.	We live in schools and like to spawn in rivers, but unfortunately that's almost impossible in the Netherlands. We used to live, for instance, in the Zuiderzee, but due to barriers we seldom live in freshwater anymore.
Water: what quality of water you need, how much per day?	I need calm water surfaces for hunting such as ponds, lakes and rivers. Freshwater and brackish water are suitable for me.	I do not have any specific needs for water	100% per day, we live in saline, brackish and freshwater. We need clean water to survive.
Biodiversity: what is your habitat, what kind of landscape you feel at home	I feel at home in peat meadows and sea clay areas where there villages for me to roost and nearby water for hunting.	I am living solitarily, spotting the surroundings from a roof, electricity pole, pollard willow or a pasture post. I fabricate my nest in hollow trees, walls, buildings, rabbit holes, nest boxes or wood mites, for which I do not use any materials; a hole will suffice. I am living in a small-scale landscape of meadows, pollard willows, fruit trees and old barns. Flower meadows provide the mice and worms I desire. Hedges and wooded banks give me shelter.	We enjoy living in schools in coastal areas where we switch easily between saline and freshwater and everything in between.
Food-nutrients: what do you eat, how much?	I live off a diet of insects. I need to eat a quarter to a third of my body weight in insects every night, except in winter when I am hibernating. My colony and I can eat up to 36 kilograms of insects in one summer.	I eat mice, but prefer earthworms, beetles and other insects and frogs. I even have an appetite for young birds.	All day, zooplankton, small crabs and fishes.
Space: how much space do you need, what is the shape of it, what is your territory?	My colony and I use a 10-20km radius feeding zone with our roost located in the center. I need linear elements (hedgerow, tree line, canal etc) in the dry landscape leading from the roost to the hunting zone. I need minimal artificial or preferably no artificial light along the length of my flyways. For hunting I need moist flat meadows and calm waterways or water bodies.	My hunting strategies differ: observing from a pole, walking on the ground or hunting from a low flight. My hunting area is predominantly open with low vegetation during the year.	The Waddenzee is ideal, but what we are missing is the connection to rivers. We have family and friends in coastal areas at the North-sea, Baltic sea, White Sea, and Barents Sea. In the Netherlands, you will find a few of us in the Ijsselmeer, Friesland, and Haringvliet.

2.4 Bringing the Future to the Present.

In order to increase understanding of why and how respect for Moeder Zernike can be increased, another mental shift is required. This builds on the interactions and mutual learning capacities of students and staff at the Zernike campus. If the people working and studying at Zernike cooperatively spend time on creating, maintaining, and benefiting from nature-driven solutions in water management, energy generation, the growth of food, and establishing a new ecology, they will be given the concrete opportunity to experience, work with, and produce in a lab full of green projects by investigating, designing, realising, and monitoring. This learning lab implies a novel perspective on the way students, staff, and stakeholders are engaged. Establishing this living learning lab requires a novel way of engaging students, visitors, residents, and stakeholders at Zernike. Living on campus, one becomes part of Moeder Zernike, spending time working, studying, enjoying free time, learning, teaching, and investigating, no matter in what stage of life you are. One spends a lifetime of 'monkness' in a localised community open to and inviting the world, working together on self-sufficiency, and becoming the guides for shepherding the future.

Figure 5. *Main lessons learnt from five major global environmental policies*

2.5 The Moeder Zernike project.

The prompt for the Moeder Zernike design is described as: 'design a Reitdeep-axis which imagines the reciprocal connection between urban and rural, Stad and Ommeland, in a climate adaptive, resilient way (panarchy). Because the Reitdeep has also historically been the supply route of food and goods, a new perspective on the cultivation of food (circular, local, organic) is fundamental to this axis.'

The Reitdeep-axis runs from the city to the outer areas, but also vice versa. It forms the northern, natural entrance, which also links cultural history (e.g., of Middag Humsterland) with the history of the city. Besides this, Reitdeep is the vein which connects Groningen with the Waddenzee, and which, until recently, was still in open connection (with natural tides in the city, and (more) salty water). Within this landscape context, this team zooms in on the Zernike Campus, which functions as the link between city and country.

The results express themselves in an inspiring and integral spatial vision for the Reitdeep-axis, and a detailed sketch design for the Zernike Campus.

The site for the design links the campus with the northern Groninger landscape, connecting it with the city of Groningen. The design process is divided into four phases: Analysis and Conceptual Design, Landscape Master Planning and Design of the Zernike campus, Detailed Design, and the Visualisation and Presentation.

Within the team, a range of disciplines and areas of expertise has been gathered so that this complex task can be achieved. In the team, students, staff, and external experts work together in a creative, energetic, and inspirational environment. The expertise consists of, but is not limited to, landscape architecture, ecology, urban design, architecture, graphic design, water management, climate change adaptation, GIS, agro-economy, housing, circularity and regenerative urbanism, IoT, and sustainability.

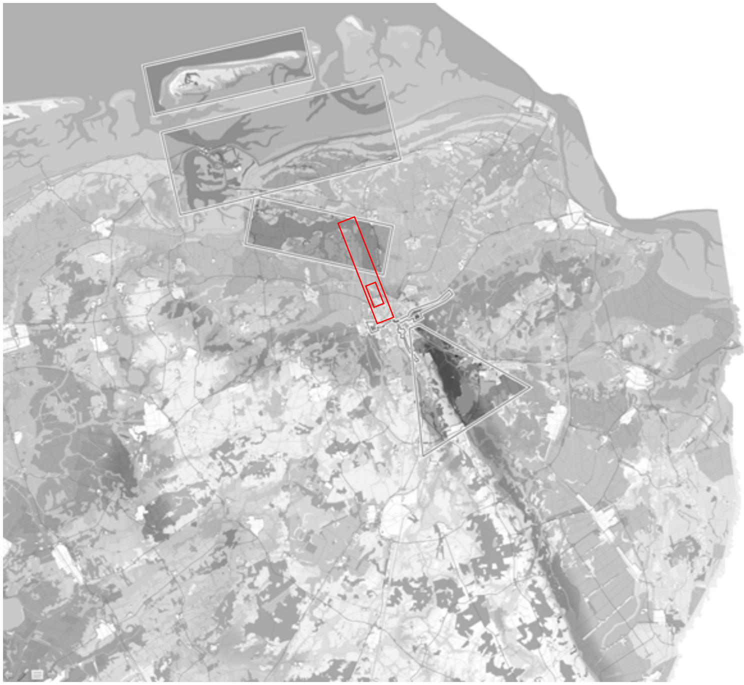


Figure 6. *The site.*

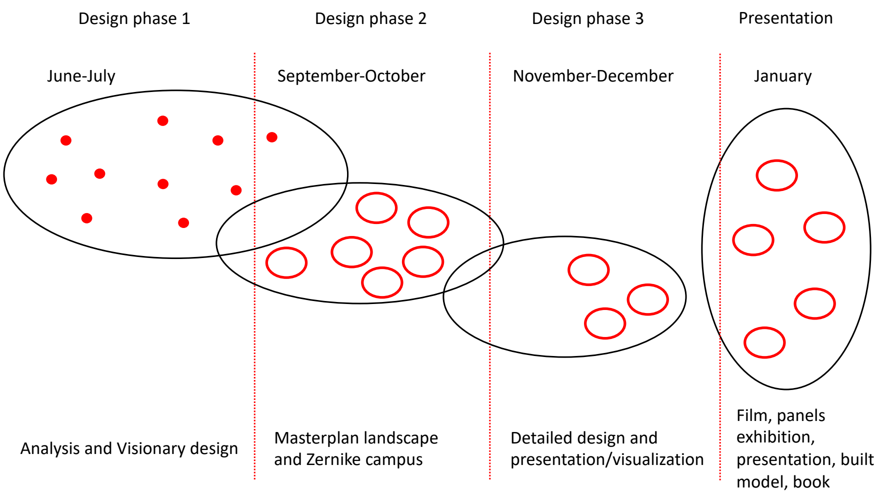


Figure 7. *Design process in phases*

3. METHODOLOGY

3.1 A nature-driven landscape.

The term 'nature-based solutions' was coined by the European Union and is an umbrella term for a number of different approaches that use nature to improve urban sustainability, such as green infrastructure, green space, restoring rivers, ecosystem services, and ecosystem-based adaptation (Mccormick, 2020). In the EU research and innovation policy agenda (European Commission, 2015), the following description is given: 'nature-based solutions aim to help societies address a variety of environmental, social and economic challenges in sustainable ways. They are actions inspired by, supported by or copied from nature; both using and enhancing existing solutions to challenges, as well as exploring more novel solutions, for example, mimicking how non-human organisms and communities cope with environmental extremes. Nature-based solutions use the features and complex system processes of nature, such as its ability to store carbon and regulate water flows, in order to achieve desired outcomes, such as reduced disaster risk and an environment that improves human well-being and socially inclusive green growth. This implies that maintaining and enhancing natural capital is of crucial importance, as it forms the basis for solutions. These nature-based solutions ideally are resilient to change, as well as energy and resource efficient, but in order to achieve these criteria, they must be adapted to local conditions'. In short, the European Commission (2015) defines nature-based solutions as: 'solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions'. Hence, nature-based solutions are seen as deliberate interventions seeking to use the properties of nature to address societal challenges.

3.2 Urban nature.

The city is nature. In many ways, this bold statement can be contested, but at the same time, wildlife is so abundant that the city of Rotterdam has recently been presented as a wilderness park (Reumer, 2014). Following this, the city becomes a piece of nature; hence, it should not be treated as something worthy of preservation, but rather as something to enrich. In many studies, ‘green Infrastructure’ is declared to be beneficial for citizens, such as through decreasing concentration disorders in children, reducing domestic violence, minimising obesity, reducing the recovery time after illness, and improving the exercise rate of people living close to green spaces (Roggema, 2020). Green cover, trees, green roofs and facades all have the ability to reduce the Urban Heat Island (UHI) effect, a phenomenon that, with climate change, will increase in the (near) future.

People value green and landscape spaces closer to urban or industrialised land use, significantly less than green and undisrupted areas (Buijs et al., 2019). On one hand, people value green and nature in their vicinity, and this has benefits for their wellbeing. At the same time, green spaces are diminishing, becoming more fragmented, and losing a critical size. The question being, do we really take the values that nature brings to cities seriously or does it operate as greenwashing the ongoing economic growth? For all the good reasons, giving nature a prominent role in city planning and development is a no-brainer, however, existing habits in urbanisation and urban planning prove differently.

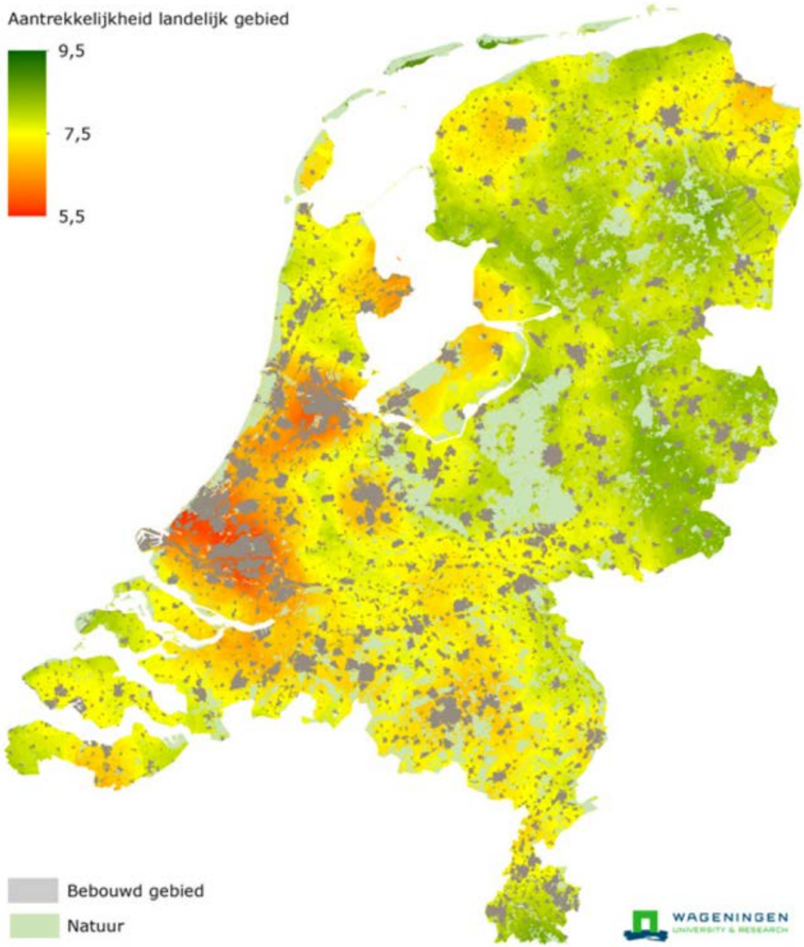


Figure 8. *Average attractiveness of the Dutch landscape (Buijs et al., 2019)*

New approaches to urban design are readily available, but it requires a mental transformation 'from red to green' to place nature, green, and landscape upfront in the planning process. Every step, from the regional planning of land-use to the detailed design of public spaces, should start with the spatial analysis of the ecological system, followed by an iterative process of designing green and ecological options through the scales, evaluating their benefits as a ground layer for programmatic demands of other land uses. Where current practice often starts with the (economically driven) program to be realised, after which green spaces are fitted in, this new mental model starts with the ecological system, and even the experience of non-human species, to be used for designing a robust foundation, within which other (urban) functions are embedded. At every spatial scale, nature-driven approaches to urban design add quality to built structures and to the quality of life of the people living there.

The relationship between green/nature and the city can be represented as a triage 'Contrast-Contact-Contract' (Sijmons, 2020). The perspective of contrast emphasises the distinction between the urban and nature, as opposites and spatially separated. When these are brought into contact, nature becomes part of the city, for instance, in the form of green structures. Though this increases the integration of green and nature in urban areas, at the lower scale, it is still a separation of uses. Contract hybridises the relationship: the city becomes nature and vice versa. In other words, the natural conditions determine the being of the city and human activities are seen as being part of nature.

Table 2. *Relationships between nature and the city (Sijmons, 2020)*

	CONTRAST	CONTACT	CONTRACT
IMAGE OF NATURE	wilderness	accessible nature	ecosystem services
Formal Interaction	city and nature have sharp boundaries, protected areas	city and nature intertwine	city and nature take each others form
commentary	*bring the city to nature 'satellites' and 'garden cities'*	*insert nature into the city 'green wedges' and 'parks'*	*go for a complete mix, 'reweaving the urban tapestry' and 'broadacre city'*
Functional Interaction	city and nature are each others jungle	city and nature come to each others rescue	city and nature take on each others form
commentary	*'places to get lost'*	*regulated leisure in nature*	*produce food on your own gardenlot*
Physical Interaction	city and nature keep their distance	city and nature exchange information	city and nature take on each others construction
commentary	*natural expression of the city 'non human' outside*	*natural expression of the city 'well tempered' environment outside*	*expression of city and agriculture 'new hybrids' in- and outside the city*
VISION OF THE CITY	from 'Cabanes' to 'Metropolis'	'Green-Blue infrastructure' to 'Lobe city'	from 'Subtopia' to 'Metabolic City'

Within arranging contracts, different gradations are possible. The essence is to achieve balance in the exchange of materials, resources, and the potential to allow co-existential living systems, urban and natural, to emerge and evolve. In some ways, this is meant to be arranged through creating regenerative urbanism (Girardet, 2014; 2017; Du Plessis, 2012; Thompson and Newman, 2018). Key to this thinking is the orientation on the city as a system, allowing the urban system to regenerate itself. Because cities have been extracting natural resources at a large scale ever since the industrial revolution, regeneration only is not enough. The city, in the true nature of what the contract perspective aims for, should become reciprocal, striving for (a) ReciproCity (Roggema, 2019). In this city, both the physical and the mental city will give more back to their environment than they take, and they do so at three different paces of development: fast, slow, and sudden (Roggema, 2015).

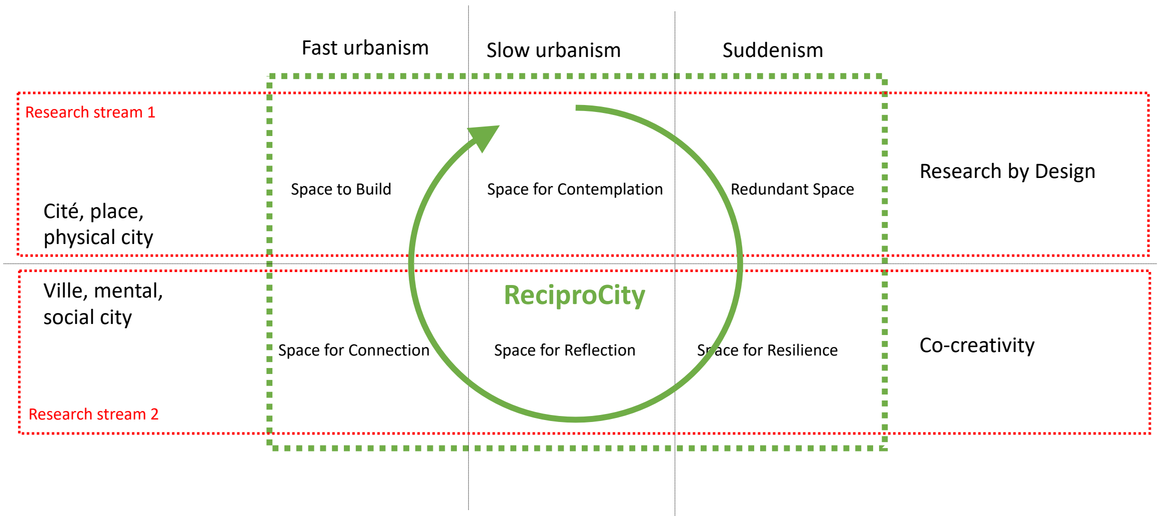


Figure 9. *The mental and physical city in three paces (Roggema, 2019)*

3.3 Design-led.

The design-led approach used in Moeder Zernike establishes a continuous interaction of conceiving design propositions, which pose questions for specific analyses, which then are used to initiate a next design step. For the Moeder Zernike project, a methodological basis of separating the natural aspects, such as the water system, ecosystem, coastal landscape, soil, regional landscape, flood regime, etc., mapped in layers (McHarg, 1969), puts them at the basis of the planning and design process, shaping the further urban environment.

The iterations between design propositions and analytical responses make it possible to guide the analyses according to the different nature-based layers. Mapping of the elevation, soil, vegetation, waterways, future flood-risk, and ecological remnants are used to first understand the nuanced sensitivities of life, and the reliability on available water, sunlight, shade, coolness, and other factors that determine the chance the existing plant- and animal life can coexist with future human occupation in the area. The landscape is there and is taken as the basis for development. The Reitdeep river and its side streams, the contours and potential intrusion of seawater, and the natural vegetation are taken as the basis for any future development.

The systemic way of designerly intervention to which analyses respond until, in the end, an integrated design emerges at different spatial scales, is in reality a chaotic process of concurrent pieces of work, simultaneously carried out interactively, cross-fertilising each other. When the parts of the design-led methodology are put together, these conjunctions represent the creation of new insights and knowledge, exactly because of the simultaneous processes and interactions of the collaborating team members during the entire process.

4.
DESIGN.

The design for adapting to future climate change on the Zernike Campus is primarily concerned with the changing climate itself. The temperatures are rising, causing the weather to change with more tropical days and heat stress as a result, while rainfall patterns will also not stay the same. A significant drought problem is being signalled, while the rain that does fall comes in larger downpours. The global temperature change also causes the sea level to rise at a quicker pace. These changes affect nature, our food supply, health, and the risk of overload. The effects of climate change are difficult to take away without looking at the global way in which (and how much) energy we use. Because of this, the energy transition is in full swing, but even if this occurs quickly and efficiently, big or small adjustment is still necessary.

For the design of the Zernike Campus, which must be prepared for a future climate, water, food, and ecology are the topics that are under the most pressure from coming changes. Hence, these have been taken as the basis for the design of Moeder Zernike.

Adaptation begins with the food supply, because this has far-reaching consequences for the natural system, through the type of production methods and the necessary amount of nutrients and water. The design for Moeder Zernike thus takes a futuristic diet as a starting point (Willett et al., 2019). This diet provides everyone with a healthy, nutritious menu, without overloading the Earth via climate change, social exploitation, or decline of biodiversity. If all the food that is necessary to deliver this menu every day to all the inhabitants of the campus is also cultivated on the campus, this would have a minimal impact on Mother Earth and everyone would become independent of food from elsewhere, meaning they would be less susceptible to the availability of food or possible diseases, epidemics, or pandemics.

Figure 10. *Andrew Pelling, Grace Knight and Orkan Telhan, "Ouroboros Steak," 2019, photo courtesy of the Philadelphia Museum of Art*

There are two critical factors for the enabling of this food system: the available amount of space, and the available amount of water. Our research has shown that there is (more than) enough space available on the campus, in the unbuilt environment and in or on buildings, to grow the desired amount of food. However, our research has also pointed out that in future climate scenarios, on a yearly basis there will emerge a shortage of water; for the cultivation of all the food, not enough water can be retained in the area, without supply from elsewhere. An isolated look at just the Zernike Campus would make supply possible, however, this would also mean that that water would no longer be available for other areas in and around the city of Groningen. Solving the water problem at Zernike would thus cause new water availability issues in other parts of the city and province. To avoid this, we must attain water from an infinite source, of which there is only one (which, luckily, is very close by): the (Wadden)sea. Hence, it is essential for the design that a new connection between this infinite source and the Zernike grounds is established. By doing this, security can be created for the perpetual presence of sufficient water. We also have the great advantage that in the cultural-historically so rich northern Groningen landscape, old meanders of Reit- and other deeps still exist. By reconnecting these, a functional, beautiful, and valuable connection with the sea can be developed. The salty water thus reaches the Zernike complex, where it is filtered in a sandy dune-dike. This offers an extra opportunity for the protection of the campus against possible floods. The dike-dune creates an inverse wierde, which besides its filtering function also offers protection for the open connection with the sea. Within the inverse wierde, plenty of experiments can be conducted with the alignment of the amounts of water, the filtering, and the administration to the crops. New cultivation techniques emerge, and a range of spin-offs in the food and technology sector are born. For students, the campus forms a welcoming environment in which they come into contact with an adaptive, healthy, and sustainable lifestyle.

Because a connection with the sea from a food production point of view will be desirable, if not necessary, other advantages can also be profited from immediately. In the northern landscape, between city and sea, there are favourable side effects for agriculture, nature, and safety.

Embracing the salinisation process in the northern coastal zone which has already begun, is strengthened by allowing the influence of the sea. This offers opportunity for new agriculture in the form of mussel and oyster banks, sea food farms for lobster, langoustine, and prawns, and the cultivation of salty crops such as samphire and seakale. Our research has demonstrated that, thanks to the higher prices of these new forms of agriculture, the current farmer can maintain the same income on just 20% of their current productive land area. At a decrease of the productive land area to 40%, each farmer could thus potentially earn twice as much. With a larger availability, the price obviously will not stay this high, but a positive economic development in the agricultural sector as a result of such a transition is evident.

The salty sea water also causes a new wealth of landscape environments, from salty to brackish to fresh. The increasing number of gradients between water qualities and wealth of food is strengthened by the daily dynamic of the Waddensea, which also becomes noticeable deep into the landscape. This dynamic brings to the area food for the countless species that inhabit the landscape, and nutrients for food production. Through this, an enormous increase of the biodiversity can be expected, which stretches out from the typical mudflats, creeks and creek ridges, to brackish land and peat formation in freshwater areas.

Finally, letting in the water from the sea also triggers the sediment flow. Large amounts of silt from the Waddensea will cover the ever-descending landscape of Groningen with sand and clay, layer by layer. This sediment thus raises the landscape and can keep up with the rising sea level in a natural way, and, just like the current salt marshes, form new land. Through this, the natural coastal system can contribute to the fact that living in this landscape becomes safer. After all, even though the chances are small that the delta dike breaks, if it happens, the misery would be incalculable. A gradually growing land is thus a positive side effect of the sea water that flows to Zernike.

For a climate adaptive Zernike, it is essential to design at at least three scale levels:

- On the campus itself and the present buildings. Here, balance is brought between the water availability, cooling, food production, and conducting experiments. In this objective, sufficient space must be found in and on existing buildings to cultivate the food necessary for all Zernikers. In each building on campus, a transformation will need to take place from monofunctional (learning)environments to spaces that are used to learn, work, live, and produce at the same time. In the public spaces, food is cultivated, water is filtered and collected, and nature is enriched. As a result of this living experiment area, Moeder Zernike will become a guide for other urban environments, to begin with the city of Groningen. An important demand from the Zernike complex on its environment is the extra need for water, which it gladly receives from the surrounding landscape.
- The northern Groningen coastal landscape offers the possibility for keeping the water supply on Zernike on level through the supply of salty Waddenwater. Hereby, multiple birds can be killed with one stone. It offers the farmers in the area the knowledge of a long-term economically prosperous future, it enriches the biodiversity, and it contributes to the strengthening of the water safety. Lastly, the Groninger lives and works in an attractive landscape.
- The north-western European coasts can take the plans for Moeder Zernike as an example. Thinking in terms of innovative and integral concepts in which nature forms the entrance to transformative spatial developments can be applied along the entire North- and

Waddensea coastline. Thus, the Moeder Zernike plan can become the guide to other projects to trigger a more dynamic and safer development in other regions. In this regard, the adage Copy & Adapt may be best used.

4.1 Zernike campus.

It is only possible to design a resilient campus when a mental shift is established. This shift should enforce the traditional 'red'-oriented focus on infrastructure and buildings (the hardware of areas) to a green mindset in which the landscape is firstly taken as the guide for development (the software) within which hard elements are integrated at a later stage. This also means that the fundamental needs for humans and non-humans to survive on this planet are crucial, given the climatic conditions of that future, such as increased risks of flooding from heavy rainfall or increased sea levels, or the impact of droughts. Moreover, it implies that a self-organising ecosystem should be established that is safeguarding its own existence, in which humans but also non-human organisms can survive. Besides preventing the current ecological drain (Almond et al., 2020), food should be grown locally, a cooling environment must mitigate the urban heat island effect, sufficient renewable energy should be generated within the area, and a mixed-use urban precinct should combine education facilities, working environments and residential use at building and campus scale.

To step away from threats and problems only and enhance a turn towards positive landscapes, the local characteristics of farming and the growth of food are brought together with the biggest threat in the region, the risk of accelerated sea level rise, causing flooding, salinity, and loss of biodiversity. The growth of food locally in these novel conditions forms the basis for the design of Moeder Zernike, in accordance with the findings of the EAT-research (Willett et al., 2019). The required amounts of food are calculated on the basis of providing the new diet to 30,000 students and staff and an additional 33% of new residents that are estimated to be living on campus in the future.

The key design-question is: how to unite fresh and saline water systems on campus whilst anticipating a further integration of land-use and local growth of food? The future campus is seen as a lab of experimentation for people as learners, no matter which phase of their lives they are, aiming to form a community that is able to become reciprocal: it uses, reuses and shares their newly found knowledge, designs, realises, maintains, and investigates the way urban flows of energy, nutrients, water, and ecology can be closed, or can even become net-positive, giving more back to the environment than is used, and waste becomes a resource.

The Zernike campus is placed in its ecological surroundings. The connection to the non-human organisms in the direct vicinity of the campus, such as the novel saline stream, is planned to be a thriving part of the campus area. As this implies that saltwater will be entering the area, fresh and saline are meeting each other. This requires a spatial intervention, which has been found by introducing an inversed 'wierde' (an artificial hill), which is hollow inside, forming a freshwater reservoir.

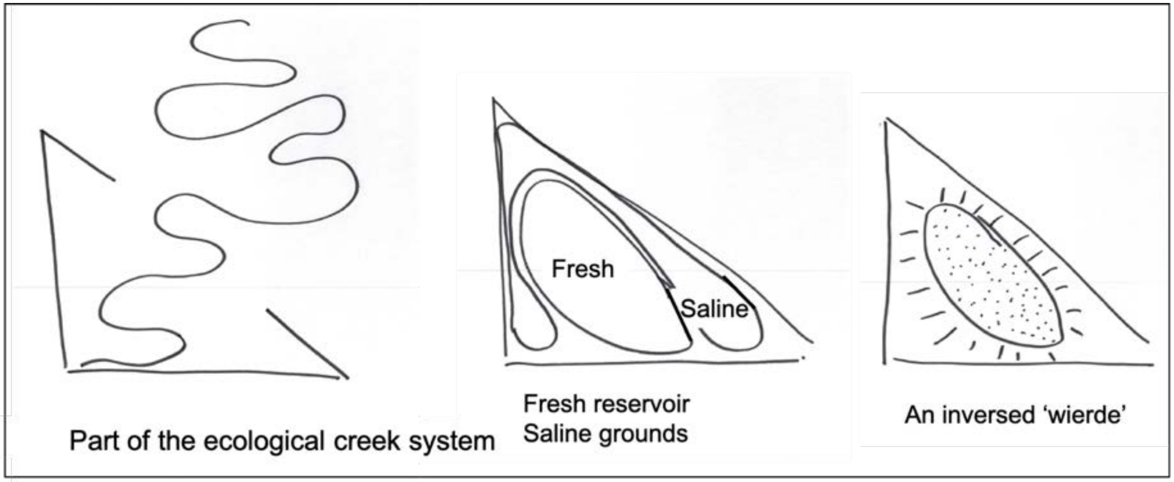


Figure 11. *Moeder Zernike becomes part of its ecological context, embraces fresh and saltwater and creating an inversed wierde for freshwater storage*

Connecting the northern landscape with Zernike allows for saline circumstances to become part of the campus. It also means the Van Starkenborgh canal is suddenly part of the saltwater system. It keeps its maritime function but is simultaneously embraced by the landscape. The saltwater flows around the freshwater reservoir, creating distinct ecological typologies and unique conditions for food production.

Figure 12. *The inversed wierde as freshwater storage on the Zernike campus*

The campus itself starts to behave differently in periods of high and low tide, as the water will surround the edges of Zernike, at the same time bringing salinity, nutrients and sediment. When, at low tide, the water retreats, fertile soils remain and come to the surface; the area is attractive for a range of species in a dynamical environment.

Figure 13. *Different appearance of Moeder Zernike at low and high tide.*

Moeder Zernike is located at the edge of both the city and the landscape. It is internally oriented and not very well linked with its surrounding urban and rural landscape. The purpose of the design is to break barriers so that Zernike can become a real part of both the HogeLandscape and the City of Groningen.

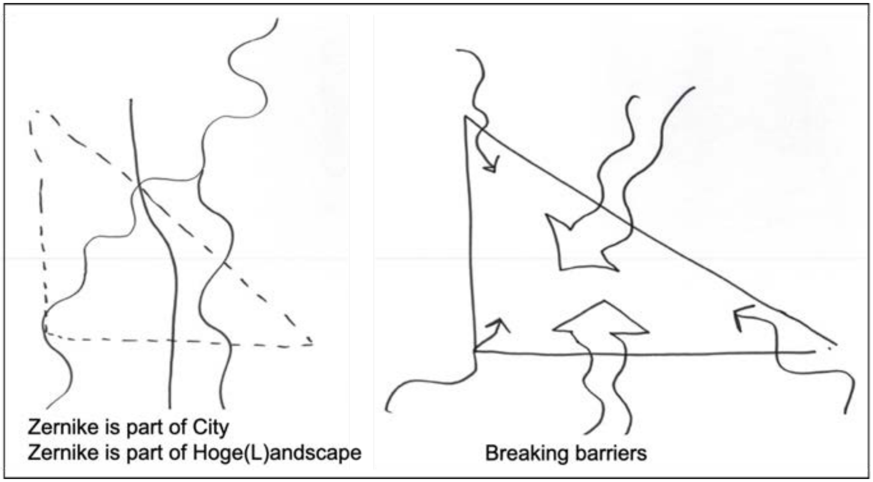


Figure 14. *Breaking the barriers with the surrounding landscapes*

In order to transform into an urban precinct, the campus will also change from being a parasite, fetching its lifelines from resources outside its own area, to behaving as an amoebe, self-sufficient and generating its resources from within. By doing so, the campus is able to transform into a mixed-use area where building scale education, working, and living will be combined. The material cycles are reciprocal, so all waste becomes a resource, and the area itself operates as a resource for its environment, generating surpluses of food, clean water, and renewable energy.

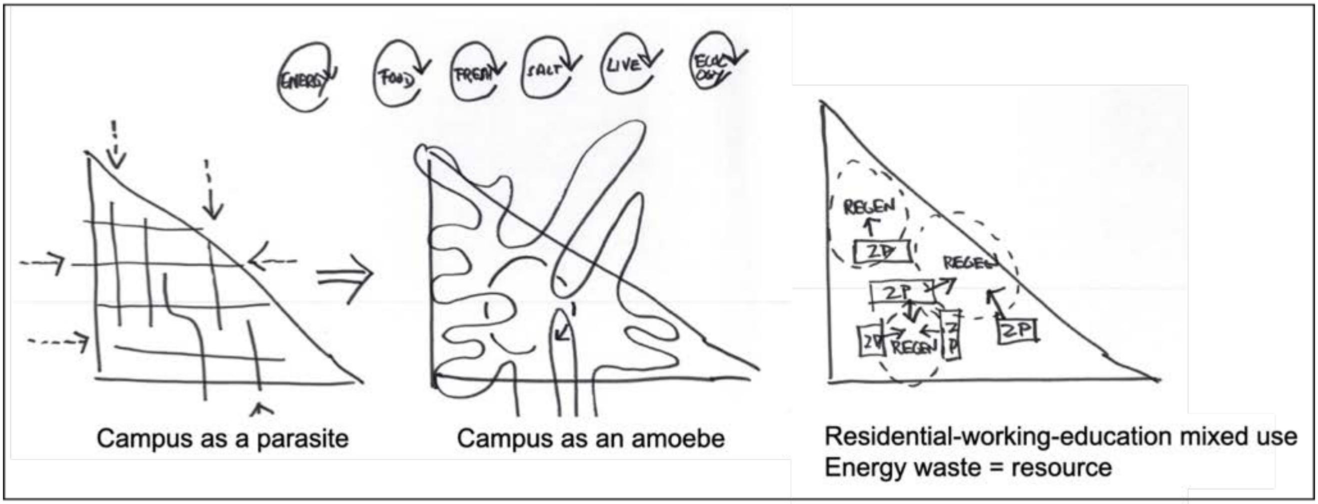


Figure 15. *The Zernike amoebe, regenerating its material flows*

Moeder Zernike thus manifests itself as a self-sufficient cell, which can function by itself without supply from outside and without burdening the environment with waste or pollution. In this objective, all cycles are closed, and raw materials are generated and used within the region. This can only succeed if a region emerges in which functions are mixed. Food production, retaining and filtering water, and generating energy is more effective if there are various functions available in the area. Because of this, it is relevant to mix the dominant educational function with working and living areas, and to create space in buildings where food can be cultivated. For the water system, this implies that an autonomous freshwater 'island' emerges, which is able to function by itself by retaining, reusing, and filtering water. Outside of this, the environment can slowly transform into a landscape with salty and brackish characteristics.

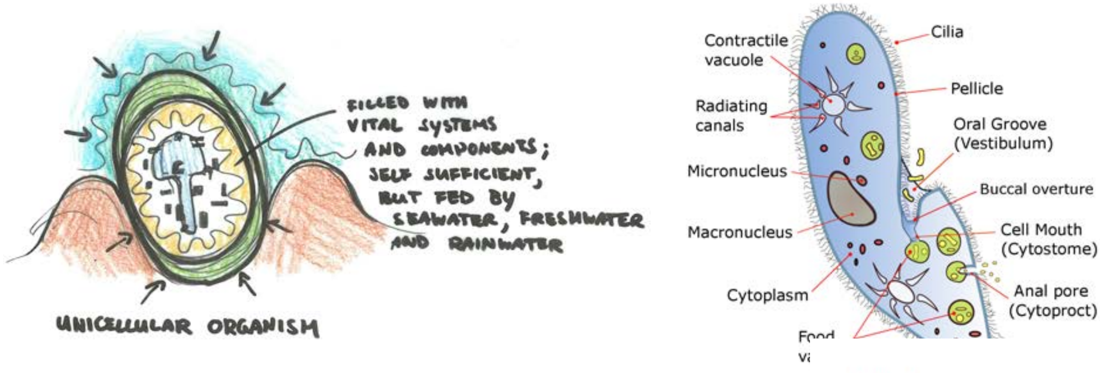


Figure 16. *Zernike campus as a self-sufficient cell*

In abstract terms, the formation of freshwater islands in a saline environment shapes the peri-urban area of Groningen. For this part of the cities edge, freshwater islands are conceived: the existing neighbourhood de Held, the Zernike campus and the Selwerderhof cemetery. The conceptual jump of surrounding the city by seawater within which these freshwater reservoirs provide the essential resource for life is extrapolated for the entire urban edge.

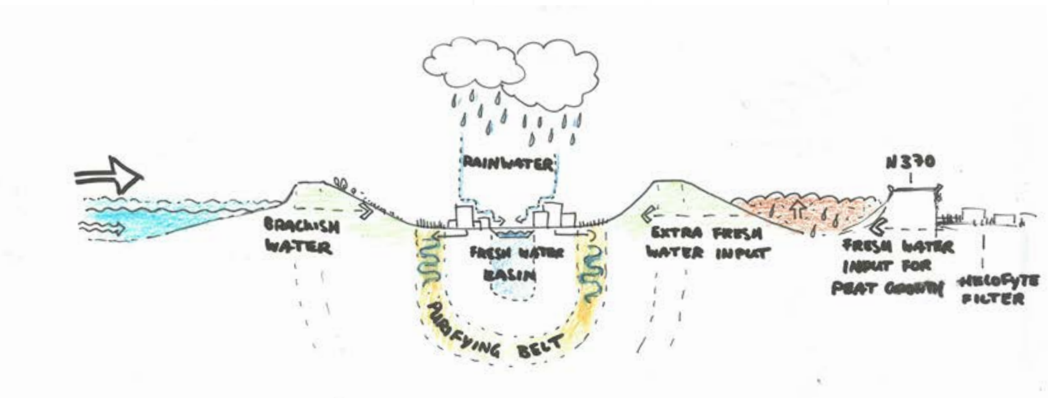


Figure 17. *Cross-section, showing the different environments and water features*

The concept plan for Moeder Zernike thus forms its own entity within the landscape, which in the future will be washed in the salty water that can reach the northern edge of the city of Groningen. As an inverse wierde, Moeder Zernike is protected against outside influences, while simultaneously a membrane emerges between salty and fresh which filters water for use on campus. Through this, food can be produced for the students and residents of the campus, and an interesting ecological gradient is created between salty, brackish, and fresh environments, causing an explosion of biodiversity. Spatially, a coherent inner world emerges, in which the experimental life within Moeder Zernike takes place while outwardly, the campus presents itself as a spatial entity within the surrounding land.

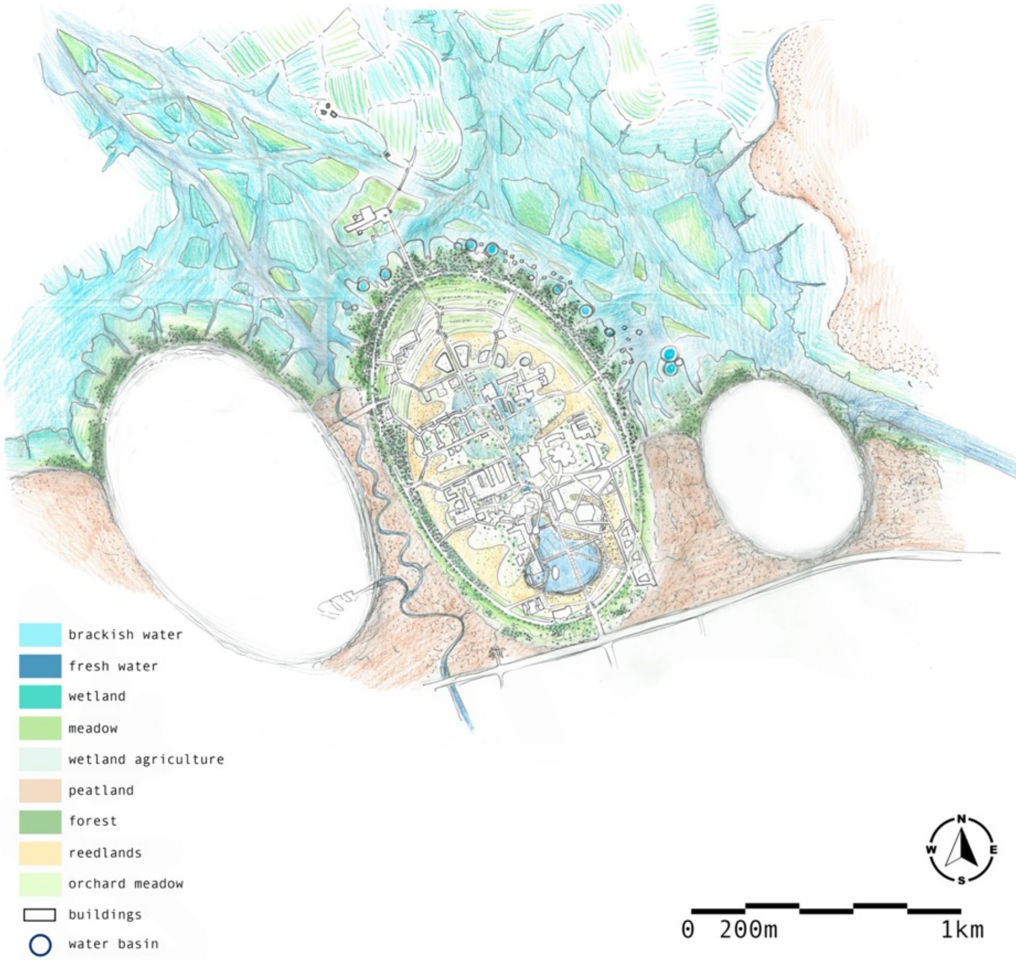


Figure 18. *Freshwater reservoirs in a saline landscape*

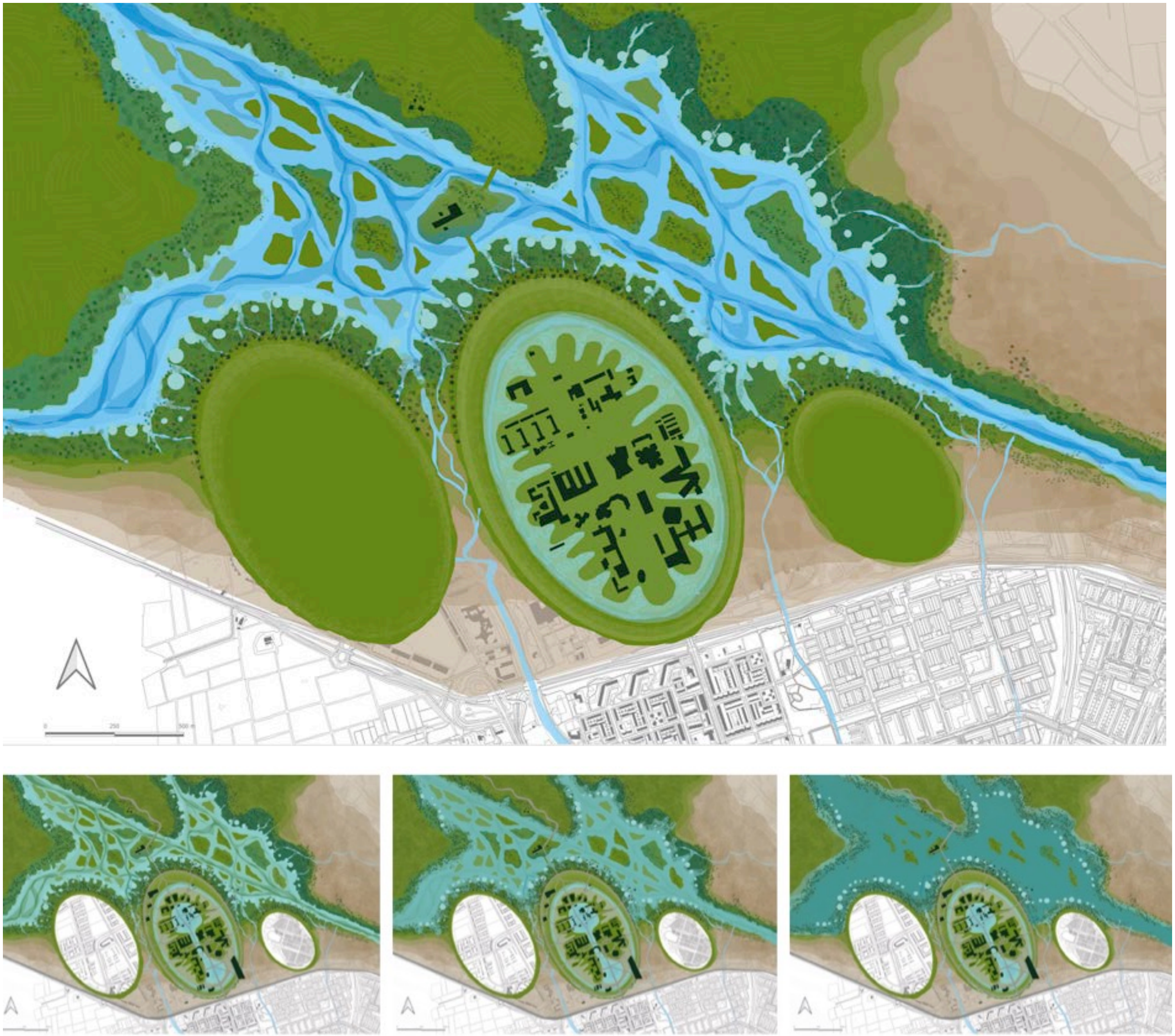


Figure 19. *Moeder Zernike situated in a water rich landscape*

Because eventually Waddensea water will be connected with the Northern Groningen city edge, the tide will also reemerge. This fluctuating water level has a positive effect on the spatial changeability, as each moment of the day the landscape will look different; thus, for everyone, a new experience is created each time. Ecologically speaking, too, the changing water level is a welcome addition to the enriching of the biodiversity, because constantly changing growth and foraging circumstances appear.

Figure 20. *Birds-eye view of the Moeder Zernike plan*

The cross sections illustrate the different qualities that emerge for spatial experience, ecology, food, and water respectively.

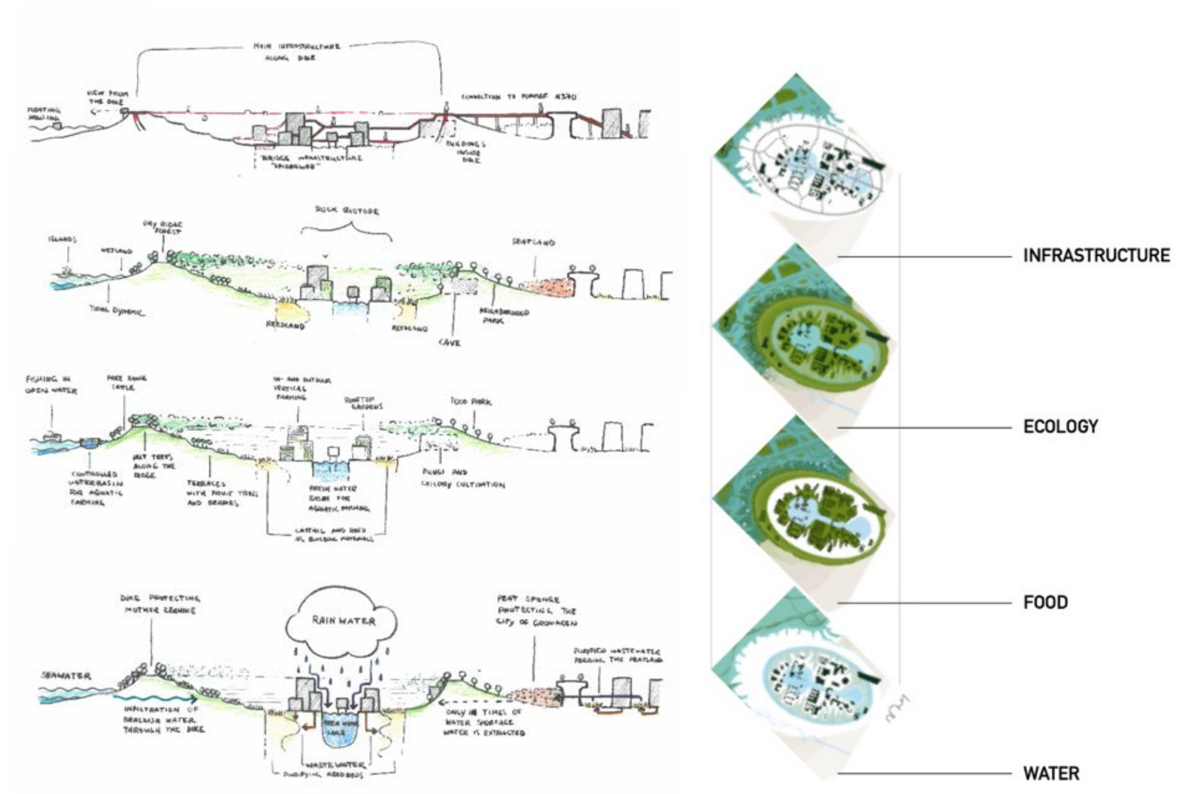


Figure 21. *Cross-sections (from top to bottom): spatial connectivity, ecological biotopes, growing food, and the water system*

Figure 22. *Moeder Zernike: freshwater lake, food growing buildings in a saline environment*

4.1.1 Food on Zernike.

The food required to feed the entire student and staff population of the campus, and an additional 10,000 new residents, is calculated based on the amounts of the recalculated EAT-diet for the Dutch context.

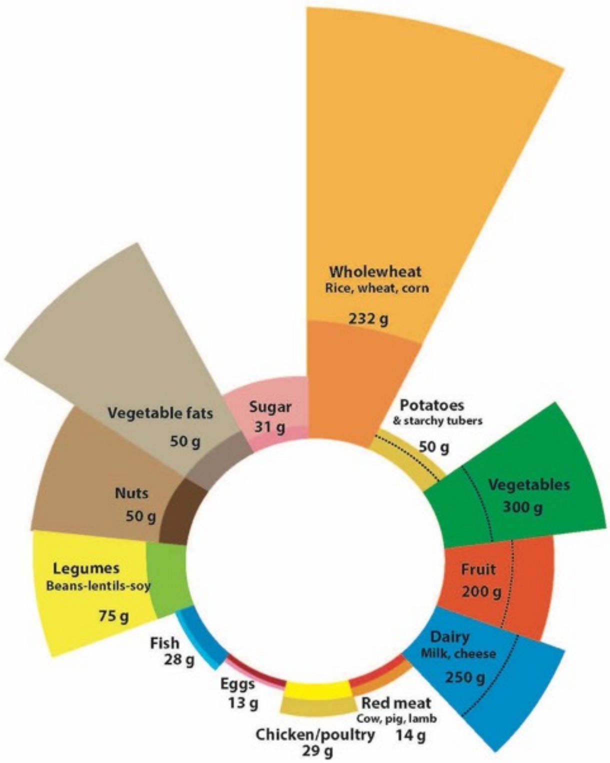


Figure 23. *Amounts of food for a healthy diet, recalculated for the Dutch context*

The amounts of food per person according to the Lancet diet (Willett et al., 2019) are combined with the number of meals the different categories of people are expected to consume on campus. This is different for students (mainly lunches) and for residents (mainly breakfast and dinner).

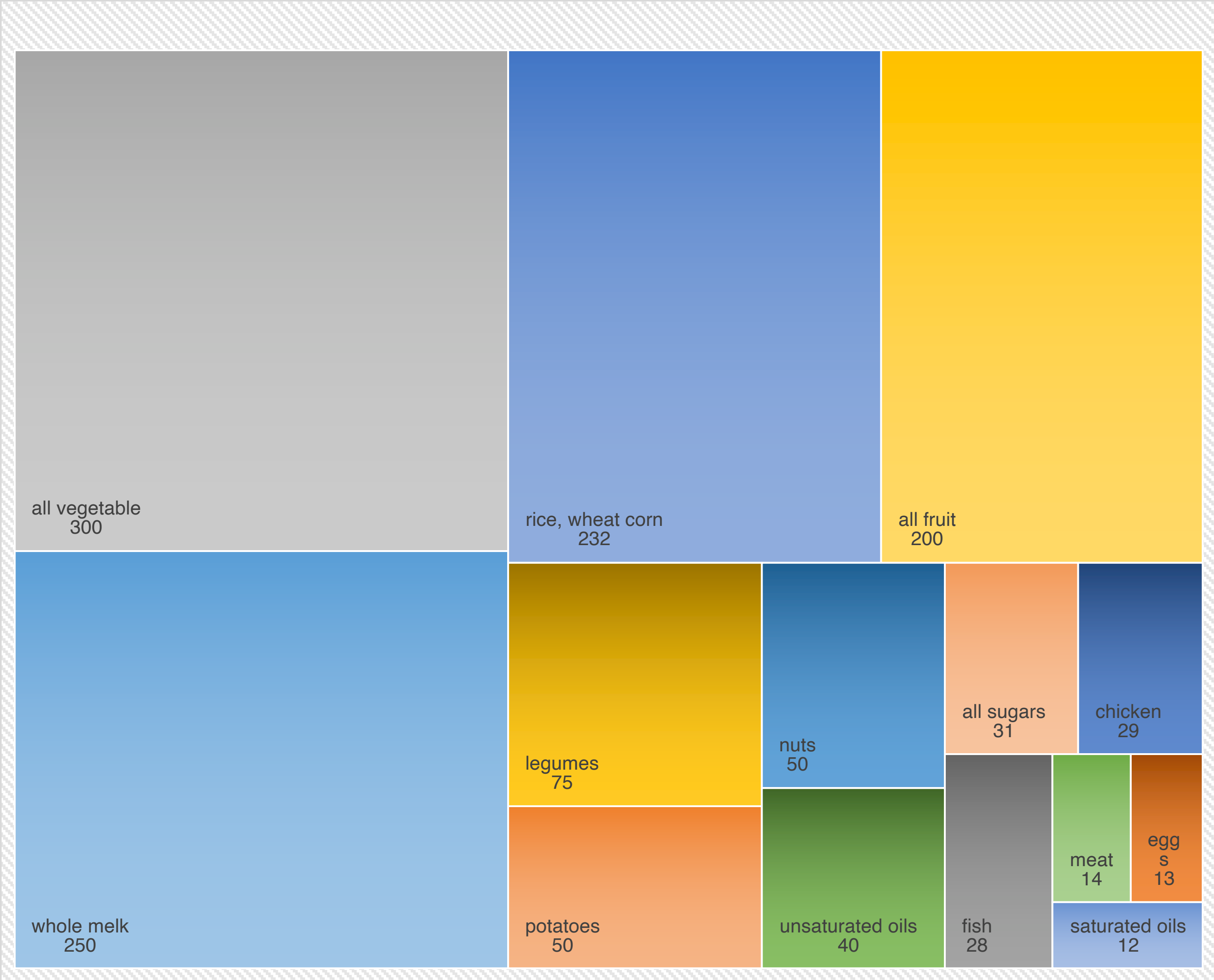


Figure 24. *Amount of food (in grams) needed per person/day, according to the Lancet diet (Willett et al., 2019)*

Assuming there are approx. 30,000 students and staff on campus, and that an estimated 10,000 additional people will in the future reside on campus, a detailed calculation has been made for the total amount of food needed to be consumed for all people live or spend time on campus, taking into account holiday periods. The total amount is almost 5.5 million kgs per year (see table in chapter 5).

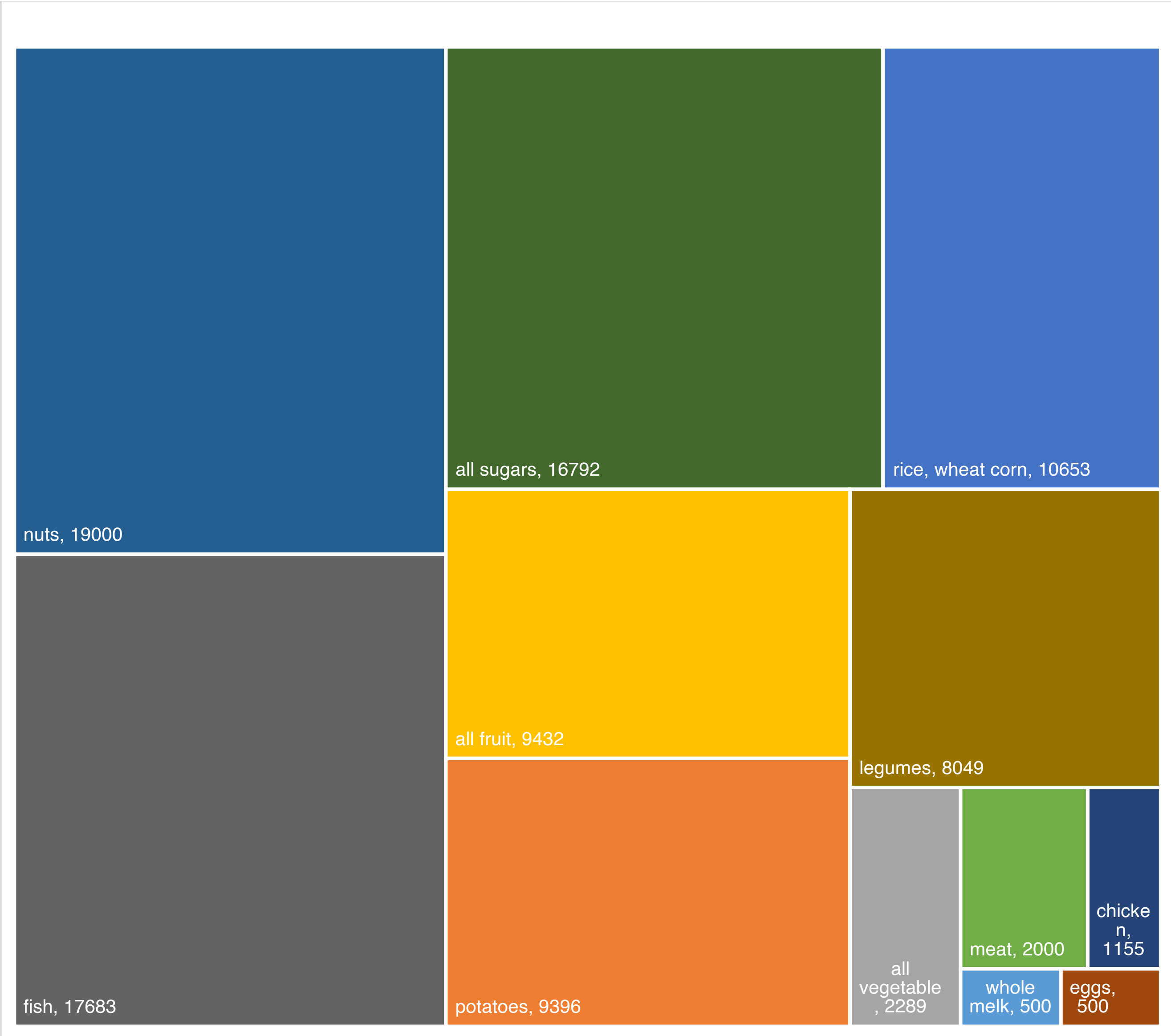


Figure 25. *Area needed to produce food in m²*

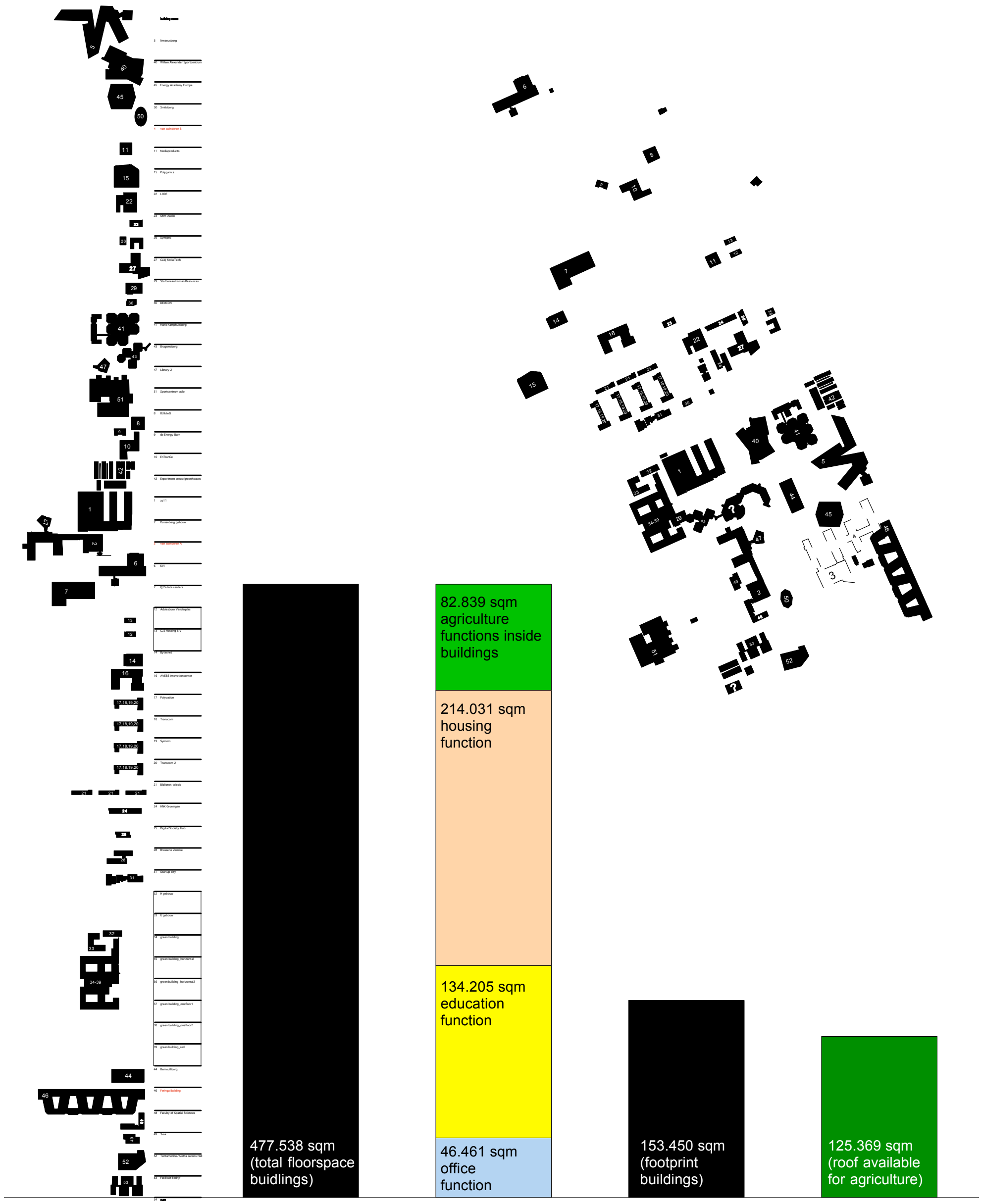


Figure 26. *Estimated sqms available for agricultural production in and on buildings*

The area needed for growing the different crops, distributed according the Lancet diet, has been calculated and adds up to a required area of approximately 0,1 km² (or 100,000 m², see chapter 5). The required area for controlled food-growing environments, using novel highly productive technologies that have multiple harvests per year, such as aqua- and aeroponic systems, can be implemented inside current buildings, on rooftops or clinging to the facades of campus buildings. Therefore, an inventory has been made to estimate the availability of useful spaces. For every building, the current area is calculated (floor space, number of storeys, roof area) and is subsequently analysed for its potential for mixed use (% office, teaching, residential and growth of food (see chapter 5). Approximately 140,000 m² of rooftop area is potentially available for agricultural purposes, and indoors, nearly 90,000 m² can be found. Additionally, inside existing buildings almost 10,000 homes can be realised. The total potential for growing food in and on buildings on Zernike is therefore 230,000 m². This is more than twice the area as is needed to grow the required amounts.

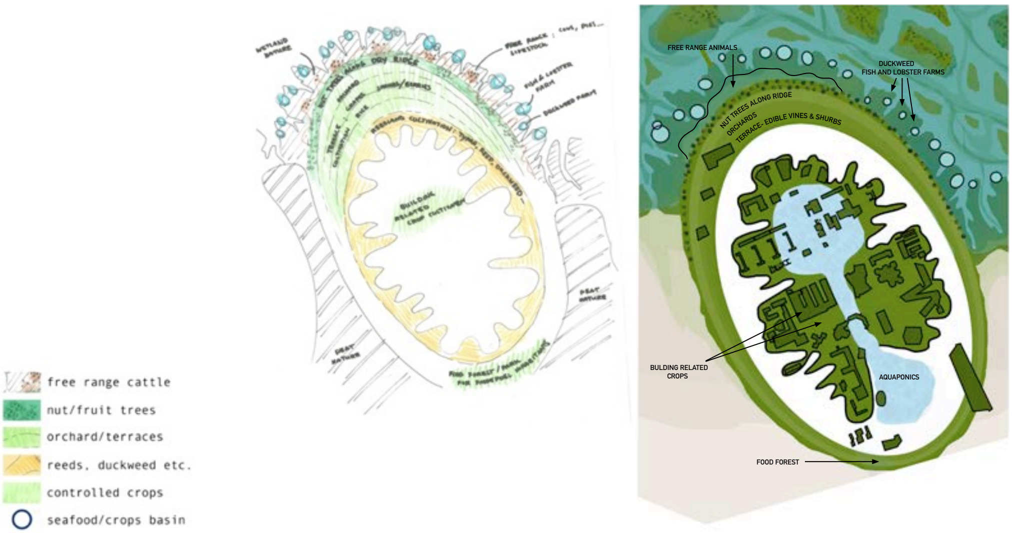


Figure 27. *FoodSCAPE Zernike*

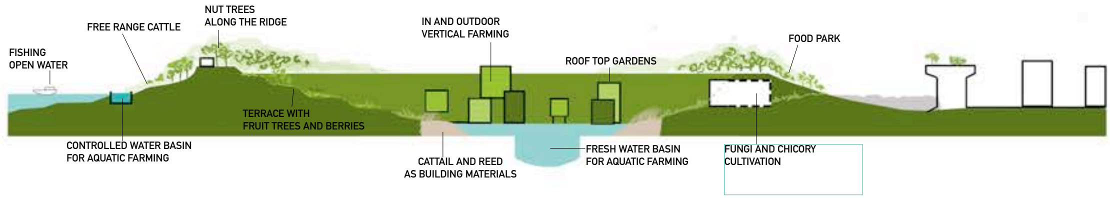


Figure 28. *Cross-section FoodSCAPE*

Besides the food that can be grown inside and on top of buildings, open space is also available and can become productive. A range of growing environments emerge:

- Around the edges of Moeder Zernike, the open water offers the opportunity to go fishing. Eventually, salmon, eel, and sturgeon will return to these areas, making use of the restored connection with the sea.
- Attached to the Moeder Zernike edge, saline aquatic farming is possible in aquafarms. Lobster, prawn, and langoustine are potential culinary quality products.
- On the slope of the dune-dike, free range cattle, such as cows, sheep, and pigs can wander around, feeding themselves with what nature offers while producing tasty meat.
- On the inside ridge, orchards with nut trees are foreseen to be planted.
- By creating terraces on the inside curve of Moeder Zernike, water dripples down and can be used multiple times. This allows for dryer species, such as fruit trees and berry scrubs to be planted on the higher terraces and potentially rice in the lower regions.
- The freshwater reservoir, or lake, at the heart of Moeder Zernike is suitable for creating a freshwater aquatic pond for carp and tilapia, or other freshwater fish.
- Inside the southern curve of the dune-dike structure, a series of caves are predicted, where chicory and fungi, mushrooms and insects can be grown and harvested.
- Besides these, a publicly accessible food park, where free range picking of crops and fruit is attractive to the residents of Paddepoel, Selwerd and the Zernike inhabitants may be created.

4.1.2 Water on Zernike.

The growth of the crops needed to feed the Moeder Zernike community in this intensive manner, requires a large amount of water, which is calculated as the water footprint of each of the crops. In total, almost 3.5 billion litres of water are needed on a yearly basis, which is equal to nearly 1400 Olympic swimming pools. On top of this, there are nearly 400 Olympic swimming pools, approx. 1 billion litres, of drinking water for daily use required (see table on building calculations in chapter 5). The total amount of water needed per year is therefore

1800 Olympic swimming pools. Analysis (chapter 5) of the expected amounts of precipitation on Zernike shows that, taking the driest climate scenario as the point of departure, 2500 Olympic pools are available. Of this 2500 pools around 50% evaporates (Schuetze and Calleri, 2013) hence only 1250 will be available for use. This analysis implies that on a yearly basis there is a shortage of 550 pools (= 1.4 billion litres). This makes it clear that, especially in the context of increased droughts in the Netherlands, the current rainfall will not be sufficient to grow all the crops and provide drinking water on Zernike. Besides the need to harvest and store all rainwater and the cleaned effluent from the buildings on campus, it is necessary to supply water from outside the campus. In order to avoid extracting water from other users in neighbourhoods across the city, the only option is to use seawater to meet demand.

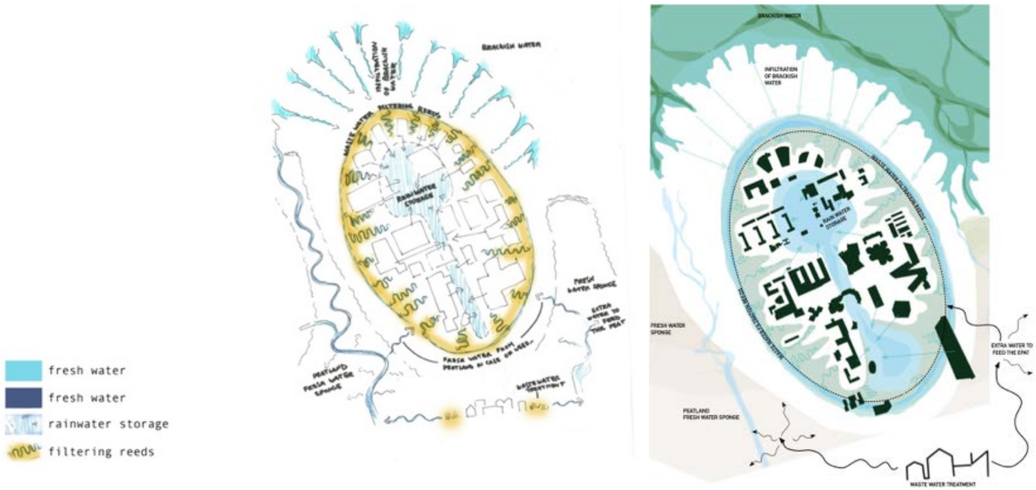


Figure 29. *WaterSCAPE Zernike*

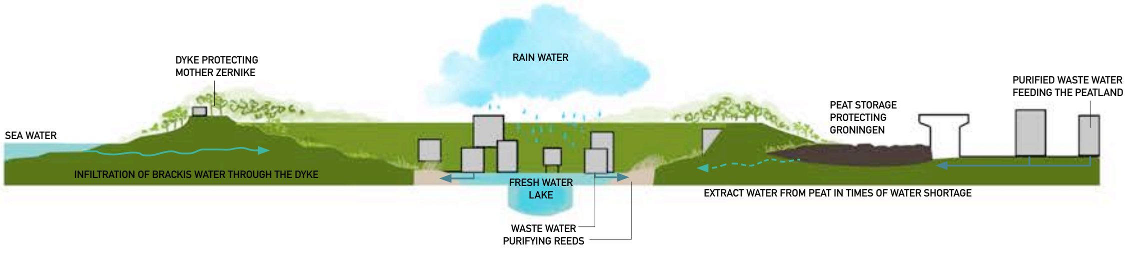


Figure 29. *Cross-section WaterSCAPE*

As the need to keep all fresh water possible and provide additionally salt water to campus is clear, the design of the water system brings these components together in the design:

- Saline-brackish water, which is cleaned while infiltrating through the sandy dune-dike. The constructed dune-dike at the same time protects Moeder Zernike against eventual spring tides. Moreover, the saline grounds offer possibilities for a saline food-forest and creating a saline-brackish ecology around the edges of Moeder Zernike.
- Wastewater purifying reeds are projected at the inner ring. All wastewater from the Zernike buildings is collected in this helophyte system and subsequently purified, making it usable for agricultural purposes.
- In the freshwater lake, rainwater is captured and stored in periods of heavy rainfall. The water is suitable for keeping fish, but also provides a source for growing crops in the campus buildings. Moreover, the large amounts of water stored here mean these areas provide a cooling environment, which is highly welcome in the summer when temperatures will rise. Also, the surface water has the possibility to generate heat through heat exchangers, a very clean way of providing energy to the campus buildings.
- In the southern parts of the campus, peat accumulation is expected by creating standing waters. This requires an influx of clean water and offers the possibility of occasionally supplying the freshwater lake, in periods of longer droughts.
- Wastewater from the northern neighbourhoods (Paddepoel and Selwerd) is purified in a natural way and the clean water will be fed into the peatland area.

4.1.3 Ecology on Zernike.

The ecological quality of Moeder Zernike is determined by the confrontation of brackish-saline wet conditions of the northern landscape and the freshwater world inside the inversed wierde. This implies the emergence of new gradients, from saline to fresh, wet to dry, and nutrient rich and poor circumstances.

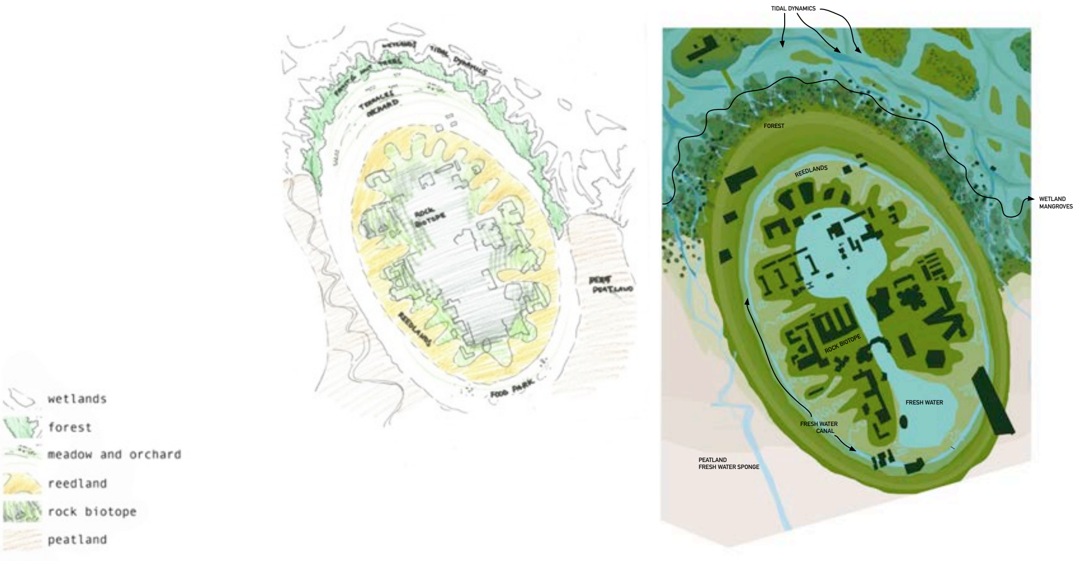


Figure 30. *EcoSCAPE on Moeder Zernike*

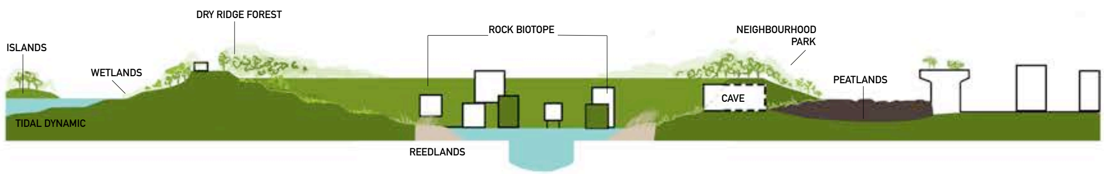


Figure 31. *Cross-section EcoSCAPE*

The range of different ecotypes create a rich biodiversity, responding to the loss of natural values:

- To the north of Moeder Zernike, the tidal dynamics will form islands, temporarily dry, and permanently wet landscapes. Saline ecology on the edge between dry and wet land will develop here.
- The wetlands with reed, scrubs, and open water will form at the lowest parts around the dune-dike surrounding Moeder Zernike.
- On the inside ridge, a dry forest will grow, consisting of oak, nut, and beech trees.
- The reedlands, operating as a helophyte filter also have ecological value, for insects, small fish, and reptiles. These species in turn attract birds that will feed here.

- A particular opportunity arising from the buildings on Moeder Zernike is the concrete and brick environment forming a rock-biotope, offering a unique habitat for rock plants, butterflies, and bees, and nesting places for birds and bats.
- The peatlands in the south of the area will grow slowly over time and are home to water birds, insects, and a range of reed plants.

Figure 32. *A natural, ecologically valuable, landscape along the Reitdiep.*

As a whole, the Moeder Zernike area will function as one organism. In an ecological sense it breathes, respirates, and performs growth and decline, just as natural systems do. All the buildings and open spaces play a role in the functioning of the whole, the waste flows are used as a resource elsewhere, and materials are added and produced during the life cycle of the organism. Similarly to a natural organism, the buildings on campus have their own specific function, both in use by the people studying and working at Zernike, but also in the role they play in the urban flows, and the basis they form for ecological niches.

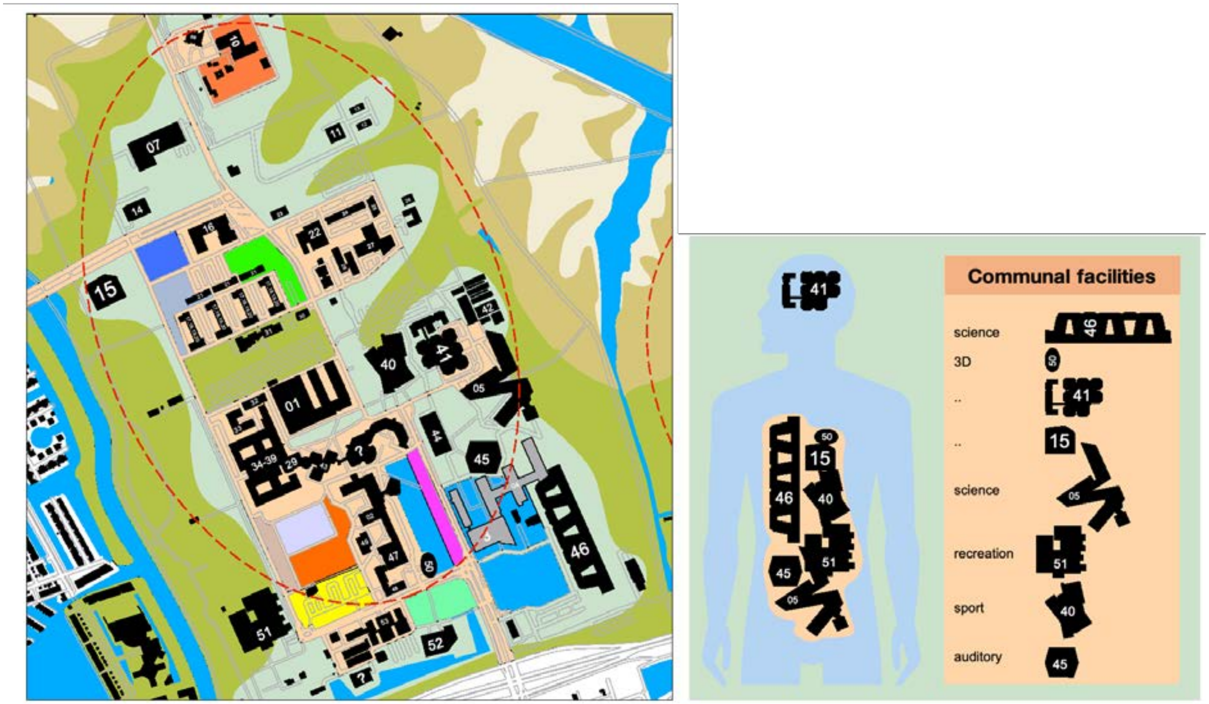


Figure 33. *Moeder Zernike as a super-organism*

4.1.4 Energy on Zernike.

The energy concept for Moeder Zernike is based on the principle of generating more energy than is used, capturing more carbon than is emitted by using renewable resources, and reducing the energy use to a minimum. Therefore, the principle is to adjust the energy demand to the specific seasonal conditions and apply specific heat and electricity conditions to applicable uses. For instance, by adjusting temperature to the function of specific spaces within buildings.

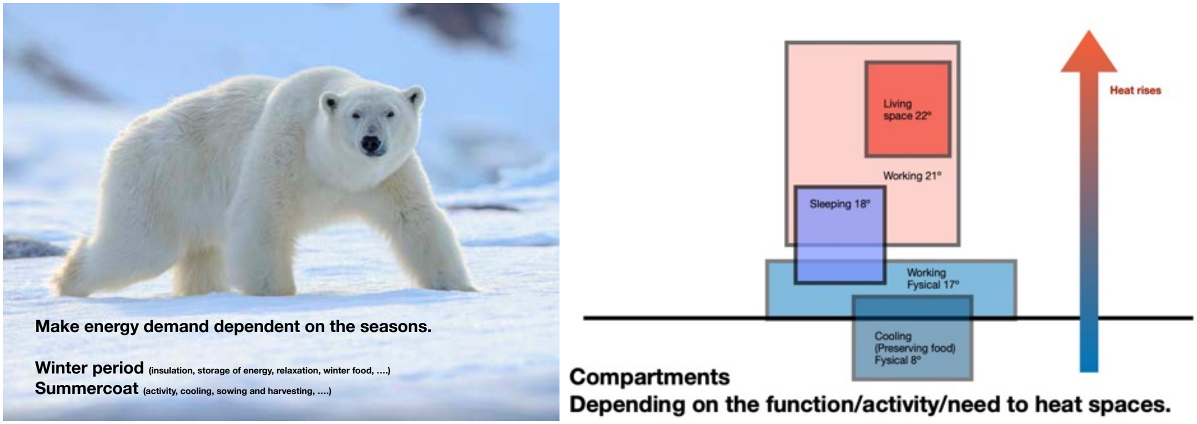


Figure 34. *Adjusting energy supply to season and function*

All buildings and people on campus use energy and produce waste heat and carbon. The heat can be reused in residential, office, and educational buildings, and increase the productivity of controlled food growing spaces. The waste energy and carbon that is produced within the Moeder Zernike area can be reused in other buildings and spaces. When this is applied to all corners of the campus, it can become an energy and carbon positive area.

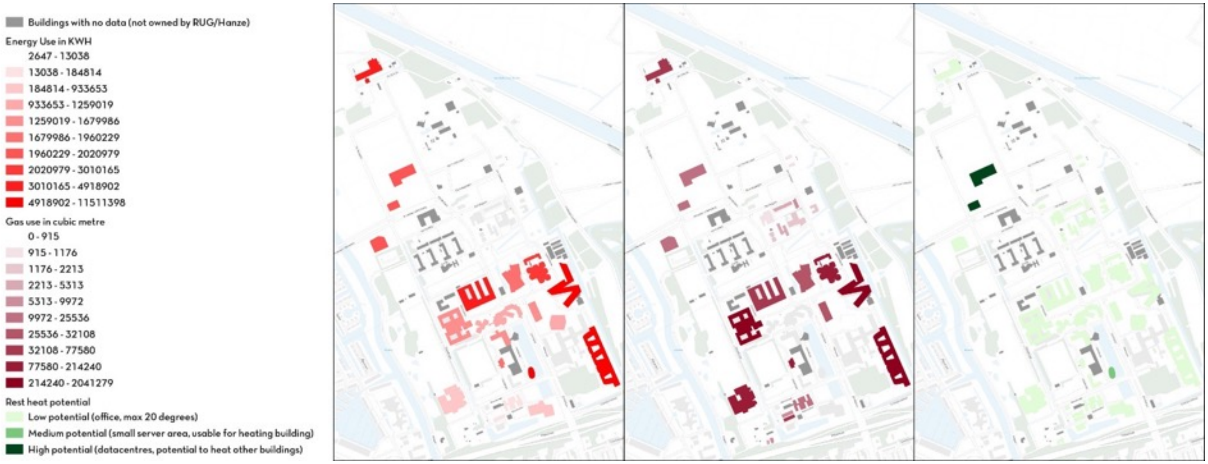


Figure 35. *Building by building analysis of the energy and gas use, as well as the potential to use waste heat*

Every building on campus has been analysed for its electricity and heat use (including its water use, see chapter 5). Using existing technologies, it is possible, through creating a smart system of heat and electricity exchange, to supply all that is needed within the boundaries of campus. Most of the buildings have the opportunity to become a net energy supplier. Waste heat from the buildings can be used to heat residential and greenhouses/polytunnels. The electricity required to supply each building can be provided through placing solar arrays on flat roofs and placing greenhouses and polytunnels on and in between buildings using carbon and waste heat to grow crops.

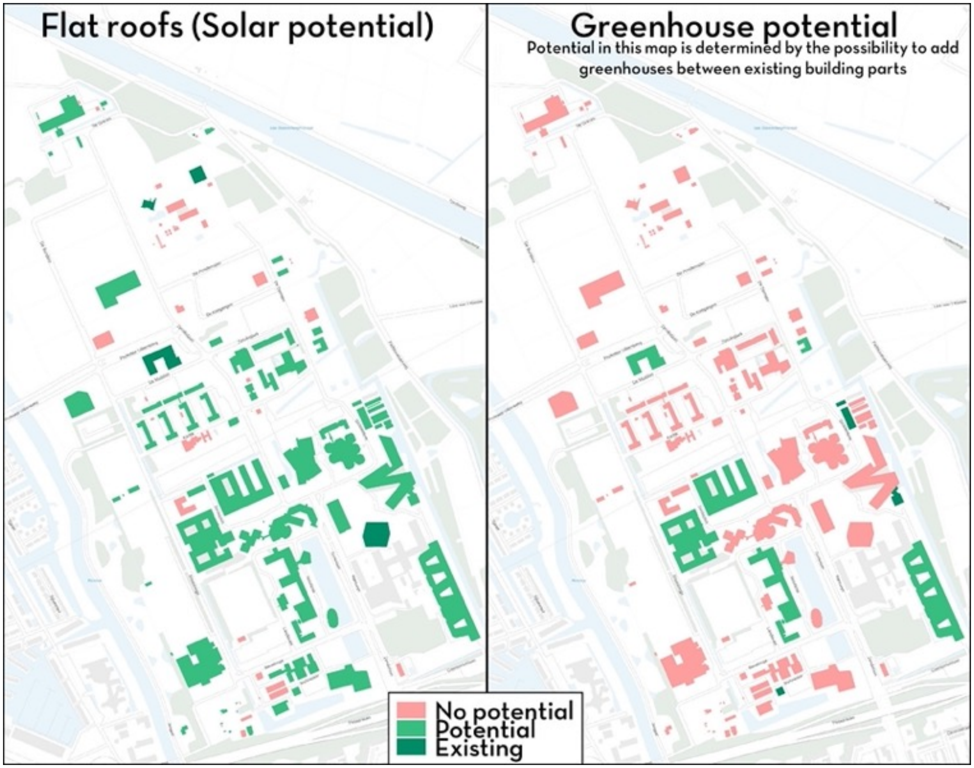


Figure 36. *Potentials for solar and greenhouses on and in between campus buildings*

Additionally, a new form of solar grids will be introduced for the wetland and freshwater lake, where solar energy generation is paired with an emergent ecological development.

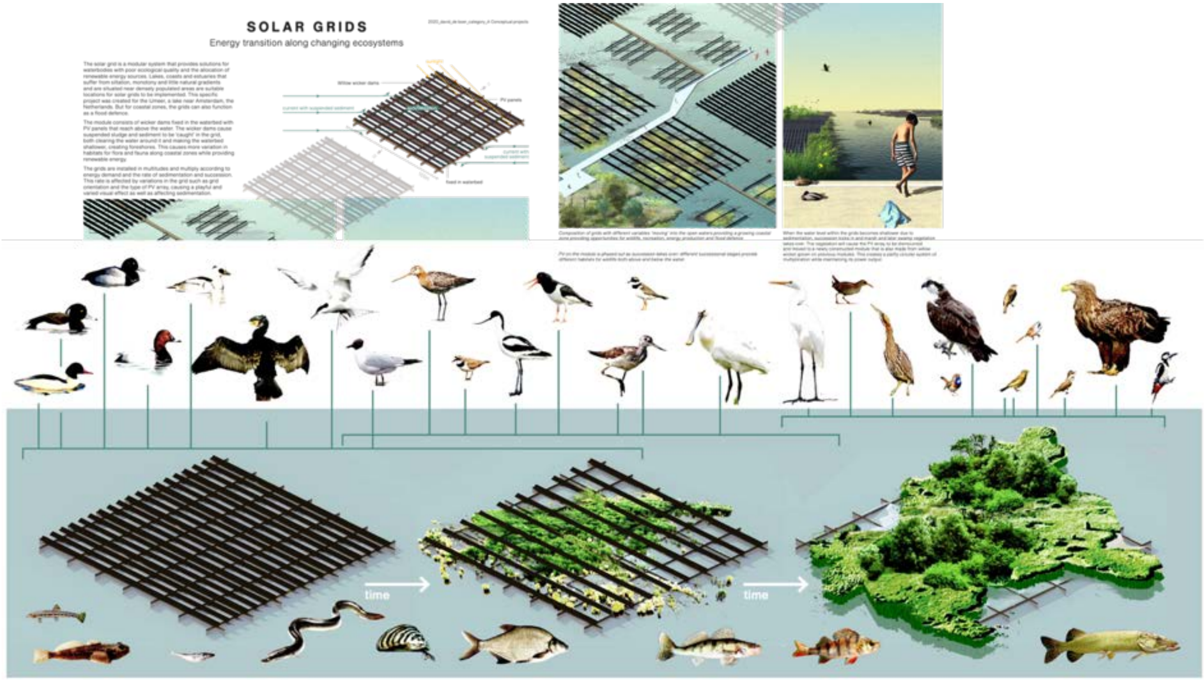


Figure 37. *Solar grids for electricity generation, thriving ecological succession*

Preliminary calculations show that all waste heat can be reused in agricultural production units and other buildings, and electricity can be generated using renewables on campus.

Carbon can be captured and used for growing food in greenhouses or polytunnels, though not directly. The estimated carbon emission per building has been calculated (see chapter 5) showing that a total of 42 million tonnes carbon is emitted each year. This can be compensated by adding the following interventions on campus:

- 530 hectares of forest planted
- 2100 smog towers
- 110 Moisture Swing air containers

Table 3. *Transformation of energy use in a 100-year future for Moeder Zernike*

Overview usage of energy per person per year HANZE per 24 hours in GIGA JOULES GJ					
	2021 •			2121 **	
	24 HRS	8 HRS		24 HRS	8 HRS
Building					
Heating	-17,0	-5,7		0,0	0,0
Lightning	-1,3	-0,4		0,0	0,0
Living /Working					
Warm water	-7,0	-2,3		7,0	2,3
Electricity	-5,0	-1,7		5,0	1,7
total	**-30,3**	**-10,1**		**12,0**	**4,0**
* based on figure https://www.milieucentraal.nl					
** based on passive building techniques (ABT - 2020 interview)					
m3 building estimation 2021	m2 total building	m3 evarage hight 12m	m3 per person evarage Campus	total persons on campus	Total energy per 8 hours a day 364 days in GJ
total	**160000,0**	**1920000,0**	**55,0**	**34909,1**	**-352581,8**

4.1.5 Housing on Zernike.

Moeder Zernike aims to create an urban precinct in which education, working facilities, and living is mixed, and which is connected to the surrounding urban area and the landscape.

Figure 38. *Potential iconic housing on Moeder Zernike*

The mix of functions at campus is extrapolated to the campus area, the buildings, and the internal spaces. The building typologies are made reciprocal and circular, closing the loops of producing food, delivering energy, and purifying water. The Moeder Zernike area overcomes the traditional barrier that the ring-road and the Van Starkenborgh canal impose, and infrastructure on campus is kept to an ultimate minimal level or even absent. This means car space is reduced or even removed, and pedestrian and cycling spaces are increased. Building materials, such as concrete, wood, glass, and brick are reused in adjusted or new buildings, and additional materials are sourced from the direct vicinity, using local biodegradable components. These ambitions resonate strongly with the objectives of ReGen Villages, which provides the content for future integrated living on Moeder Zernike.

ReGen Villages.

ReGen Villages proposes a neighbourhood in which people are supported in leading exciting, healthy, and safe lives (ReGen Villages, 2018). This neighbourhood uses the best of what technology has to offer, hand in hand with the power of nature. It supports life without damaging the future of next generations, and where social gatherings, food production, and living with nature are part of everyday life. It is not a place for just a few lucky people, but affordable and attainable by all.

Apartments

Detached house

Row house

Semi-detached

Figure 39. *Housing typologies*

It is necessary to rethink the way we live, in order to sustain a growing global population. In a ReGen Villages neighbourhood, this is turned into regenerative living. This village powers itself, stores electricity for times of need, produces the majority of its own food, and cleans its own water, while bringing happiness and an increased quality of life for its inhabitants.

Figure 40. *The ReGen Villages neighbourhood*

ReGen Villages is prepared for the future of a moving world. It accommodates a wide spectrum of transport technology; whether we will be driving to work in a self-driving electric car that parks itself at the end of the day, working from the co-working spaces in the village, or receiving deliveries from drones, ReGen makes it possible.

The sensor network of ReGen Villages keeps everything working optimally, and is prepared for future expansion and adaptability. ReGen houses are powered by energy captured in the neighborhood from the sun and the biomass that surrounds them, and safeguarded through energy storage in times of need. This decentralised energy infrastructure can stand the test of time. The materials used to build the houses are toxin free, bringing clean air and water back into our lives as naturally as it should be.

Figure 41. *Mass timber, prefab assembly*

Smart water management reduces the pressure on the environment, and the neigh- bourhood is elegantly prepared for a changing climate. ReGen Villages brings the needs of modern citizens in sync with smart applied technology for the benefit of the planet and its residents. The neighbourhood merges design and sustainable technology to deliver a powerful message: it is possible to make a sustainable living environment for everyone, that is inspiring, healthy, and continues to adapt with its residents in time, through the IoT based VillageOs system.

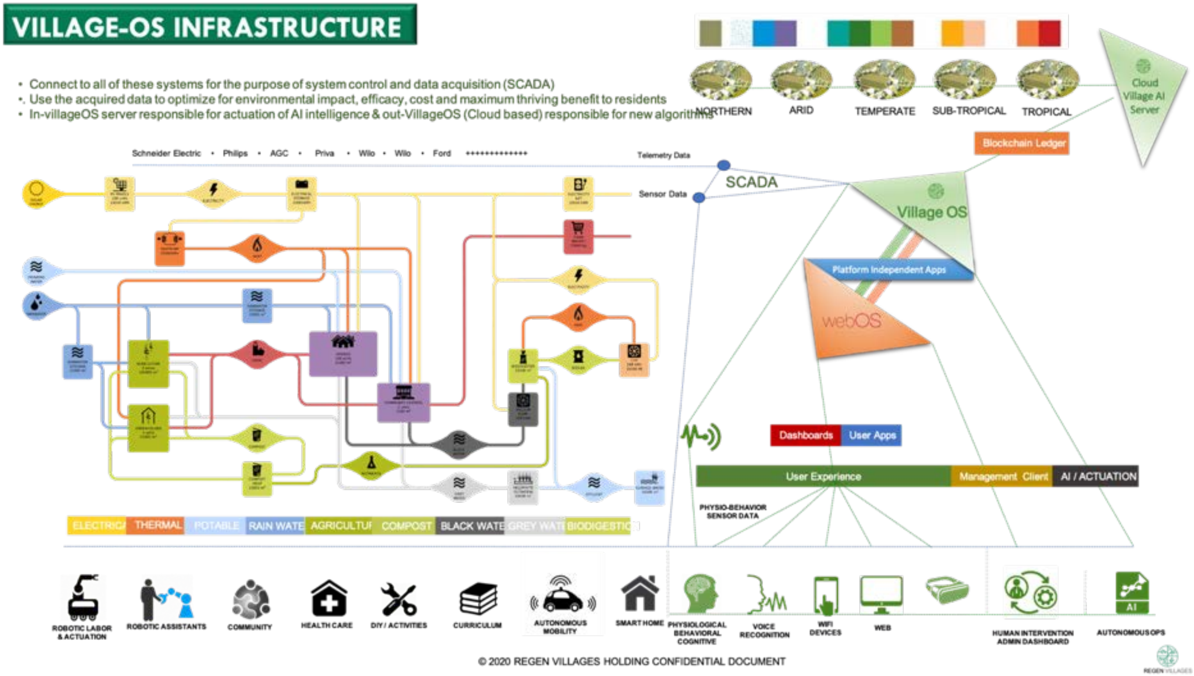


Figure 42. *Village Os, IoT system*

ReGen Villages uses methods of the circular economy to connect all the flows of energy, water, waste, and food for itself and its environment. It meets its food demand by producing the necessary vegetables, fruits, and nuts for a balanced diet in the village. It recycles waste into energy and nutrients. Residents are invited and encouraged to participate in the food production, as part of the community.

Figure 43. *Urban agriculture practices*

The community offers workshops, places for the yearly harvest festival, and is supplied with ample amenities for interaction, cultural exploration, education, relaxation, sports, and play. ReGen Villages sets a global precedent for the next generations of smart neighbourhoods and sustainable living solutions. The neighbourhood is regenerative and autonomous, and capable of sharing gained knowledge through its partnerships, supporting adaptation to changing times in order to start inhabiting a healthy, beautiful, safe, and inspiring future.

Figure 44. *An inspiring future*

4.1.6 Local sustainable building materials

The materials used on Moeder Zernike are locally sourced and made, to create modern, impressive architectural spaces. The Groningen landscape offers these materials such as hemp, straw, clay and mud, grass, and wood. Local growth of green roofs is applied to all flat building surfaces.

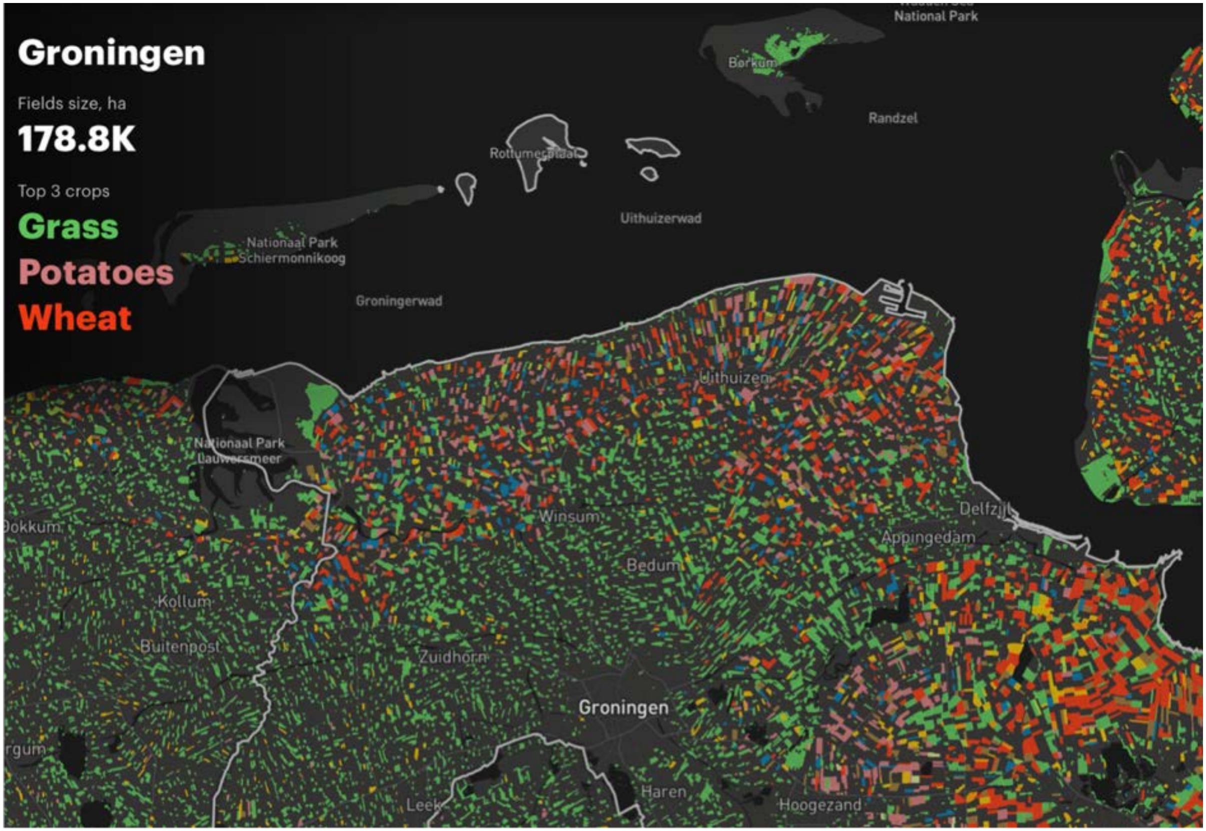


Figure 45. *Potential local building material in Groningen*

STRAWBALE WALL

WHEAT
Amount per hectare 150 bales
Growth time 8 months
Per/bi/annual Annual
Soil Drained, Loam
Exhaustion 3 years
Climate Temperate 25°
Precipitation 30-35cm
Alternative use Consumption

Wall Dimention 3x5x0.5m
Bale Dimension 35x100x50cm
Amount 33 bales per 15m2 wall
Land space per wall 2200m2

Life expectancy 100 years
Fire rating 2 hours
Weight per wall 590kg
Compressive Strength 0.017 N/mm2
U Value 0.35 w/m2 k
R Value R-2.8

Carbon sequestration
https://www.researchgate.net/publication/239789765_The_carbon-reduction_potential_of_straw-bale_housing

Con
Mildrew in moist enviroment



STRAWBALE WALL

RICE
Amount per hectare 150 bales
Growth time 5 months
Per/bi/annual Annual
Soil Silt clay
Exhaustion 3 years
Climate Temperate 30°
Precipitation 115-300 cm
Alternative use Consumption

Wall Dimention 3x5x0.5m
Bale Dimension 35x100x50cm
Amount 33 bales per 15m2 wall
Land space per wall 2200m2

Life expectancy 100 years
Fire rating 2 hours
Weight per wall 590kg
Compressive Strength 0.017 N/mm2
U Value 0.35 w/m2 k
R Value R-2.8

Con high precipitation needed




THATCH WALL/ROOF

REED
Amount per hectare 750 bundles
Growth time 5 months
Per/bi/annual Perennial
Soil Silt clay
Exhaustion 3 years
Climate Temperate 20°
Precipitation min 60 cm
Alternative use Water filtration

Wall Dimention 3x5x0.3
Bundle Dimension 30Ø
Amount 150 bundles per 15m2 wall
Land space per wall 2000m2

Life expectancy 30-60 years
Fire rating 30 min
Weight per wall 510kg
U Value 0.35 w/m2 k
R Value R-2.8

Carbon sequestration
http://endeavourcentre.org/2017/04/thatch-roof-basics/

Con Low fire resistance



PAPERCRETE

Sustainable building material due to reduced amount of waste

Lightweight, Low cost

Wall Dimention 3x5x0.16m
Life expectancy wall -
Fire rating 2 hours
Weight per wall -
Compressive Strength 260 N/mm2
U Value 0.12 w/m2 k
R Value R-8.3

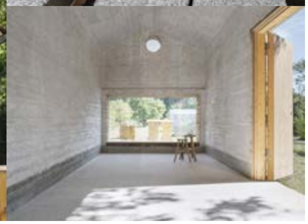
https://etsj.futminna.edu.ng/images/ETSJ_Journals/ETSJ_Volume_10_number_1_June_2018/Determining-Properties-of-a-Lightweight.pdf

https://www.researchgate.net/publication/322418488_Properties_of_papercrete

https://www.researchgate.net/publication/324989875_Mechanical_properties_of_papercrete

Con Difficult to waterproof





HEMPCRETE

HEMP
Amount per hectare 72000 plants
Growth time 4 months
Per/bi/annual Annual
Soil Drained loamy
Exhaustion 3 years
Climate Humid temperate 25°
Precipitation 60-70 cm
Alternative use Fabric

Wall Dimention 3x5x0.16m
Life expectancy wall 500 years
Fire rating 2 hours
Weight per wall -
Compressive Strength 0.017 N/mm2
U Value 0.17 w/m2 k
R Value R-5.8

Carbon sequestration
https://www.researchgate.net/publication/320058537_Assessment_of_Carbon_Sequestration_of_Hemp_Concrete



MYCELIUM BRICK WALL

Wall Dimention 3x5x0.16m
Life expectancy wall 20 years
Fire rating -
Weight per wall -
Compress Strength 0.30 N/mm2
U Value 0.13 w/m2 k
R Value R-7.8

CO2 Emission
CO2 Reduction
https://www.researchgate.net/publication/239789765_The_carbon-reduction_potential_of_straw-bale_housing



RAMMED EARTH WALL

Wall Dimention 3x5x0.6m
Amount 9m3 per 15m2 wall
Life expectancy wall 1000 years
Fire rating 4 hours
Weight per wall 18000 kg
Compressive Strength 90 N/mm2
U Value 1,9 w/m2 k
R Value R-0.5

Embodied energy
https://suw.biblos.pk.edu.pl/resources/i1/i4/i5/i2/i3/r14523/StoneC_EmbodiedEnergy.pdf

EARTHBAG WALL

Wall Dimention 3x5x0.6m
Amount 9m2 per 15m2 wall
Life expectancy wall 100 years
Fire rating 4 hours
Weight per wall 14000 kg
Compressive Strength 90 N/mm2
U Value 1,9 w/m2 k
R Value R-0.5

http://www.earthbagbuilding.com/pdf/NEA%20Technical%20Journal.pdf

EARTHEN FLOOR

Floor Dimention 3x5x0.3m
Amount 3.8m3 per 15m2 floor
Life expectancy wall 30 years
Fire rating 4 hours
Weight per wall 5900kg
U Value -
R Value -
https://www.lowimpact.org/low-impact-topic/earthen-floors/

CLAY FINISH

Thickness 3cm
Amount 0.5m3 per 15m2 wall
Life expectancy wall 100 years
Fire rating 2 hours
Weight per wall 420kg
U Value -
R Value -

https://www.lowimpact.org/lowimpact-topic/clay-earth-plasters/

TADELAKT FINISH

Waterproof surface

Thickness 3cm
Amount 0.5m3 per 15m2 wall
Life expectancy wall 100 years
Fire rating 2 hours
Weight per wall 420kg
U Value -
R Value -

https://www.permaculturenews.org/2015/01/02/the-art-and-practice-of-tadelakt/#:~:text=Tadelakt%20is%20a%20technique%20to,and%20burnished%20with%20precious%20stones.

LIME FINISH

Thickness 3cm
Amount 0.5m3 per 15m2 wall
Life expectancy wall 100 years
Fire rating 2 hours
Weight per wall 420kg
U Value -
R Value -

https://www.lowimpact.org/low-impact-topic/lime/

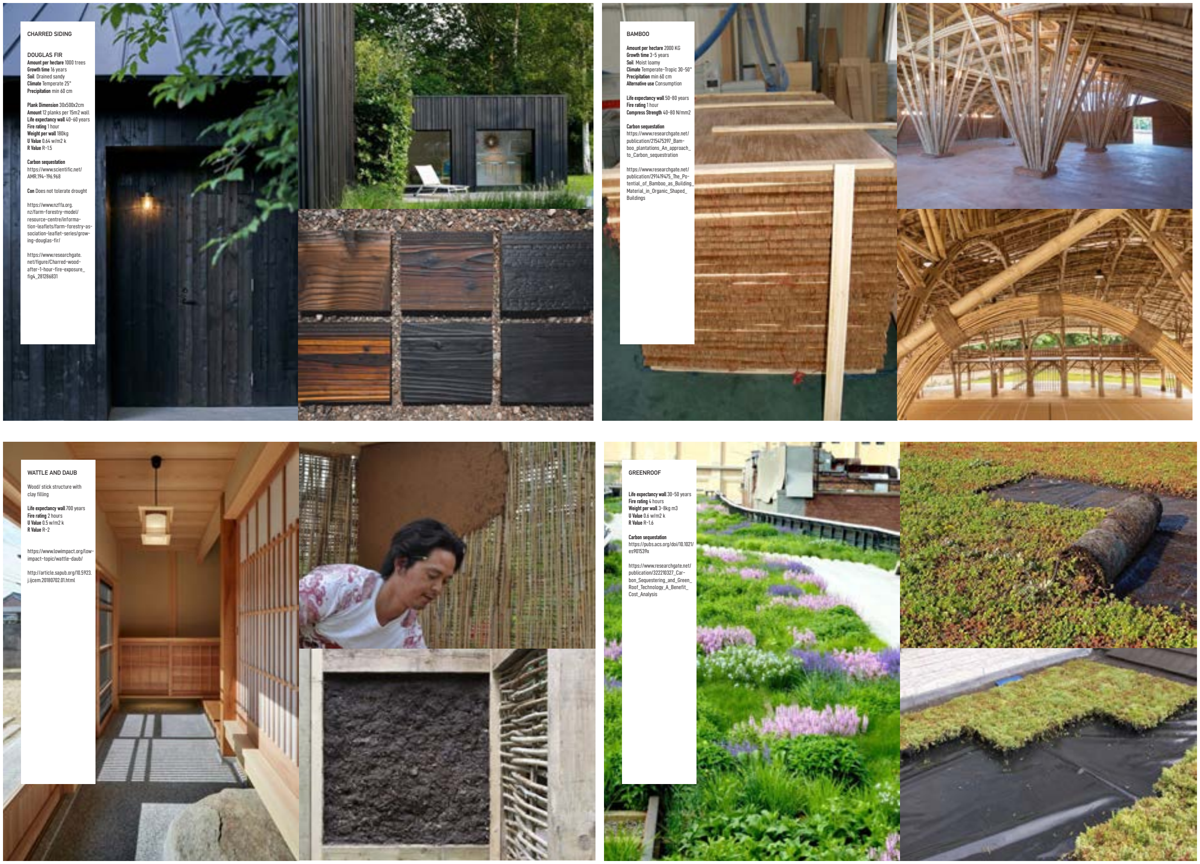
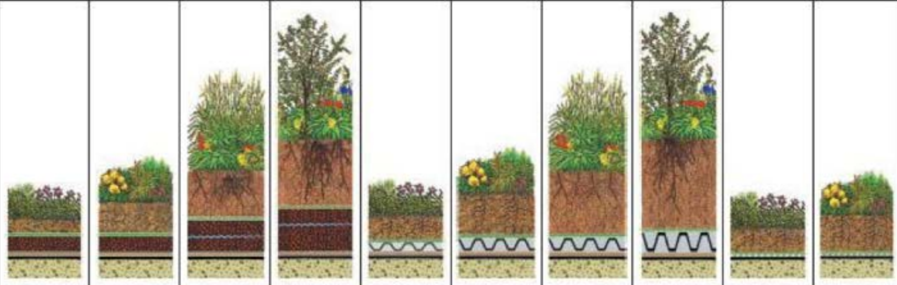


Figure 46. *Application of local building materials in architecture*



GREEN ROOF SYSTEMS	SYSTEMS WITH GRANULAR DRAINAGE				SYSTEMS WITH DRAINAGE PLATES				SYSTEMS WITH DRAINAGE MATS	
system designation	G1	G2	G3	G4	P1	P2	P3	P4	M1	M2
typical plants	sedum herbs	sedum herbs perennials	perennials grasses shrubs	grasses shrubs trees	sedum herbs	sedum herbs perennials	perrenials grasses shrubs	grasses shrubs trees	sedum herbs	sedum herbs perennials
extensive soil mix	2"	4"	-	-	3"	5"	-	-	3"	5"
intensive soil mix	-	-	6"	9"	-	-	8"	12"	-	-
separation fabric	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	-	-
granular drainage	2"	2"	4"	6"	-	-	-	-	-	-
drainage plate	-	-	-	-	1"	1-1/2"	1-1/2"	2-1/2"	-	-
drainage mat	-	-	-	-	-	-	-	-	3/8"	3/8"
protection mat	1/4"	1/4"	1/4"	1/4"	1/4"	1/4"	1/4"	1/4"	-	-
nominal thickness	4"	6"	10"	15"	4"	7"	10"	15"	3"	5"
dry weight	19 lbs/ft²	28 lbs/ft²	45 lbs/ft²	69 lbs/ft²	14 lbs/ft²	23 lbs/ft²	34 lbs/ft²	52 lbs/ft²	14 lbs/ft²	22 lbs/ft²
saturated weight	26 lbs/ft²	41 lbs/ft²	70 lbs/ft²	105 lbs/ft²	23 lbs/ft²	37 lbs/ft²	57 lbs/ft²	85 lbs/ft²	23 lbs/ft²	37 lbs/ft²
minimum slope	0:12	0:12	0:12	0:12	1/4:12	1/4:12	1/4:12	1/4:12	1:12	1:12
maximum slope	1:12	1:12	1:12	1:12	1:12	1:12	1:12	1:12	3:12	3:12
water retention	50%	60%	70%	80%	50%	60%	70%	80%	50%	60%
irrigation system	-	-	subsurface	subsurface	-	-	surface	surface	-	-

Figure 47. *Green roof systems applications*

4.1.7 Buildings and public space.

The program of uses for each building is designed in detail. Several concrete projects for Moeder Zernike are developed as the novel exemplars for specific locations.

The ZP11-building is designed as a living machine. This education building is transformed into a combination of housing, spaces for start-ups, residential space, and food production. Food is located wherever possible: on the roof, clinging to the façade, in greenhouses and polytunnels, or in the form of hanging greenhouses.

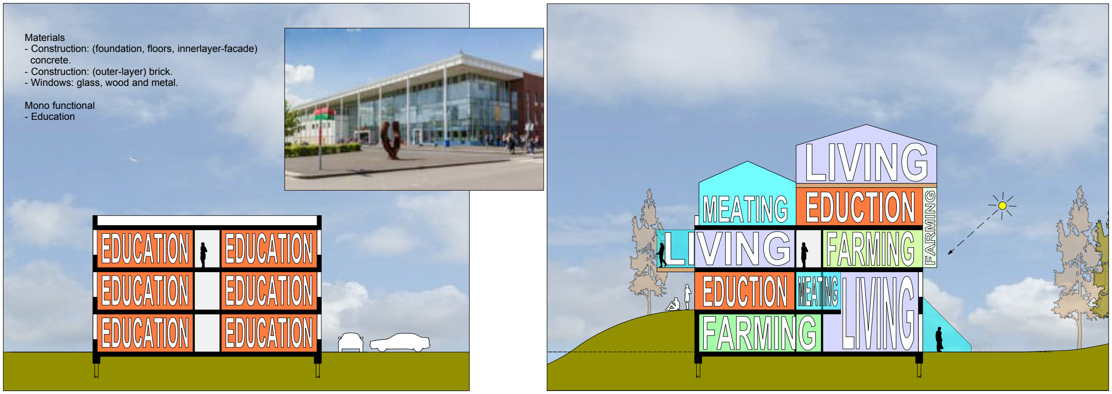


Figure 48. *Transforming a monofunctional education building into multifunctionality*

Figure 49. *Design for a redesigned education building as a mixed-use facility for learning, living, and food growing*

The building is a closed water and energy system, in which all required resources are generated inside or in close vicinity to the building itself, making it completely reciprocal and circular. Waste flows are the resources for other applications inside the building.

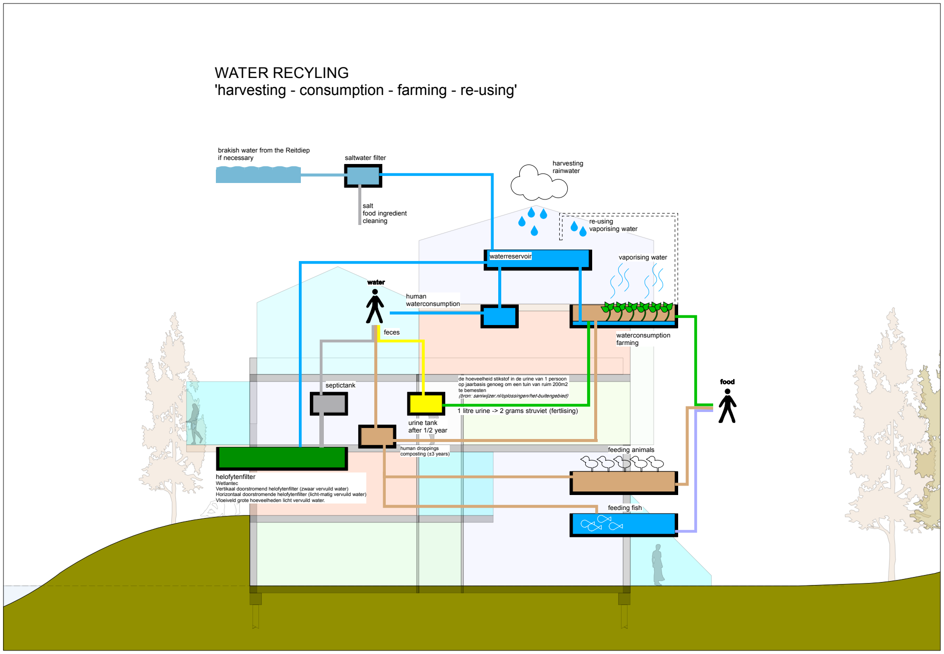
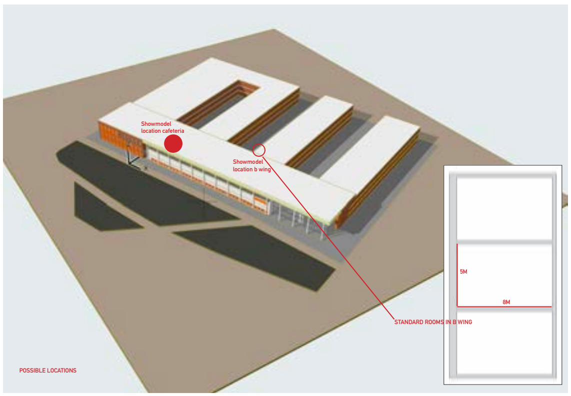


Figure 50. *Future water system for ZP11*

The building will be transformed in several ways:

- Adjustability of internal spaces in order to be able to use every space for different purposes by introducing flexible walls.



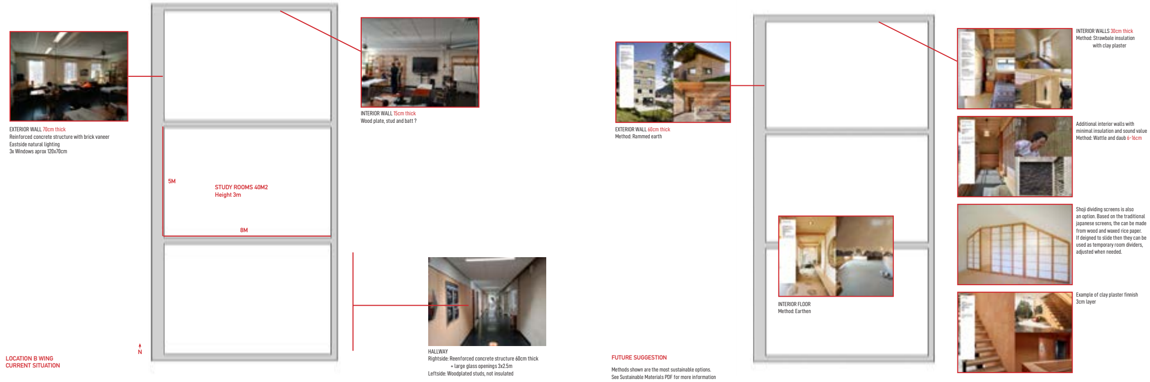


Figure 51. *Adjustability of ZP11*

Figure 52. *Internal flexibility, capability of adjusting spaces with amendable walls*

- Interior spaces are turned into productive green areas which contribute to the indoor air quality and provide substantial amounts of food.

Figure 53. *Green indoor spaces: plant as curtains providing shade and improving air quality*

- The atmosphere of indoor spaces is warm, down to earth and made from locally available materials, newly assembled or reused.

Figure 54. *Earthen spaces*

Besides the ZP11-building, other small experiments form the primer for future development. Each of these experiments contribute to breaking down the barrier between human artificiality and natural capability.

- The façade of the Van Olst tower is entirely refurbished, turning the current steel into a hanging garden, where vines are grown, suitable for producing some of the finest Hanze wine.

Figure 55. *Transforming the Van Olst tower into a 'hanging food-façade', a vineyard*

- Along the saline edge of Moeder Zernike, shrimp, langoustine, and lobster farms are introduced as a luxury delicacy for new Groningen cuisine.

Figure 56. *Saline farming along the saline edge*

- The southern landscape is dominated by raised peat bog, slowly growing in size and quality, fed by high quality water from its surroundings and given the time to let the plants rot.

Figure 57. *Raised peat bog*

- In between the saline waters and the peat landscape, there is ample space for creating large scale duckweed farming, which provides the best protein ratio of many local crops. It has been recently discovered as a tasty alternative for meat or algae; it grows fast and can be harvested throughout the year.

Figure 58. *Duckweed farming*

4.1.8 Infrastructure and accessibility

The design for the internal infrastructure starts from the point of view that in the future, car use will be a rarity, and most of mobility will be self-driving or collective electric, such as possibly a cable car system. This also implies that parking largely becomes redundant and can and needs to be used for other purposes such as the ones described before in this chapter. The main infrastructure on Moeder Zernike will facilitate pedestrians and cyclists, through a superpositioned layer of free-hanging pathways, connecting different levels of the campus buildings with each other and the ground level.

Figure 59. *InfraSCAPE on Moeder Zernike*

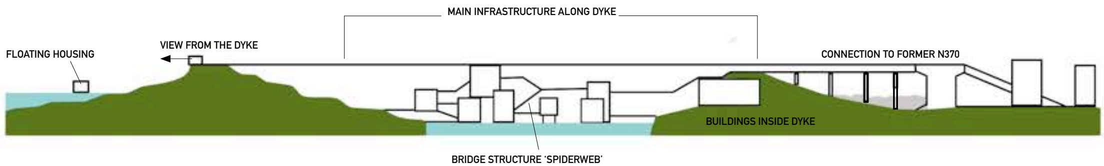


Figure 60. *Cross-section InfraSCAPE*

Figure 61. *Internal infrastructure for leisure and play linking mobility with the water*

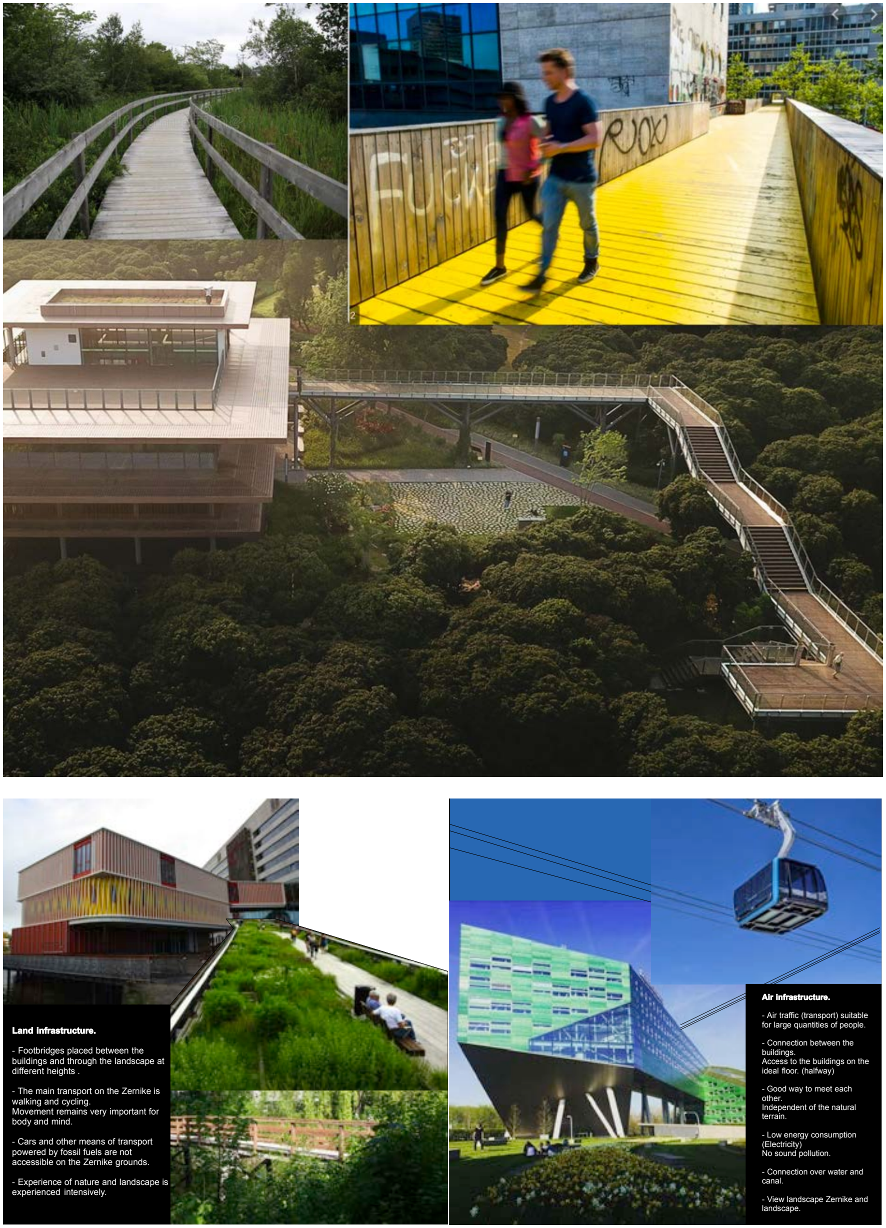


Figure 62. *Multilevel connecting paths for pedestrians and cyclists, in combination with collective electric transport through a cable car system*

4.2 Northern landscape.

Moeder Zernike investigates the forming of the northern landscape in a designerly way. Spatial-historic mapping of the emergence and continuously changing interaction of land and sea brought the genesis of the area to the foreground. This makes it possible to view the dynamic and the ecology of the landscape system and identifies the factors of a resilient environment.

Figure 62. *The Reitdiep landscape, just north of the Zernike campus*

4.2.1 Historic landscape dynamics

The landscape in the northern part of the Netherlands is formed as a result of a dynamic interplay of freshwater discharge from the higher plateau, land-forming in the intertidal zone, and the intrusion and retraction of sea water. This can be defined as the constant search for balance of time and tide. Creeks connected the higher areas with the sea and found their way determined by the harder and softer parts in the landscape. The sediment that the sea brought inland allowed the land to grow, coping with changing sea levels. In parallel, large zones of raised bog were formed, tempering the powers of the sea, hence creating a safe coastal landscape.

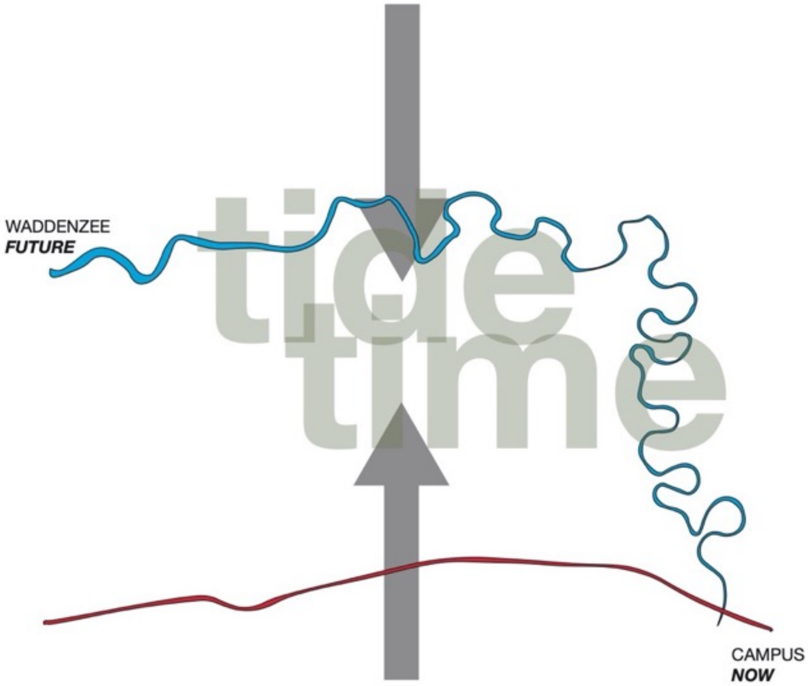


Figure 63. *Balance of tide and time*

In the year 600 BC, the City of Groningen stood in direct contact with the sea. The saline creek penetrated deep into the landscape, creating an almost straight connection from north to south. In the year 1200, this system had changed quite dramatically due to several inundations, one of which created the Lauwers Sea. At this stage, men started to raise dikes to protect their villages and bounded the main creek to an east-west configuration, which also created several islands and peninsulas. In the current situation (2000), the Lauwers Sea is dammed and a huge dike closes off the entire northern coastline to protect the land against further inundations.

Figure 64. *Crucial transformative steps in landscape genesis of the northern Groningen landscape*

The design investigations show the sequence of landscape development over time. The higher grounds in dark green and the peat in brown are dominant in the early stages, while the influence of saltwater (in red) creates the salt marshes (light green). Over time, the deposition of clay increases (dark green) and this reduces the intrusion of the seawater. After humans start to control and embank the land, agricultural activities emerge, as does urbanisation. By the year 2000, a separation of land-based activities and the sea has become a divide.

The question this mapping analysis raises is how resilient and anticipative the current controlled landscape is, and to what extent the latter stages of landscape genesis provide a safe country. Especially when nature's forces evolve and make problems rise, the fear of losing control increases the sense of urgency, implying that an even more controlled coastline should be constructed. However, this ever more control in the future also increases the impact if a disaster occurs. Then, the damage and losses are incomprehensible, as cyclones and hurricanes in the US, Australia, and Japan have shown.

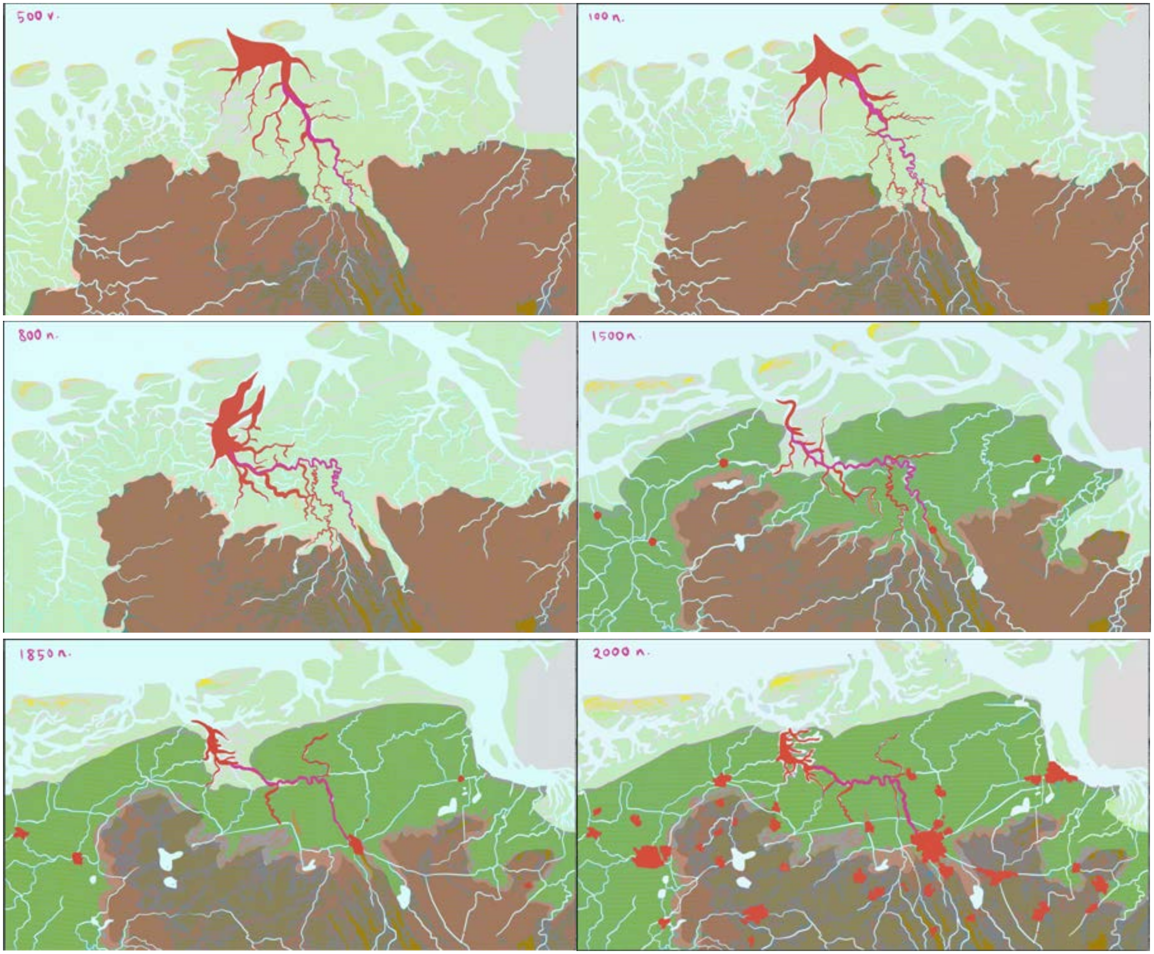


Figure 65. *Time lapse of landscape genesis from 500 BC until 2000 AC*

Could an alternative of nature-driven and self-organising coastal systems be less vulnerable? If so, then human control should be replaced by a landscape that is controlled by the ecological system instead. This will lead to a dynamic equilibrium in which the landscape itself establishes its own resilience by growing protection in the form of salt marsh, raised bog, mangroves, and barrier islands. This reduces the vulnerability of the entire system and provides resilience for all. In this context, the current timeframe is the high mass of human control, which slowly transits into a dynamic nature-driven future.

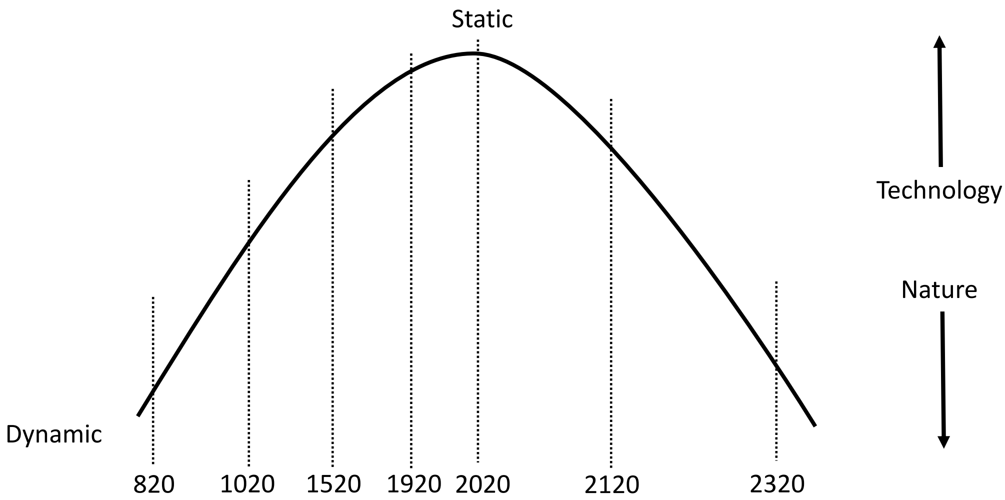


Figure 66. *Evolving towards a dynamic natural future*

4.2.2 A Saline Stream.

The historic analysis underpins the relevance of (re)introducing a saline stream in the northern landscape. The powers of the sea itself could form the land again. The sea brings sediment to places where sand and clay particles raise the land. When the sea is given the freedom to direct the landscape, the saline stream will increase the ground level of the land and enhance safety. Presently, the engineered dikes prevent this natural process from happening because they cut off the movement of sediment. This implies that the dikes should be deconstructed to allow nature to build the regrowth of the landscape. In this dynamic environment, new creeks will be filled with water from the sea and determine a new, but constantly shifting, balance between land and sea.

Simultaneously, longer droughts and more intense rain events demand a higher capacity to store freshwater, to use in drier periods and discharge the water slowly towards lower land and the sea. Slowing down the discharge of rainwater stimulates peat forming, eventually merging with salty marshes in a staged emergence of coastal dynamism. From the current separation, the land and sea systems will first join in synapses before deep intrusion of the saltwater landscape in the freshwater system and vice versa will, in the end, cause a complete merge.

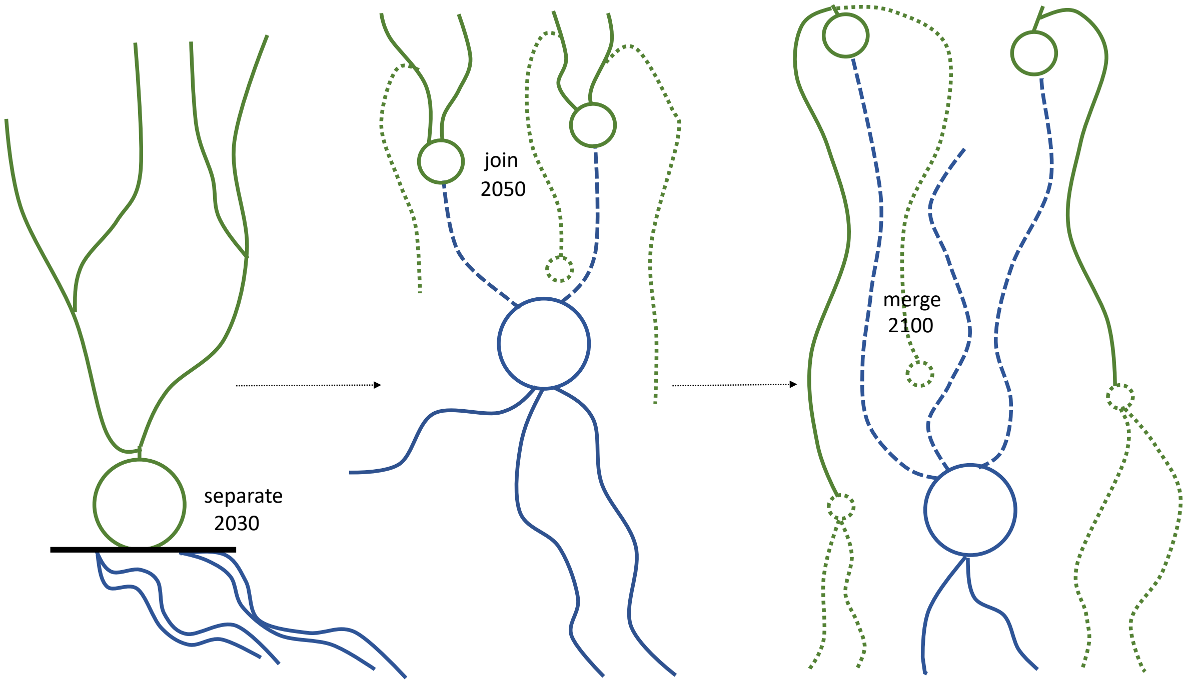


Figure 67. *From separated fresh and saltwater systems towards joint and merging systems*

A range of design principles is applied to guide this transformation. This typology of design principles for an emergent landscape can be seen as subsequent lines of protection.

Table 4. *Design principles*

name	principle
Barrier island	Natural sea dynamics forming a barrier as an island in front of the coast
Creek intrusion	Allowing for saltwater to intrude inland and to expand land forming at sea
Terra forming	Allowing the sea water in, but slowing it down on the way back at ebb tide
Dutch mangroves	Forests alongside the creeks slowing down the intruding water
Ride not crash	Protective walls preventing the flooding of houses and villages in the landscape during occasional extreme flooding
Synaptic fresh-salt	Synergies where salt and fresh water meet, and could form the basis for blue energy
Sponge-bog	sponge operation of the peat landscape

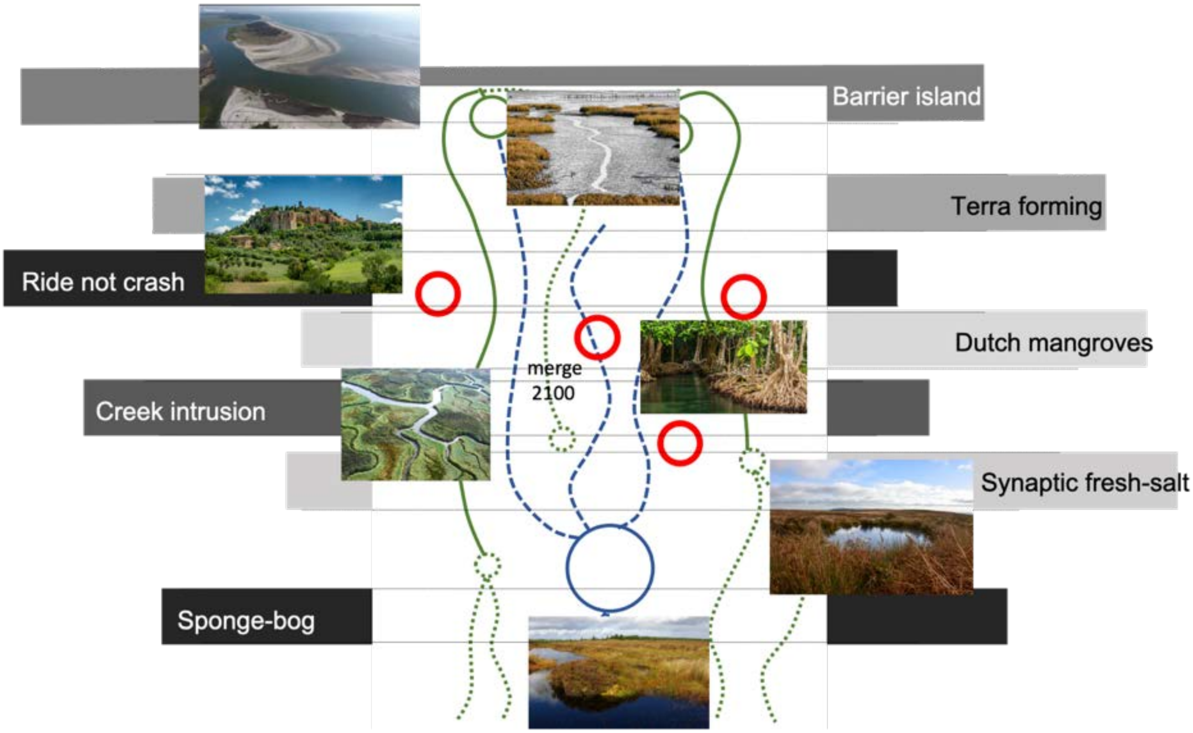


Figure 68. *Lines of protection*

4.2.3 Landscape transformation and 'upsidence'

The terraforming resulting from the appearance of seawater in the landscape creates more resilience whilst allowing the current inhabitants to stay. This transformation will not occur overnight, but in a slow process of modest emergence and change. In four stages of development, this tranquil transformation is captured.

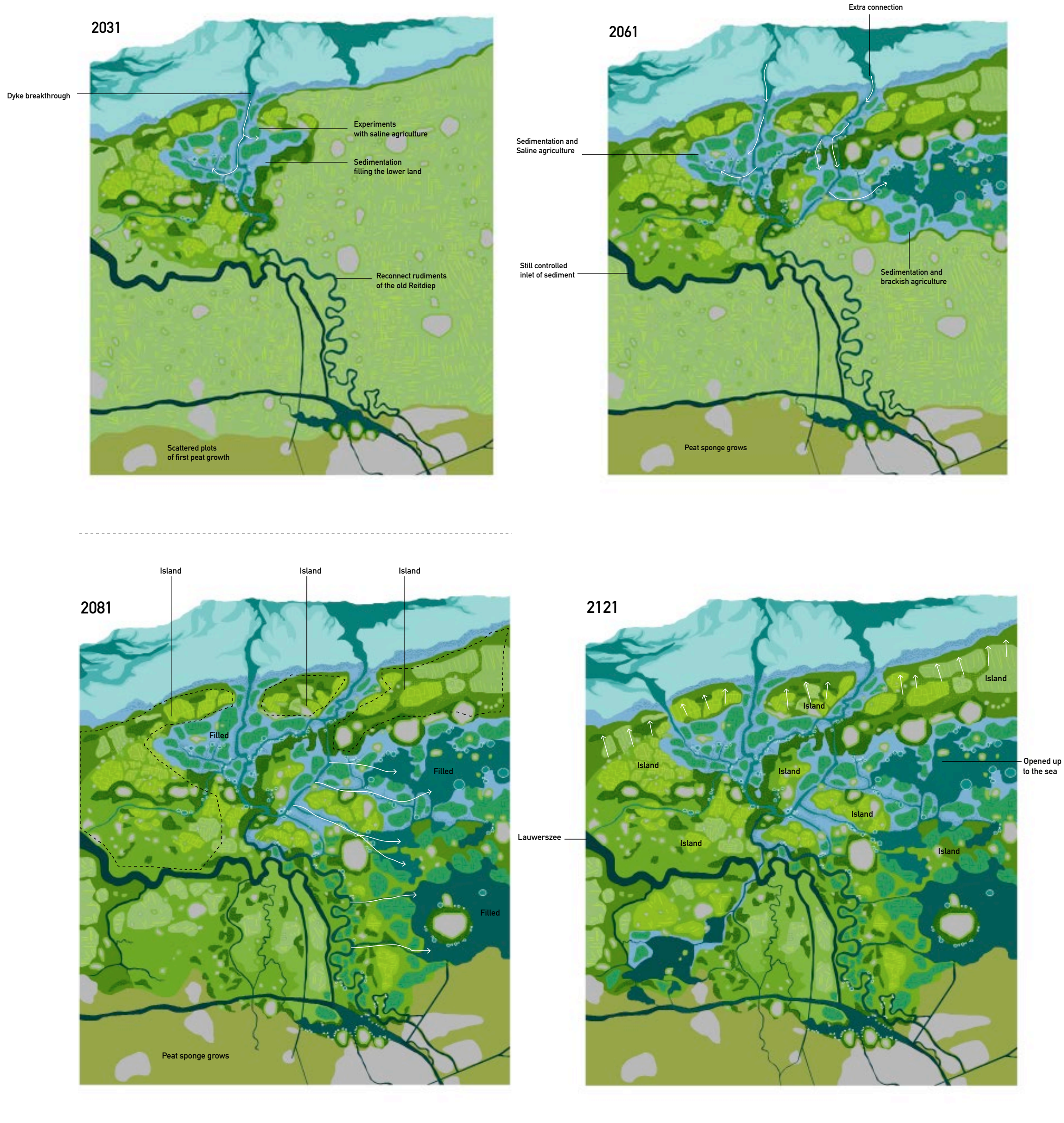


Figure 69. *Subsequent stages of landscape forming, 2031-2061-2081-2121*

In the first stage (2031) a little gap opens the hinterland for seawater in small amounts. The Wadden dike is opened at Wierhuizen to let the water enter the land behind the dike in a controlled way. Directly behind the dike, current low-lying agricultural land will be inundated, and sediment will begin raising the land. This is the first experiment, and the rising of the ground level will be adequately monitored, before decisions are taken to continue the process of seawater inlet. In this first phase, saline water will be reintroduced in the northern parts of the former meander relics of the Reitdiep stream. The first locations for peat growth are established and experimental forms of saline agri- and aquaculture are undertaken. Larger nature reserves are created along the northern coast.

The second stage, until 2061, shows a continuation of the early experiments in a larger area. The water inlet enters further, in a controlled way, into the former meanders of the Reitdiep. The north-eastern agricultural grounds are opened to the influence of sea water and are filling up with sediment, raising the ground level of the landscape. The entire peat-zone around the northern edge of the city is created and the process of reed-growing and peat forming is well under way. The historic wierden in the north part of the landscape will be reinforced and new wierden will be constructed to create places for future safe living. The transition in the food system is almost complete and the majority of the farmers have embraced new food production methods, inclusive of saline crops, seafood-farming, algae plantations, and mussel and oyster fields. The rewilding of the natural environment is well under way with reintroduction of new species, enriching the food-web of the salt marshes and brackish grounds, and starts to self-establish.

In stage three, till 2081, the connection between the sea and the Zernike complex will be fully established. The sedimentation and rising of the land continue, and the area around Bedum is now opened to the influence of the sea, allowing for the landscape to be raised. Peat is fully grown and raised peat bogs are strong enough to form a defensive line protecting the city. Agriculture is flourishing and fully adapted to the new conditions. Nature is strong and large enough to self-organise its emergent succession processes. Its growth and decline form a natural equilibrium, protecting the coast in a systemic way.

The final stage in 2121 shows the transformed northern landscape, where additional connections between sea and land are created, forming a saline-brackish landscape, in which all subsided parts of the landscape are reversed and upsided. The current freshwater in the Reitdiep is slowly transformed into a more saline stream. The peat is fully grown and protecting the city. New and old wierden form crash-proof bastions in the landscape, able to withstand extreme water levels, storms and inundation.

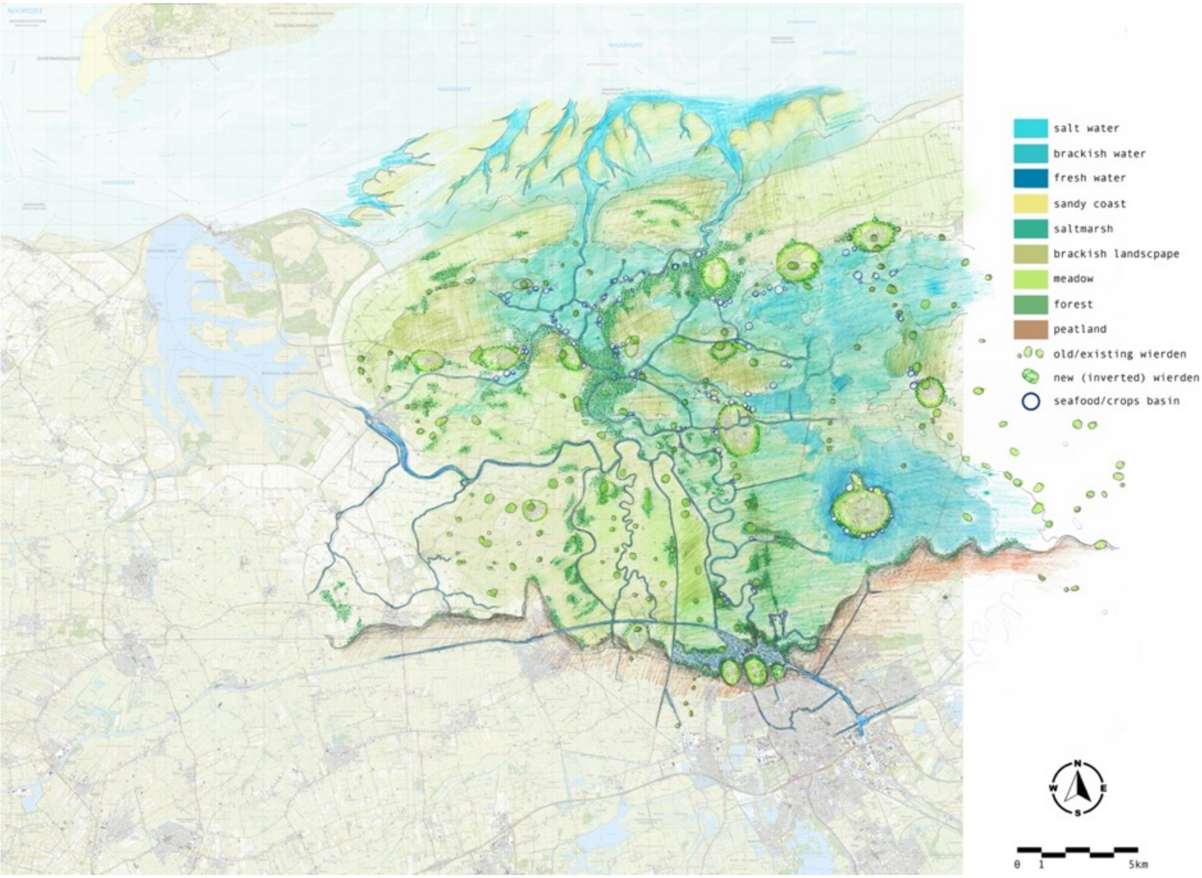


Figure 70. *Design of the saline stream next to the existing Reitdiep*

By reintroducing coastal dynamics in the saline stream, the ecological gradients will be enhanced, from saline, to brackish, to freshwater circumstances. This gradient will shift southward over time, when sea water gains more influence. The water that is brought deep southward in the landscape can be used for saline agri- and aquacultures, and creates a multi-layered coastal system, with terra forming, mangroves, ecological zoning, and water that is allowed to overflow the land. Design of the new saline stream is inspired by the historical context, flowing from the northern coast meandering towards the campus. The stream connects old 'forgotten' river arms and re-establishes the stream so that water can start flowing in and out the landscape. It is separated from the current fresh water Reitdiep-river, which is, for now, kept intact, in order to avoid disturbing the existing water management system. It therefore adds ecological quality, linking the fresh and saline streams next to each other, and provides a unique ecological landscape whilst modifying the tidal energy so it will not cause any disruptions or unexpected flooding.

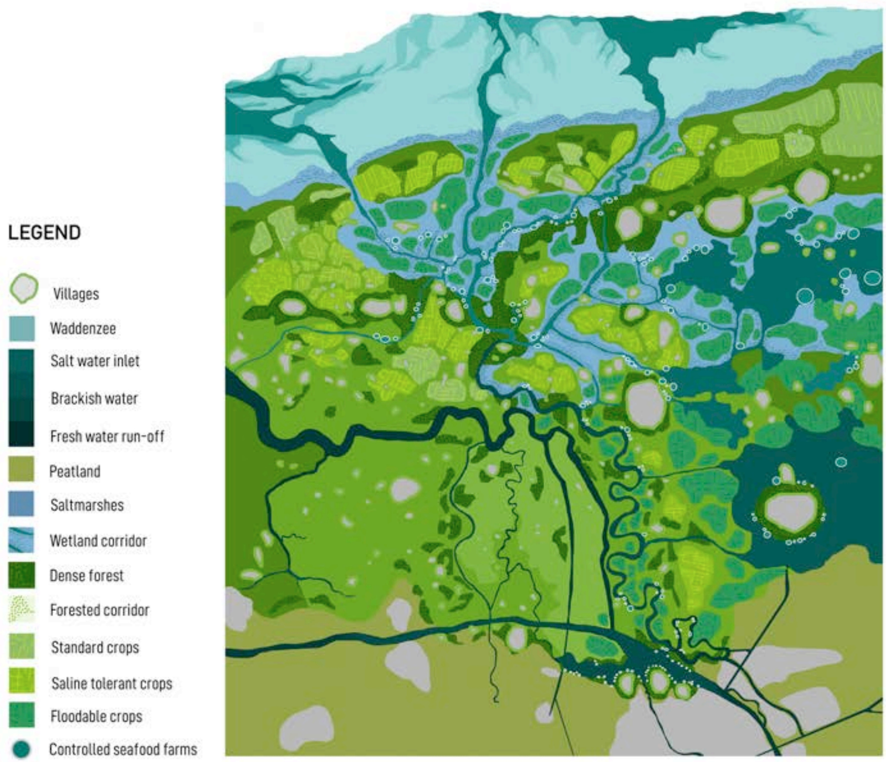


Figure 71. *Design of the Moeder Zernike lifeline*

4.2.4 Multiplicity.

Such a saline ecological food-producing landscape has multiple impacts. The processes of growth and emergence run in parallel, strengthening the reliance of the landscape and thus increasing the adaptive capacity of the entire landscape and urban system.

The process of land rising takes place over a longer period of permanent seawater supplying sediment to the land. Over time, the process of terra forming will gain more space and reach existing settlements. Though it increases the safety from flooding, it also means that the sea itself comes closer to these settlements, which urges protection in the form of new bastions or inversed wierde systems.

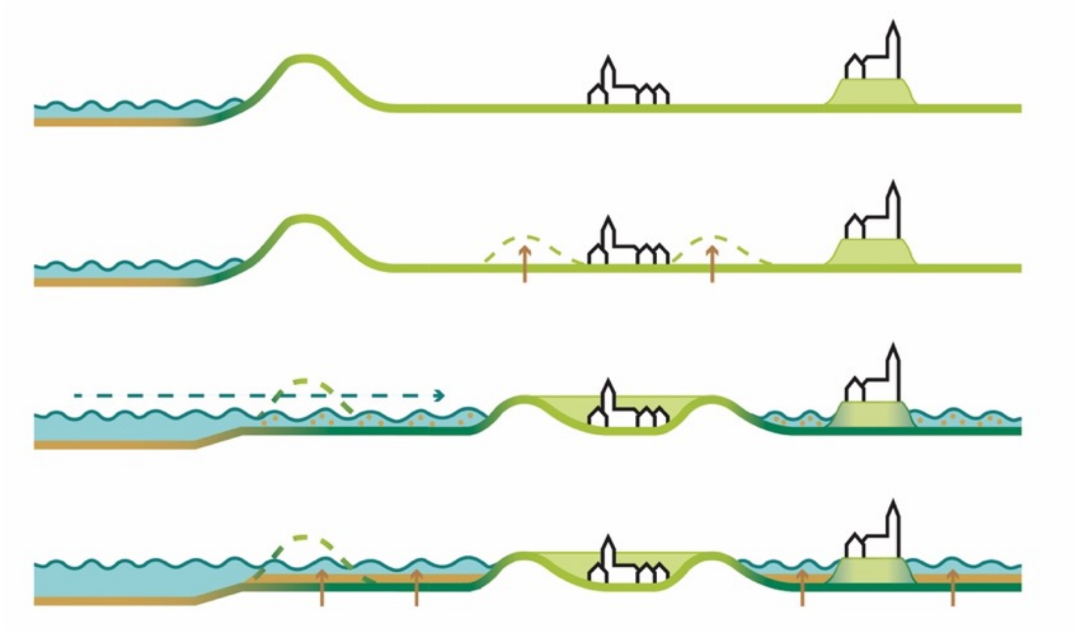


Figure 72. *Raising the landscape*

The process of peat formation is a slow development, which requires a long-term perspective. Therefore, it should start quickly, and be continued over a long period. First, the reed plants will start growing. After dying, these plants will rot to form peat. Slowly, additional layers of rotten plants will form higher levels of peat, until a raised bog emerges. Once this occurs, the peat landscape will have protective power for the inhabited urban areas. In the river system, a river forest will grow to minimise the influence of high water levels in the streams.

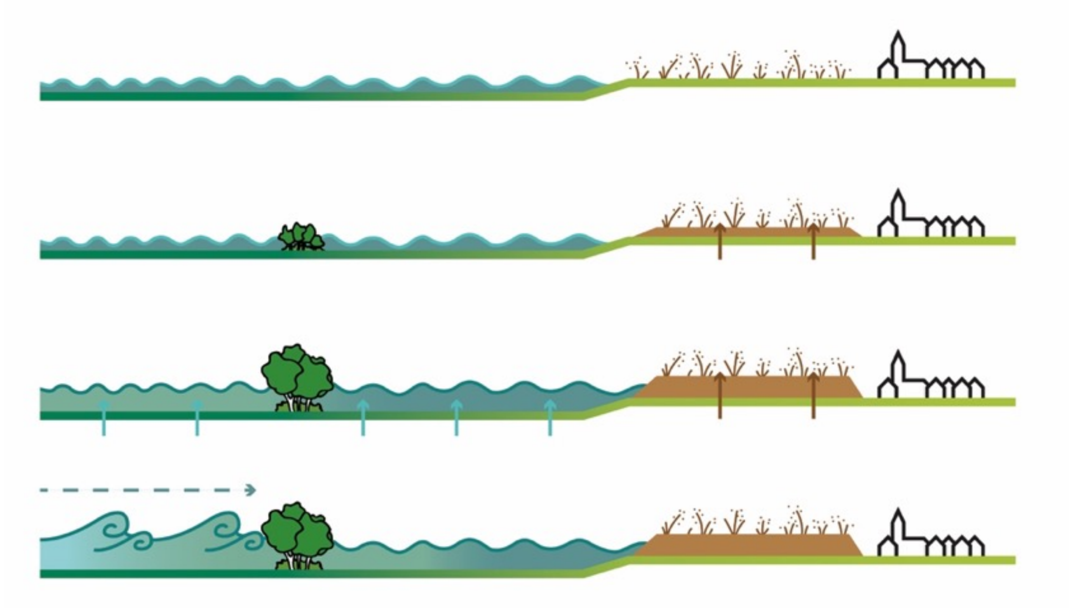


Figure 73. *Peat formation*

The food system increasingly comes under the influence of saline conditions. This means the traditional agricultural crops, such as potatoes, sugar beet or grassland, will over time be replaced by saline crops, fish in farms or natural environments, free range livestock, and controlled aquaculture.

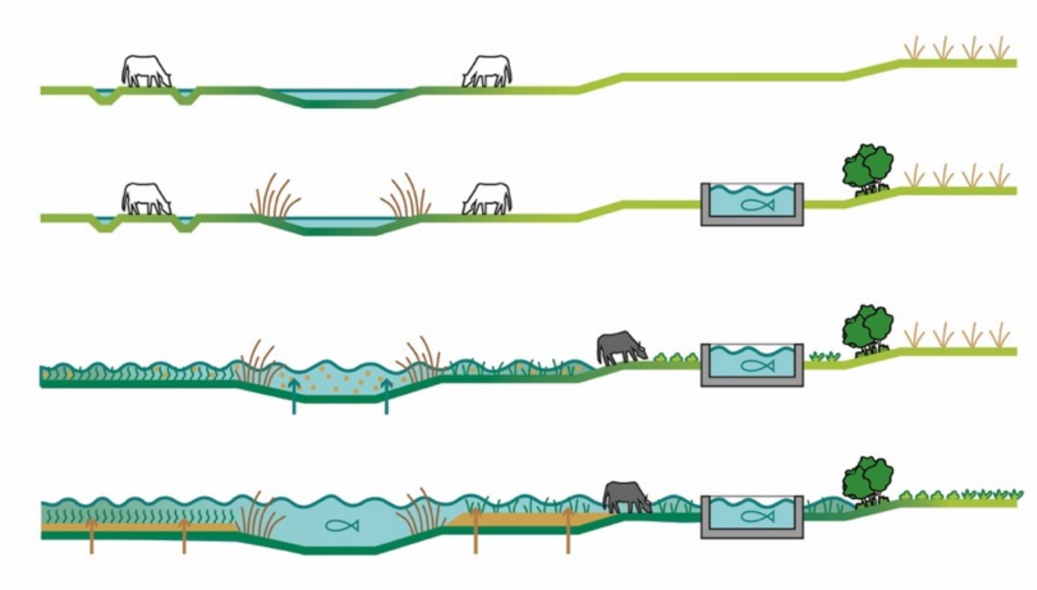


Figure 74. *Salinifying the food system*

4.2.5 Ecology.

The introduction of saline conditions with tidal dynamics creates a transition gradient between saline, brackish, and freshwater. This process will evolve over time in two directions: the deeper the saline influence comes into the river itself, the more noticeable the gradient will be. At the same time, the gradient merges from the riverbed towards the landscape on both sides of the riverbanks. A complex interplay of saline, brackish, and fresh conditions will provide the richness that can improve both the natural conditions in the landscape and the biodiversity. The variety in landscape typologies enriches the range of ecological habitats for non-human organisms.

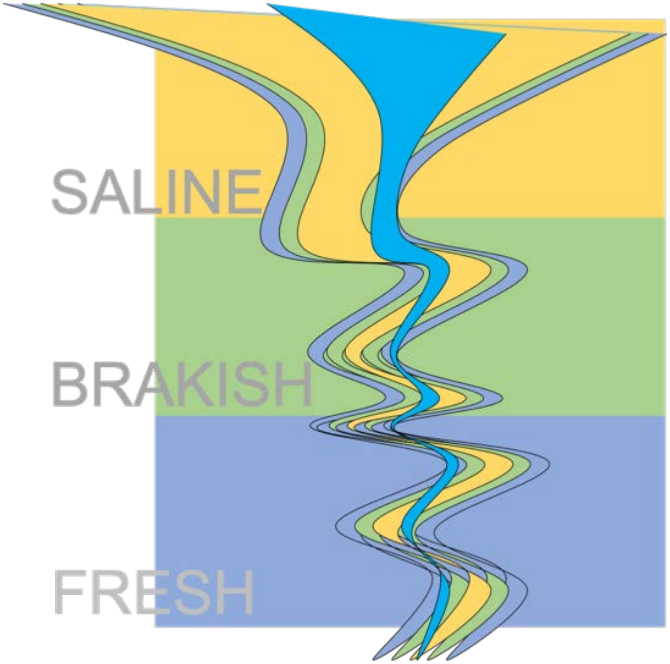


Figure 75. *A rich ecological diversity emerges as result of the saline stream overflowing the landscape*

Figure 76. *An emerging gradient from the Wadden Sea coast inland, changing ecological conditions*

Each part of this large-scale gradient is characterised by typical plant communities that fit the climatic, soil, and dynamic circumstances. These range from samphire, to willow, and everything in between.

Figure 77. *Ecological succession: from saline, to brackish, to freshwater conditions*

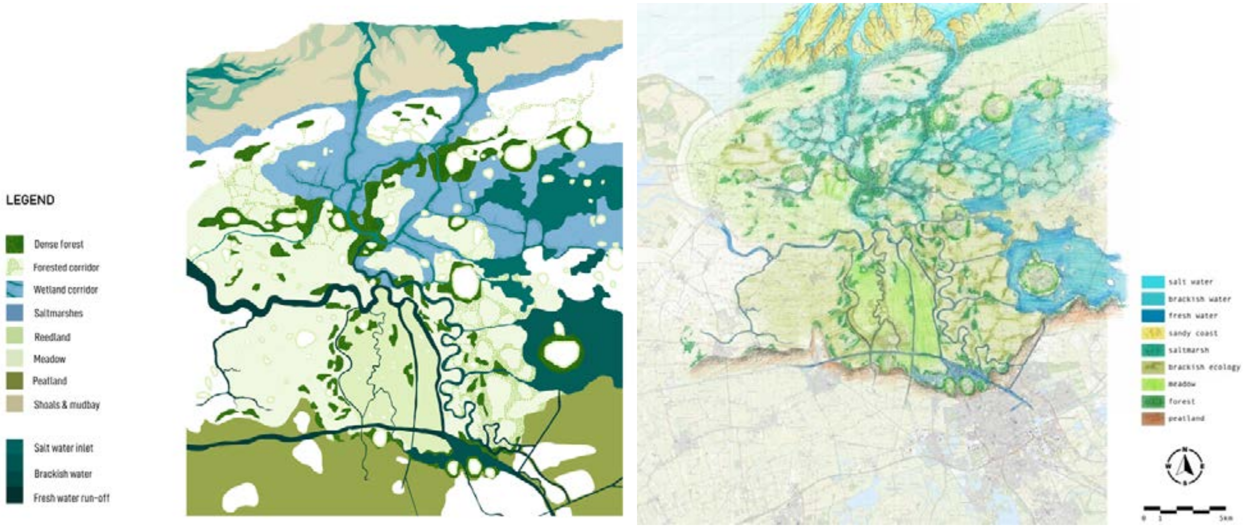


Figure 78. *Interplay of ecological landscapes: tidal flats, salt marshes, wetlands, river forests, brackish creeks, and meadows*

Figure 79. *Wetland river forest*

4.2.6 Water.

Water is the driving force of the entire transformation the landscape will undergo. It is the reason behind the necessity to connect the sea with the Zernike campus, it pushes the rising of the ground level of the land, it provides the novel conditions for future agriculture, and it offers the rich gradient for ecology. The water system will need to be adjusted accordingly. This is not planned as a rigorous intervention that is thoughtlessly opening the landscape for the whims of the sea. On the contrary, the transformation of the water system is a strictly controlled process of small steps, which are evaluated before a next step can be undertaken. It starts, therefore, in the northernmost area of the Groninger landscape, where a small gap allows the water to enter the landscape. This area has been chosen because it is a relatively higher landscape, where the risk of flooding is minimal. The first experiments will offer insights into how the dynamics of the sea might encounter the status of the landscape as we know it. In well-considered steps - only after thorough deliberation and consideration - more freedom for the natural dynamics can be allowed. Eventually, the water system reaches the lower grounds and the farthest inland areas. The salinity of the water will slowly increase, and sediment is brought in. Because the sea water enters the landscape, a symbiosis will develop: a balance between the giving and taking of water, land, nature, and people.

Figure 80. *Plan for adjusting the water system of the Moeder Zernike landscape*

Figure 81. *Tidal flat in the northernmost area*

4.2.7 Food.

Currently, the agricultural sector has to deal with various problematic issues: these range from dewatering and soils subsidence, nitrogen deposits, monoculture leading to loss of biodiversity, decrease of European subsidies (European Commission, 2020) and reduction of economic profitability, and more. This places the current agriculture before a transitional question. How to change the agricultural system in a way that it can grow sufficient food, stay economically viable, reduce the impact on the environment and climate change, and enhance the biodiversity in the area.

As aforementioned, the future of food will increasingly impact the preferred diet of all people. The so-called Lancet diet reduces certain crops and products while others are increased. For every region in the world, this plays out in a different way: the Argentinian pampas will have a different context to work with than the coastal zone of the north of the Netherlands.

A large portion of the North Groninger landscape is currently in use for agricultural purposes. The most important crops grown in this landscape are sugar beet, potato, wheat, and grassland, mainly in use for grazing cattle.

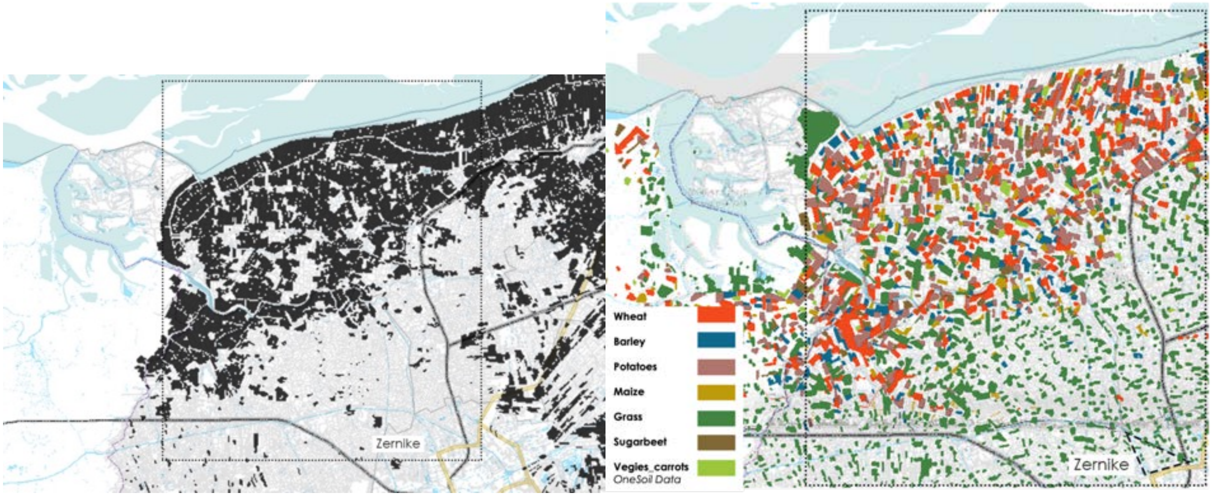


Figure 82. *Current farmland and crop types*

With the reduction of European subsidies (European Commission, 2020), the economic viability of these crops come under pressure. Not every farmer is as profitable as they would want. Therefore, a new perspective is needed for the farmers to enter the coming century with confidence and pride. This perspective is found in a transition to agriculture in saline and brackish conditions; we estimate that the economic profitability thereof will improve.

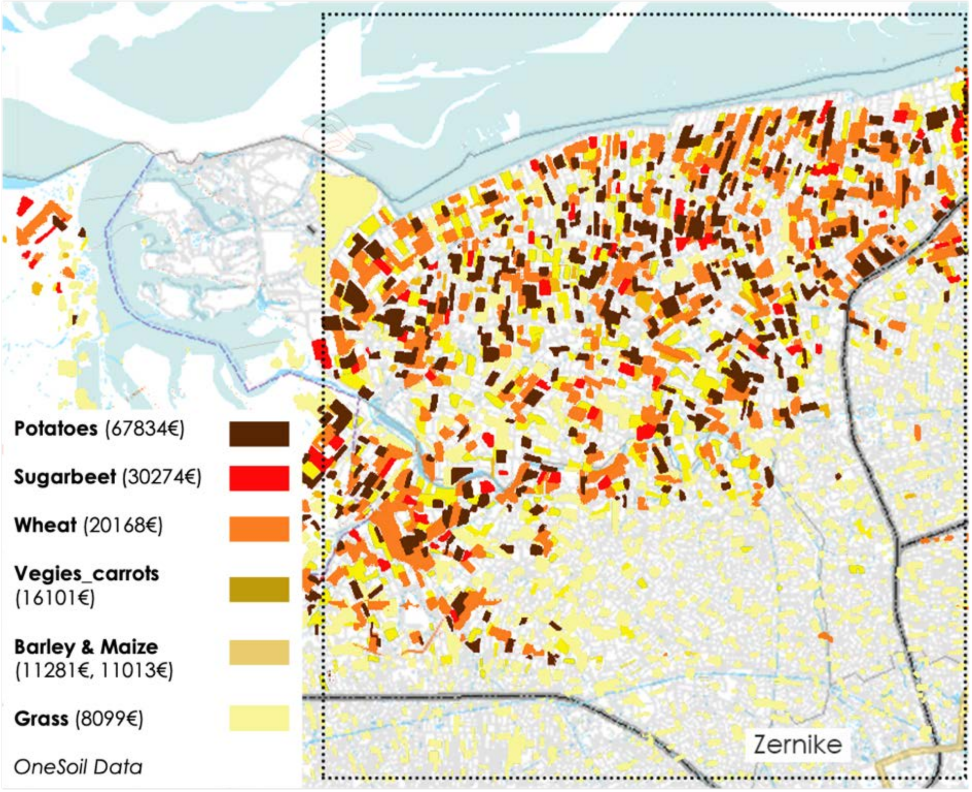


Figure 83. *Current income per crop type (Copernicus Sentinel Data, 2018)*

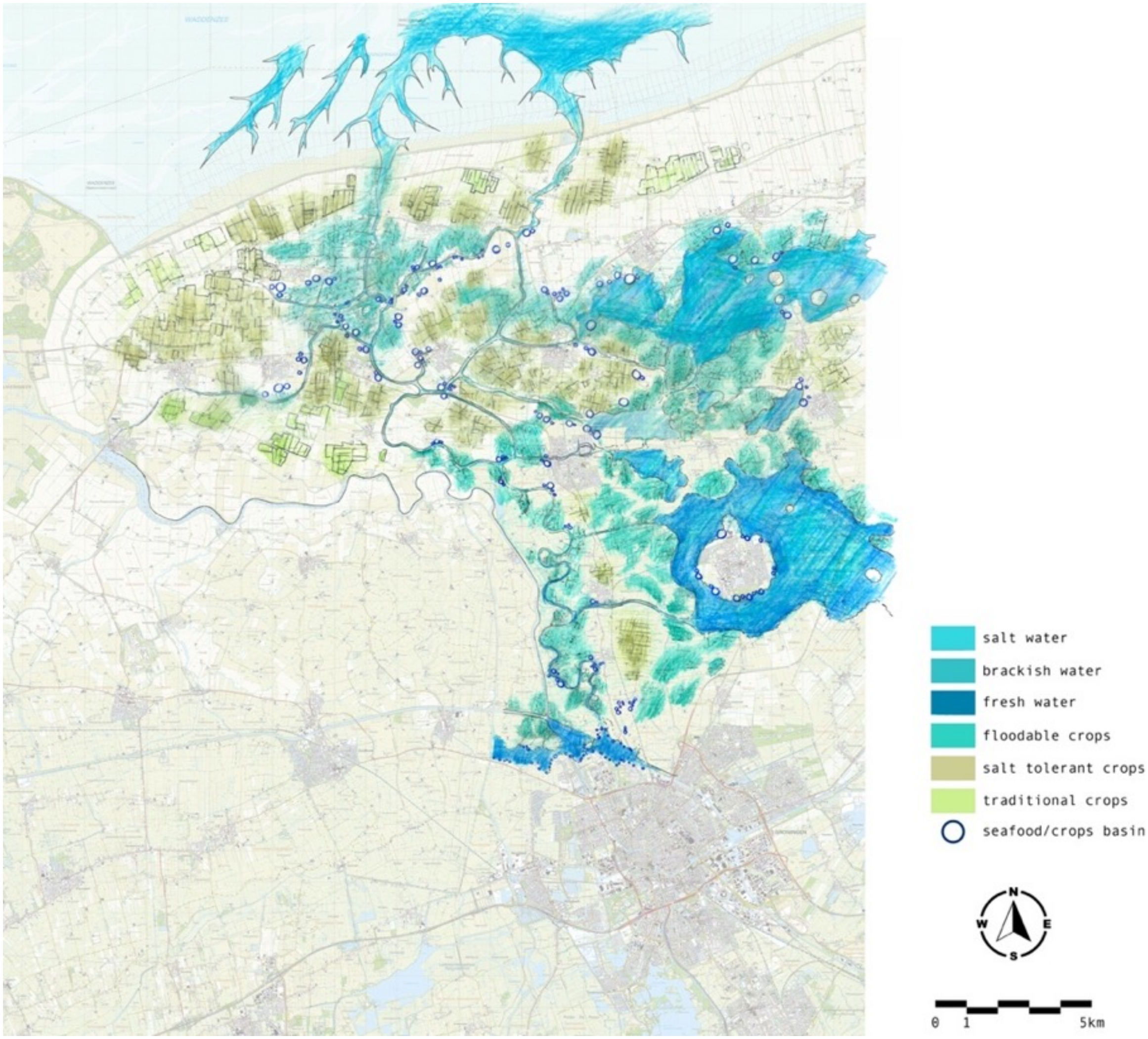


Figure 84. *Saline stream bringing new agricultural perspectives*

The saline stream brings new conditions determining the growing circumstances for an adapted food system. Saline water implies alternative forms of agriculture which could well mean a more profitable agricultural economy. The northern landscape therefore transforms into a saline farm landscape, in which saline crops, such as samphire, seaweed or sea kale, as well as lobster, langoustine, eel, prawn and shrimp can be harvested. This could solve the current ecological problem of the invasive American langoustine, which can be caught and consumed in large quantities.

Figure 85. *Saltmarsh with productive land*

Allowing saline water into the current land-managed Groningen landscape could potentially raise profits for individual farmers. Firstly, calculations point out that the existing business model for farming in the north is marginal, subsidised and lacking a long-term perspective. An alternative business model in which saline crops and seafood are the main produce is promising. The higher prices, in combination with lower labour investments, mean this is potentially more profitable for individual farmers. This could imply that a reduced area is necessary to gain similar profits for the farmer as they do today. Still, this is a tough choice for many, who might need support in making such a transition.

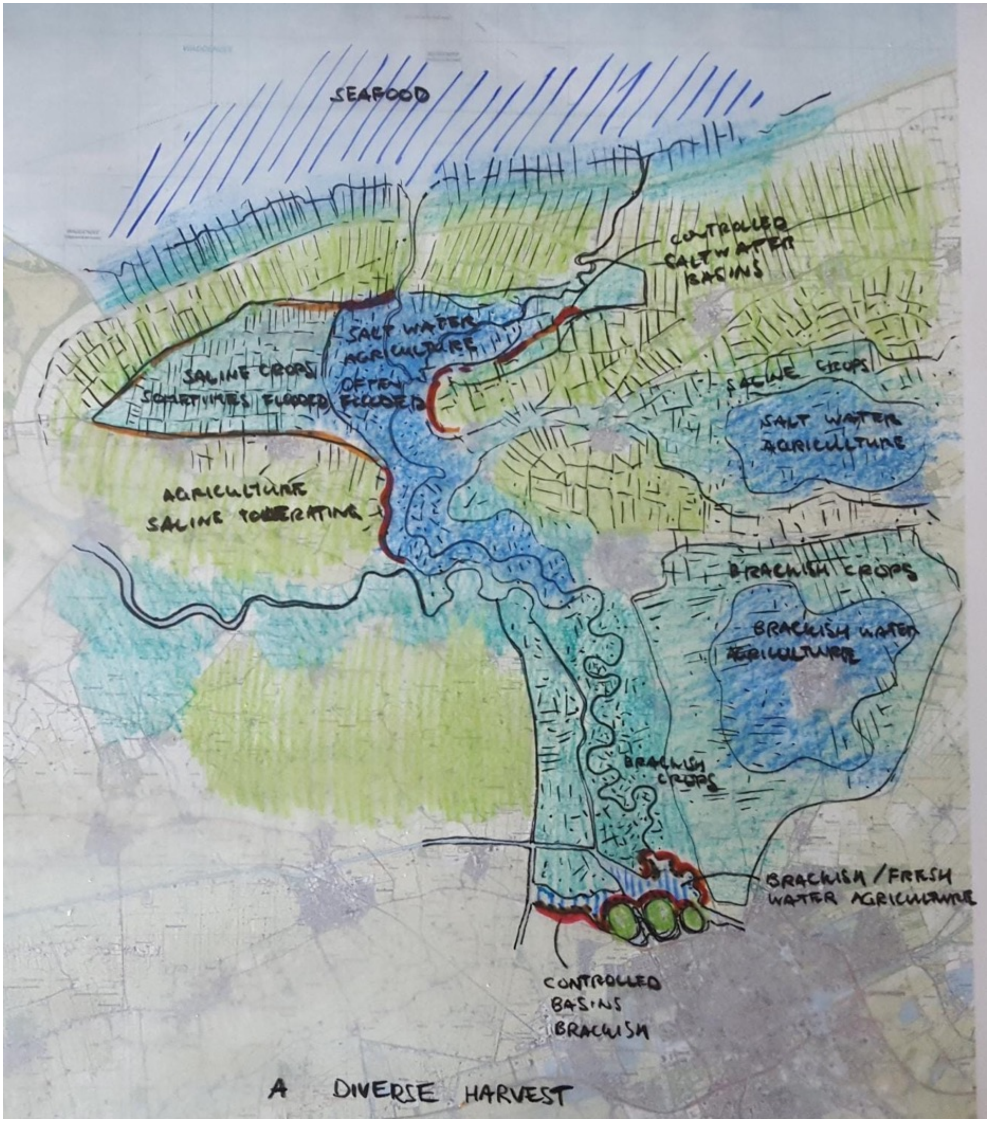
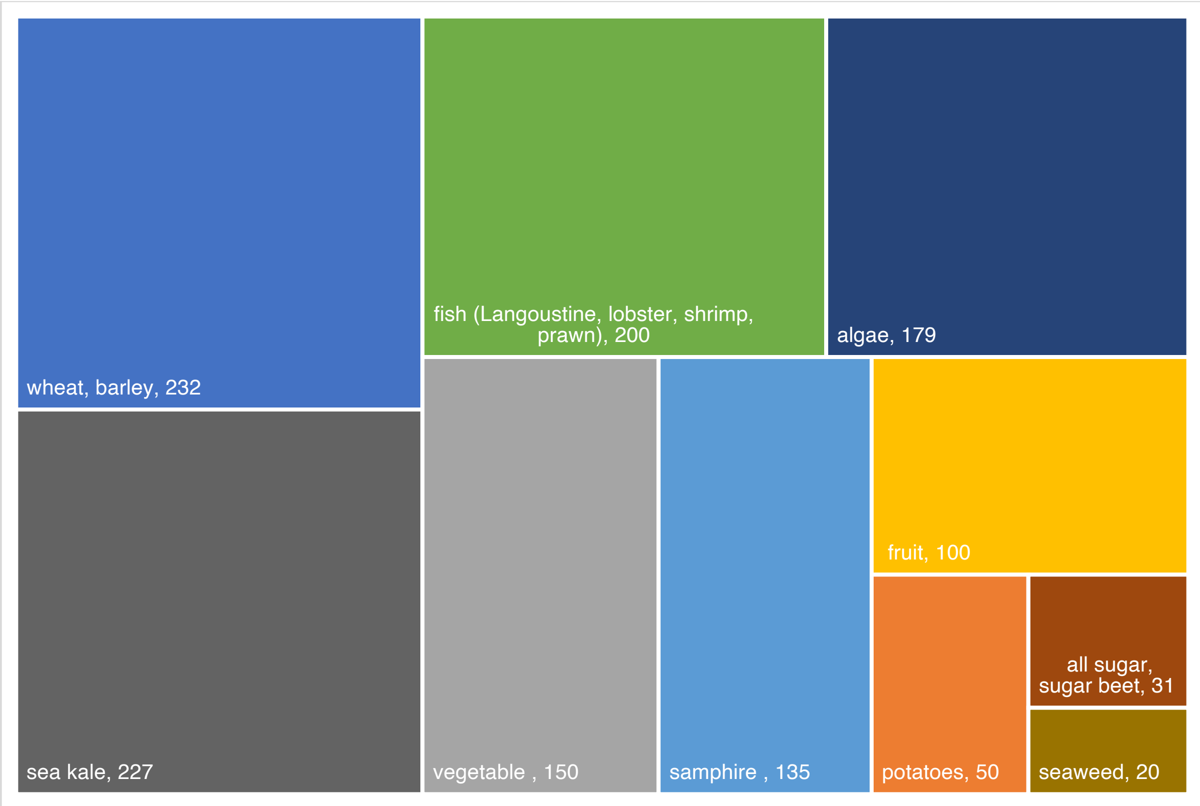


Figure 86. *Diversity of agricultural crops in the Groninger landscape*

The Moeder Zernike future proposition for the food system is to transform two-thirds of the current agricultural production into saline forms of agriculture. This also changes the amounts of food required for each person. When the Lancet diet is adjusted to a two-thirds saline produce, a healthy diet is still possible, however, the types and amounts of produce are different.

Table 5. *Amount of food needed per person/day/gram according a 66% transformation to saline agriculture*



This transition should be painless for the farmers. The plan proposes that every farmer should have as a minimum the same income as they currently do, possibly even more. The current income level per produce type is given in the table below. When this is compared with current prices for aquacultures, the possibility to make a painless or even profitable transition seems apparent.

Table 6. *Current income level per type of produce*

Crop/animal	Average area of a field or farm /ha	Total value of production/ Euro	subsidy/Euro	Total income (Euro/year)
Wheat	9,6	16088	4080	20168
Barley	6,4	8561	2720	11281
Potatoes	8	64434	3400	67834
Maize	5,9	8505	2508	11013
Grass	3,2	6739	1360	8099
Sugar beet	8,7	26577	3698	30274
Vegetables (Carrots)	6,8	13211	2890	16101
Beef	51	73806	24250	44056
Milk Cow	47	300314	21405	43720
Goat	7	142651	3416	46566
Pig	9	397207	3402	256609
Chicken	6	23378	3400	15778
Sheep	8	15108	6824	15433

Table 7. *Current prices of a range of fish and seafood*

Fish type	price (Euro/tonne)
European lobster	**13586**
Brill	**6724**
Shrimp	**2760**
Norway lobster	**5677**
Mussel	**1197**
Oysters	**5389**
Codfish	**2908**
Red gurnard	**2337**
Dab	**917**
Haddock	**1936**
Plaice	**2456**
Turbot /rhombus	**9831**
Sole	**11815**
Whiting	**1157**
Sea bass	**12360**

If the current subsidies and profits are calculated, the existing crops provide the farmer with an income as given in the table below.

Table 8. *Current income level for four types of farming (Van der Meulen, 2020)*

Farm type	Farm size (ha)	subsidy (euro/year)	net income(euro/year)
Sugar beet	20	8500	47,600
Potatoes	20	8500	147,600
Wheat	20	8500	21,000
Milk (cow)	20	10800	22,000

If the profits are estimated for a 100% seafood farm, a saline crop farm and two mixes of saline and seafood farm, it shows that the potential income, on the same size of land, is much higher.

Table 9. *Potential income levels for different hypothetical saline produce farm types*

Farm type		Farm size (ha)	net income(euro/year)
seafood farm	shrimp/lobster/langoustine/prawn (25% each)	20	583,000
saline crops farm	samphire (glasswort)/seaweed/algae/seakale (25% each)	20	1,110,000
mix of seafood sea crops farm (50%/50%)		20	846,500
mix of seafood sea crops farm(20%/80%)		20	1,004,600

When a mix of current production (30%) and saline methods (20% seafood and 50% sea crops) is applied (see table below), the estimated income is lower than purely saline farming, but on average still around seven times as high as traditional cropping.

Table 10. *Estimated income levels for four hypothetical mixed farms*

Farm type	type of produce	Farm size (ha)	net income(euro/year)
A	30% sugar beet/ 20% seafood/ 50% sea crops	20	685,880
B	30% potato/ 20% seafood/ 50% sea crop	20	715,880
C	30% wheat/ 20% seafood/ 50% sea crops	20	677,900
D	30% cow milk/ 20% seafood/ 50% sea crops	20	678,200

This can be brought back to the required area the original farms require to gain the same profit. For every 20 hectares of farmland, the required area to keep the same income is much lower, ranging between 0.6 and 1.4 hectares, a substantial difference. The reason for this is the relatively higher prices for saline produce. Averaging the required area out, this implies that an average farm in Groningen can earn the same amount of income on 1.65 hectares instead of 20, and economically viable agriculture is possible on only approximately 8% of the productive space currently used.

Table 11. *Required area (ha) to keep the same income for four traditional crops*

Farm type	Farm size (m2)	net income (euro/year)	Farm type	type of produce	area (m2) required to grow mixed farms in order to get traditional farm income
Sugar beet	200000	47600	A	30% sugar beet/ 20% seafood/ 50% sea crops	13878
Potatoes	200000	147600	B	30% potatoes/ 20% seafood/ 50% sea crop	41229
Wheat	200000	21000	C	30% wheat/ 20% seafood/ 50% sea crops	6195
Milk (cow)	200000	22000	D	30% cow milk/ 20% seafood/ 50% sea crops	6471

Table 12. *Average area needed for similar income per farm*

	100% current crop	30% current crop-20 % seafood&fish-50% seacrops	Same income on % of the land	Average
Potato	20 ha	4.1 ha	20.5 %	8% of the land must be used to get the same income (without subsidy) as current (with subsidy)
Sugar beet	20 ha	1.3 ha	6.5 %	
Wheat	20 ha	0.6 ha	3 %	
Milk cow	20 ha	0.6 ha	3 %	

As soon as saline produce become a success, and the amount of produced crops and seafood grows, the prices will go down. Assuming the prices will drop till 33% of the current prices, the required area to break even will be three times as much. Instead of 8% the required area for farming is 25% of its current space. For a potato farm, the portion of the current 20 hectares needed to earn the same income is only 12 hectares (3 times 4,1), as the potato is currently relatively expensive. For the relatively cheaper sugar beet farm, this portion is only about 4 hectares (3 times 1,3) and for wheat and milk even lower at approximately 2 hectares (3 times 0,6).

Table 13. *Amount of space that can potentially be taken out of production per farm type*

Crop	Hectare	Productive land after transition (ha)	Land taken out of production (ha)
Potato	20	12	8
Sugar beet	20	4	16
Wheat	20	2	18
Milk cow	20	2	18
Average	20	5	25%

After making these assumptions, the productive land can be divided according to the 30-20-50% crop types and the number of hectares on each farm can be calculated.

Table 14. *Area for the produce, after transition, divided on the basis of the existing farms*

Farm	New nature (ha)	Existing crop (ha)	Sea food (ha)	Saline crops (ha)	Total (ha)
Potato	8	3.5 ha potato	2.5 ha sea food	6 ha saline crops	20
Sugar beet	16	1.5 ha sugar beet	0.5 ha sea food	2 ha saline crops	20
Wheat	18	0.6 ha wheat	0.4 ha sea food	1 ha saline crops	20
Milk cow	18	0.6 milk cow	0.4 ha sea food	1 ha saline crops	20

Future land use can then be calculated on the basis of the area of current land use after applying the 30-20-50 division. Because current expensive farms shrink relatively modestly, and cheaper crop types require only a small area to earn the same income, for every farm the division leads to an adjusted number of hectares. Because there is, for instance, a larger area for potato farming than sugar beet, the final percentages for each category can be calculated on the basis of the real size of production. This calculation concludes that 6% of current cropping remains, and 4% sea food and 10% saline crops are required to keep the same income for every farmer, when estimated that the prices of saline agriculture produce drops to 33% of current prices. In total, the economic viability of farming can be guaranteed, with the above assumptions, on only 20% of the current area of productive land.

Table 15. *Recalculated area for existing and saline produce needed to earn similar income*

Crop	Existing area current land use (ha)	New nature (ha)	Area for existing crop after transition (30%)	Area for sea food (20%)	Area for saline crops (50%)
Potato	6875	2750	1203	859	2063
Sugar beet	2475	1980	186	62	248
Wheat	7500	6750	225	150	375
Milk cows	9975	8978	299	200	499
Grassland	9975	8978	299	200	499
Carrots	1200	480	210	150	360
Maize	1860	1674	55.8	37.2	91
Barley	2060	1854	61.8	41.2	103
Total (ha)	41920	33444	2540	1700	4238
%	100%	80%	6%	4%	10%

Based on the amounts of hectares of different crops and produce, a design can be conceived taking into account the growing conditions for the different produce types. Seafood can be harvested in saltwater conditions, saline crops in brackish circumstances, and traditional crops can be grown in areas where the saline influence is kept to a minimum.

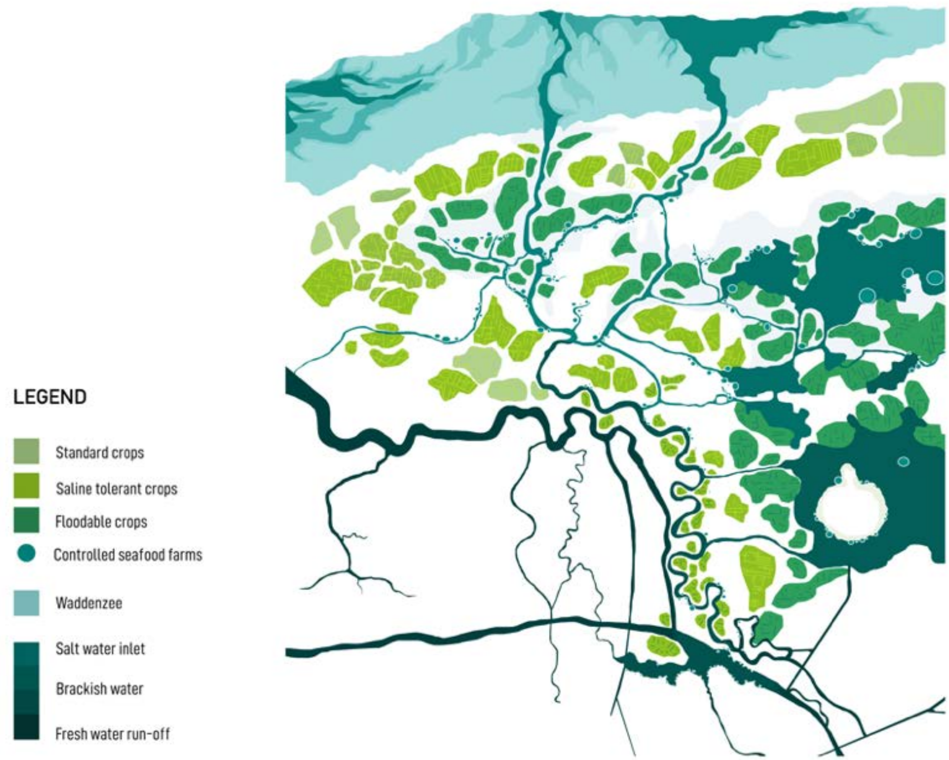


Figure 87. *Design for future agriculture in the northern landscape*

The area per produce can be recalculated as yield in kg/ha. As the total area per produce is known, the total yield in the project area can be calculated (see table below).

Table 16. *Estimated yield per produce type in the entire project area*

crop	Hectare in our plan	Kg yield/ha	Total yield (kg) in our area
Potato	1203	36,610	44,041,830
Sugar beet	186	76,370	14,204,820
Wheat	225	8,820	1,984,500
Milk cows	299	17,075.52	5,105,580.48
Grass	299	10,800	3,299,200
Carrot	210	57,140	11,999,400
Maize	55.8	9,010	502,758

Barley	61.8	7,040	435,072
Lobster ¼ (425 ha)	Shellfish (seafood) Total 20% 1700 ha	50,000	21,250,000
Langoustine ¼ (425 ha)		28,000	11,900,000
Shrimp ¼ (425 ha)		25,000	10,625,000
Prawn ¼ (425 ha)		26,000	11,050,000
Mussels	275	79,636	21,899,900
Oysters	275	5,000	1,375,000
Fish	3000 ha	6,500,000	19,500,000,000
Seaweed	300 ha	195,000	58,500,000
Algae	300 ha	39,000	11,700,000
Duckweed	300 ha	45,000	13,500,000
Samphire (zeekraal) ¼ (1059,5 ha)	Total 50% 4238 ha	18,000	19,071,000
Lamsoor/zeeaster (sea lavender) ¼ (1059,5 ha)		4,000	4,238,000
Sea kale (zeekool) ¼ (1059,5 ha)		37,000	39,201,500
Sea lettuce 1/8 (529.75 ha)		50,000	26,487,500
Beach beet (strandbiet) 1/8 (529.75 ha)		80,000	42,380,000

With an estimated 100,000 people living in the area and requiring the total amount of food according the Lancet diet (transitioned to 66% saline agriculture), the total demand is known (see table below).

Table 17. *Total food demand in kgs per produce type to feed everyone the Lancet diet*

Crop according lancet	Required #g/person (lancet)	Total kgs (Lancet) needed to be grown to feed all inhabitants of the area (estimated at 100,000 people
Fish	28	1,022,000
Eggs	13	474,500
Chicken/poultry	29	1,058,500
Red meat	14	511,000
Dairy	250	9,125,000
Fruit	200	7,300,000
Vegetables	300	10,950,000
Potatoes	50	1,825,000
Wholewheat	232	8,468,000
Sugar	31	1,131,500
Unsaturated oil	40	1,460,000
Saturated oil	12	438,000
Nuts	50	1,825,000
Legumes	75	2,737,500

The final quest is to match demand and produce. The current estimated yields are not yet completely in line with the required amounts of food that people in the area demand. Further research is necessary to finetune these results and to come to an outcome that provides a healthy sufficient diet for all north Groninger people using two-thirds saline produce.

Table 18. *Matching of demand and produce, showing the gaps, surpluses and shortages in production per crop*

Crop	Total yield (kg) in our area	Required for all inhabitants (100k)	Surplus/shortage
Potato	44,041,830	1,825,000	+ 42,216,830
Sugar beet	14,204,820 (= 2,367,470kg sugar)	1,131,500	+ 1,235,970
Wheat + Barley	1,984,500 + 435,072 = 2,419,572	8,468,000	- 6,048,428
Milk (cows)	5,105,580.48	9,125,000	- 4,019,420
Grass	3,299,200	0	+ 3,299,200
Carrot	11,999,400	10,950,000 (all veg)	+ 1,049,400
Maize	502,758		
Lobster ¼ (425 ha)	21,250,000		
Langoustine ¼ (425 ha)	11,900,000		
Shrimp ¼ (425 ha)	10,625,000		
Prawn ¼ (425 ja)	11,050,000		
Fish	19,500,000,000	1,022,000	+ 19,499,078,000
Seaweed	58,500,000		
Algae	11,700,000		
Duckweed	13,500,000		
Samphire (zeekraal)	19,071,000		
Sea lavender (lamsoor)	4,238,000		
Sea kale (zeekool)	39,201,500		
Sea lettuce	26,487,500		
Beach beet (strandbiet)	42,380,000		
Eggs	-	474,500	
Chicken/poultry	-	1,058,500	
Red meat	-	511,000	
Fruit		7,300,000	
Unsaturated oil		1,460,000	
Saturated oil		438,000	
Nuts		1,825,000	
Legumes		2,737,500	

Figure 88. *Aquaculture in the Groninger landscape*

4.2.8 Linking Zernike with the City of Groningen.

The plan for Moeder Zernike establishes a wet lifeline for bringing sufficient water to grow all the food needed for the people living, working, and studying on the campus, as well as those living in the northern landscape. This physical connection links the landscape to the campus and vice versa. The connection with the (inner) urban of the City of Groningen is not seen as a physical one per se, but rather as a psychological connection. The spaceship Zernike, landed as a self-sufficient entity in the north Groningen landscape, engulfed by the saline waters of the Wadden Sea, is more an example for future copying than a spatial connection. The Moeder Zernike area is the leading and experimental example worth taking note of and using in every other entity of the City of Groningen, and beyond. This way, every part of the City can apply the way of thinking everywhere in its own way, guided by identical principles: restoring and rewilding nature, supplying its food growth with an endless source of external water, using all its currently available water within the area, growing its own food locally, integrating living, learning, and working, and growing inside, on top of and attached to buildings. This ReGenerative future will guide the lives of all inhabitants in the province of Groningen and will be seen internationally as the guiding way forward.

4.3 North-western European coastal zone.

Beyond the Groningen region, the design concept is suited to serve many other regions across the world. The Wadden Sea itself consists of many similar dynamic coastal flats, where mud is caught, and saline waters intrude the land, offering all the advantages designed in Moeder Zernike. The Hanze bekken, as it is called, is one of many, and could be easily copied along the entire north-western coastline, from the south of Denmark to the North Sea coast of the Netherlands and Flanders. Thinking a little bit bigger, there are ample opportunities for extending these approaches to the eastern UK coast, maybe even the southern Norwegian landscape and the entire Danish coastal zone. Furthermore, we can find similar coasts in the rest of the world where inlets are still intact, such as along the southern Australian and the southwestern Indian coast. With a quick look at the globe, we can find many opportunities to give nature the space it requires to provide a safe coastal zone for all the people currently living in the most vulnerable conditions.

Figure 89. *Natural mud catchers in the Wadden Sea area (Vos and Knol, 2015)*

The Dutch to Danish coast can be freed up and disconnected from its current stiff boundaries, which squeeze out all ecological liveability and expelling all human experience of dynamics, richness, and an impressive environment.

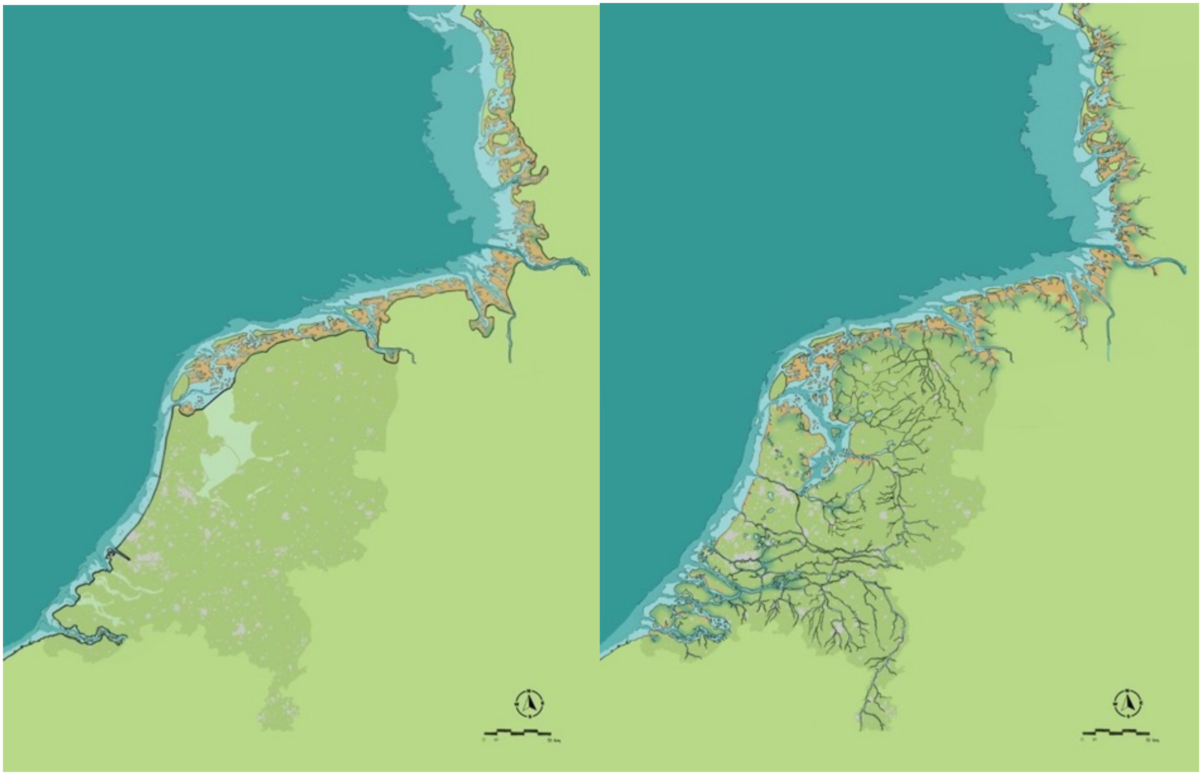


Figure 90. *From caught to freed up: bringing back resilience in the lowlands*

5.
ANALYSES.

Based on the landscape genesis, the question emerges of what the actual benefits would be of a transformation towards a more balanced, self-organising coastal system. Why would it make sense to (re)introduce a saline stream in the landscape? In this chapter, background analyses are presented that have been investigated as the basis behind the proposed plan for Moeder Zernike. Water, Food, Ecology, and Energy have all been extensively studied, without prejudice and with sometimes surprising outcomes. Taking these data as the point of departure for design has woken us up and shown us the way to unprecedented futures: a Moeder Zernike no-one could have apprehended before the start of the project. The data is presented as raw material, without extensive explanation, as most of it speaks for itself.

5.1 Water.

The need for water. Counterintuitively, the future Dutch landscape will have to face a water deficit. The analysis shows that, according to different climate scenarios of the KNMI, the cumulative rainwater availability on a yearly basis is 3500 Olympic swimming pools. This seems like quite a lot; however, it is not enough to meet the future agricultural demand. An additional water source is therefore needed to grow all the food that is consumed on campus. The infinite source of the sea is close by, no more than roughly 25km north of the campus, and is needed to compensate for the yearly deficit.

Table 19. *Month by month rainfall on Zernike in different climate scenarios for 2080*

Month	Campus Area	Liters	Cubic Meters	Olympic Swimming pools	Liters	Cubic Meters	Olympic Swimming pools	Liters	Cubic Meters	Olympic Swimming pools	Liters	Cubic Meters	Olympic Swimming pools	Liters	Cubic Meters	Olympic Swimming pools
Jan	25000000	1775000000	1775000	710	2018000000	2018000	807,2	1650750000	1650750	660,3	2342500000	2342500	937	1920000000	1920000	768
Feb	25000000	1000000000	1000000	400	1156250000	1156250	462,5	619500000	619500	247,8	1375000000	1375000	550	757500000	757500	303
Mar	25000000	975000000	975000	390	1157750000	1157750	463,1	2542000000	2542000	1016,8	1427500000	1427500	571	3020000000	3020000	1208
Apr	25000000	-325000000	-325000	-130	-243250000	-243250	-97,3	-674500000	-674500	-269,8	-335000000	-335000	-134	-755000000	-755000	-302
May	25000000	-600000000	-600000	-240	-498750000	-498750	-199,5	-1418750000	-1418750	-567,5	-629500000	-629500	-251,8	-1525500000	-1525500	-610,2
Jun	25000000	-275000000	-275000	-110	-116000000	-116000	-46,4	-374750000	-374750	-149,9	-263500000	-263500	-105,4	-515500000	-515500	-206,2
Jul	25000000	-350000000	-350000	-140	-665000000	-665000	-266	-2113750000	-2113750	-845,5	-1172000000	-1172000	-468,8	-2346250000	-2346250	-938,5
Aug	25000000	25000000	25000	10	-252750000	-252750	-101,1	-609000000	-609000	-243,6	-731250000	-731250	-292,5	-1020000000	-1020000	-408
Sep	25000000	850000000	850000	340	632500000	632500	253	2247500000	2247500	899	179500000	179500	71,8	1488500000	1488500	595,4
Oct	25000000	1375000000	1375000	550	1467750000	1467750	587,1	2186625000	2186625	874,65	1553500000	1553500	621,4	2309500000	2309500	923,8
Nov	25000000	1850000000	1850000	740	1971625000	1971625	788,65	1465750000	1465750	586,3	2077500000	2077500	831	1545500000	1545500	618,2
Dec	25000000	1900000000	1900000	760	2024125000	2024125	809,65	1385125000	1385125	554,05	2130500000	2130500	852,2	1458500000	1458500	583,4
			8200000	3280		8652250	3460,9		6906500	2762,6		7954750	3181,9		6337250	2534,9
		Current Climate (1981-2010)			2085 Wl scenario based on climate data (+3.5 degrees/no changes in currents)			2085 Wl Scenario based on 2019 weather (+3.5 degrees/no changes in currents)			2085 Wh Scenario based on climate data (+3.5 degrees, +changes in currents)			2085 Wh Scenario based on 2019 weather (+3.5 degrees, +changes in currents)		

Table 20. *Summary of the rainfall on Zernike calculated in Olympic swimming pools*

Month	Rain (In olympic swimming pool	Cumulative												
Jan	710	710		580	807,2		660,3	660,3		937	937		768	768
Feb	400	1110		210	1269,7		247,8	908,1		550	1487		303	1071
Mar	390	1500		880	1732,8		1016,8	1924,9		571	2058		1208	2279
Apr	-130	1370		-280	1635,5		-269,8	1655,1		-134	1924		-302	1977
May	-240	1130		-560	1436		-567,5	1087,6		-251,8	1672,2		-610,2	1366,8
Jun	-110	1020		-200	1389,6		-149,9	937,7		-105,4	1566,8		-206,2	1160,6
Jul	-140	880		-750	1123,6		-845,5	92,2		-468,8	1098		-938,5	222,1
Aug	10	890		-140	1022,5		-243,6	-151,4		-292,5	805,5		-408	-185,9
Sep	340	1230		1020	1275,5		899	747,6		71,8	877,3		595,4	409,5
Oct	550	1780		820	1862,6		874,65	1622,25		621,4	1498,7		923,8	1333,3
Nov	740	2520		550	2651,25		586,3	2208,55		831	2329,7		618,2	1951,5
Dec	760	3280		520	3460,9		554,05	2762,6		852,2	3181,9		583,4	2534,9
		3280			3460,9			2762,6			3181,9			2534,9
	Current Climate (1981-2010)			2085 Wl Scenario based on 2019 weather (+3.5 degrees/no changes in currents)			2085 Wl Scenario based on 2019 weather (+3.5 degrees/no changes in currents)			2085 Wh Scenario based on climate data (+3.5 degrees, +changes in currents)			2085 Wh Scenario based on 2019 weather (+3.5 degrees, +changes in currents)	

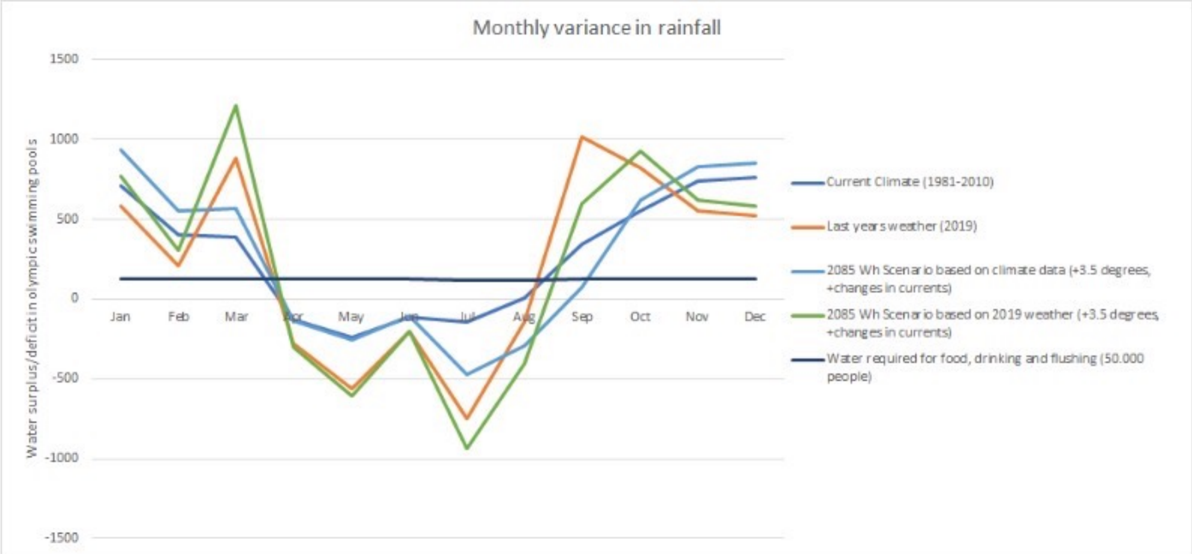


Figure 91. *Monthly variance in rainfall*

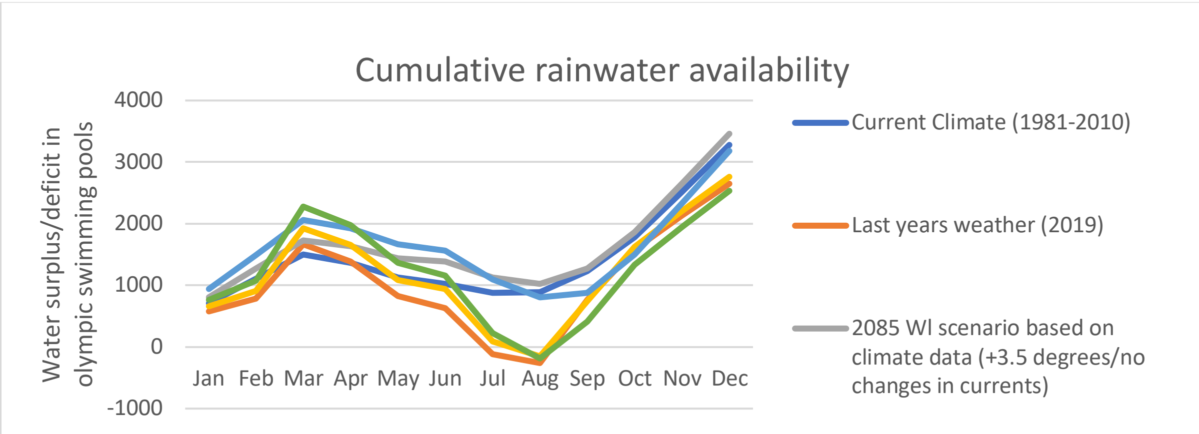


Figure 92. *Cumulative annual rainfall on campus*

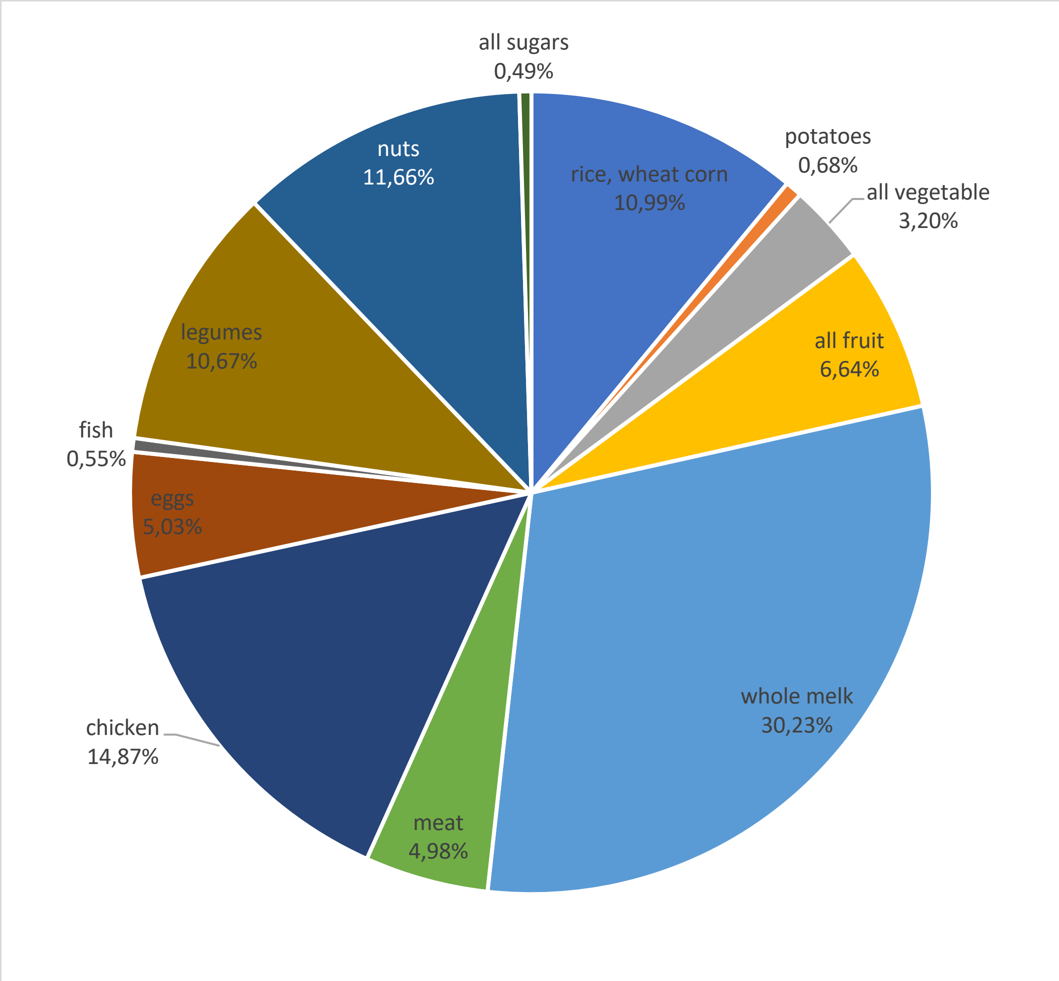


Figure 93. *Water requirements of crops and animal products (Lovarelli et al., 2016)*

Table 21. *Water requirement in litres per year (Lovarelli et al., 2016)*

Food type	water requirement (liter/year)
rice, wheat corn	382,752,720
potatoes	23,692,654
all vegetable	111,446,550
all fruit	231,1484,00
whole melk	1,052,548,200
meat	173,370,000
chicken	517,706,825
eggs	175,199,900
fish	19,261,666
legumes	371,487,600
nuts	405,994,670
all sugars	16,890,720
Total in Liters	3,481,499,905
Total in Olympic swimming pool (an Olympic pool= 2500000 Liters of water)	1393

5.2 Soil.

The soil in the landscape represents a toxic mix of increasing salinity, soil subsidence, and desiccation of the land, mutually exaggerating each other's impacts. When the soil subsides, the influence of seepage from the sea increases, which gains even more influence when the land dries out as result of climatic droughts. The impact of this process for traditional agriculture in the area (potato and sugar beet cropping, as well as grassland) is devastating and makes it difficult for these farming types to stay economically viable. Bringing saline seawater into the area seems to be counterintuitive, however, it will compensate for the subsidence of the soil as new sediments are brought in and could imply a transition to saline cropping and seafood-farming. Every disadvantage has its advantage.

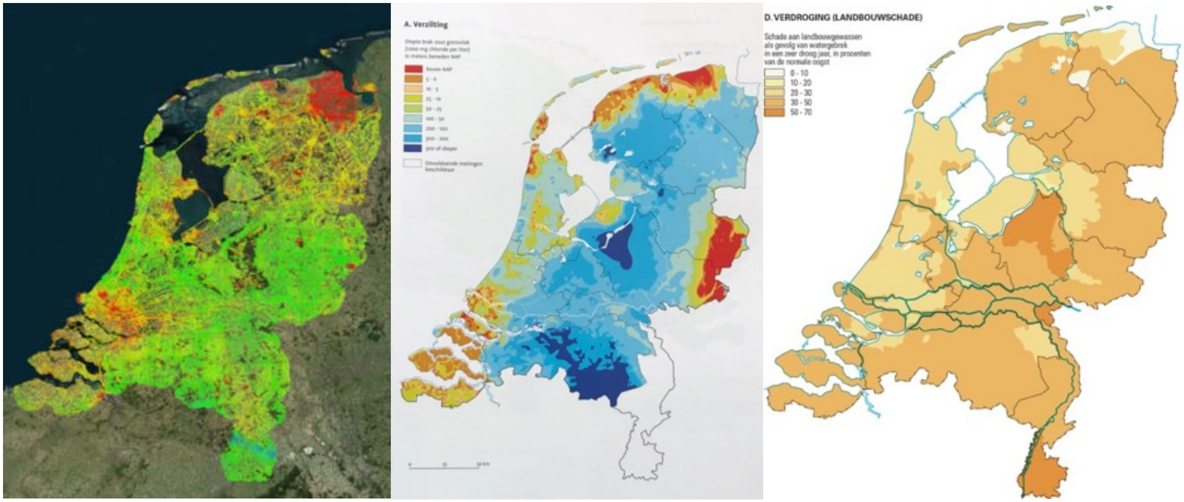


Figure 94. *Soil subsidence, salinity, and agricultural loss as result of desiccation of the Dutch soil*

5.3 Food.

The EAT-research (Willett et al., 2019), which mitigates climate emergencies such as the rise of sea levels, carbon emissions, and intense salinity, manages extreme surpluses and shortages of water and generates a renewable energy supply, hence keeping life on Earth within the planetary boundaries. It also implies a fundamental change in the diet for its planetary citizens. The amounts of food per category have been recalculated for the Dutch context, and are used to calculate the required food to be grown locally for consumption of all food on campus.

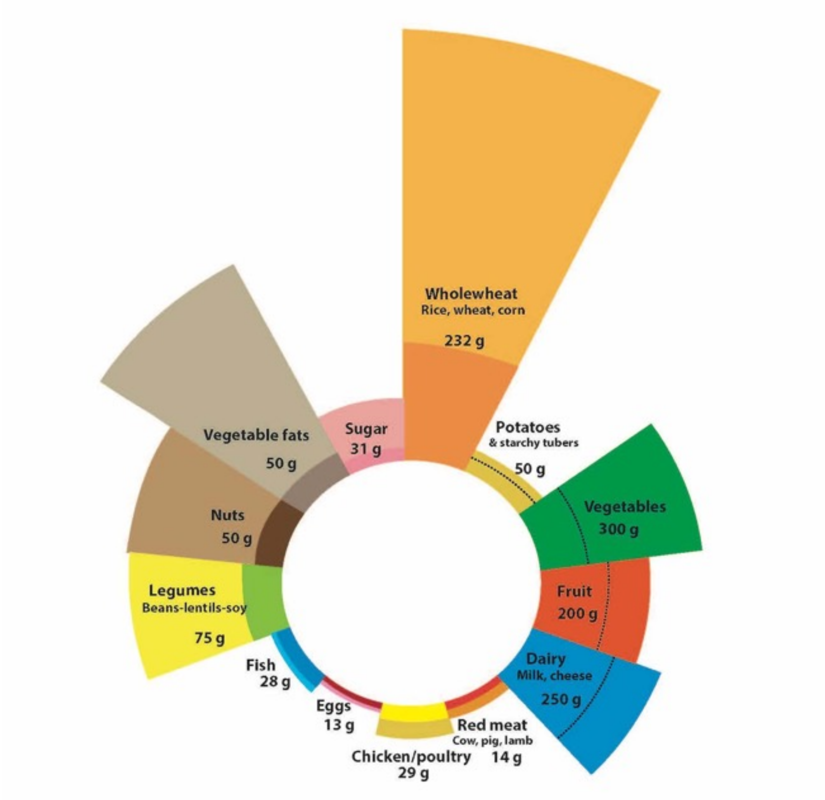


Figure 95. *Amounts of food for a healthy diet, recalculated for the Dutch context*

5.3.1 Food on Zernike.

In the urban precinct of Moeder Zernike, as it emerges, the question is: how much space for the growth of food and a new mix of uses can each building and the public space provide? For every building, the analysis has been undertaken to determine what a suitable future mix of use would be. A combination of studying and learning, working, living, and cropping is set for every building, depending the construction, spatial flexibility, energy, and water infrastructure of each category of buildings. This quantitative analysis gave the sqm-program as the input for redesigning the current buildings on campus. At campus, building and internal level, functionalities are mixed as suited. Within every building the energy provision, water purification, and growth of food is circular and reciprocal. The adjustments to buildings are carried out by reusing building materials, such as concrete, wood, glass, brick, etc. These materials are sourced from the Groningen environment, are biodegradable, or locally grown. In the public space, the 'hard' infrastructure is reduced to the ultimate minimal, or is absent. Spaces for pedestrians and bicycles is increased, while the dominance of cars is reduced or made redundant.

How much food do we need to produce for all consumers on campus and how much space does this require? The amounts of food per person, according the Lancet diet, is combined with the number of meals different people are expected to consume on campus. This is different for students (mainly lunches) than for residents (mainly breakfast and dinner).

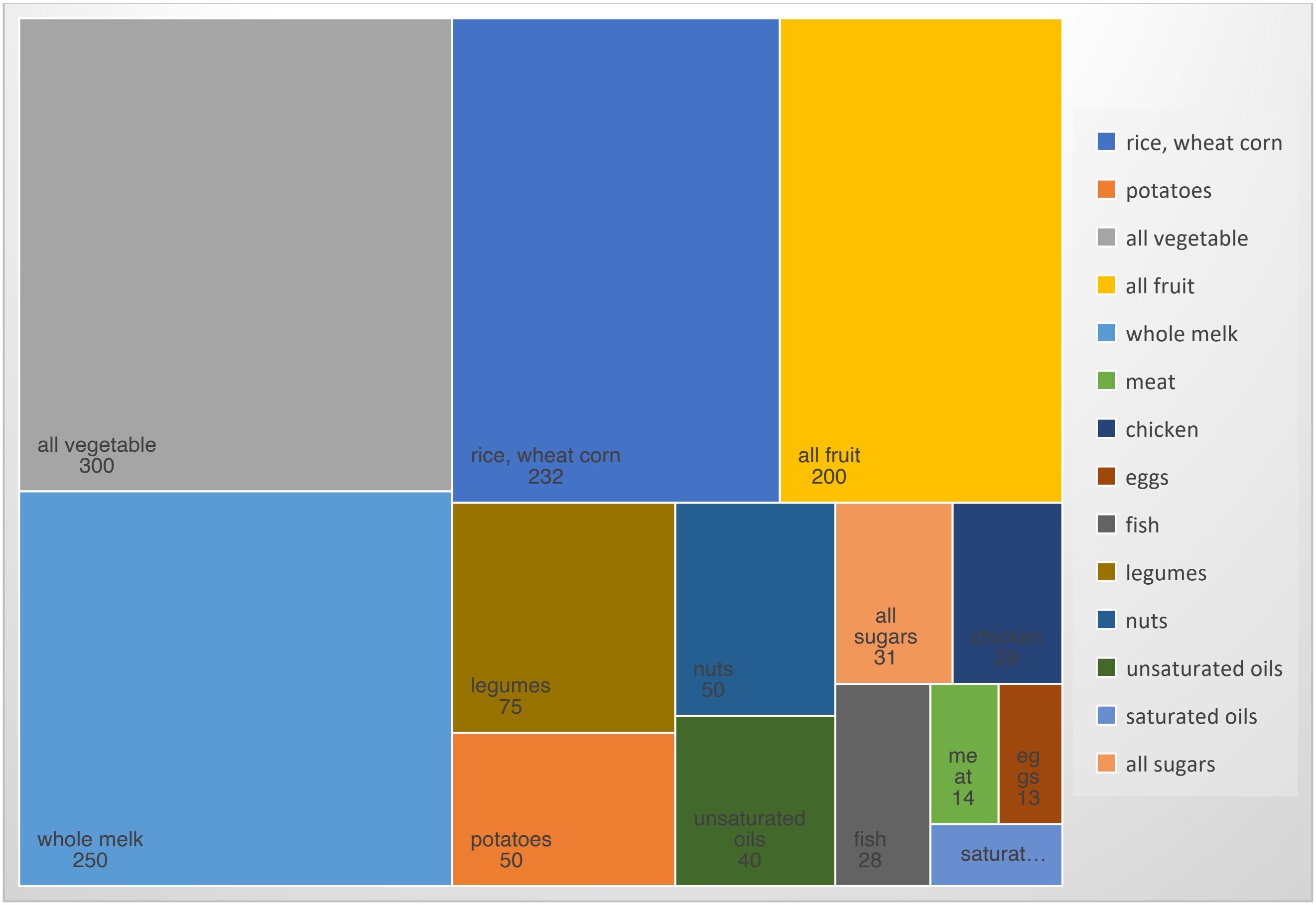


Figure 95. *Amount of food (g) needed per person/day, according to Lancet diet Willett et al., 2019)*

Assuming that we have approximately 30,000 students and staff on campus, and that an estimated 10,000 additional people will in future reside on campus, a detailed calculation has been made for the total amount of food needed to be consumed every day by people living or spending time on campus, taking into account holiday periods. The total amount is almost 5.5 million kgs per year.

Table 22. *Number of people on campus*

students	30000
residents	10000
Total	40000

Table 23. *Estimated portion of the total consumption for breakfast, lunch and dinner*

	percentage of the total amount of food, per person (3 meals)	portion per meal/ person/gram
Breakfast	20%	264,8
Lunch	35%	463,4
Dinner	45%	595,8
Total	100%	1324

Table 24. *Time spent on campus for different categories of people*

	days
students and residents are present at campus	working days 168
residents only present at campus	130 working days + 52 weekend days
No one present at campus	days 15

Table 25. *Who eats what during working days*

	presence percentage for 168 days	
meals	students	residents
Breakfast	5%	95%
Lunch	85%	10%
Dinner	5%	95%

Table 26. *Who eats what during holidays*

	presence percentage for 130 days	
meals	students	residents
Breakfast	0	95%
Lunch	0	10%
Dinner	0	95%

Table 27. *Who eats what during the weekends*

	presence percentage for 52 days	
meals	students	residents
Breakfast	0%	100%
Lunch	0%	100%
Dinner	0%	100%

Table 28. *Amount of food (in kg) necessary per year on campus*

food/EAT-Lancet diet	Gram per person/day	Kg per 40,000 people/year. Before applying the assumptions	Kgs of food needed for production per year. After applying all the assumptions
rice, wheat corn	232	3,387,200	957615
potatoes	50	730,000	206383
all vegetable	300	4,380,000	1238295
all fruit	200	2,920,000	825530
whole melk	250	3,650,000	1031913
meat	14	204,400	57787
chicken	29	423,400	119702
eggs	13	189,800	53659
fish	28	408,800	115574
legumes	75	1,095,000	309574
nuts	50	730,000	206383
unsaturated oils	40	584,000	165106
saturated oils	12	175,200	49532
all sugars	31	452,600	127957
Total amount of food, per person (3 meals)	1324	19,330,400	5,465,009

The space needed to grow these crops (again the distribution of food categories according the Lancet diet), has also been calculated and is almost 100,000 m^2.

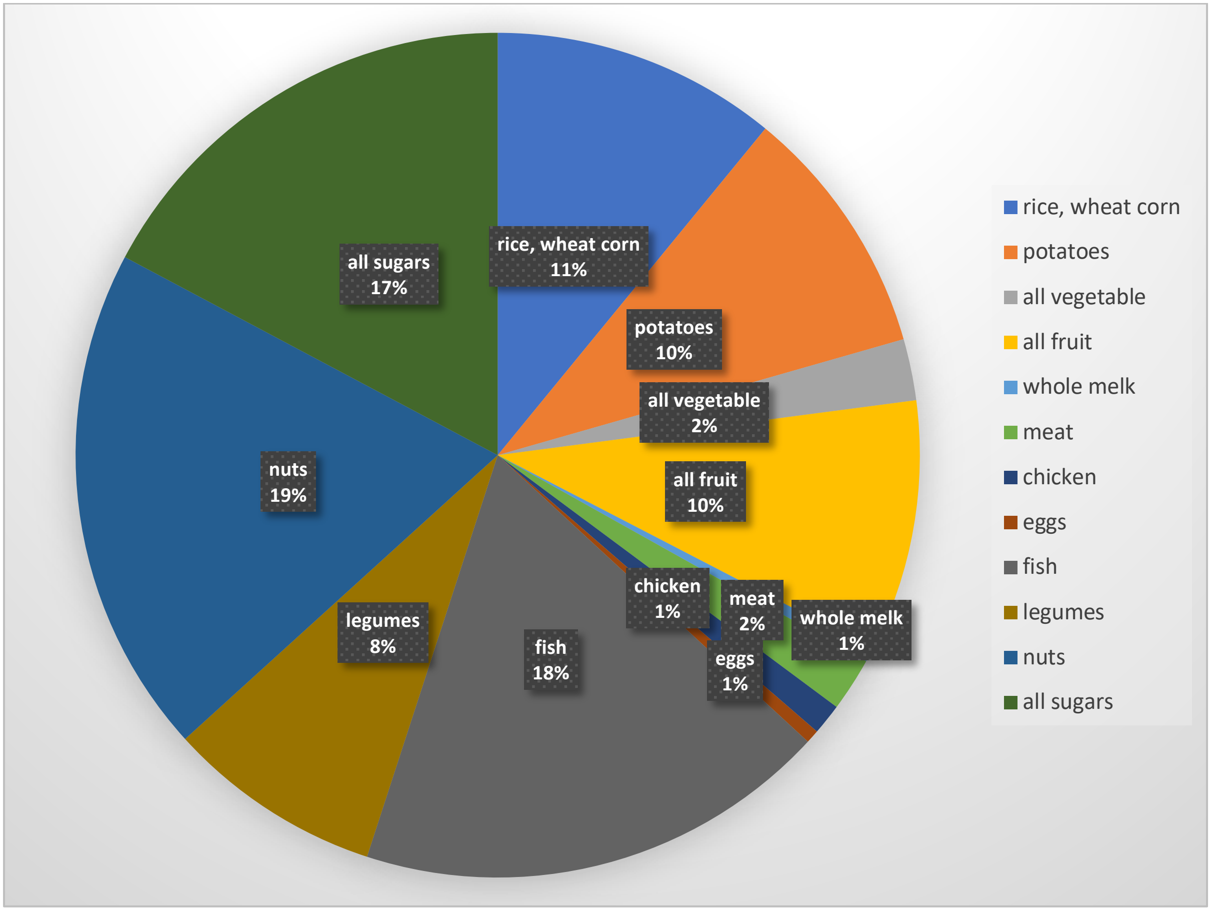


Figure 96. *Area needed to grow crops, in percentages*

Table 29. *Area needed for specific produce*

Food/animal	Area needed (m^2)
rice, wheat corn	10653
potatoes	9396
all vegetable	2289
all fruit	9432
whole milk	500
meat	2000
chicken	1155
eggs	500
fish	17683
legumes	8049
nuts	19000
all sugars	16792
Total area needed	97449

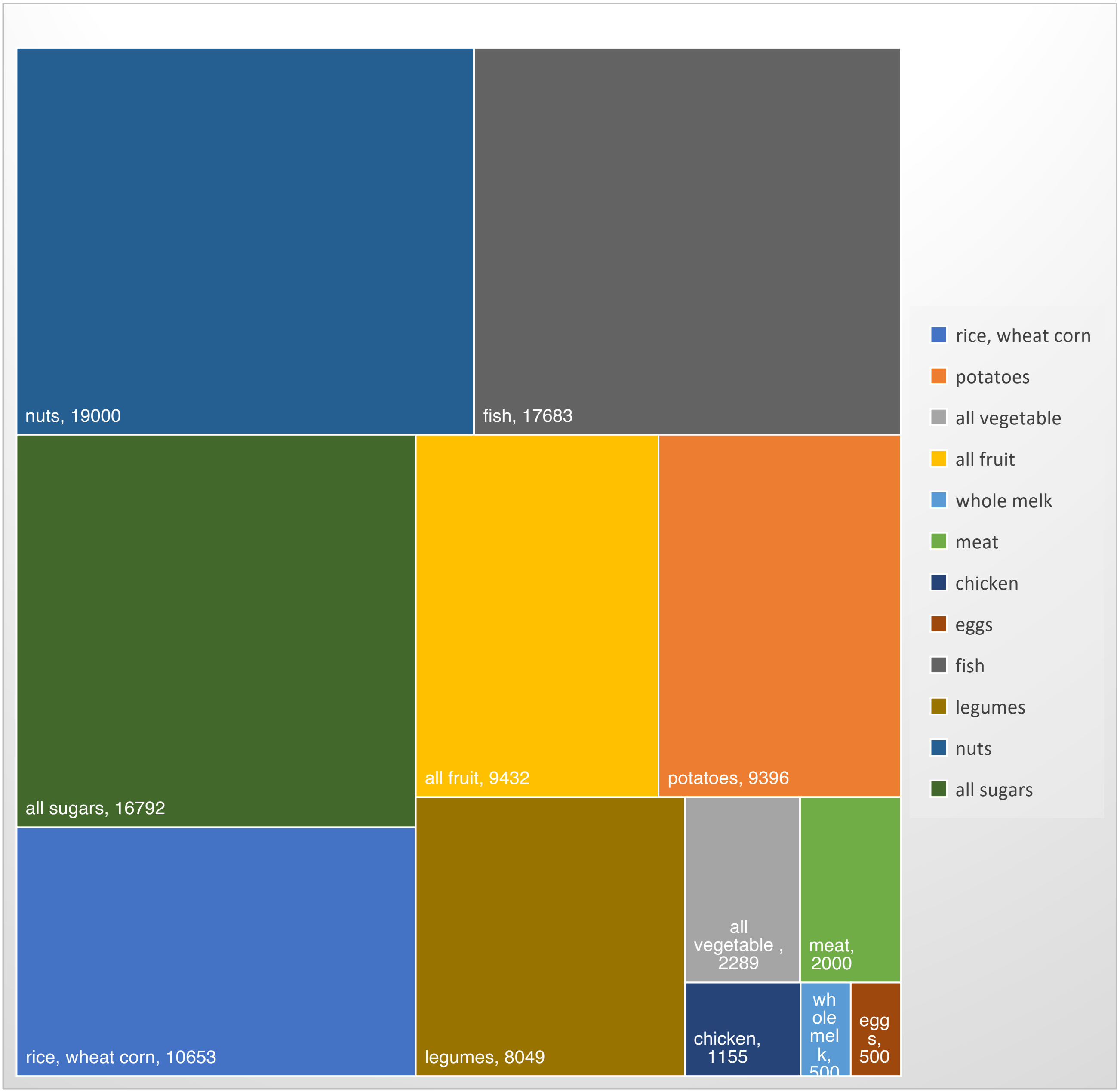


Figure 97. *Area needed to produce food in m²*

How much space is available in, on top of, attached to, or in between buildings on campus? The required area is limited, using novel technologies that are highly productive and have multiple harvests per year, such as aqua- and aeroponic systems, which can be implemented inside current buildings, on rooftops, or clinging to facades of campus buildings. An inventory of the current buildings on campus has been made, and for every building the current area has been calculated (floor space, number of storeys, roof area). Every building has been subsequently analysed for its potential for mixed use (% office, teaching, residential, and growth of food).

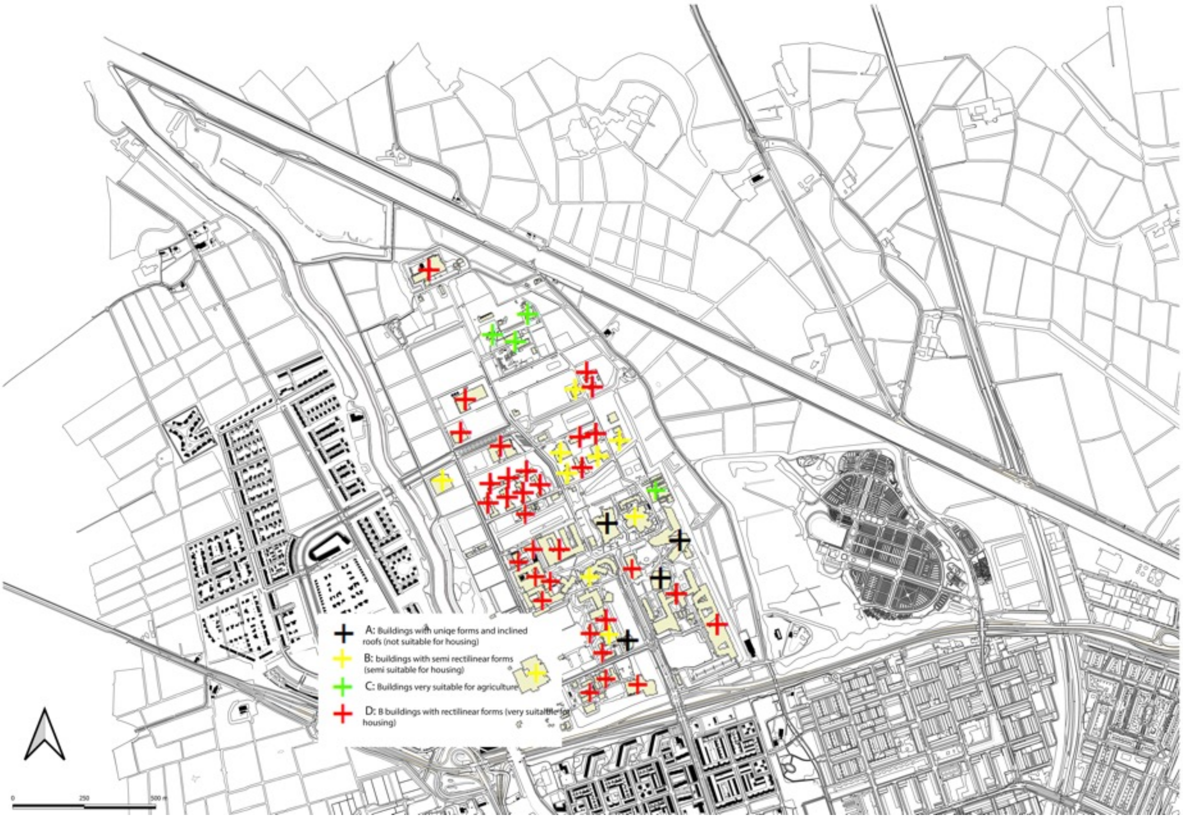


Figure 98. *Typology of current buildings on campus*

Table 30. *Calculation of space use in each building and potential use in 2121*

		2020								2120				
	building name	Building type	office function 2020 (%)	education function 2020 (%)	floor area	storeys	total sqm (closed space)	roof available for agriculture	south facade	office function 2120 (sqm)	education function 2120 (sqm)	housing function 2120 (sqm)	agriculture function (indoor) 2120 (sqm)	housing capacity (25 sqm/person)
5	Linnaeusborg	A	0	100	10425,9	5	52129,5	0		10425,9	20851,8	5212,95	15638,85	209
40	Willem Alexander Sports Centre	A	0	100	6723	2,25	15126,75	0		3025,35	6050,7	1512,675	4538,025	61
45	Energy Academy Europe	A	50	50	4030	3	12090	0		2418	4836	1209	3627	48
50	Smitsborg	A	0	100	1186	3	3558	0		711,6	1423,2	355,8	1067,4	14
4	Van Swinderen B	B	0	100	6000	2	12000	6000		1800	5400	3600	1200	144
11	Media products	B	100	0	999,2	1	999,2	999,2		149,88	449,64	299,76	99,92	12
15	Polygenics	B	100	0	3619,5	2	7239	3619,5		1085,85	3257,55	2171,7	723,9	87
22	LODE	B	100	0	2510	2	5020	2510		753	2259	1506	502	60
23	Ohm Audio	B	100	0	538	1	538	538		80,7	242,1	161,4	53,8	6
26	Synspec	B	100	0	847,5	2	1695	847,5		254,25	762,75	508,5	169,5	20
27	CLiQ SwissTech	B	100	0	2717	1	2717	2717		407,55	1222,65	815,1	271,7	33
29	Staff Desk Human Resources	B	0	100	731	2	1462	731		219,3	657,9	438,6	146,2	18
30	DEMCON	B	100	0	441,7	3	1325,1	441,7		198,765	596,295	397,53	132,51	16
41	Marie Kamphuisborg	B	0	100	7304	3	21912	7304		3286,8	9860,4	6573,6	2191,2	263
43	Brugsmaborg	B	0	100	7637,91	3	22913,73	7637,91		3437,0595	10311,1785	6874,119	2291,373	275
47	Library 2	B	0	100	2257	1,5	3385,5	2257		507,825	1523,475	1015,65	338,55	41
51	Sports Centre ACLO	B	0	100	9684,25	1,5	14526,375	9684,25		2178,95625	6536,86875	4357,9125	1452,6375	174
8	BUildinG	C	40	60	1317	2	2634	0		526,8	790,2	263,4	1053,6	11

9	the Energy Barn	C	0	100	674	1,50	1011	0		202,2	303,3	101,1	404,4	4
10	EnTranCe	C	0	100	1852,44	2	3704,88	1852,44		740,976	1111,464	370,488	1481,952	15
42	Experiment areas/greenhouses	C	0	100	4489	1	4489	4489		897,8	1346,7	448,9	1795,6	18
1	zp11	D	0	100	10792	3	32376	10792		1618,8	6475,2	19425,6	4856,4	777
2	Library Zernike	D	0	100	1800	10	18000	1800		900	3600	10800	2700	432
3	Van Swinderen A	D	0	100	8698	4	34792	8698		1739,6	6958,4	20875,2	5218,8	835
6	KVI	D	0	100	4890	3	14670	4890		733,5	2934	8802	2200,5	352
7	QTS data centres	D	100	0	5571,43	3	16714,29	5571,43		835,7145	3342,858	10028,574	2507,1435	401
12	Adviesburo Vanderplas	D	100	0	364,7	3	1094,1	364,7		54,705	218,82	656,46	164,115	26
13	CJ2 Hosting B.V.	D	100	0	365,7	2	731,4	365,7		36,57	146,28	438,84	109,71	18
14	Bytesnet	D	100	0	1647,47	3	4942,41	1647,47		247,1205	988,482	2965,446	741,3615	119
16	AVEBE Innovation Centre	D	100	0	3725	3	11175	0		558,75	2235	6705	1676,25	268
17	Polyvation	D	100	0	1250	3	3750	1250		187,5	750	2250	562,5	90
18	Transcom	D	100	0	1250	3	3750	1250		187,5	750	2250	562,5	90
19	Syncom	D	100	0	1250	3	3750	1250		187,5	750	2250	562,5	90
20	Transcom 2	D	100	0	1250	3	3750	1250		187,5	750	2250	562,5	90
21	Biblionet telesis	D	100	0	1950	3	5850	1950		292,5	1170	3510	877,5	140
24	HNK Groningen	D	100	0	1260	3	3780	1260		189	756	2268	567	91
25	Digital Society Hub	D	100	0	613	3	1839	613		91,95	367,8	1103,4	275,85	44
28	Brasserie Zernike	D	100	0	1364,5	2	2729	1364,5		136,45	545,8	1637,4	409,35	65
31	Start-up city	D	100	0	1448	2	2896	1448		144,8	579,2	1737,6	434,4	70
32	H building	D	0	100	762	2	1524	762		76,2	304,8	914,4	228,6	37
33	U building	D	0	100	1351	3	4053	1351		202,65	810,6	2431,8	607,95	97
34	green building	D	0	100	602	10	6020	602		301	1204	3612	903	144
35	green building_horizontal	D	0	100	2251	4	9004	2251		450,2	1800,8	5402,4	1350,6	216

36	green building_horizontal2	D	0	100	5536	3	16608	5536		830,4	3321,6	9964,8	2491,2	399
37	green building_onefloor1	D	0	100	489	1	489	489		24,45	97,8	293,4	73,35	12
38	green building_onefloor2	D	0	100	1150	1	1150	1150		57,5	230	690	172,5	28
39	green building_red	D	0	100	680	3	2040	680		102	408	1224	306	49
44	Bernoulliborg	D	0	100	2849	5,5	15669,5	2849		783,475	3133,9	9401,7	2350,425	376
46	Feringa Building	D	0	100	14182,18	6	85093,08	14182,18		4254,654	17018,616	51055,848	12763,962	2042
48	Faculty of Spatial Sciences	D	0	100	1347	4	5388	1347		269,4	1077,6	3232,8	808,2	129
49	3-aa	D	0	100	861,93	2	1723,86	861,93		86,193	344,772	1034,316	258,579	41
52	Exam Hall/Aletta Jacobs Hall	D	0	100	5166,8	2	10333,6	5166,8		516,68	2066,72	6200,16	1550,04	248
53	Facility Building	D	0	100	5446	1,5	8169	5446		408,45	1633,8	4901,4	1225,35	196
54	sum				168148,11	0	524330,275	140067,21		50001,27375	146564,0193	238506,7285	89258,2535	9540
55														
56												resource		
	type A: buildings with unique forms and inclined roofs (not suitable for housing)			20% office, 40% education, 10% housing, 30% agriculture										
	Type B: buildings with semi rectilinear forms (semi suitable for housing)			15% office, 45% education, 30% housing, 10% agriculture										
	type C: Buildings very suitable for agriculture (indoor)			20% office, 30% education, 10% housing, 40% agriculture										
	type D: buildings with rectilinear forms (very suitable for housing)			5% office, 20% education, 60% housing, 15% agriculture										

5.3.2 Food in the landscape.

Current agricultural crops and related income levels

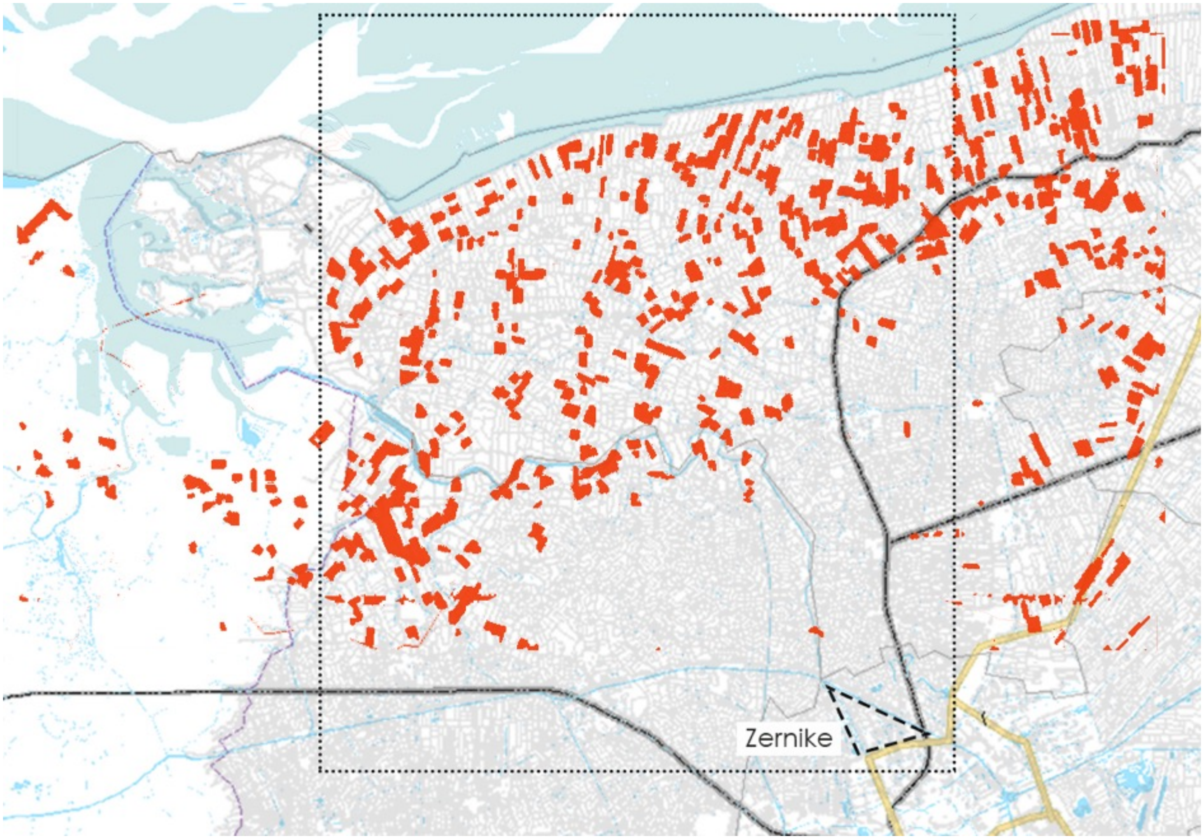


Figure 99. *Wheat (Copernicus Sentinel Data, 2018)*

Table 31. *Wheat*

Wheat	
Average area per field	9,6 ha
Annual yield	8,82 tonne/ha
Annual production	84,7 tonnes
Subsidy	425 Euro//ha
Price per tonne	190 Euro
Value of production	16.087 Euro
Total subsidy/year	4080 Euro
Total income/year	20.168ro

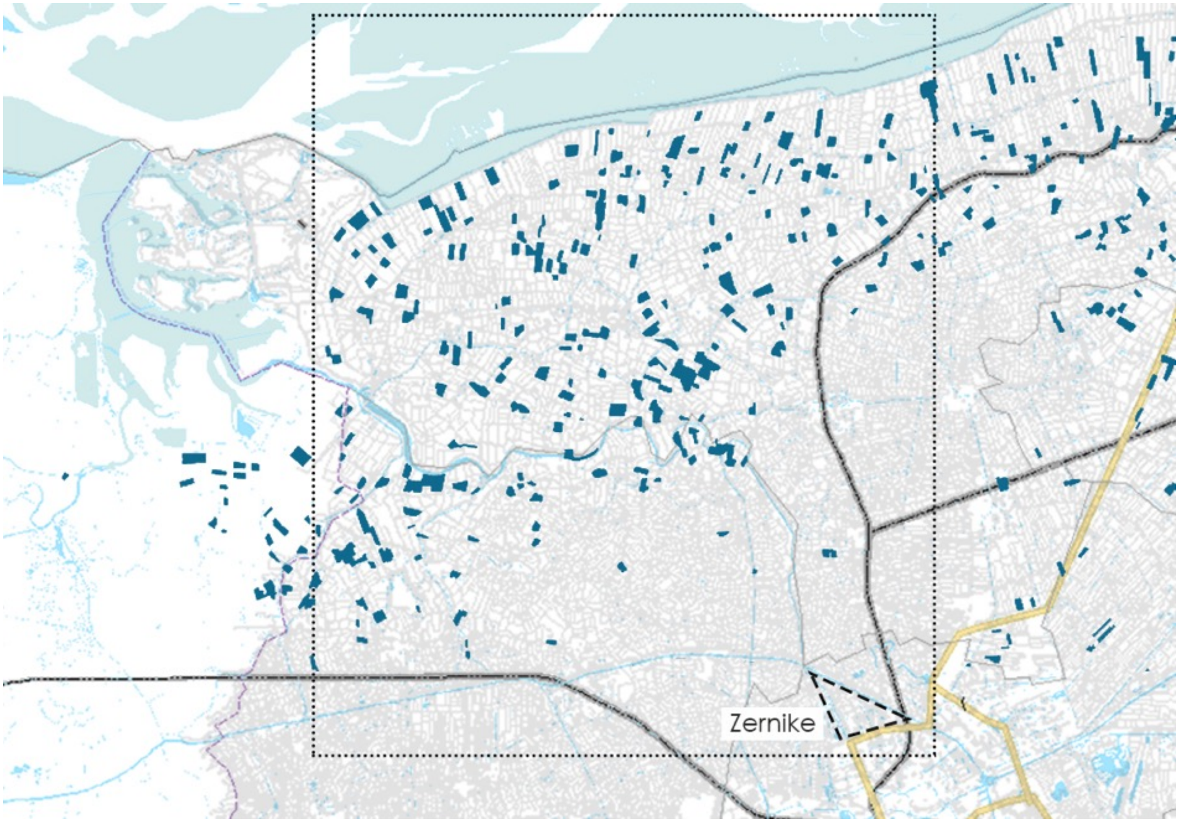


Figure 100. *Barley (Copernicus Sentinel Data, 2018)*

Table 32. *Barley*

Barley	
Average area per field	6,4 ha
Annual yield	7,04 tonne/ha
Annual production	45.056 tonnes
Subsidy	425 Euro//ha
Price per tonne	190 Euro
Value of production	8361 Euro
Total subsidy/year	2720 Euro
Total income/year	11.281ro

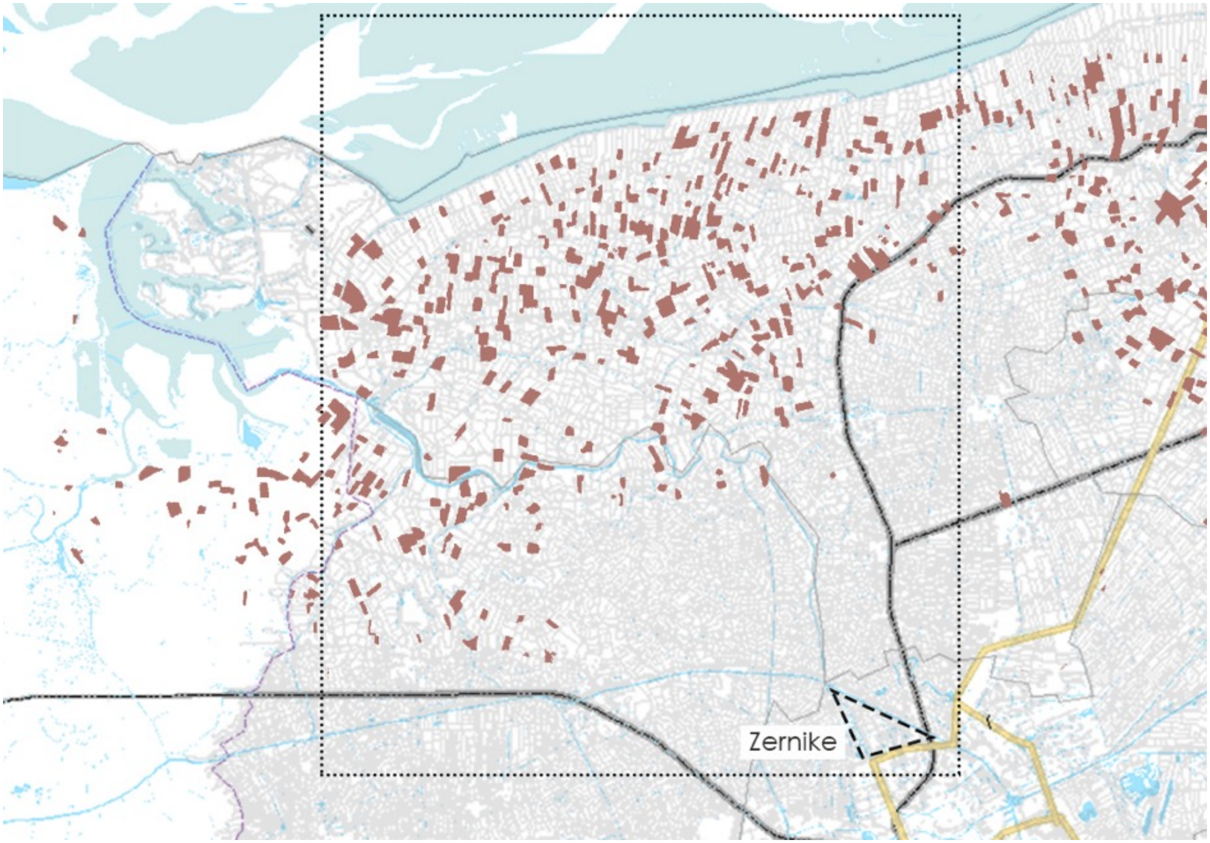


Figure 101. *Potato (Copernicus Sentinel Data, 2018)*

Table 33. *Potato*

Potato	
Average area per field	8,0 ha
Annual yield	36,61 tonne/ha
Annual production	292,88 tonnes
Subsidy	425 Euro//ha
Price per tonne	220 Euro
Value of production	64.434 Euro
Total subsidy/year	3400 Euro
Total income/year	67.834ro

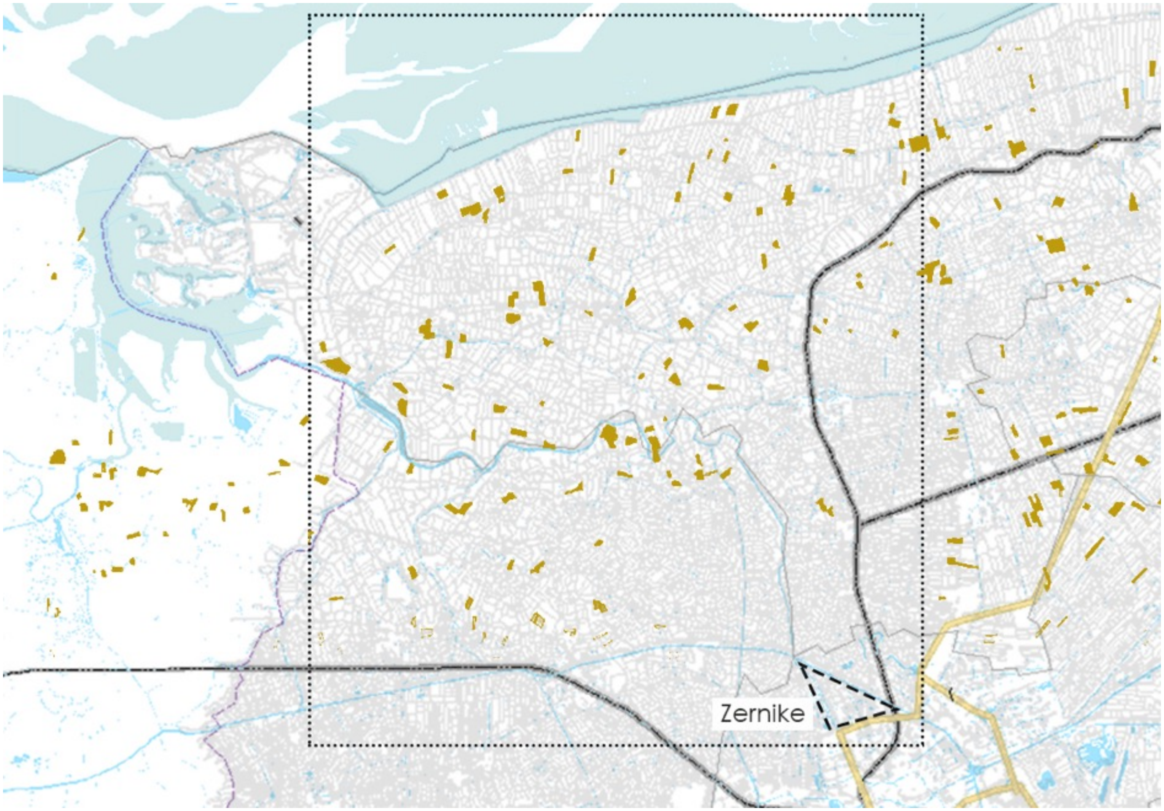


Figure 102. *Corn (Copernicus Sentinel Data, 2018)*

Table 34. *Corn*

Corn	
Average area per field	5,9 ha
Annual yield	9,01 tonne/ha
Annual production	53,159 tonnes
Subsidy	425 Euro//ha
Price per tonne	160 Euro
Value of production	8505 Euro
Total subsidy/year	2508 Euro
Total income/year	11.13 ro

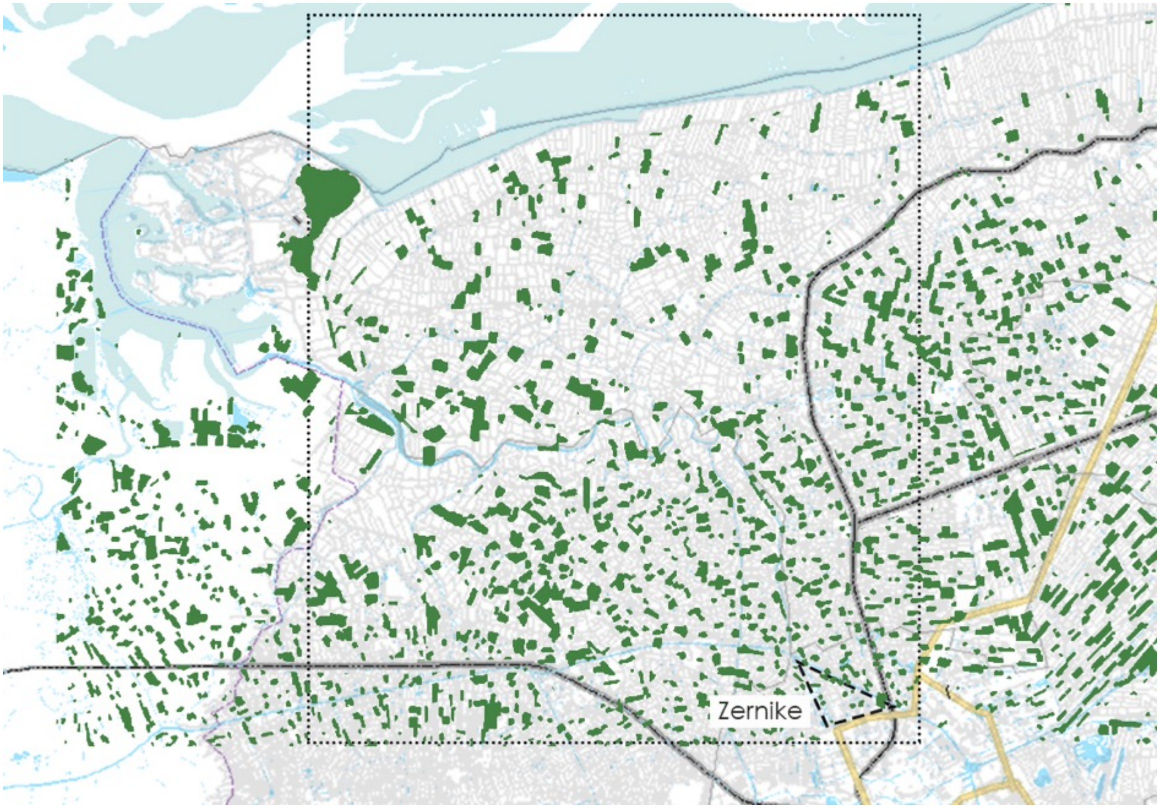


Figure 103. Grassland *(Copernicus Sentinel Data, 2018)*

Table 35. *Grassland*

Grassland	
Average area per field	3,2 ha
Annual yield	10,8 tonne/ha
Annual production	34,56 tonnes
Subsidy	425 Euro//ha
Price per tonne	195 Euro
Value of production	16739 Euro
Total subsidy/year	1360 Euro
Total income/year	8099 Euro

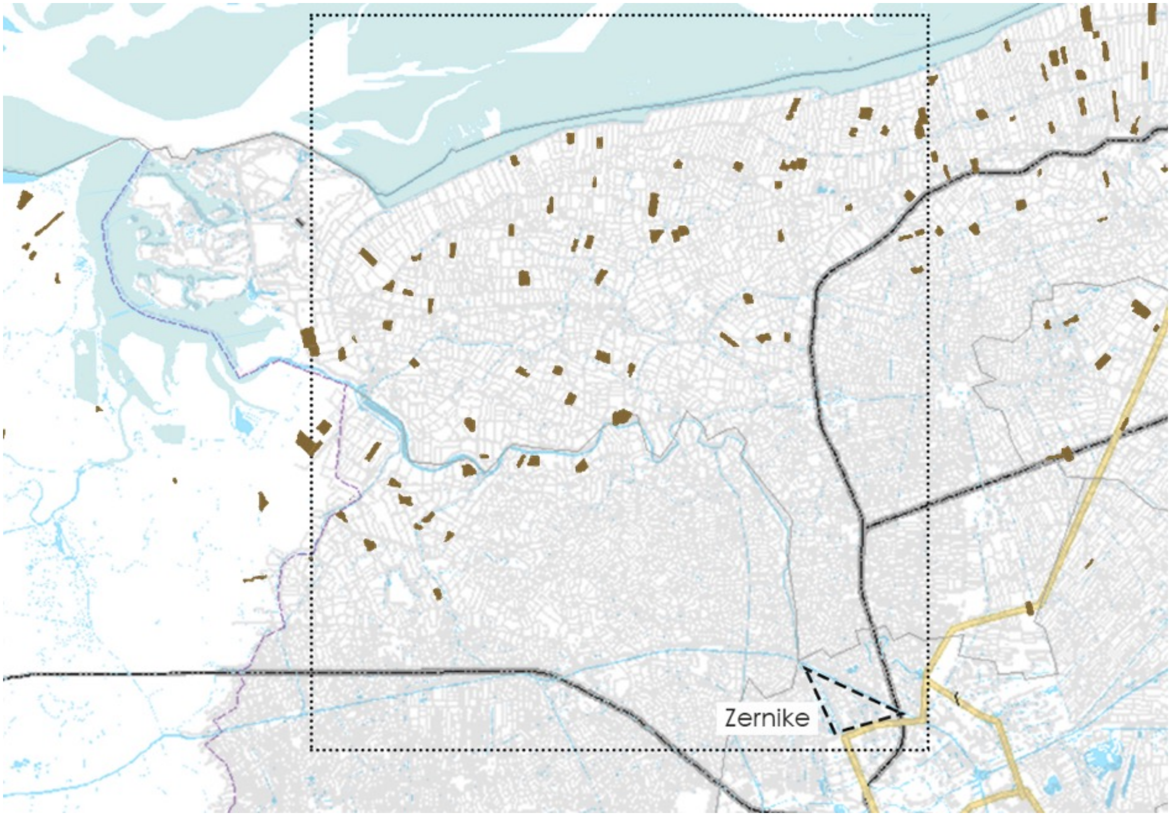


Figure 104. *Sugar beet (Copernicus Sentinel Data, 2018)*

Table 36. *Sugar beet*

Sugar beet	
Average area per field	8,7 ha
Annual yield	76,37 tonne/ha
Annual production	665 tonnes
Subsidy	425 Euro//ha
Price per tonne	40 Euro
Value of production	26.577 Euro
Total subsidy/year	3698 Euro
Total income/year	30.274 Euro

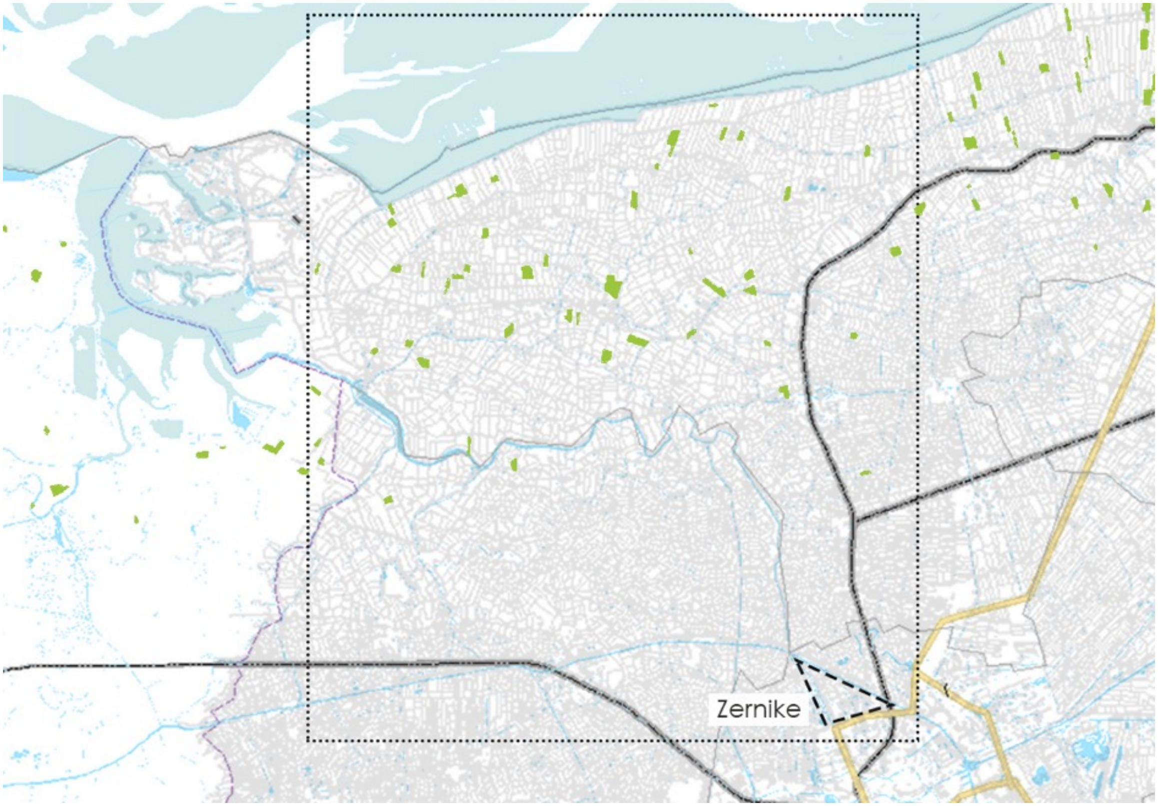


Figure 105. *Carrot (Copernicus Sentinel Data, 2018)*

Table 37. *Carrot*

Carrot	
Average area per field	6,8 ha
Annual yield	57,14 tonne/ha
Annual production	389 tonnes
Subsidy	425 Euro//ha
Price per tonne	34 Euro
Value of production	13.211 Euro
Total subsidy/year	2890 Euro
Total income/year	16.101 Euro

Table 37. *Income per crop type (Copernicus Sentinel Data, 2018; Van der Meulen, 2020)*

Crop/animal	Average area of a field or farm /ha	Total value of production/ Euro	subsidy/Euro	Total income. Euro/year
Wheat	9,6	16088	4080	20168
Barley	6,4	8561	2720	11281
Potatoes	8	64434	3400	67834
Maize	5,9	8505	2508	11013
Grass	3,2	6739	1360	8099
Sugar beet	8,7	26577	3698	30274
Vegetables (Carrots)	6,8	13211	2890	16101
Beef	51	73806	24250	44056
Milk Cow	47	300314	21405	43720
Goat	7	142651	3416	46566
Pig	9	397207	3402	256609
Chicken	6	23378	3400	15778
Sheep	8	15108	6824	15433

The saline transition

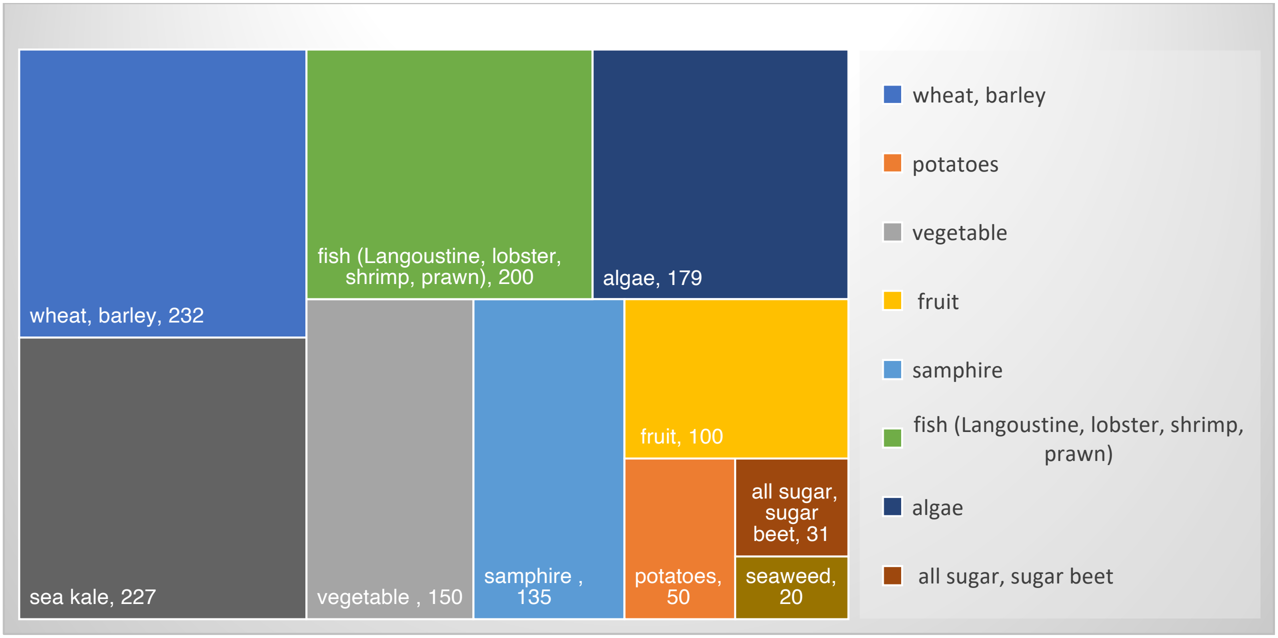


Figure 106. *Amount of food (g) needed per person/day, according to 66% transformation to saline tolerant crops*

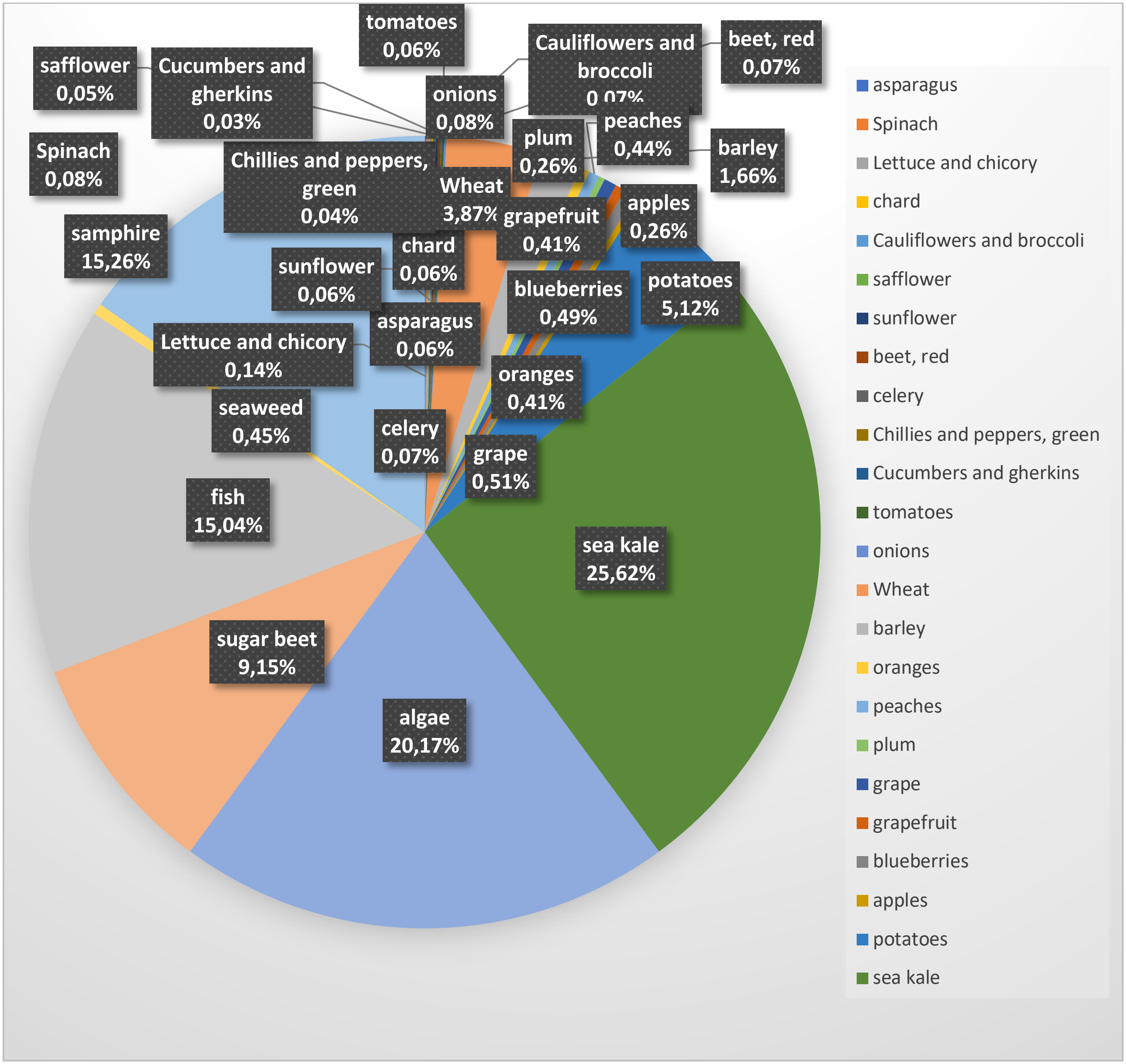


Figure 107. *66% transition to saline: distribution of crop types and products*

Table 38. *Area needed to grow crops under 66% tolerant saline crops (per m2/year)*

crop	area needed for the (66%) m2/year
asparagus	115
Spinach	150
Lettuce and chicory	250
chard	115
Cauliflowers and broccoli	126
safflower	100
sunflower	104
beet, red	125
celery	135
Chilies and peppers, green	75
Cucumbers and gherkins	57
tomatoes	115
onions	149
Wheat	7102
barley	3050
oranges	750
peaches	800
plum	472
grape	943
grapefruit	750
blueberries	896
apples	472
potatoes	9396
sea kale	47000
algae	37000
sugar beet	16792
fish	27600
seaweed	827
samphire	28000
total	183464

Prices of sea food/saline crops

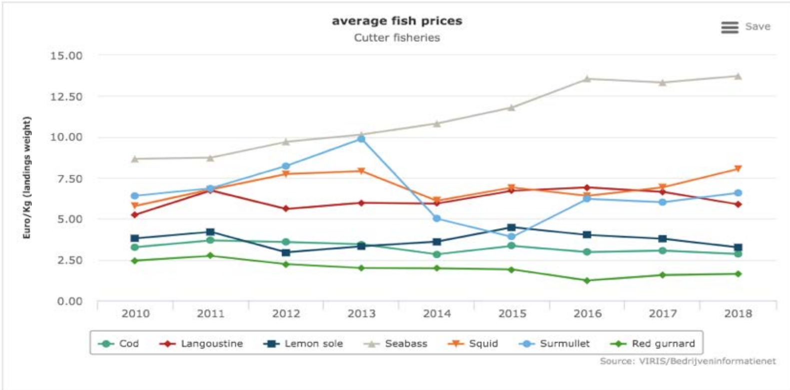


Figure 108. *Average fish price (VIRIS-Bedrijveninformatienet)*

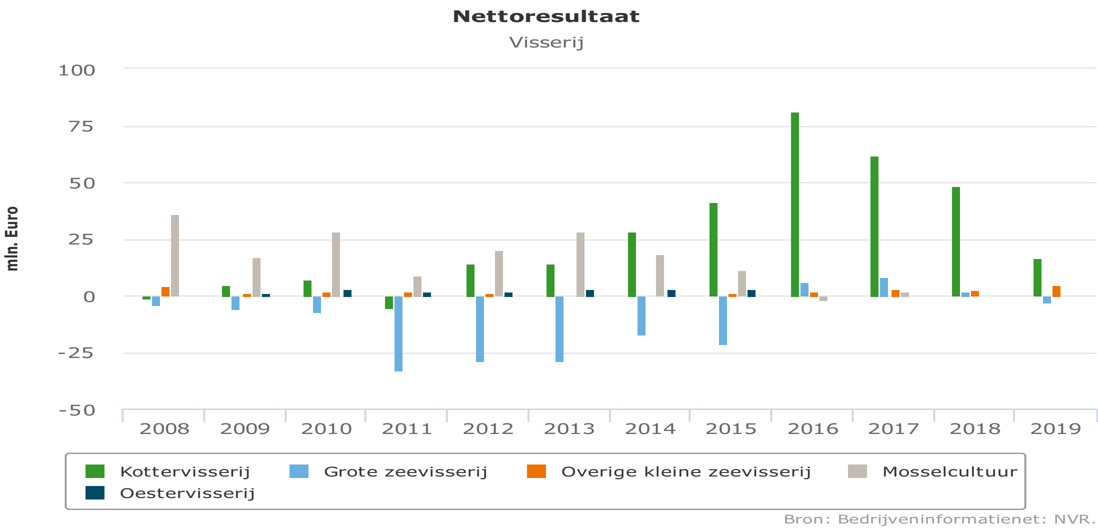


Figure 109. *Net result fisheries (Bedrijveninformatienet: NVR)*

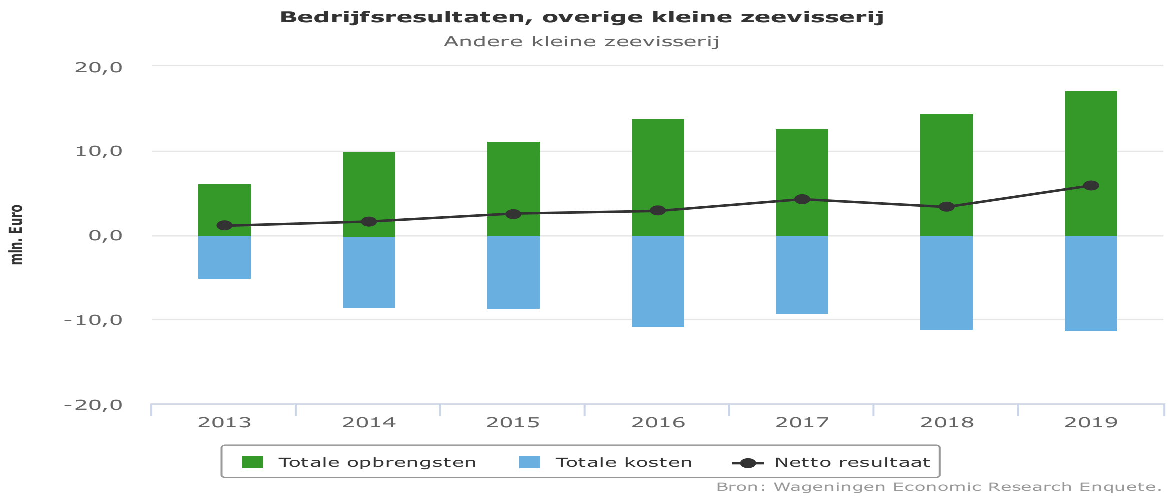


Figure 110. *Result small fisheries (Wageningen Economic Research Enquete)*

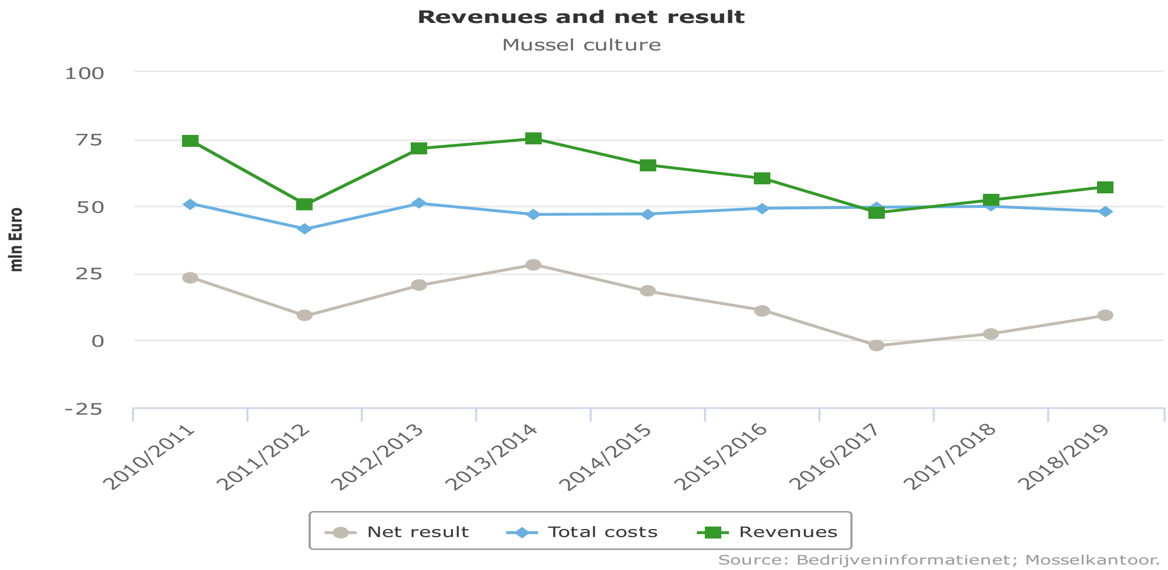


Figure 111. *Revenue and net result mussels (Bedrijveninformatienet: Mosselkantoor)*

Figure 112. *Average price mussels (Bedrijveninformatienet: Mosselkantoor)*

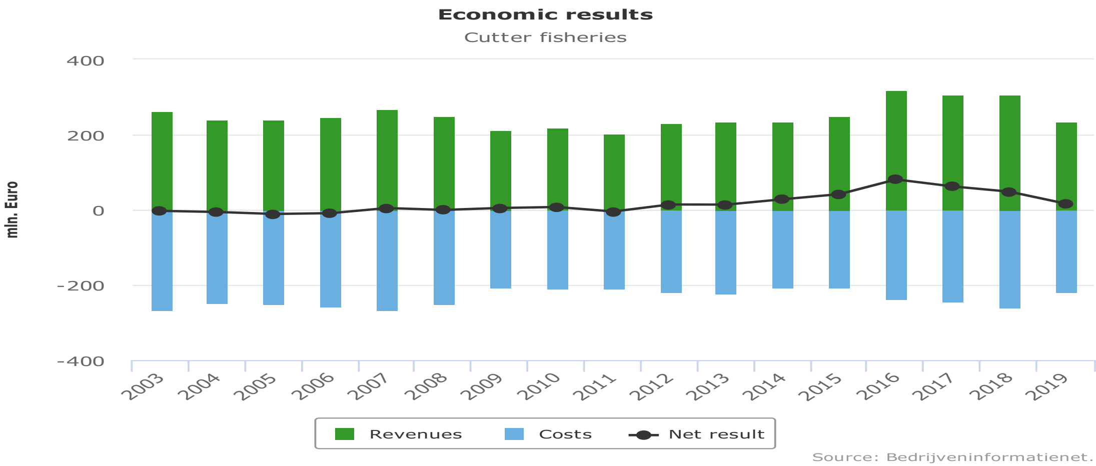


Figure 113. *Result cutter fisheries (Bedrijveninformatienet)*

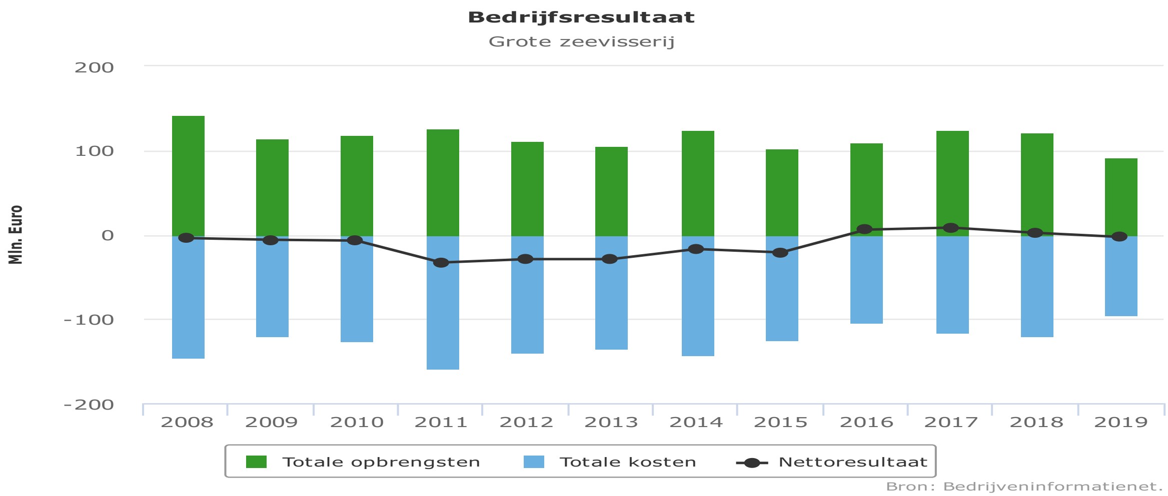


Figure 114. *Result large fisheries (Bedrijveninformatienet)*

Table 39. *Prices of fish and seafood*

Fish type	price (Euro/tonne)
European lobster	13586
Brill	6724
Shrimp	2760
Norway lobster	5677
Mussel	1197
Oysters	5389
Codfish	2908
Red gurnard	2337
Dab	917
Haddock	1936
Plaice	2456
Turbot /rhombus	9831
Sole	11815
Whiting	1157
Sea bass	12360

5.4 Ecology

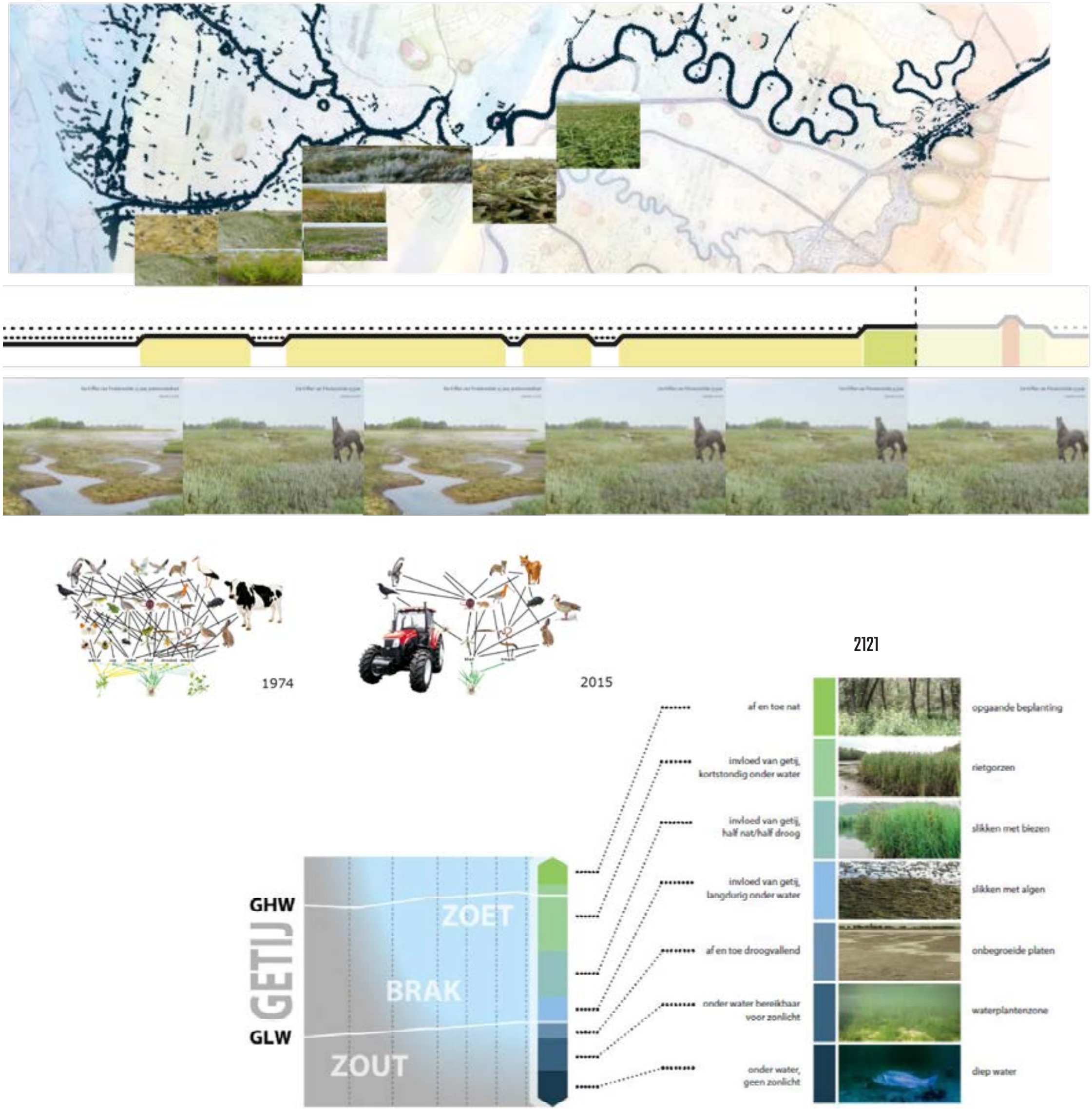


Figure 115. *Salt to freshwater gradient*

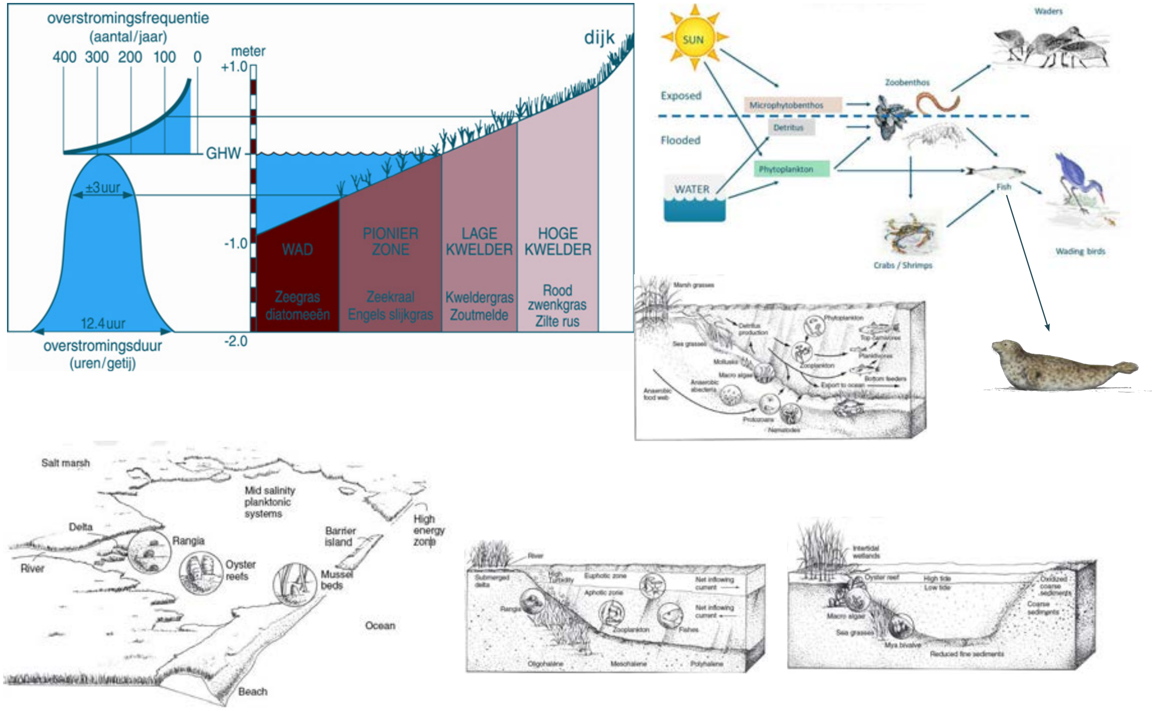


Figure 116. *Ecology of the salt marshes*

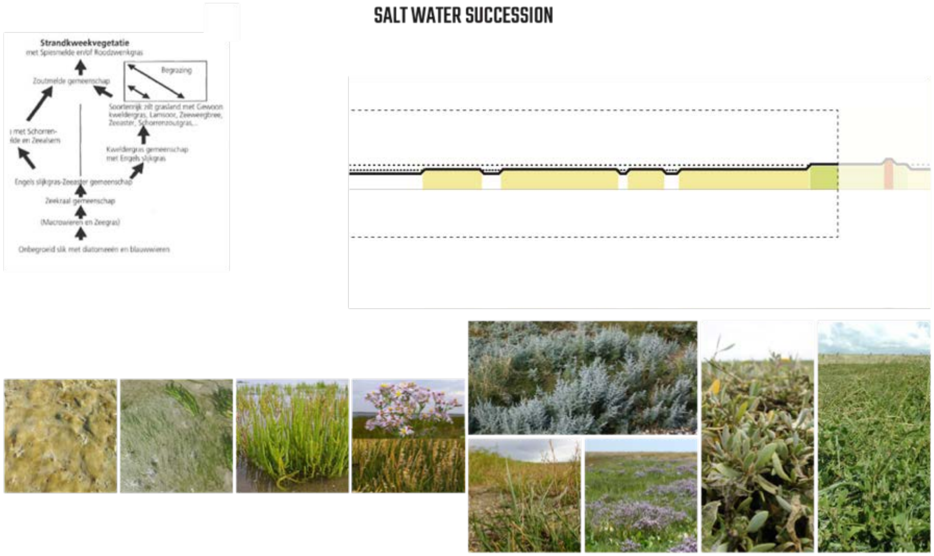


Figure 117. *Succession in salt conditions*

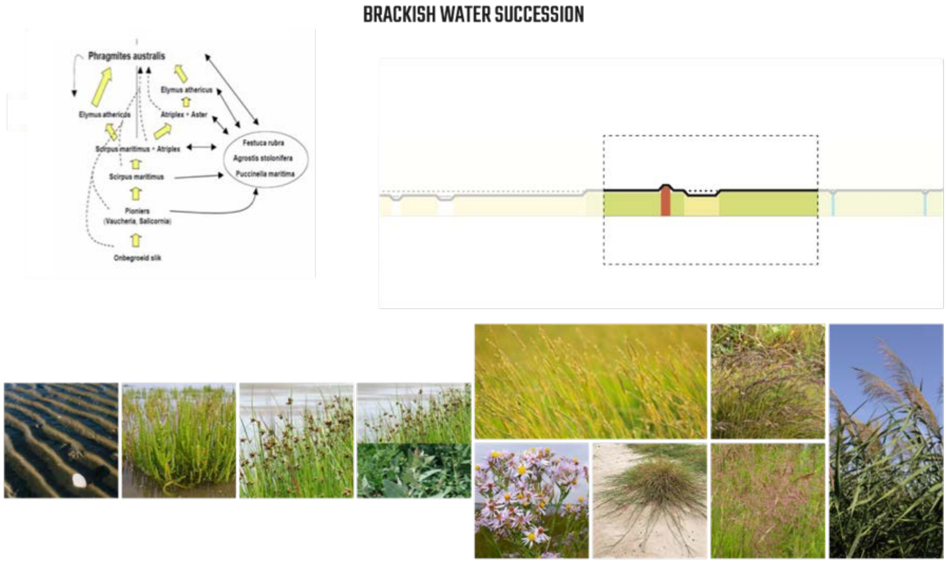


Figure 118. *Succession in brackish conditions*

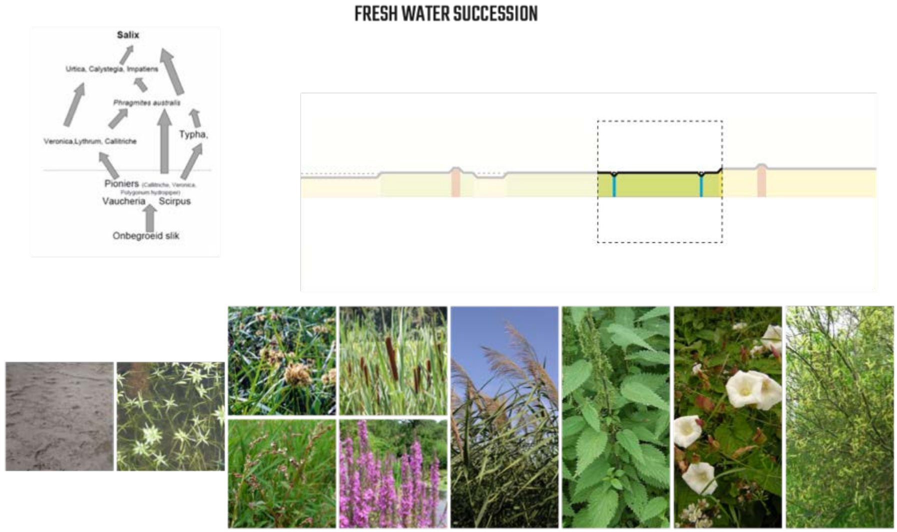


Figure 119. *Succession in freshwater conditions*

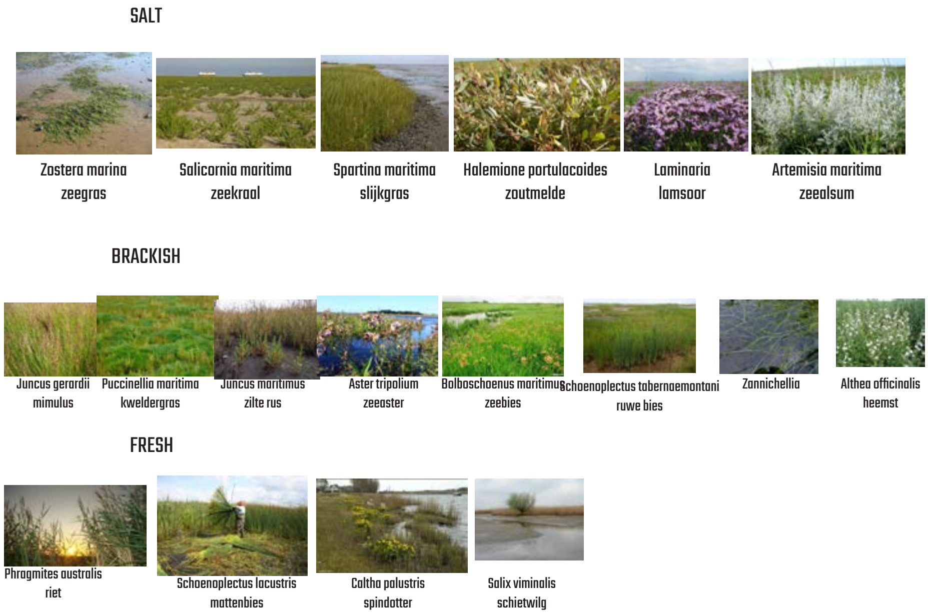
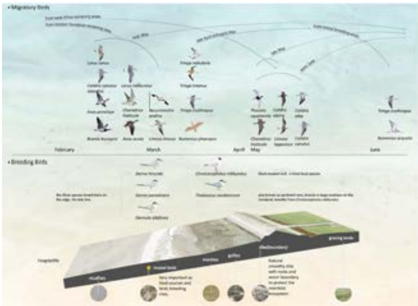


Figure 120. *Typical plant species in different conditions*

Tabel 5.Referentie van de soortensamenstelling van vissoorten in een natuurlijk estuarium zoals deze is vastgesteld vanuit de Kaderrichtlijn Water (Jager 2008).

Diadroom	Estuarien resident	Marien juveniel	Marien seizoensgast
Steur – *Acipenser sturio*	**Harnasman** – *Agonus cataphractus*	**Haring** – *Clupea harengus*	**Geep** – *Belone belone*
Elft – *Alosa alosa*	**Zandspiering** – *Ammodytes tobianus*	**Zeebaars** – *Dicentrarchus labrax*	**Pijlstaartrog** – *Dasyatis pastinaca*
Fint – *Alosa fallax*	**Glasgrondel** – *Aphia minuta*	**Kabeljauw** – *Gadus morhua*	**Snotolf** – *Cyclopterus lumpus*
Paling – *Anguilla anguilla*	**Slakdolf** – *Liparis liparis*	**Schar** – *Limanda limanda*	**Ansjovis** – *Engraulis encrasicolus*
Driedoornige stekelbaars – *Gasterosteus aculeatus*	**Zeedonderpad** – *Myoxocephalus scorpius*	**Wijting** – *Merlangius merlangus*	**Sprot** – *Sprattus sprattus*
Rivierprik – *Lampetra fluviatilis*	**Botervis** – *Pholis gunnellus*	**Schol** – *Pleuronectes platessa*	**Diklipharder** – *Chelon labrosus*
Spiering – *Osmerus eperlanus*	**Bot** – *Platichthys flesus*	**Tarbot** – *Scophthalmus maximus*	
Zeeprik – *Petromyzon marinus*	**Brakwatergrondel** – *Pomatoschistus microps*	**Griet** – *Scophthalmus rhombus*	
Zalm – *Salmo salar*	**Dikkopje** – *Pomatoschistus minutus*	**Tong** – *Solea solea*	
Zeeforel – *Salmo trutta*	**Grote zeenaald** – *Syngnathus acus*	**Rode poon** – *Trigla lucerna*	
Houting – *Coregonus oxyrinchus**	**Kleine zeenaald** – *Syngnathus rostellatus*		
	Puitaal – *Zoarces viviparus*		

Figure 121. *Residents of the water*



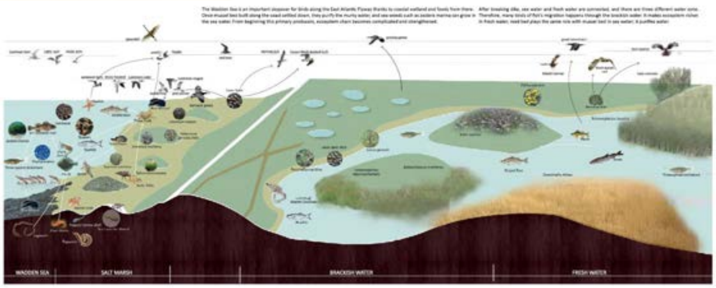


Figure 122. *Residents of the air*

5.5 Buildings and energy

The buildings on campus use energy and produce waste heat and carbon. The heat can be reused in residential, office, and educational buildings, and increase the productivity of controlled food growing spaces. Preliminary calculations show that all waste heat and carbon can be reused and captured by new functions on campus. Carbon, though not directly, can be captured and used for growing food in greenhouses or polytunnels. Additionally, electricity is generated by implementing solar arrays on top of buildings and facades. This way, all waste energy and carbon can be reused, and the campus becomes energy- and carbon-positive.

5.5.1 Available technologies

Much can be learned from natural systems; biomimicry for short. Termites create meter-high structures to survive without air conditioning in warm conditions in Africa, Australia and South America. The nest itself is underground and can have a diameter of 30 metres. A tower will be built on top of the nest for natural ventilation. The air in the nest heats up by the activity of the workers and the tower heats up by the sun. Natural migration occurs because the warm air wants to take off and the tower extracts air from the nest, as it were. In this way the temperature inside the nest remains 30 degrees Celsius while outside it is 40 degrees Celsius. The shape of the tower is often such that it catches minimal sun during the hottest part of the day and maximum sun at the beginning and end of the day to warm the nest properly. African architect Mick Pearce is known for designs inspired by termite mounds, such as The Eastgate Building in Harare, Zimbabwe.

A building that cools itself

https://www.youtube.com/watch?time_continue=152&v=620omdSZzBs&feature=emb_logo

Werking

De windvanger kan op drie verschillende manieren functioneren: door de luchtstroom naar beneden af te buigen, door luchtstroom omhoog af te buigen middels een door de tocht gecreëerde temperatuurgradiënt, of door luchtstroom omhoog af te buigen middels een door zonlicht gecreëerde temperatuurgradiënt.

Neerwaartse luchtstroom

Een van de meestgebruikte toepassingen van de windvanger is om de binnenzijde van het gebouw af te koelen. Dit wordt vaak gedaan in combinatie met hofjes en koepels als onderdeel van een hittebeheersingsplan. Het gaat dan in feite om een hoge afgedekte toren met een zijkant geopend aan de bovenkant waarin de wind wordt 'opgevangen'. De wind wordt dan afgebogen in de toren, en naar het hart van het gebouw geleid. Doordat er zo een tocht ontstaat, wordt het gebouw afgekoeld.[4]

Opwaartse luchtstroom

Werking van een windvanger in combinatie met een qanat.
Coandă-effect

Windvangers worden ook wel toegepast in combinatie met een qanat, een ondergronds kanaal. Bij deze methode wordt de open zijde van de toren juist van de wind afgekeerd, zodat een onderdruk ontstaat, en de lucht omhoog wordt 'gezogen' (vanwege het Coandă-effect).

Door het verschil in luchtdruk wordt warme (droge) lucht via een andere luchtingang naar binnen gezogen, en via de qanat het huis in geleid. De lucht wordt in de qanat afgekoeld door contact met de koude aarde en het stromende water, en koelt het gebouw af. Deze methode heeft als bijwerking dat de lucht bevochtigd wordt voordat deze het huis binnenkomt.

Zonlicht

In een windarme omgeving, of wanneer er geen qanat gebruikt kan worden, kan een windvanger als een zonnetoren worden ingezet. De toren, met de lucht erin, wordt opgewarmd door de zon, en de lichtere warme lucht stijgt omhoog in de toren. Op die manier ontstaat ook een drukverschil waardoor ook een tocht ontstaat. De koude lucht die in de onderste lagen van het gebouw is opgeslagen wordt zo omhoog gezogen. Dit is vooral nuttig wanneer er grote temperatuurverschillen gedurende een etmaal zijn, zodat de koude lucht kan worden opgeslagen in de nachtelijke uren. Het is met deze methode niet mogelijk om het gebouw kouder te krijgen dan de nachtelijke temperatuur.

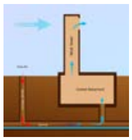
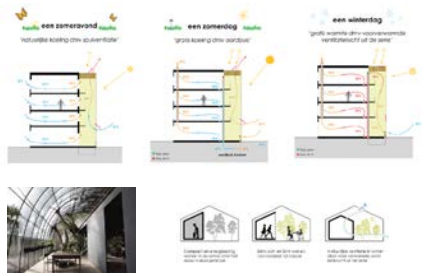


Figure 123. *Cooling technologies*



Box in a box
https://transitieenduurzaamheid.wordpress.com/2017/11/08/serres-op-mensenmaat-woonvormen-voor-de-toekomst/

heat from plants.
(broodingn haystack)

heat accumulation.
mass heat/cold storage
(water, brick and concrete)

Figure 124. *Dealing with heat*

Table 40. *Calculations of energy (and water) use per building*

Property of	OBJECT	ADDRESS	Function	Gas in cubic m	Year	Electricity in KWH	Drinking water in cubic m	water in M3/M2	nm3/m2	kWh/m2	GJ total	Building size	Flat roof?		
RUG	Physics and Chemistry	Nijenborgh 4	Education / Other	2041279	2019	9431262	0	35,70	164,94	149.488	2,61	15153	y		
RUG	Physics and Chemistry	Nijenborgh 4	Education / Other	incl	2019	incl	0	incl	incl		incl				
RUG	Physics and Chemistry	Nijenborgh 4	Education / Other	incl	2019	incl	19986	incl	incl		incl				
RUG	Physics and Chemistry	Nijenborgh 4	Education / Other	incl	2019	incl	0	incl	incl		incl				
RUG	Physics and Chemistry	Nijenborgh 4	Education / Other	incl	2019	incl	0	incl	incl		incl				
RUG	Physics and Chemistry	Nijenborgh 4	Education / Other	incl	2019	incl	0	incl	incl		incl				
RUG	Physics and Chemistry	Nijenborgh 4	Education / Other	incl	2019	incl	0	incl	incl		incl				
RUG	Physics and Chemistry	Nijenborgh 4	Education / Other	incl	2019	incl	0	incl	incl		incl				
RUG	Physics and Chemistry	Nijenborgh 4	Education / Other	incl	2019	incl	0	incl	incl		incl				
RUG	Physics and Chemistry	Nijenborgh 4	Education / Other	incl	2019	incl	0	incl	incl		incl				
RUG	Physics and Chemistry	Nijenborgh 4	Education / Other	incl	2019	incl	0	incl	incl		incl				

RUG	Physics and Chemistry	Nijenborgh 4	Education / Other	incl	2019	incl	0	incl	incl		incl				
RUG	5124 cryogen	Nijenborgh 4	Education / Other	incl	2019	incl	0	incl	incl		incl				
RUG	5134 Solutions Building	Nijenborgh 4	Education / Other	incl	2019	incl	0	incl	incl		incl				
RUG	Porter's lodge	Zernikelaan 1	Education	2101	2019	23323	51	6,73	74,75	276	0,89				
RUG	Energy Academy	Nijenborgh 6	Education / Other / Offices / Assembly	0	2019	1046106	1311	-	86,95	9.415	0,78	4029,7	y		
RUG	Bernoulliborg	Nijenborgh 9	Education	31364	2019	1679986	3585	2,24	120,17	16.113	1,15				
RUG	Linnaeusborg as a whole	Nijenborgh 7	Education	280971	2019	11511398	0	7,03	288,11	112.495	2,82	10443	p		
RUG	Linnaeusborg part 1	Nijenborgh 7	Education	incl	2019	incl	36538	incl	incl		incl				
RUG	Linnaeusborg part 2	Nijenborgh 7	Education	incl	2019	incl	0	incl	incl		incl				
RUG	Linnaeusborg part 3	Nijenborgh 7	Education	incl	2019	incl	0	incl	incl		incl				
RUG	Linnaeusborg part 4	Nijenborgh 7	Education	incl	2019	incl	0	incl	incl		incl				
RUG	Greenhouses	Nijenborgh 7	Education	incl	2019	incl	0	incl	incl		incl				
RUG	Aviaries	Nijenborgh 7	Unknown	n/a	2019	n/a	0	n/a	n/a		n/a				
					2019										
					2019										
RUG	Sports Centre	Blauwborgje 16	Sport	163973	2019	831949	0	16,54	83,92	12.677	1,28	9683,6			
RUG	Sports Centre	Blauwborgje 16	Sport	incl	2019	incl	7173	incl	incl		incl				
Hanze HS	Sports Centre	Blauwborgje 16	Sport	incl	2019	incl	0	incl	incl		incl				
RUG	Sports Centre, Tennis Hall	Blauwborgje 16	Sport	incl	2019	incl	0	incl	incl		incl				
RUG	Aerial dome 1	Blauwborgje 16	Sport	incl	2019	incl	0	incl	incl		incl				
RUG	Blaashal 2	Blauwborgje 16	Sport	incl	2019	incl	0	incl	incl		incl				
RUG	Balance Building	Blauwborgje 5	Offices	0	2019	0									

RUG	Central Transport Service	Nadorstplein 2a	Education	9711	2019	2647	74	9,22	2,51	331	0,31				
RUG	Facility office (old)	Blauwborgje 8	Education	35546	2019	78073	0	10,70	23,51	1.828	0,55				
RUG	Clean Water Cellar	Nadorstplein 3	Education	6819	2019	124503	57	2,23	40,78	1.336	0,44				
RUG	GTW	Nadorstplein 4	Education	6188	2019	7753	76	11,31	14,17	266	0,49				
RUG	Archaeology	Nadorstplein 4a	Unknown	2390	2019	3566	1	11,06	16,51	108	0,50				
RUG	Museum Collection	Nadorstplein 2d	Education	0	2019	0	21	-	-	-	-				
RUG	Facility office (new)	Blauwborgje 10	Education	10233	2019	34176	892	7,17	23,93	631	0,44				
RUG	Aletta Jacobs Hall	Blauwborgje 4	Education	WKO	2019	344926	1880		58,89	3.104	0,53	516 6,6			
					2019										
					2019										
RUG	WKO Zernike West	Landleven 5	Education	147386	2019	1945042			2.140	22.170	24,39				
RUG	WSN High-rise	Landleven 5	Education	WKO	2019	1312247	8995		66,18	11.810	0,60				
RUG	WSN Lecture Halls	Landleven 5	Education	WKO	2019	incl.	0								
RUG	WSN Library	Landleven 5	Education	WKO	2019	WKO	0								
RUG	Computational Centre	Landleven 1	Education	WKO	2019	3196838	0		796,62	28.772	7,17				
RUG	Mercator (+office 5415)	Landleven 1	Education	WKO	2019	WKO	0								
RUG	Mathematics and Informatics	Blauwborgje 3	Education	WKO	2019	WKO	0								
RUG	Pavilion	Nettelbosje 3	Unknown	WKO	2019	WKO	0								
RUG	Food Court	Nettelbosje 3	Education	WKO	2019	WKO	0								
RUG	Kapteynborg (old)	Landleven 12	Education	WKO	2019	819.505	6739		72,16	7.376	0,65				
RUG	Kapteynborg (new)	Landleven 12	Education	WKO	2019	181.950	0		75,00	1.638	0,68				
RUG	Smitsborg	Nettelbosje 1	Education	25536	2019	2020979	717	4,99	394,88	18.997	3,71				
RUG	KVI-complex	Zernikelaan 25	Education	60128	2019	3337021	8976	4,45	246,93	31.936	2,36				

Hanze	Marie Kamphuisborg	Zernikeplein 23	Education	######	2014	##############					6.546	7303,6		Average kWh/m2 for RUG	
Hanze	Willem Alexander	Zernikeplein 17	Education	28.993	2014	##############					4.716	6723,5		21.538	
Hanze	Van Olst Tower	Zernikeplein 7	Education	######	2014	##############					9.873	11781			
Hanze	Van DoorenVeste	Zernikeplein 11	Education	33.844	2014	23071073,98					1.071	10791			
Hanze	Brugsmaborg	Zernikeplein 9	Education	######	2014	54.741.867,98					17.450	2541,6			
Third party	De Mudden (10-14)		Offices		2014						1.100				
Third party	De Mudden 16		Offices		2014						1.500				
Third party	De Mudden 18		Offices		2014						1.500				
Third party	Zernike Park 1		Offices	100	2014						51				
Third party	Zernike Park 2		Offices	1200	2014						613				
Third party	Zernike Park 4		Offices	4000	2014						2.044				
Third party	Zernike Park 6-8		Offices	1800	2014						1.203				
Third party	Zernike Park 10 NHL / Idea Centre		Offices	8000	2014						4.088				
Third party	Zernike Park 16 (Lode)		Offices	4000	2014						2.044				
Third party	Zernike Park 21		Offices	1000	2014						511				
Third party	De Deimten 1, (LSE monitors)		Offices	1260	2014						644				
Third party	De Deimten 3, (Kits)		Offices	150	2014						77				
Third party	De Deimten 9, (van der Plas)		Offices	1080	2014						552				
Third party	De Deimten 11, (Deerns)		Offices	1080	2014						552				
Third party	Kadijk 1		Offices	unknown	2014						1.300				
Third party	Kadijk 3		Offices	unknown	2014						1.700				

Third party	Kadijk 5		Offices	unknown	2014						1.300				
Third party	Kadijk 7		Offices	unknown	2014						1.300				
				unknown	2014										
				unknown											
				4E+06		######### #####	97.072 ,00	129,39	##### ###	##### ###	##### ####				
				(E83*0,363)											

Table 41. *Estimated carbon emission Zernike campus*

	Gas in m3	Electricity in KWH	Total	Combined
Total emission on Zernike per year	4031295	53947743		
CO2 emission per year	7619148	35012085	42631233	
CO2 emission per hour	870	3997	4867	
trees needed to compensate emissions			2115904	
hectare needed to compensate			564	188
Smog towers needed to capture CO2			2212	737
Moist swing air CO2 capture containers			117	39
Moist swing air filters (60 per container)			7008	

Table 42. *Energy use, carbon data per building on the Zernike campus*

OBJECT	Gas in m3	Electricity in KWH	CO_2 emission per year (kg)	CO_2 emissions per hour	CO_2 uptake per tree per hour (kg)	Trees per hectare	smog towers needed	carbon carousels needed	waste heat exhaust		Drinking water in m3							
			1,89 per m3 gas, 0,649 per kwh		0,0023	3750			'									
Physics/Chemistry	2041279	9431262	9978906	1139	495280		518	27			19986							
Porter's lodge	2101	23323	19108	2	948		1	0			51			Average kWh per year per Zernike building				
Energy Academy	0	1046106	678923	78	33697		35	2			1311			1896663				
Bernoulliborg	31364	1679986	1149589	131	57057		60	3			3585							
Linnaeusborg	280971	11511398	8001932	913	397158		415	22			36538							
Sports Centre	163973	831949	849844	97	42180		44	2										
Balance Building			0	0	0		0	0										
Central Transport Service	9711	2647	20072	2	996		1	0			74							
Facility Offices (old)	35546	78073	117851	13	5849		6	0			0							
Clean Water Cellar	6819	124503	93690	11	4650		5	0			57							
GTW	6188	7753	16727	2	830		1	0			76							
Archaeology	2390	3566	6831	1	339		0	0			1							
Museum Collection			0	0	0		0	0			21							
Facility Offices (new)	10233	34176	41521	5	2061		2	0			892							
Aletta Jacobs Hall		344926	223857	26	11111		12	1			1880							

WKO Zernike West	147386	1945042	1540892	176	76479		80	4										
WSN High-rise		1312247	851648	97	42270		44	2			8995							
Computational Centre		3196838	2074748	237	102975		108	6										
Mercator (+offices 5415)		WKO		0	0		0	0										
Mathematics and Informatics		WKO		0	0		0	0										
Pavilion		WKO		0	0		0	0										
Food Court		WKO		0	0		0	0										
Kapteynborg (old)		819.505	531859	61	26398		28	1			6739							
Kapteynborg (new)		181.950	118086	13	5861		6	0										
Smitsborg	25536	2020979	1359878	155	67494		71	4			717							
KVI-complex	60128	3337021	2279369	260	113131		118	6			8976							
Marie Kamphuisborg	206.825	2519880	2026301	231	100571		105	6										
Willem Alexander	28.993	1739490	1183726	135	58752		61	3										
Van Olst Tower	311.934	1354815	1468830	168	72902		76	4										
Van DoorenVeste	33.844	3723240	2480348	283	123106		129	7										
Brugsmaborg	551.332	2635110	2752204	314	136599		143	8										
De Mudden (10-14, 16, 18)			0	0	0		0	0										
Bytesnet	25536	2020979	1359878	155	67494		71	4										
QTS	25536	2020979	1359878	155	67494		71	4										
Zernike Park 1	100		189	0	9		0	0										
Zernike Park 2	1200		2268	0	113		0	0										
Zernike Park 4	4000		7560	1	375		0	0										
Zernike Park 6-8	1800		3402	0	169		0	0										

Zernike Park 10 NHL / Idea Centre	8000		15120	2	750		1	0										
Zernike Park 16 (Lode)	4000		7560	1	375		0	0										
Zernike Park 21	1000		1890	0	94		0	0										
De Deimten 1, (LSE monitors)	1260		2381	0	118		0	0										
De Deimten 3, (Kits)	150		284	0	14		0	0										
De Deimten 9, (van der Plas)	1080		2041	0	101		0	0										
De Deimten 11, (Deerns)	1080		2041	0	101		0	0										
Kadijk 1			0	0	0		0	0										
Kadijk 3			0	0	0		0	0										
Kadijk 5			0	0	0		0	0										
Kadijk 7			0	0	0		0	0										
sum	4031295	53.947.743	42631233	4867	2115904	564	2212	117			89.899							

5.5.2 Potential carbon capture

CO2 COMPENSATION

Planting trees to compensate CO^2 emission

CO^2 emissions per m^3 natural gas = 1,89 kg
CO^2 emissions per kwh grey electricity = 0,649 kg

Total use gas Zernike per year = 4.000.000 m^3
CO^2 emission on Zernike from gas =
7.560.000 kg/year
: 8766 hour/year = 862 kg/hour

Total electricity use Zernike per year =
50.000.000 kwh
CO^2 emission on Zernike from electricity =
32.450.000 kg/year
: 8766 hour/year = 3.702 kg/hour

Total CO^2 emission Zernike per hour = 4.565 kg

: 0.0023 kg CO^2 storage per hour per tree =
1.984.532 trees
: 3750 trees per hectare =

529,2 hectare

https://www.milieubarometer.nl/CO2-footprints/co2-footprint/actuele-co2-parameters-2016/
https://www.milieubarometer.nl/co2-factoren/

Wich trees absorb most CO^2?

fast growing trees
long-lived trees
large leaves and wide crowns
native spiecies
desease-resistance and low-maintenance spiecies

https://learn.eartheasy.com/articles/10-carbon-storing-trees-and-how-to-plant-them/

Figure 125. *Compensation through planting trees*

CO2 CAPTURE

Smog Free Tower

Cleans 30.000 m3 air per hour and uses a small amount of green electricity.
https://www.studioroosegaarde.net/project/smog-free-tower

x 0,04% CO^2 per m^3 air = 1,2 m^3 CO^2
1m^3 CO^2 = 1,836 kg
1,2 x 1,836 = 2,2 kg CO^2 p/h
4.565 kg CO^2 emission p/h : 2,2
=
2.075 towers in total

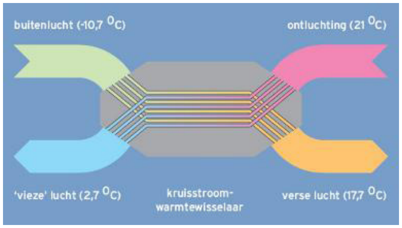
Figure 126. *Carbon capture using smog towers*

WASTE HEAT FROM THE BUILDING TO USE FOR HEATING RESIDENTIAL AND GREENHOUSES/POLYTUNNEL

Heat recovery by heat exchanger

The heated air is reused to preheat the cold air from outside, wich means less heating
https://www.joostdevree.nl/shtmls/warmteterugwinning.shtml

Hoeveel kwh komt er uit de ontluchting?
Wat je er uit haalt kan je er weer instoppen
Hoeveel m² is de kas?
Hoe sla je het op?



Hoeveel kwh/m² win je door zon? 1000 per jaar
Hoeveel kwh/m² verbuikt 1 persoon per jaar?

Voorbeeld:
kas = 1000m²
Instraling zon in nederland per jaar: 1000 kwh/m²
= energieopbrengst van 1.000.000 kwh

1 persoons huishouden verbruikt jaarlijks 1500 kwh (in 2020)

1.000.000 : 1500 = 666,67 personen

over 50 jaar zal dit 500 zijn? = 2.000

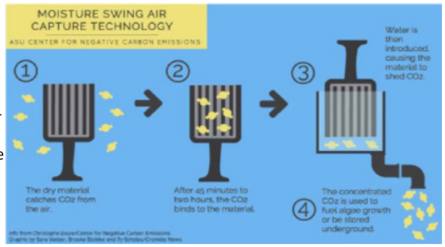
The rest heat in buildings are probapbly to cold to re-use.
The Suikerunie uses its rest heat, about 80 degrees, to heat houses.

Figure 127. *Use of waste heat*

CARBON CAPTURE

Moisture Swing Air Capture Technology

“A passive, sorbent-based air collector can be viewed as a large filter standing in an airflow with the filter surfaces covered with or made from a CO² selective sorbent. Air that comes in contact with sorbent surfac-es will relinquish some or all of its CO². The larger the surface area and the longer the contact time, the more CO² is removed from the air.”
the CO2 captured using this system is almost 4 times the amount CO2 released as a result of the process of energy generated for its use.



Carbon Carousel
One container captures one ton carbon per day
1.000 kg per day = 41,67 kg per hour
4.565 kg CO² emission p/h : 41,67
= **110 containers**

https://www.researchgate.net/publication/...730...330_Building-integrated_Carbon_Capture_Development_of_an_Appropriate_and_Applicable_Building-integrated_System_for_Carbon_Capture_and_Shade

Figure 128. *Moisture swing air capture*

MOISTURE SWING AIR CAPTURE TECHNOLOGY

Moisture Swing Air Capture Technology

In addition to the above-mentioned utilization activities, another interesting approach is to turn CO2 into fuel using sunlight. According to a new study developed by the U.S. Department of Energy's Argonne National Laboratory and the University of Illinois at Chicago, the process developed is similar to the one found in trees and other plants, which capture CO2 from the atmosphere and convert it into sugar that stores energy using sunlight [15]. This technology can work hand in hand with the building integrated carbon capturing technology described here can be implemented within buildings, as it can occupy the roofs of buildings for solar exposure to facilitate the process.

The captured CO2 can be used in a number of industrial applications, but that means shipping it to remote locations. Within buildings/cities: greenhouses, refrigeration, beverage carbonation, laundry, or the production of dry ice.

Carbon chambers
One container fits 60 filters (60 x 160 x 10 cm)
16,67 kg per filter per day = 0,695 kg per hour
4.565 kg CO^2 emission p/h : 0,695
= **(110 containers or) 6.570 filters in total**

https://www.researchgate.net/publication/327309550_Building-integrated_Carbon_Capture_Development_of_an_Appropriate_and_Applicable_Building-integrated_System_for_Carbon_Capture_and_Shade

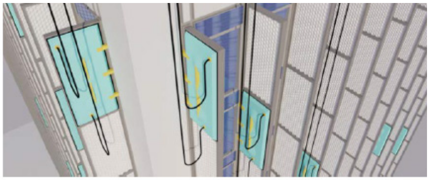


Figure 9. Representation of cleaning chambers with hoses connected roof tanks.

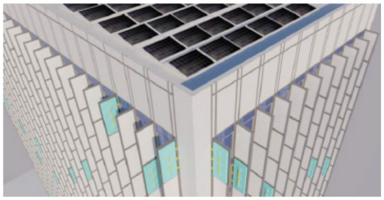


Figure 11. Roof solar installation for carbon dioxide utilization

Figure 129. *Moisture swing air capture*

CO2 CAPTURE

Algea

Bio fuel
Animal food
Suplements

https://openresource.suez.com/en//-/transforming-co2-into-green-energy
https://www.netl.doe.gov/coal/carbon-utilization
https://www.youtube.com/watch?v=QI3Al1dpuUY&feature=share&ab_channel=UniversityofKentucky
https://www.businessinsider.nl/algen-klimaatverandering-co2/

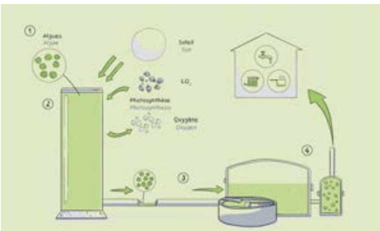


Figure 130. *Carbon capture using algae*

USE HEAT THROUGH HEAT EXCHANGERS WITH WATER

Aquathermie

Surface water, from waste water and from drinking water. Also stored underground.
https://www.linkedin.com/pulse/gecascadeerde-warmtenetten-voor-ohg-amsterdam-rik-altena
https://www.nieuweoogst.nl/nieuws/2019/05/27/sloot-naast-kas-is-leverancier-van-warmte

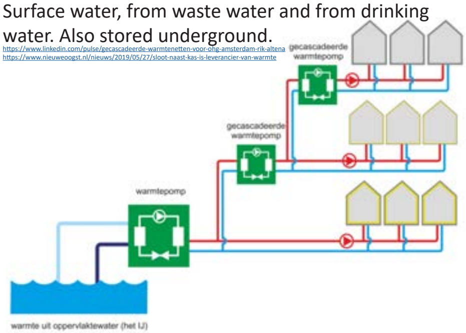


Figure 131. *Heat exchangers*

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