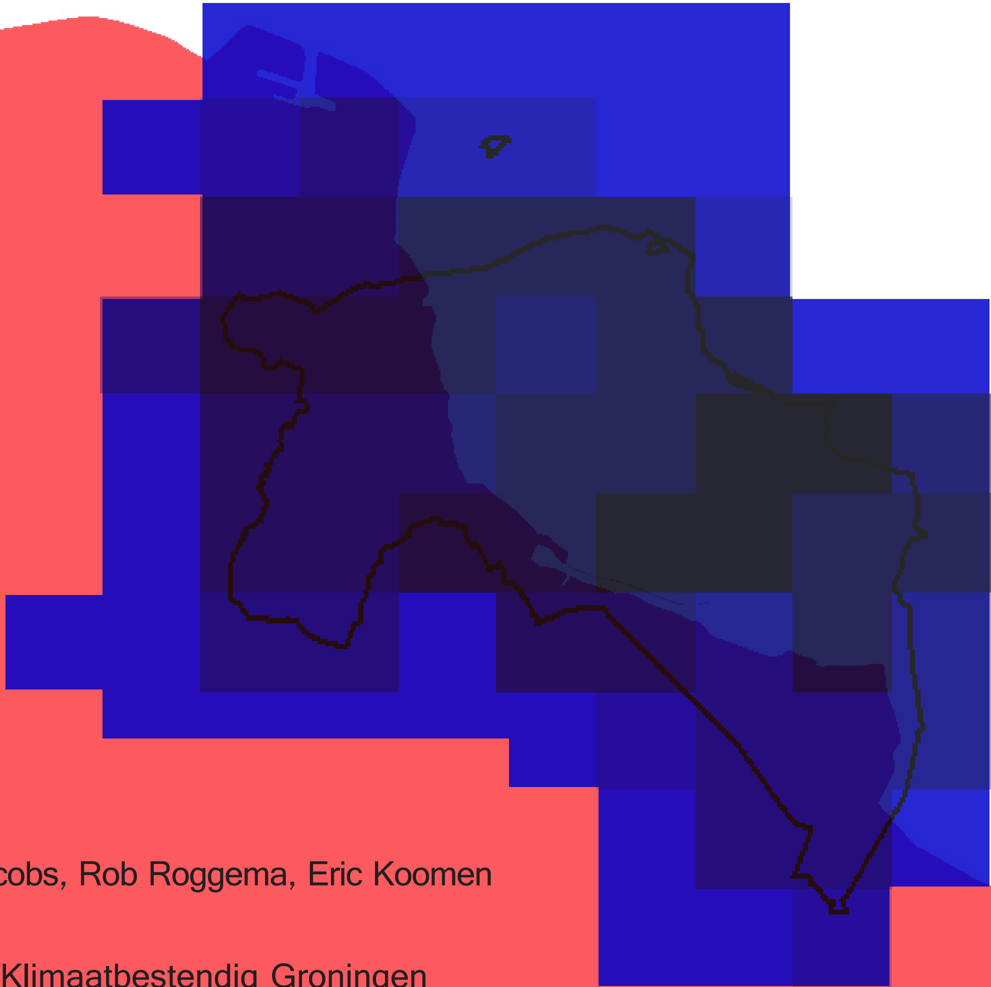
Towards an integrated vision of a climate proof Groningen



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1. Introduction

The Groningen province is gathering ideas on spatial adaptations for climate proofing the province. Such ideas on spatial adaptations for climate change have been produced and collected during a number of workshops in which experts on (e.g.) energy, ecology, water, agriculture and the climate shared their vision on how to make Groningen ready for climate change. Two kinds of workshop sessions were organized to define a coherent set of adaptation measures. Sector-specific workshops focused on generating solutions for problems in a specific domain (e.g. nature or energy), while more general sessions aimed to establish integrated visions for climate change adaption in Groningen.
In the sector-specific sessions, experts gathered adaptation measures for societal domains such as energy generation, ecology, coastal management and water management. Gathering these ideas led to a large number of maps that show threats and proposed measures for a specific theme. In total, four sessions produced 28 separate maps, each with a (partially) different set of adaptation measures for Groningen. Some session results are shown in Figure 1.

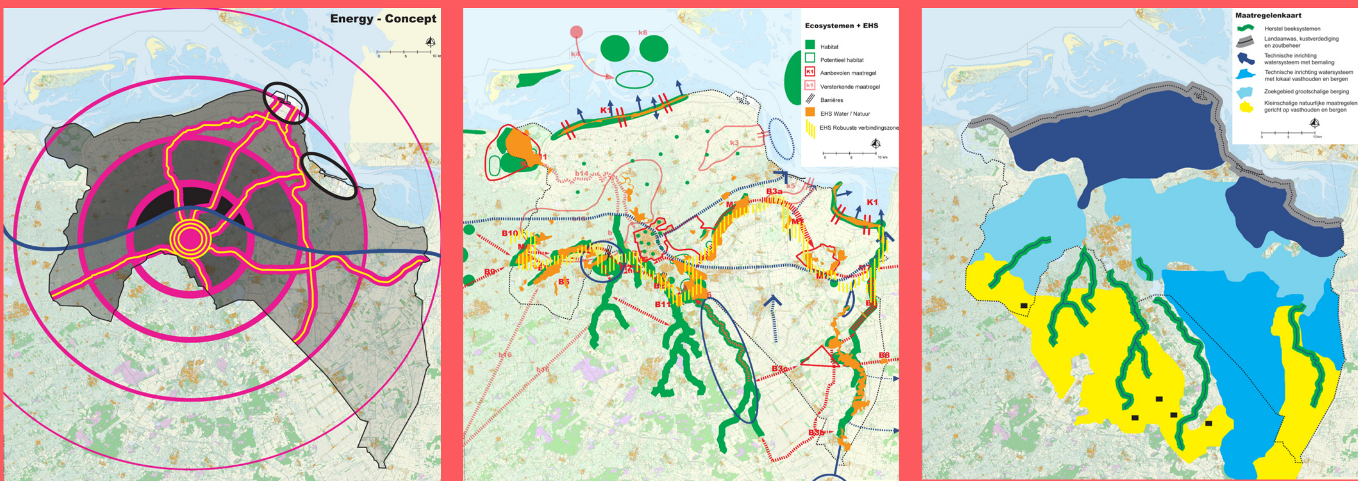

Figure 1: Examples of different climate adaptation measures from the specialist sessions in Groningen. Left: potential for alternative energy generation. Middle: proposed adaptations for nature. Right: suggested changes in water management.

The general sessions started according to the backcasting method (Robinson, 1982). In the first session the participants created two visions of a climate-change adapted Groningen in the year 2100 taking into account different sea-level rise scenarios. The visions were visualized with clay on a map. In a second session, the same participants decided which policies were necessary to establish this vision and a third vision was created. This implementation-oriented session also enabled the groups to rethink and adjust their visions. In the end, three visualizations of a climate change proof Groningen were produced, and some adaptation measures were proposed (Van 't Klooster et al., 2008).
The final part of the process focused on the integration of the results of all preceding sessions. This integrative process had two aims. First, adaptation scenarios for climate proofing Groningen were explored. Second, the robustness of proposed adaptation measures was studied. Robustness was defined here as being applicable in all foreseeable contexts.

2. Methods

The integration of the many differing ideas on climate adaptation encountered several challenges. These were:

- An overview had to be established over a large number of essentially differing ideas;
- Many ideas on climate adaptation, varying in nature, form and message, had to be converted into exchangeable and comparable information units; furthermore
- The goals and choices for a climate proof Groningen had to be shown and explained to participants; while
- Participation and creativity in the process had to be stimulated while the amount of time and energy participants could share was limited.

To optimize the usefulness of specialist participants (given their limited time and energy), the participants' involvement was limited to a final session in which a nearly completed vision of a climate proof Groningen was shown and the participants helped to sketch different scenarios. This left the preparations for the vision to the VU University and Groningen province. These parties tried a four step working method for the transparent and justifiable integration and testing of adaptation measures. These steps will be detailed in the next paragraphs.

A first step of this method was a selection of measures. To limit the supply of adaptation ideas to measures that are comparable, the VU University and Groningen province agreed to select only proposed ideas of a spatially explicit nature. Visualizations or parts of visualizations that contained schematics rather than land use, visualizations that covered all of Groningen and three-dimensional objects in visualizations were removed from the set of ideas.

The second step was iteratively defining, localizing and combining adaptation measures (see Figure 2). Where necessary, visualizations were first turned into more accurately defined and more accurately located claims of land of a proposed land use type. In this stage the exact meaning and spatial implications of measures were defined. Opportunity areas were turned in to specific land claims for a land use type. Exact locations, or rules for exactly locating were then defined. Next, the proposed ideas were combined to find spatial overlap and potential conflict between different adaptation measures. Where possible, adaptation measures that excluded each other were moved to remove conflicting combinations. The resulting combination was then again tested for conflicts. This resulted in a map of partially integrated specialist adaptation ideas for Groningen. Finally, an overlay analysis was done to quantify spatial pressures from these combinations for square zones that covered Groningen ('gridcells').

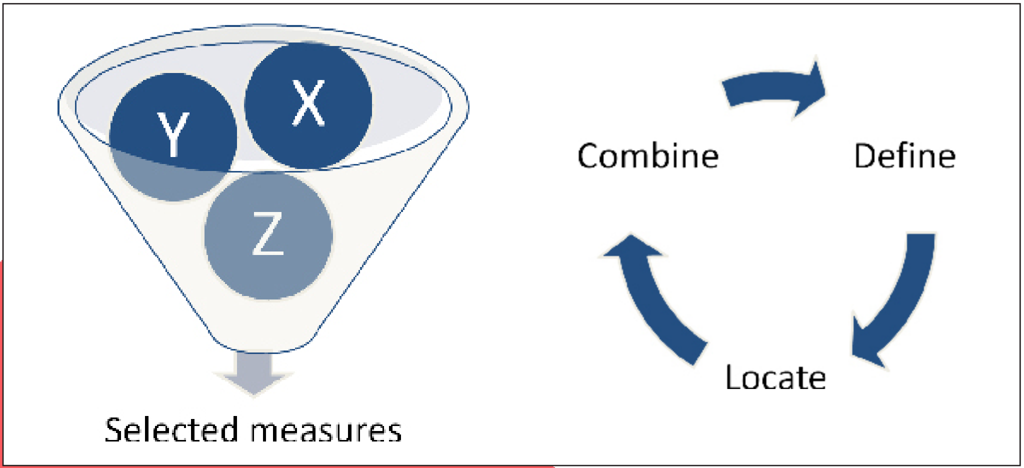

Figure 2: Scheme of integration process

The third step was testing the proposed adaptation measures. The spatial implications of integrated sector-specific adaptation measures were here compared with the spatial implications of the scenarios produced during the backcasting sessions. An expert of Groningen province assessed this step. By searching possible conflicts between sector-specific adaptation measures and the different backcasting developments the robustness was tested. For each gridcell (as created in the previously executed overlay analysis) the gravity of conflicts found in that gridcell was then scored. These conflict gravity estimates of different scenarios have been summed. These summed conflict gravity estimates give an approximation of the amount of scenarios in which the proposed sector-specific adaptation measures do not conflict strongly. The map that shows these indicators is used as an approximation of the robustness of adaptation measures in different areas.

A fourth step was creating these scenarios. For this step, six 'key problems' were designated during the conflict scoring. These key problems are important or typical examples of conflicting combinations of sector-specific measures and the backcasting scenarios. The key problems needed either solutions for conflicting goals or a more accurate or realistic definition of goals that seemed unfeasible in short term. Solving these problems was necessary for creating consistent scenarios. To create the scenarios participants were then asked to join a final session. The goal of this session was to share the results of the integrative process and to solve the key problems.

The session was divided into three parts, in each of which two groups separately solved one key problem. For every part of the session, the key problem areas were shown as clear windows on a map, while other areas were shown blotted. The participants' input in this session was more or less restricted

to solving problems in the clear areas. The participants were allowed to reflect on the integrated adaptation measures in greater extent after the session.
In the session a so-called touch table has been used to stimulate participation. Using such technology made it possible for participants to directly draw, type and present ideas and solutions. Their input was used for some changes to the backcasting scenarios. Elements of these backcasting scenarios combined with the sector-specific adaptation measures were finally used in two scenarios of a climate proof Groningen.

The changes and final products made during the integration process are detailed in the next chapter. Two novel elements of the methodology will be explained in more detail below. First, the overlay analysis that was applied to quantify potential conflicts will be explained. Second, the way interaction stimulation was tried during participatory sessions will be shown.

2.1. Overlay analysis

Geographical Information Systems (GIS) allows for storing, retrieving, visualizing and analyzing geographical information. The collected adaptation measures have all been added to such a GIS. The storage, retrieval and visualization functionalities of GIS were well used during the process. The analytical possibilities of GIS were assumed to have some value for the integration process as well. Therefore the analytical possibilities of GIS have been explored for the information used for the integration process.

All the data used in the integration process is qualitative (i.e. the sketched adaptation measures and scenarios). This eliminates many of the analytical possibilities of quantified-data oriented GIS software. Only the amount of sectors that claim land at a certain place is found to be a potentially valuable indicator for the integration process. This indicator shows spatial patterns of adaptations measures, improves overview over proposed adaptation measures and presents possible conflicts between the different adaptation measures. It does not show real conflicts - the qualitative nature of the data used does not allow assessing if adaptation measures can share space. This indicator has been calculated by automatically dividing the province over grid cells and then counting the number of sector-specific land claims per cell. The indicator has been calculated for a number of gridcell sizes. Eventually, grid cell sizes of 5x5 km and 10x10 km seemed to be most valuable, given the coarseness of the adaptation measures provided.

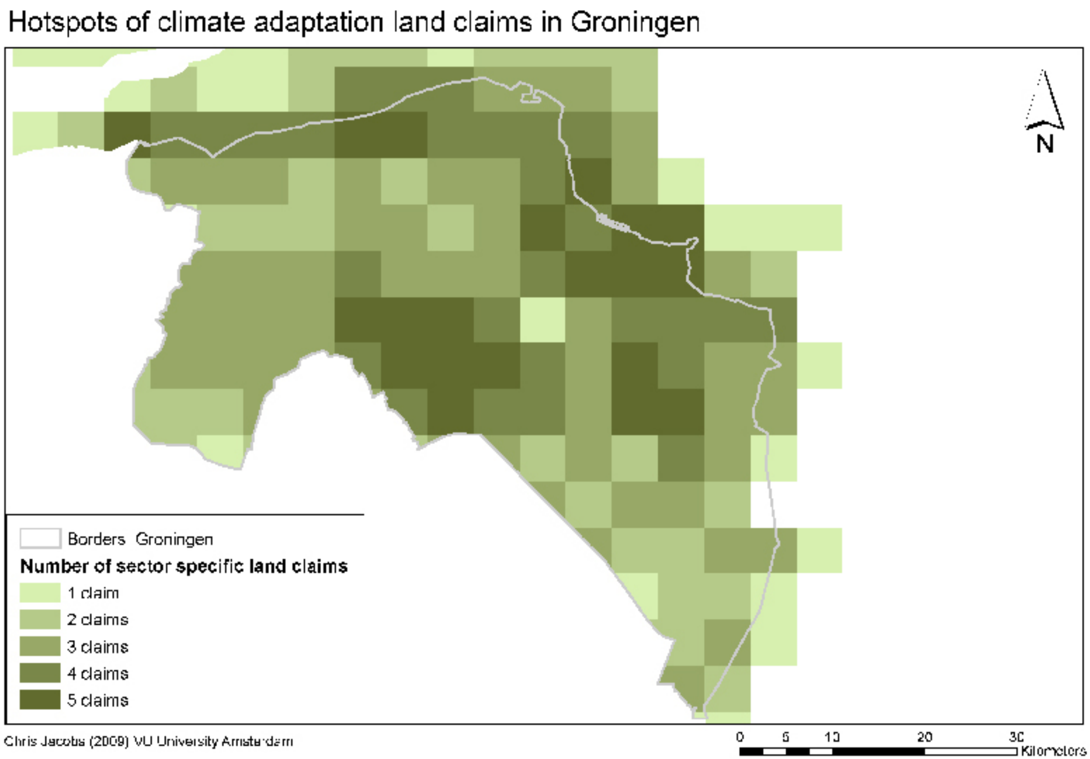

Figure 3: The number of land claims per grid cell from sector-specific climate change adaptation measures for Groningen province.

2.2. Interaction stimulation

A so-called tangible user interface or TouchTable was used in the integrative session to facilitate interaction between a limited number of participants and the spatial data stored in a computer (Scotta et al., 2006). The device shows the collected spatial information and developed GIS application on a table surface and allows participants to sketch and comment on the projected maps (see Figure 4). Anytime a participant touches the table, it registers the specifics of that touch (e.g. place on the table, movement, number of elements that touch). The software on the connected computer then translates the participants' touches into commands to the GIS application. The GIS allows participants to sketch and write on the map. The organizers presumed that using GIS on a tangible table has a number of advantages over using paper maps or a regular computer screen:

- The table setup stimulates participants to stand around and form a group. It is fun to use and has some 'gadget-value' and thus entices people to join and participate.

- Using a GIS allowed for sharing and viewing a wide array of spatial information. Furthermore, GIS facilitated easy comparison and editing of information, while allowing for reversal of changes and additions.
- The touch technology makes it enables immersion of bystanders in the activities on the screen. With touch interaction, bystanders can relate between the movement of a person generating input, and changes on the screen. When one participant zooms in, bystanders will see the person swiping the screen instead of clicking a mouse button. The bystanders can than intuitively relate the swipe movement of a participant to the map on the table zooming in.

Figure 4: the touch table setup used during the final session (left);
two participants interacting with a touch table (right)

3. Integrating sector-specific adaptation measures

As described in the previous chapter, a number of steps were taken to find possibly robust adaptation measures and to create scenarios of a climate proof Groningen. In the next paragraphs, the changes done to the sector-specific adaptation measures in these steps will be detailed. Note that the step-division used in this chapter is somewhat artificial: it does not capture the iterative nature of the processing.

3.1. Selection

The process started with establishing an overview of available adaptation measures. The sector-specific sessions produced over 30 maps with adaptation measures for the long-term spatial layout of Groningen. These adaptation measures were compared by the claim of land they implicated: both in the location and in the amount of land necessary for the adaptation measure. The adaptation measures were compared between sectors, while the internal consistence between sector-specific adaptation measures was assumed. This implicated that all spatially explicit adaptation measures specific for one sector could be put on one map, and adaptations for other sectors could be left out of the sector-specific maps.

The suitability of available adaptation measures was first analyzed (see Table 1). Some adaptation measures were accurate in location and amount of necessary land (e.g. the nature maps); other ideas combined spatially explicit and implicit information (e.g. coastal protection); yet others provided purely conceptual ideas or adaptation measures for other sectors (e.g. water supply). Some adaptation measures had already been combined into one sector-specific map (e.g. measures for ecology, surface water and surplus water storage) while other adaptation measures were not yet suited for such a combination (e.g. agriculture).

Visualization		Integration	
Theme	Number of maps	Remarks	Ready for integration
Energy supply	1	Ideas need more specific situation	No
Coastal defense	11	Some elements not spatially explicit	Yes
Agriculture	5	Ideas claim all space in the province	No
Ecology	4	Some elements not spatially explicit	Yes
Surface water for ecology and surplus storage	6	Waterclaims somewhat unclear about location and necessary area	Yes
Water supply	4	Four differing concepts; spatial implications unclear	No

Table 1: Overview of ideas available at the start of the integration process and the extent of spatial explicitness of the ideas

The ecology and coastal protection maps needed some filtering of elements to meet the spatial explicitness criterion. The ecology map was partially covered with text and diagrams. Some of these elements were filtered; compare for instance the legend at the top right or the text near the straight lines at the bottom left in Figure 5.

The coastal protection map showed some elements (e.g. windmills) that were not spatially explicit. The coastal protection map also included elements around some of the populated areas in the province that indicated target areas rather than adaptation measures. These elements were filtered out of the map of combined adaptation measures for coastal protection (see Figure 6).

The adaptation measures of the water supply and agriculture sectors needed a more elaborate definition than the nature and coastal defense ideas. Other ideas needed more specific locations. The steps taken for a better definition of these measures are shown in the next paragraph.

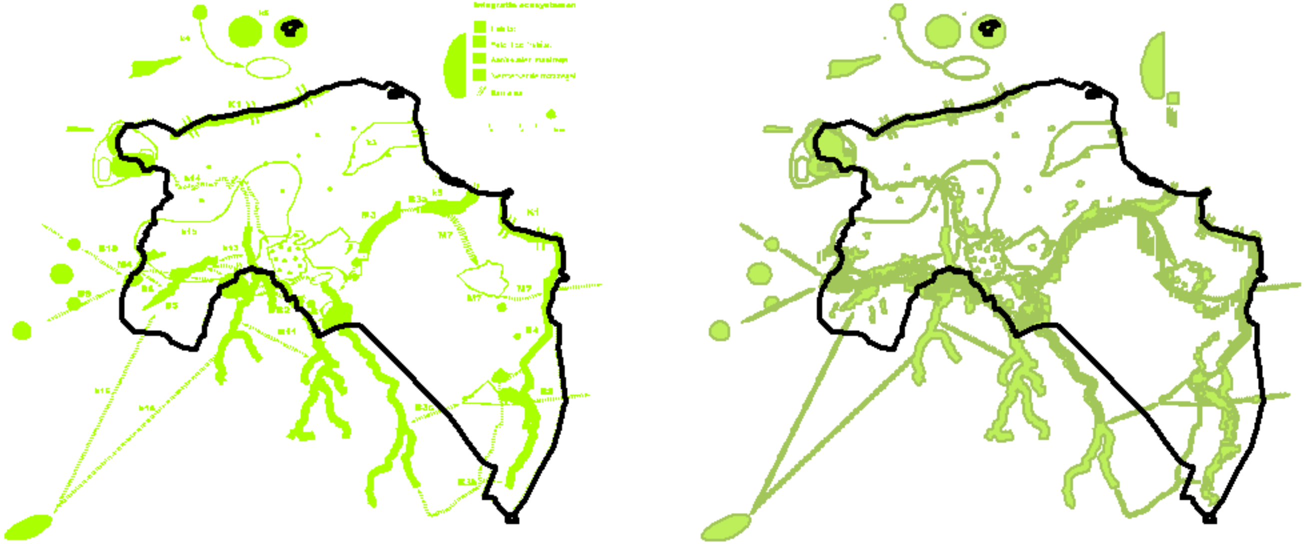

Figure 5: selection in combined ecology measures map (left: source; right: final)

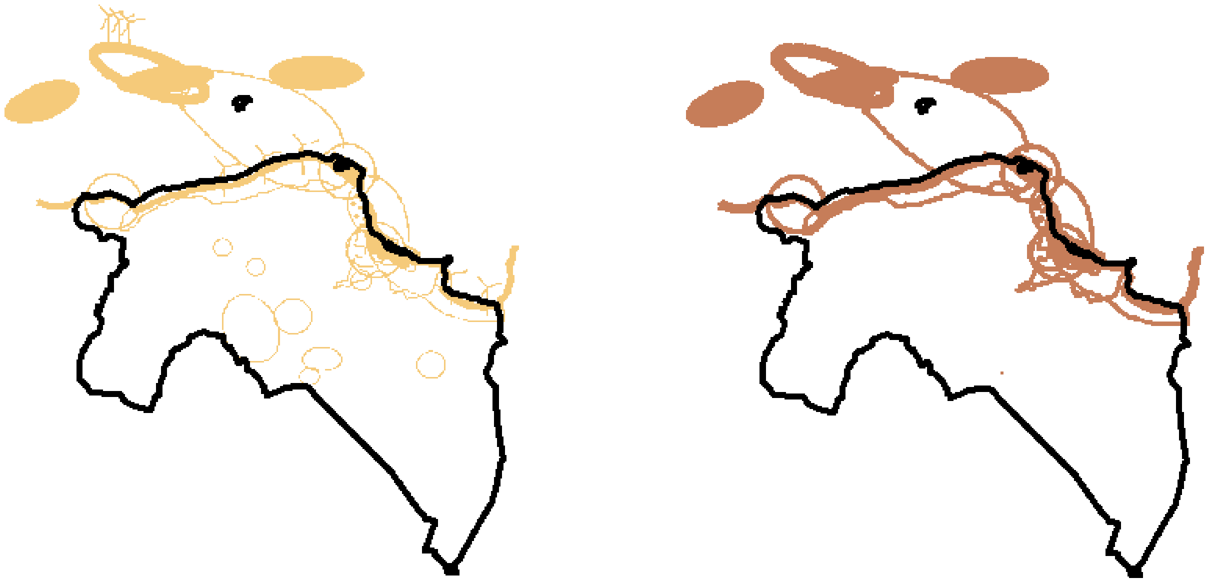

Figure 6: selection of combined coast defense measures (left: source; right: final)

3.2. Definition

The water supply measures lacked clear definition and localization. The energy supply measures mostly needed more accurate localization. The ideas in the water supply and energy supply themes were found likely to be coexistent or interdependent. Therefore, an early integration of the water supply and energy supply themes seemed a logical step. A workshop with an expert in water supply and an expert in energy supply was organized to 1) more accurately define and situate and 2) combine and find synergy between the adaptation measures of these sectors. Furthermore, the collaborative session could functions as a test for collaborative sessions using a tangible table.

The maps of water supply adaptation measures showed first a multitude of concepts to manage water supply and second consequences and opportunities of these systems for economy and ecology. However, the water supply theme did not contain many spatially explicit measures, while it did show adaptations for a number of other sectors. However, two problems were evident in most of the water supply maps. These were 1) the possibilities the Eems river and the Eems river estuary have for water supply and 2) a necessity for more surface water to store water for supplies during expected longer periods of drought. The necessity for more water-supply and the role the Eems river can have in these water supply problems were tackled in the workshop.

A number of adaptation measures based on a dam in the Eems estuary were found to be unfeasible and rejected. However, an area in Groningen near the Eems river estuary was designated as a storage area to sustain the water supply. This water supply can then be used for energy production, by utilizing the discharge of the river Eems into this water supply. The idea of a water supply near the Eems estuary needed more accurate localization. This was roughly indicated as the lowest land in an area specified during the workshop.

The amount of land necessary for water supply has been more accurately defined by specifying the necessary amount of extra water. The water supply expert estimated a necessary extra amount of about 10,000 cubic meters of water. During the initial water supply expert session some areas had roughly been designated for additional water supply. These had to be better localized. Some rules for localizing extra space for water supply have been specified during the workshop. These rules are all non-urban areas that are at least one meter below sea level within the previously sketched areas. After the workshop, the water supply claims (Eems and the rest) have been localized using these rules, height maps and GIS analyses.

The energy supply theme used ideas from a previous study on sustainable decentralized energy production and showed socio—economic opportunities from that energy production. These showed bands and circles for areas that are specifically suitable for certain types of energy production or land use. The participative session was used to better define possible locations for energy production, employment, tourism, and living (see Figure 7). The Eems river water supply designated in the workshop was designated as an opportunity for energy production.

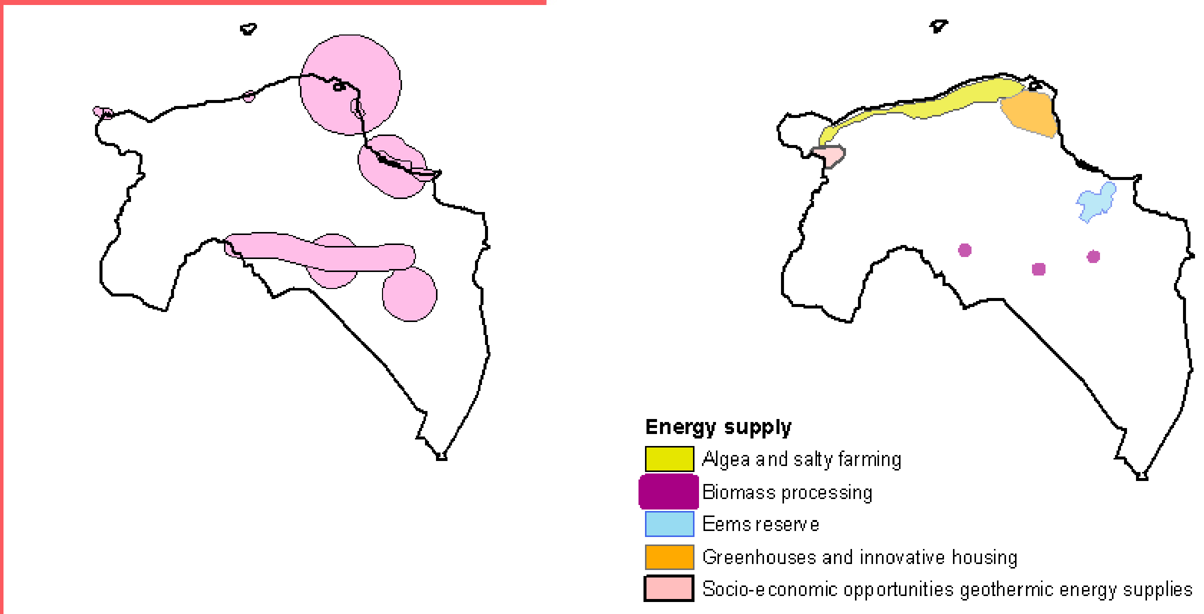

Figure 7: Results of better definition and situation of energy supply ideas (left: source; right: final including Eems water reserve)

The agriculture map was problematic for the integration in a number of aspects. These were 1) measures that covered the entire province, 2) some apparently randomly chosen locations for specific types of farms and 3) ideas on e.g. natural areas. Many of the adaptation measures within the agricultural theme seemed to be in conflict with each other. The agricultural adaptation measures have been more accurately defined in agreement with the Groningen province. The agricultural theme has been designated to be an underlying theme – meaning the adaptation measures are then valid where no other adaptations need that area. The location of some elements (e.g. so called ´agroclusters´) has been specified. Other elements (e.g. ecological areas) have been excluded. The specification led to a new map of combined agricultural measures (see Figure 8).

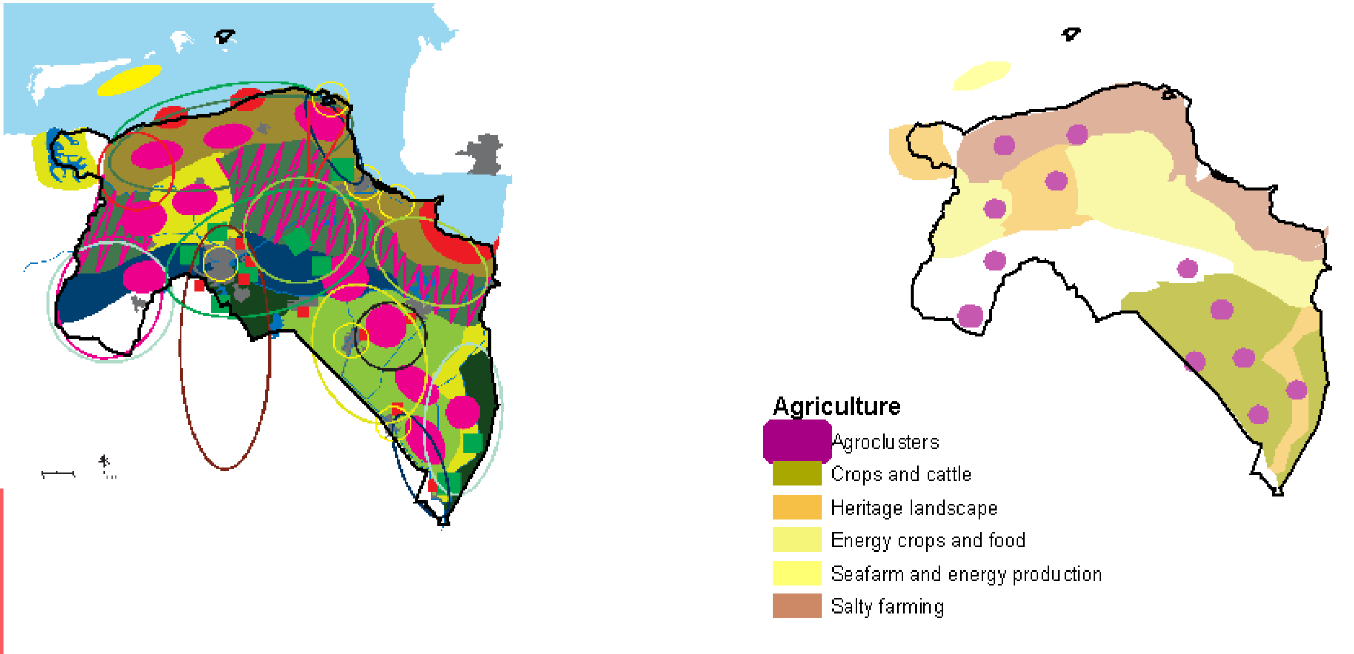

Figure 8: results further definition and situation of ideas on agriculture

At the end of the definition stage, the ideas on water with an ecological function and water meant for surplus storage needed to be situated more explicitly, using height maps. The steps taken to situate these water claims will be detailed in the next paragraph.

3.3. Localisation

Ideas on locations of surface water for both ecology and extreme rainfall surplus water storage had been roughly indicated in a map that shows the results of an integration of adaptation for both surplus water storage and ecology. The ideas for these surface waters needed to be situated more precisely. Next to the space claimed for these surface waters, the provincial water supply needs about 10,000 cubic meters extra storage capacity. This surface water is (partially) designated to low lands near the Eems river estuary, and the rest needed to be located in the lowest parts of the province. In all, new areas for water supply needed to be at least 10,000 square meters with one meter depth water. Eventually, GIS analyses have been used to map locations suitable for all surface water necessities in the province (see Figure 9).

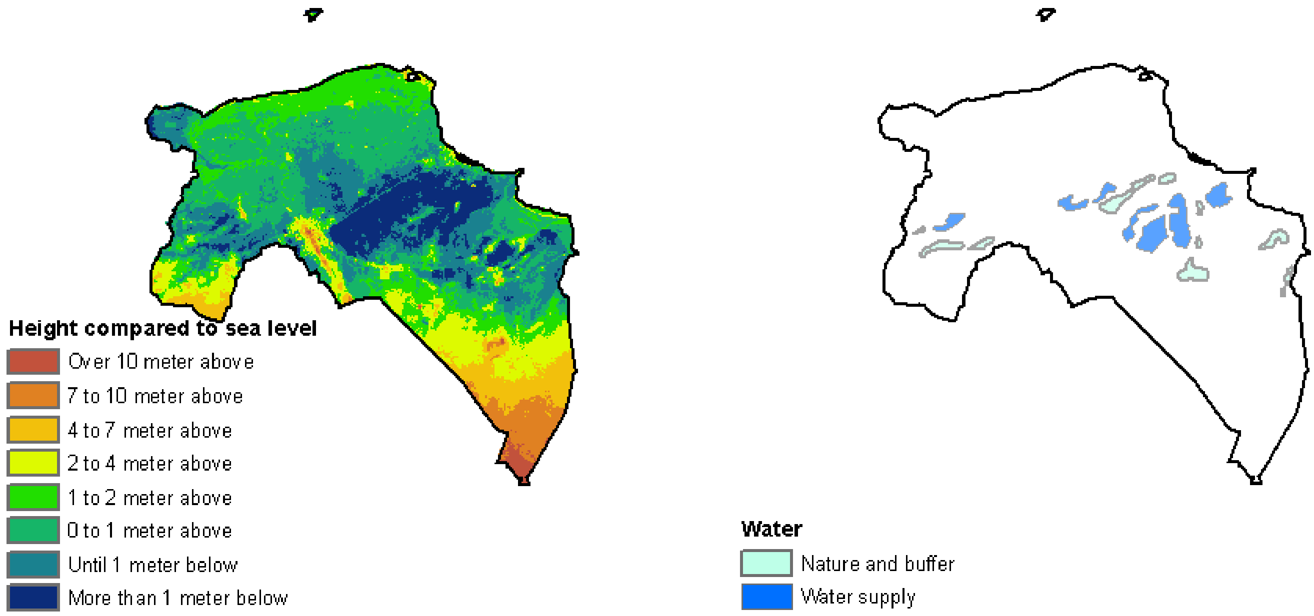

Figure 9: height map used to find land suitable for surplus water storage/ecology and water supply (left, source: AHN); final locations of surplus water storage/ecology and of water supply for times of drought (right)

3.4. Combination

The iterative stepping through situating and combining maps led to a number of preliminary combined maps of ideas. The Groningen province was consulted on all of these maps. These consults led to a number of changes and small adaptations of the measures. Steps in this combination phase and the definition and situation phase were rerun iteratively until a satisfactory integrated map of sector-specific specialist ideas was found.

Eventually, the defined and localized adaptation measures from all sectors were combined into one map. The previously presented overlay analysis was done to quantify the amount of adaptation measures for different sectors per area. The final analysis shows most possible conflicts in the low lying area between the cities of Groningen and Delfzijl and another large number of possible conflict in the coastal areas (see Figure 10).

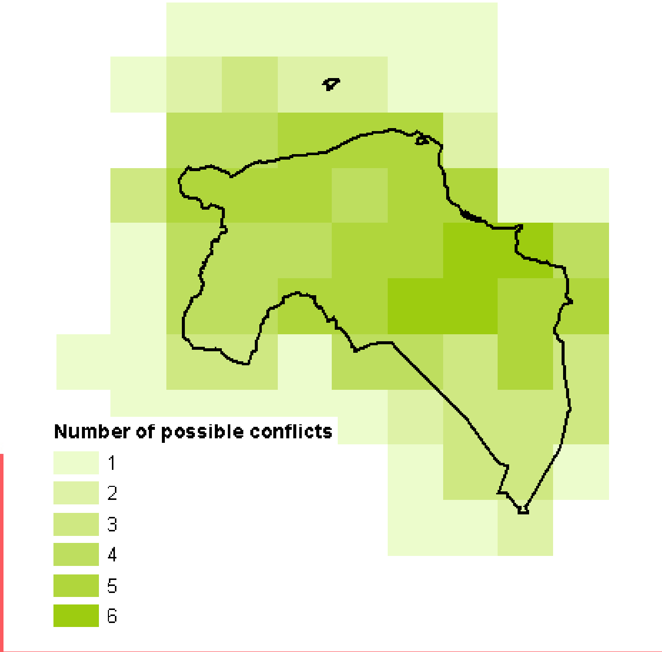

Figure 10: Result of overlay analysis showing possible conflicts between sector-specific ideas

3.5. Results

The process resulted in a number of sector-specific layers with spatially explicit, (mostly) wholly combinable adaptation measures. These were put on top of each other. This leads to the integrated map as depicted in Figure 11. It shows combinable sector-specific, realistic adaptation strategies deemed useful by experts involved in the hotspot Groningen process. To complete the map of sector-specific adaptation measures, a layer with likely built-up land in 2040 in the province has been added to the map of integrated adaptation measures. This built-up land layer is a result of the so-called Land-Use Scanner model. To show the highest likely pressure on space, the layer added to the integration map shows built-up land in a scenario with strong demographic and economic growth (the `Global Economy' scenario). More information on the Land-Use Scanner and its' applications can be found here: MNP (2007); Borsboom-van Beurden et al. (2008)

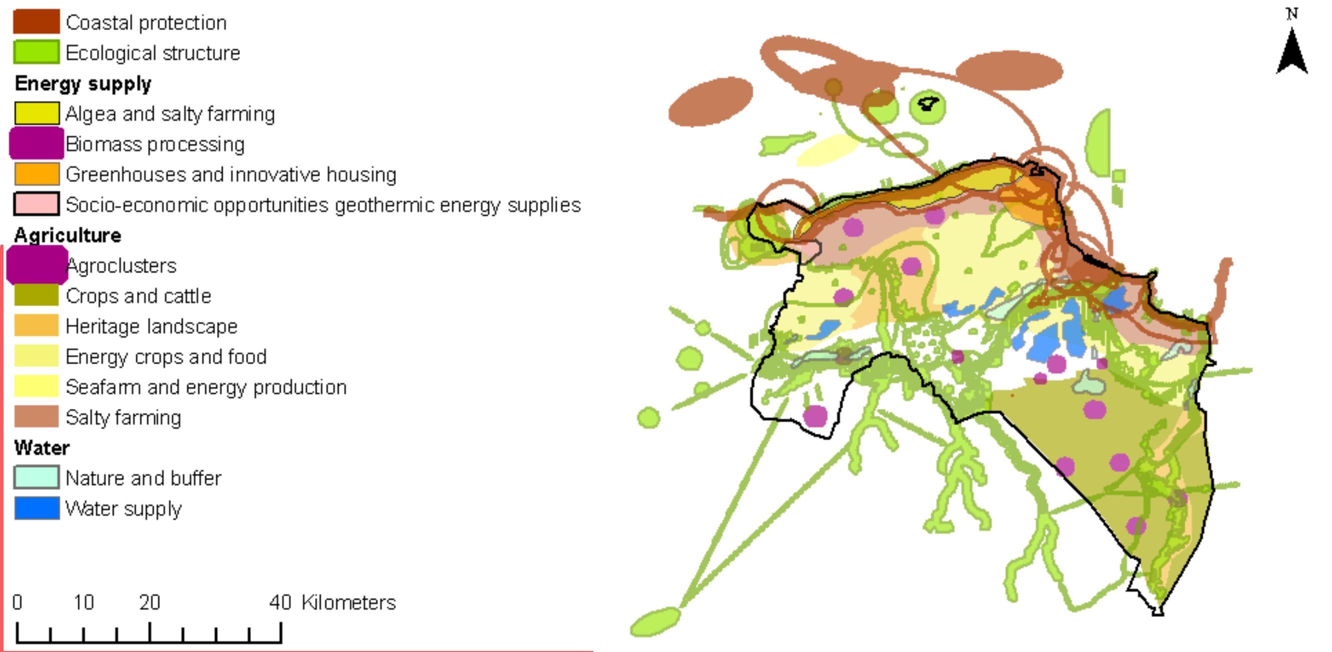

Figure 11: Integrated sector-specific adaptation measures resulting from the expert sessions in the hotspot Groningen process

4. Testing integrated sector-specific adaptation measures in scenarios

The last steps of the integration process were 1) comparing the integrated sector-specific adaptation measures with the backcasting scenarios to test for robustness and 2) creating consistent scenarios. The amount of conflicts per gridcell has been estimated for each combination of the map of integrated adaptation measures and the backcasting scenarios by an expert. Key problems to be solved in a participatory session were designated beforehand as well.

4.1. Combination of sector-specific adaptation measures and backcasting scenarios

The next paragraphs will present 1) a backcasting scenario; 2) the assessment of conflicts between on the one hand the backcasting scenario and on the other hand the map of integrated sector-specific adaptation measures; 3) the key problems of the combination; and 4) the solutions for the key problems as proposed in the participatory session.

4.1.1. Natural heightening behind the dike

The first backcasting scenario is based on a linear see level rise of 1.3 meter in the 21st century. The scenario shows controlled flooding of land by salt water. This flooding is done to heighten the land by the deposition of salt water. Another high-consequence element in this scenario is the artificial development of a lake for the provincial freshwater supply around the so-called Eems canal (see Figure 12).

Two key problems have been designated. One key problem dealt with combining the` Eems lake water supply' and `natural living' as proposed in the backcasting scenario. The second key problem dealt with the possibly conflicting combination of freshwater supply in the Eems lake and the controlled salt water flooding south of that lake (see Figure 13). These key problems and the solutions that the participants proposed will be elaborated upon in the next section.

Problem 1: Eems lake water reserve and ecological living

The first key problem of this combination was found in the combination of the Eems lake water reserve and ecological living, both proposed in the backcasting scenario. The main question was how the water reserve and ecological living functions could be better defined and combined. The questions asked were: How does the water system function? What is ecological living? How can the water reserve and residential functions be better combined with each other?

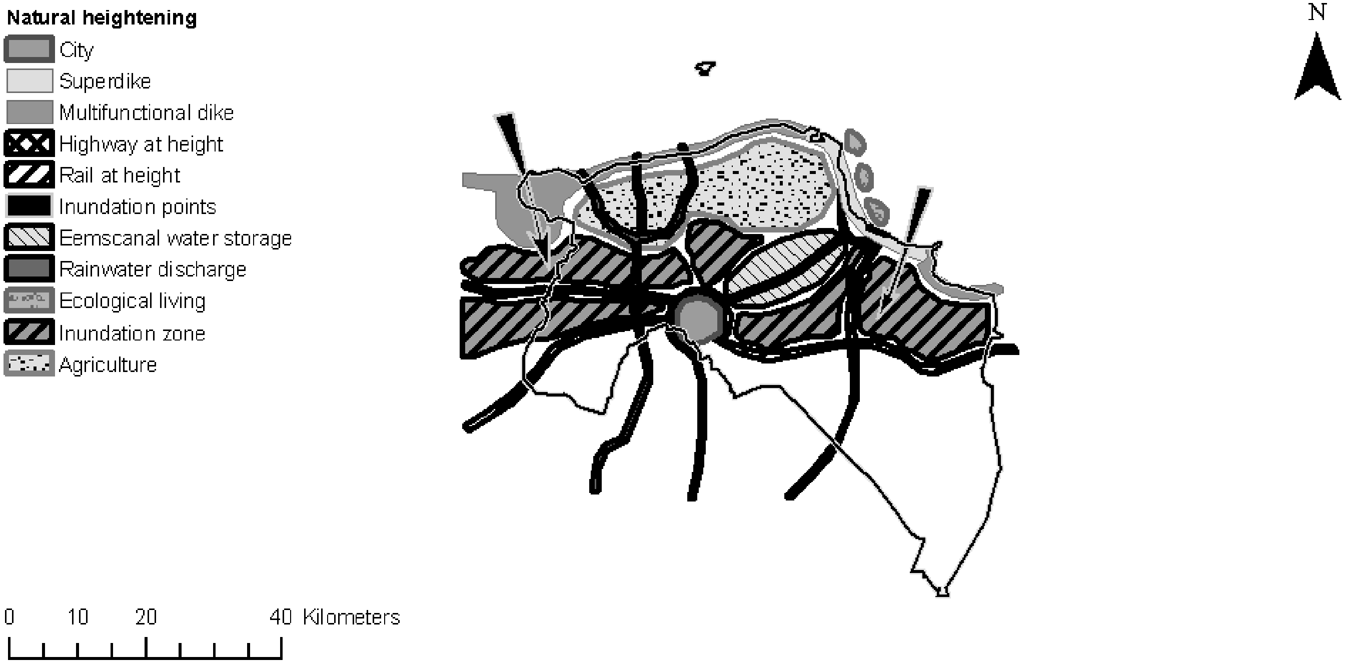

Figure 12: Natural heightening scenario

Figure 13: Conflict scores natural heightening

The participants proposed that the Eems lake waters and the Eems canal stay separated. The canal will then function as a passage for boats. Alongside that passage a reef will be created that holds a road and housing. The lake itself will be divided into compartments and the bottom will be excavated below the (managed) soil water height. That should warrant that the lake will not run dry. Rainwater will add to the water in the compartments - the amount of rainwater is expected to grow in the future. Every compartment will be assigned a target area for supplying water (see Figure 14). Amongst these target areas are agricultural areas where energy crops are grown, the city of Groningen, the Eems seaport and the so-called Peat Colonies.

The northern part of the lake is primary meant for supplying water while the southern part of the lake will only be used as a water supply in times of extreme drought. Regularly the southern part of the lake will only be used to counter the pressure of salt water pushing through soils and dikes from the flooded bordering areas. The participants estimated that the lake is big enough to have a similar function for Groningen province as the Ijssel-lake has for bordering provinces in another part of the Netherlands. The compartment structure is suited for sponsoring. Private and public organizations might fund a compartment to warrant water supply in times of drought. Last but not least, there will be opportunities for flood-proof housing in the compartments.

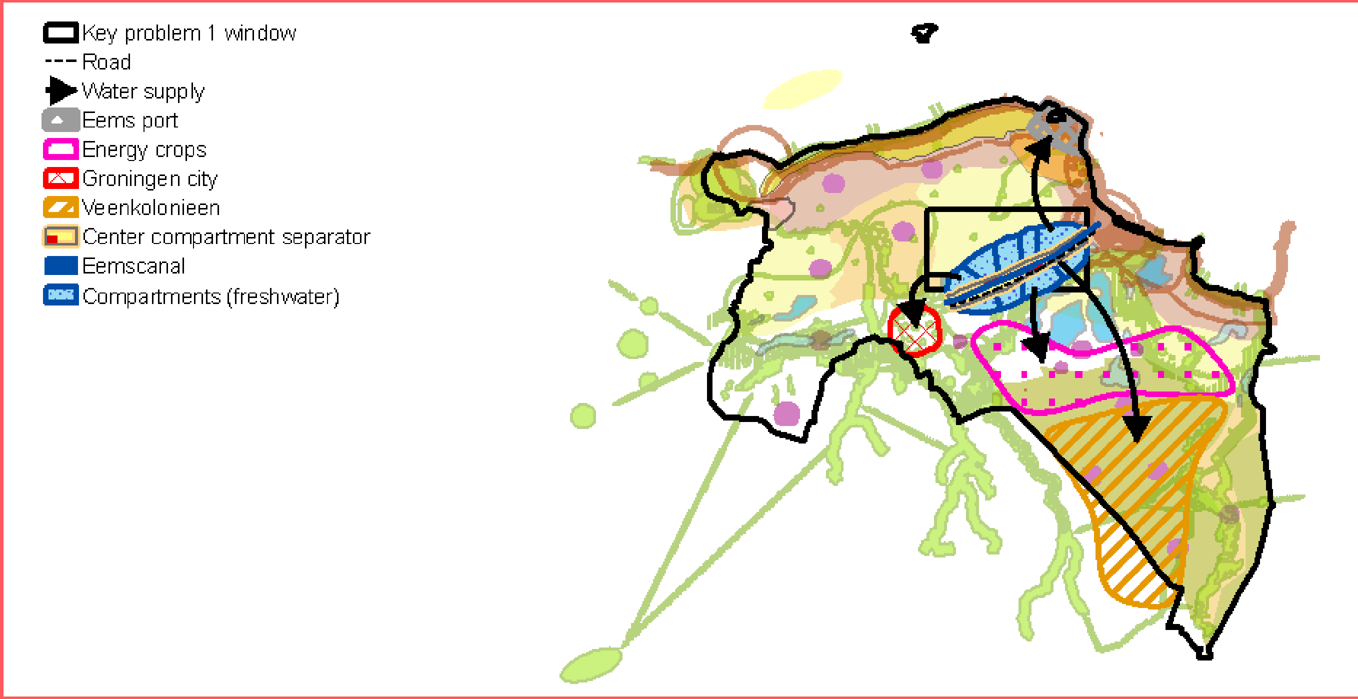

Figure 14: solutions problem 1

Problem 2: Inundation of the Dollard-area

The second key problem dealt with the zone that will be heightened by sea water deposition according to the backcasting scenario. This entire zone, south of the Eems lake, is designated to be flooded in the backcasting scenario, while it is supposed to function as a surplus water storage buffer according to the sector-specific adaptation measures. If the land rises because of the flooding strategy, there will be less room for surplus water storage in the zone. Questions asked were: should the surplus water storage function move to other places, or can it be combined with the land heightening strategy? Should all land up to the borders of Dollard-city be flooded? What are the implications for Meerstad? Can that new town be heightened by inundation?

The participants agreed that the Eems lake water supply is big enough to make the provincial water supply selfsufficient. A strong separation between (salt water) flooded areas and the Eems lake freshwater supply is necessary to prevent mixing of freshwater and salt water. The flooded areas become heightened naturally and are thus protected from flooding. But which area should be flooded first? The participants advised to start flooding near Groningen city, to warrant the safety of that area first. The safety aspect of Meerstad was found to be an important question. According to the participants, three options are available for protecting Meerstad. The city might 1) be flooded and heightened naturally like the surrounding lands, it might 2) be moved or it might 3) be shielded from water.

The participants found the heightening by flooding measure a good-functioning long-term strategy. In the flooded areas, no surplus water storage buffers are needed because the heightened soil will gain additional capacity for water storage (compared to current soils that have a relatively high soil water level). During the heightening process, water that is rich with salts and sediment will flood the landscape. During this period (about 50 years) no agricultural activities are possible in the area, and a dynamic salty water based nature will develop in the inundated areas. After 50 years the compartment is heightened, and agriculture and freshwater-based nature can again take over the area. At that point a new compartment can be flooded. The direction of flooding is detailed in Figure 15.

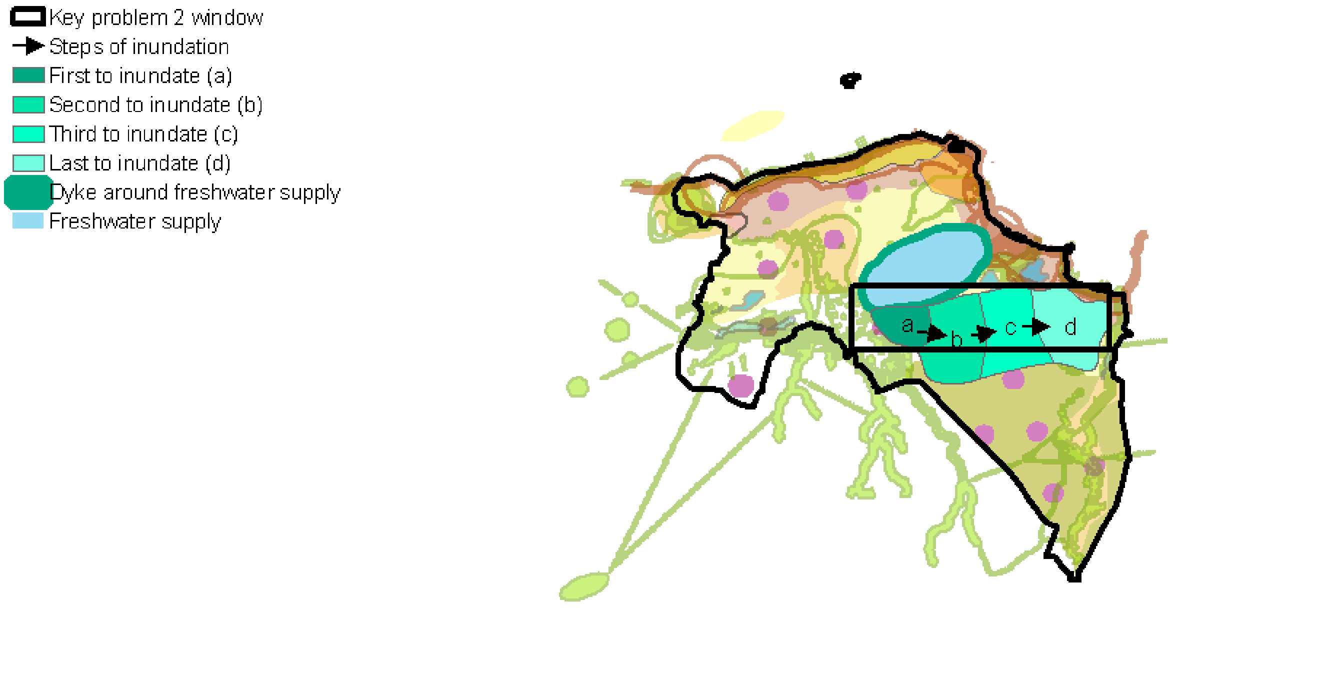

Figure 15: Solutions problem 2

4.1.2. Something above Groningen

The second backcasting scenario is a more offensive approach to safeguard Groningen from the threats of sea-level rise. In this scenario the land is protected from the sea by dividing it in compartments and creating dune rows in the neighborhood of the current Wadden islands. The remaining Waddenzee will turn into a fresh water reservoir and can serve as a provincial water supply. The Groningen landscape evolves into a number of large scale, functionally and esthetically different landscapes such as the "Granery", "Museum landscape" and the "Energy Company" (see Figure 16).

The designated key problems of combining this backcasting scenario and the map of integrated sector-specific adaptation measures dealt with moving the Wadden system as proposed in the backcasting scenario and with many conflicting goals in the vicinity of the city of Delfzijl (see Figure 17). These key problems and the solutions that the participants proposed will be elaborated upon in the next section.

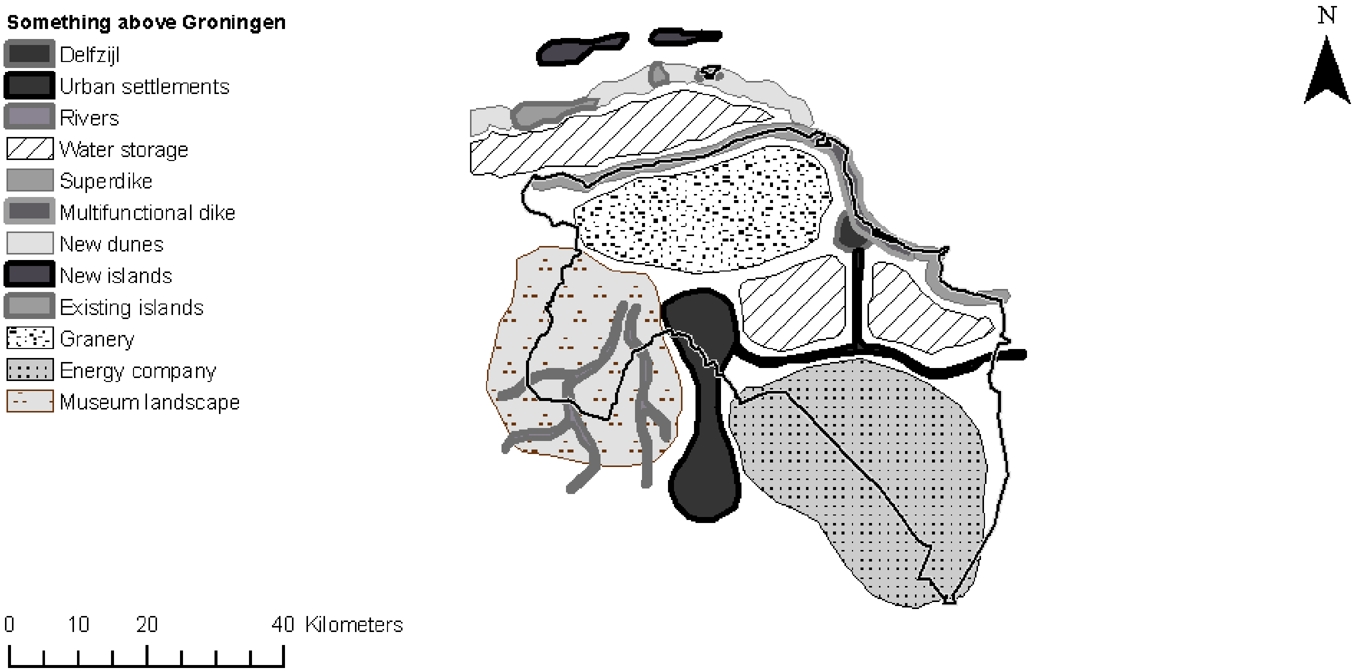

Figure 16: Something above Groningen scenario

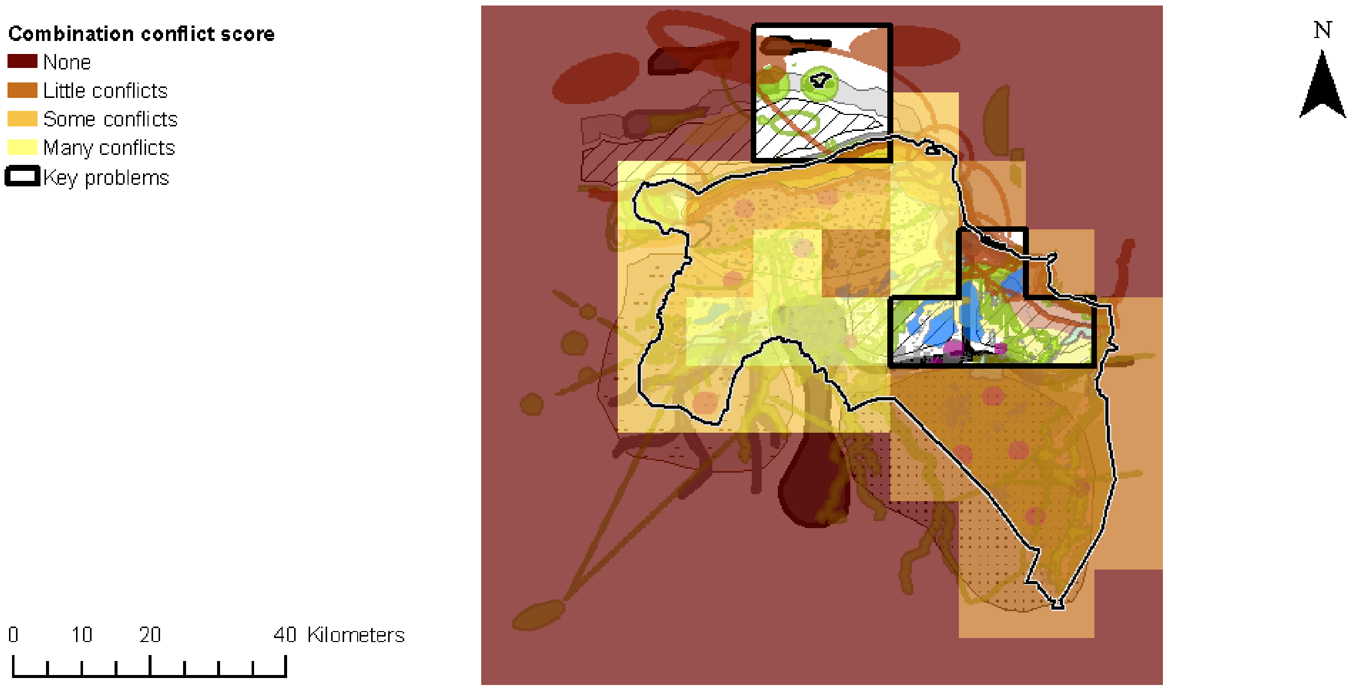

Figure 17: Conflict scores something above Groningen

Problem 3: Forward Wadden Sea

The Wadden Sea is a "large temperate, relatively flat coastal wetland environment, formed by the intricate interactions between physical and biological factors that have given rise to a multitude of transitional habitats with tidal channels, sandy shoals, sea-grass meadows, mussel beds, sandbars, mudflats, salt marshes, estuaries, beaches and dunes." (UNESCO, 2009). The third key problem dealt with the idea of using the current Wadden Sea area as a protective buffer for flooding. This idea proposed to create a new Wadden Sea and to turn the current Wadden Sea into a freshwater supply. The new Wadden would have to be made by first creating new islands and wetlands `in front' of the current Wadden isles and then interconnecting the current Wadden isles with a line of dunes. The questions asked were: what would this idea look like in more detail, and how can this relatively extreme idea be brought a bit closer to realization?

The participants agreed that by creating new islands and sand banks in front of the current Wadden Sea, the current Wadden Sea will cease to exist and a new Wadden system will grow, farther away from land (see Figure 18). Rapid sea level rise already threatens the current Wadden system with extinction. When natural processes are given free rein in a situation of sea level rise, the currently existing islands will disappear altogether. These islands would then move towards the shoreline until they vanished altogether when meeting hard dikes. At a higher sea level the dike will have to be a superdike (a dike with a very broad base), because dikes that have only been heightened will become too vulnerable.

However, a decision to move the current Wadden system is likely to encounter much political and civic opposition. Furthermore, creating a new line of wadden islands and sand banks will be technically difficult and will require huge amounts of sand. Having islands in front of the coast might impede the damaging effect of strong waves hitting the coast, but these islands will frequently need large sand supplements.

Conclusively, a great amount of extreme actions has been proposed in the map of integrated adaption measures and the backcasting scenarios. The participants agreed that more research is needed to understand the consequences of proposed adaptation measures, especially when proposing something as rigorous as moving the Wadden Sea. The participants stated that more research should answer 1) what the effects of rapid sea level rise will be on the Wadden Sea and the safety of the mainland and 2) what measures can possibly cope with rapid sea level rise while protecting the mainland. Furthermore, the participants wondered if proposing the 'Forward Wadden' adaptation measure would be politically feasible, considering the mishmash of interests in the Wadden area. To many participants, surrendering the current Wadden Sea seems to be out of the question. Yet, to the participants it is clear that something has to be done north of Groningen in case of rapid sea level rise. In such a scenario the Wadden Sea will disappear, the coast is threatened and the Wadden islands become very vulnerable. Doing nothing is not an option in that scenario.

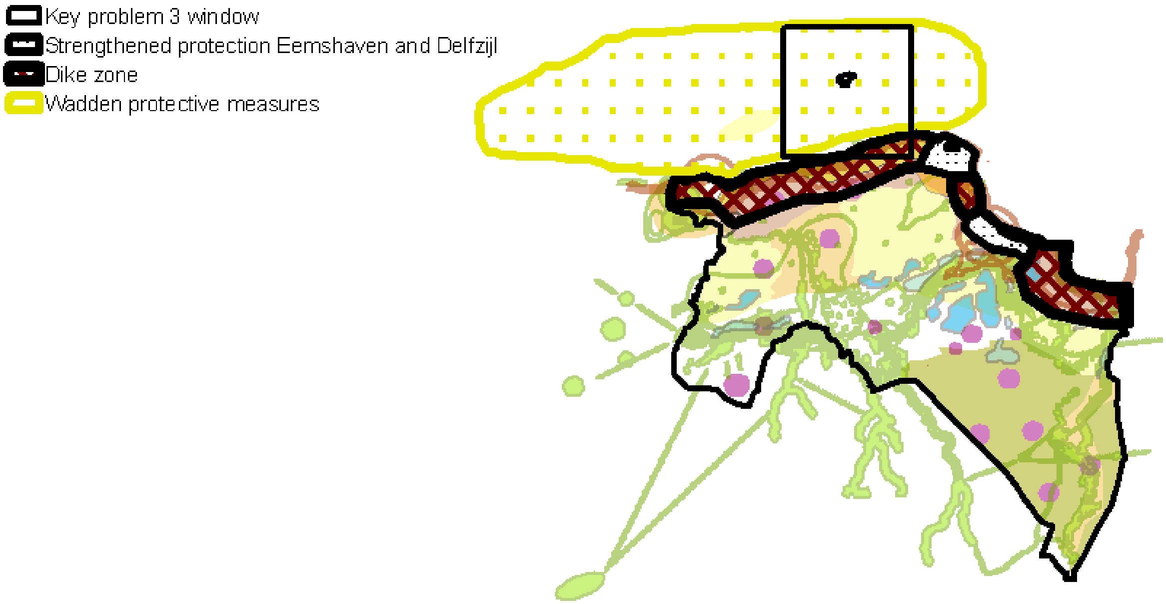

Figure 18: solutions problem 3

Problem 4: South Delfzijl

The fourth key problem deals with the area south of Delfzijl. In this area many goals and interests seem to conflict with each other when the backcasting scenario and the integrated adaptation measures are combined. A large water supply will have to be combined with ecological areas and expansions of the city of Delfzijl. Questions asked were: Are the various interests in this area conflicting or can they be united? Can the quality of surface water area be warranted or improved when Delfzijl expands towards the south? Is that urban expansion even necessary, given expected demographic decline? In case of demographic decline, what can fund the large-scale water supply and development of ecological areas?

The participants found that the area south of Delfzijl did not contain real conflicts of interest. According to them, the different interests can be combined (e.g. by building floating housing, or housing on poles). Furthermore, the rapidly melting polar caps will create a new chance for Delfzijl. The participants thought that a shipping route across the North pole will become increasingly popular for recreational boating and cruises. Delfzijl can use this new northern passage to transform from a small town on the banks of the Eems into an important stop for cruises. For this transformation Delfzijl will have to undergo massive changes (see Figure 19). The participants envisioned Delfzijl as an Ushuaia of the Northern hemisphere. Large parts of Delfzijl will have to be demolished. The Delfzijl industry will have to be moved towards the Eems Harbour and replaced with an `alluring urban area' around the cruise harbor. A city bay will be developed with world class facilities for nightlife, culture, leisure and shopping. New Delfzijl will be powered by sustainable energy extracted from overproduction in the Eems port (both warmth and electricity).

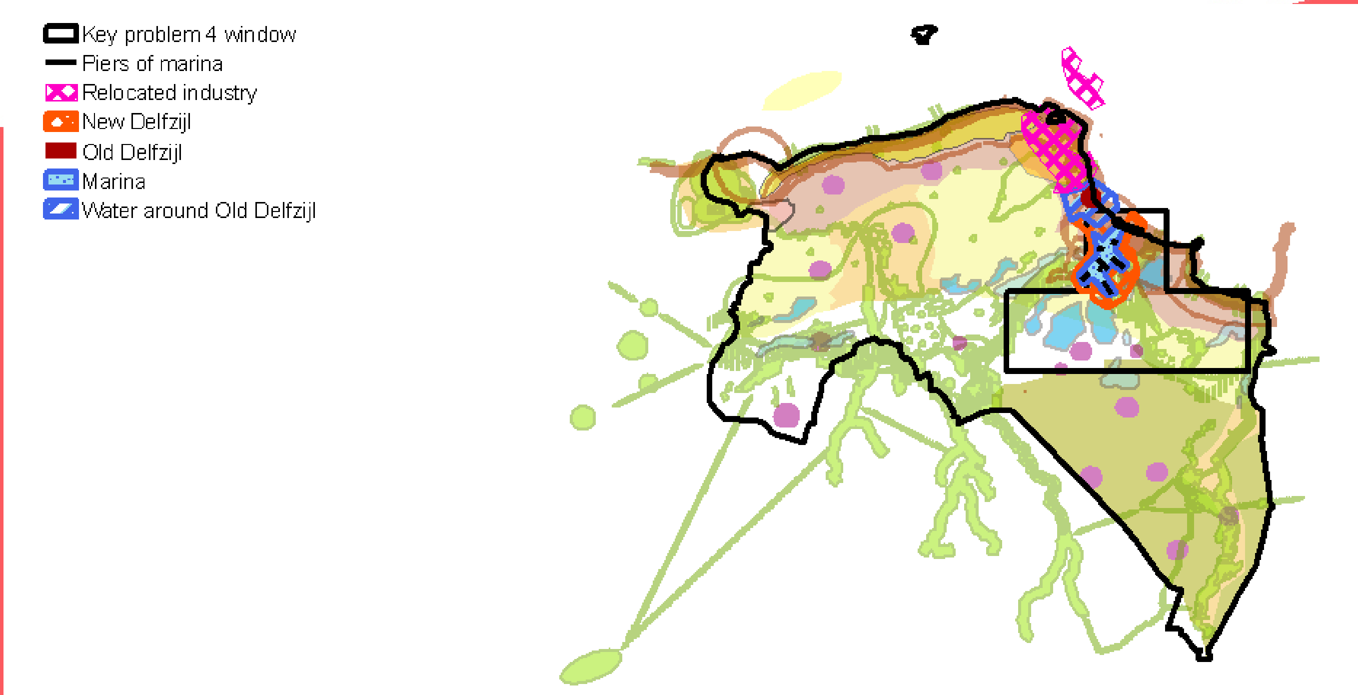

Figure 19: solutions problem 4

4.1.3. Drowned land of Groningen

The third scenario sketches a situation where all inhabitants and important functions of the province 'retreat' from most of the Groningen area onto all places that are at least 5 meter higher than the current sea level. The lower parts of the province flood and the remaining areas are protected from the sea. The north of Groningen becomes a basin for deposition and obtains many of the properties of the current Waddenzee - with sandbanks, wetlands, plates that fall dry at low tides and dunes (see Figure 20).

Figure 20: drowned land scenario

The designated key problems of combining this backcasting scenario and the map of integrated sector-specific adaptation measures dealt with tidal rivers planned where currently the Reitdiep runs and with the future of the Peat Colonies when this area will be flooded by the sea (Figure 21).These key problems and the solutions that the participants proposed will be elaborated upon in the next section.

Problem 5: Flooding tidal river Reitdiep

The fifth key problem dealt with the proposed introduction of two tidal rivers in the backcasting scenario. These were envisioned at the current location of the Reitdiep and the so-called “oude Fivelloop”. In the scenario, the Reitdiep tidal river would then take salt water and tidal effects up to the edges of Groningen city. Questions asked were: What effects does this tidal river have on the landscape and nature, and what does the tidal river mean for the Lauwers Lake? Can a tidal river exist amidst flooded land? How does that work?

Figure 21: conflict scores drowned land scenario

The participants agreed that, in contrast to the backcasting-scenario, tidal rivers will not develop in the flooded landscape of northern Groningen. They felt that when the Groningen landscape is surrendered to the sea, tidal rivers might develop descending from the lightly sloped banks of the Drenthe plateau. Because of the flooding a kind of Wadden landscape will develop in the lower lying parts of Groningen with gullies, plates and sandbanks that flood periodically (see Figure 22).

The participants felt that a discussion on the desirability of the sketched scenario was more important than the exact location of tidal rivers and sandbanks. When does a government decide to return its' land to the sea? If the sea level will rise with 5 meters in a short amount of time, surrendering parts of the province seems unavoidable. However, choosing to return land to sea seemed to be a farfetched idea for the participants. The participants presumed that technical measures to sustain the land are in any case more beneficial than buying out the landowners to and letting the land flood. They explored conditions that can lead to a possible surrendering of land in Groningen. Some conditions that might enable land surrenders:

1. When a nation is responsible for providing safety to the landowners' properties, only the nations' bankruptcy might lead to surrendering land.
2. If the nation's power to implement technical measures is severely restricted by funding, it might decide to only improve the protection of the main urban areas in the country. This would leave inhabitants of Groningen with the choice to leave or live with flood risks.
3. The easiest way to apply a policy that gives up the country is doing nothing and waiting for a flood. It is probably the easiest to accept the effects of flooded land and take adaptive measures from that point onwards.

The participants agreed that the drowned land scenario introduces (amongst many) two important political problems. The first one has to do with choosing between surrendering the land or investing many resources to sustain the current land. The other political problem is of a communicative nature. If it becomes clear that the land will have to be surrendered to the sea, then what are the psychological implications of that decision? What will it do to morale? Who will have to tell it to the people? Lastly, in a situation of strong sea level rises politicians will find that the time for choosing adaptation measures is limited. If the sea level rises fast, technical measures that are at least challenging and expensive now, might be utmost impossible in the future.

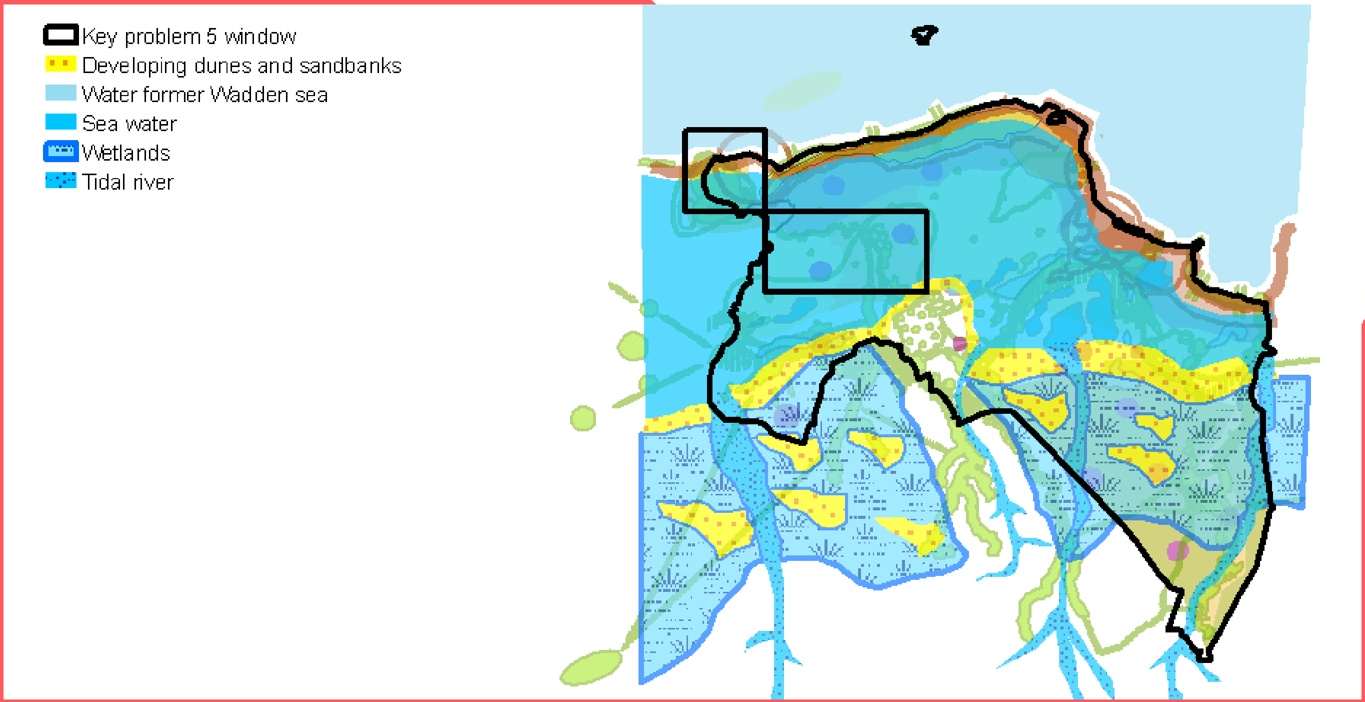

Figure 22: solutions problem 5

Problem 6: Seawater in the Peat Colonies

The sixth key problem dealt with the Peat Colonies area. Most of this area will be flooded according to the backcasting scenario. However, the integrated adaptation measures have designated the production of energy crops to that area. This conflicts. Questions asked were: will the energy crops have to move to the south? Can energy be won in another way if the Peat Colonies are flooded? If so, how and where?

The participants felt that when seawater would flood the Peat Colonies, that landscape can put the flooding to good use. They designed a landscape that would use the seawater-floods in a sustainable manner. The participants proposed to use the current landscape structure of straight line-compartments to structure an 'inverted landscape'. The canals and ditches that currently shape the compartments in the Peat Colonies will be turned into dikes that enclose lower lying land (see Figure 23). This lower lying land will periodically be flooded with seawater. Windmills positioned on these compartmental dikes can produce energy and will, if positioned carefully, strengthen the esthetical characteristics of the compartmented landscape.

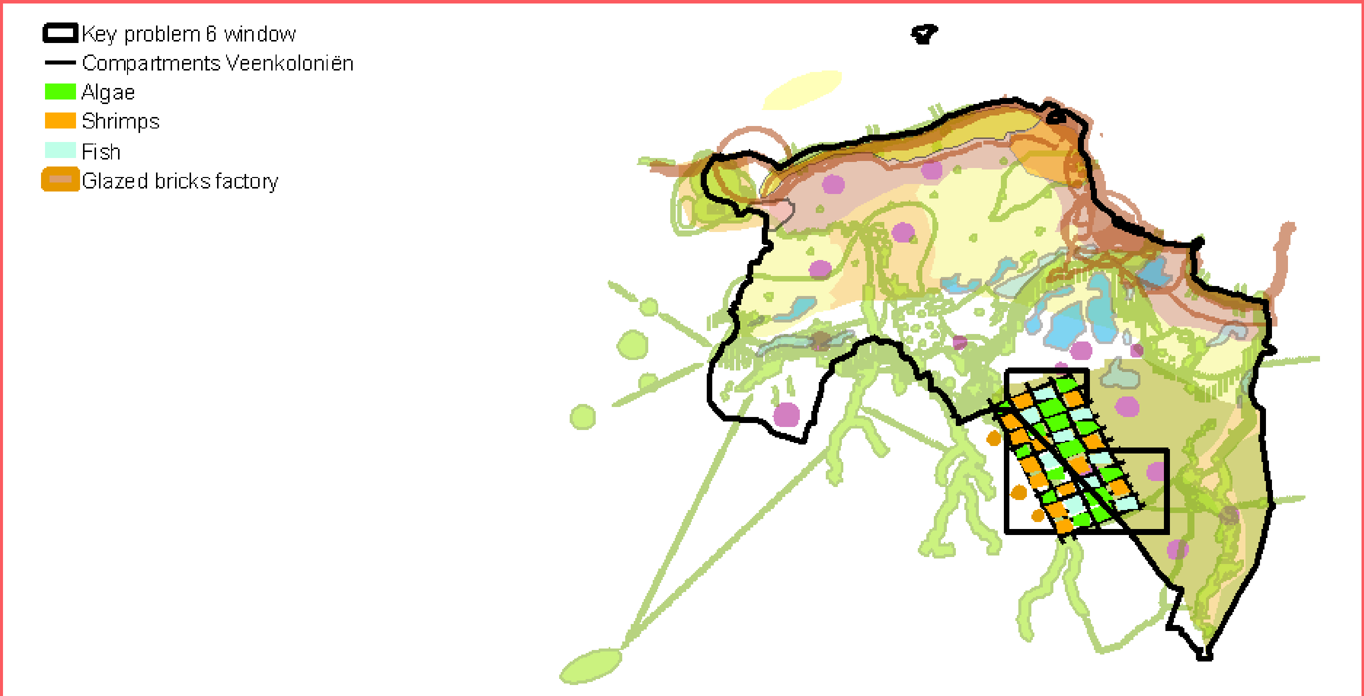

Figure 23: solutions problem 6

In the different compartments fish, shrimps and algae can be bred. The fish and shrimp can be used as food for inhabitants of the region. The algae can produce proteins, fertilizer and biodiesel. When the sediment will be deposited in the compartments and mix with the contents of the compartments. When the compartments are filled to the brim by this deposition, the compartments can be excavated and the sediment can be used to produce glazed bricks. The bricks can be baked in ovens fueled by the biodiesel that the algae produce. These bricks can again be used for housing in the region. When the compartments are empty, the production of fish, shrimps and algae can restart.

4.2. Results

In the last part of the process, the integrated sector-specific adaptation strategies were tested for robustness and as a conclusion two climate proof scenarios for Groningen were developed from the analyzed material.

4.2.1. Testing for robustness

Preliminary to the workshop an assessment of conflict gravity has been done by a Groningen province expert. A grid of cells covering the province was scored with values between one and four. These scores indicated an estimation of the relative gravity of conflicts between adaptation measures and scenarios. Cells with low conflict gravity estimates contain well combinable scenario elements and adaptation elements, while high scoring cells have highly relevant combination problems.

The conflict gravity estimates of the different scenarios were summed. These summed conflict gravity estimates give an approximation of the amount of scenarios in which the proposed sector-specific adaptation measures do not conflict strongly. The resulting map shows an approximation of the robustness of adaptation measures in different areas. This map shows four categories. Cells were the sum of conflict estimates ranged from the minimum 3, to 7, are regarded as more or less robust; cells with higher summed conflict estimates (values 8 to 12, the maximum) not. This classification of robustness is somewhat arbitrary. The results of this classification were found to be in line with the expectance of robustness that Groningen province had (see Figure 24).

The robustness analysis lead to the conclusion that in two areas proposed adaptation measures are robust.

1. The measures in the northern coastal zone: more space for coastal defense, salt water agriculture and algae production combined with the natural forming of gullies and plates. Some other measures in this area seem robust as well: using surplus heat from the plants in the Eems Harbour area for functions that need warmth; creating extra water storage to warrant water supplies; and developing one or more greenhouse or `agrocluster' zones in this area.
2. The climate adaptation measures proposed for the southern Peat Colonies are robust as well. Additional connections for the provincial ecology, and additional water storages for water supply are robust adaptations; Shifts in agriculture to produce energy-crops, developing agroclusters in this area and the concept of the sustainable greenhouse in the Peat Colonies are robust as well. Finally, the relatively high grounds of the Peat Colonies are a good place for the development of additional residential areas.

For other areas in the province sector-specific adaptation measures have been integrated and climate scenario specific solutions have been created in the participative session. The Groningen province has proposed to let these adaptation measures and solutions be adopted by area specific studies that were done during the hotspot Groningen process (e.g. studies for the Eems Estuary, Peat Colonies and Wadden Sea). Furthermore, the sector-specific adaptation measures and scenario-specific solutions have been used as building bricks for two climate proof adaptation scenarios. These are presented in the following paragraph.

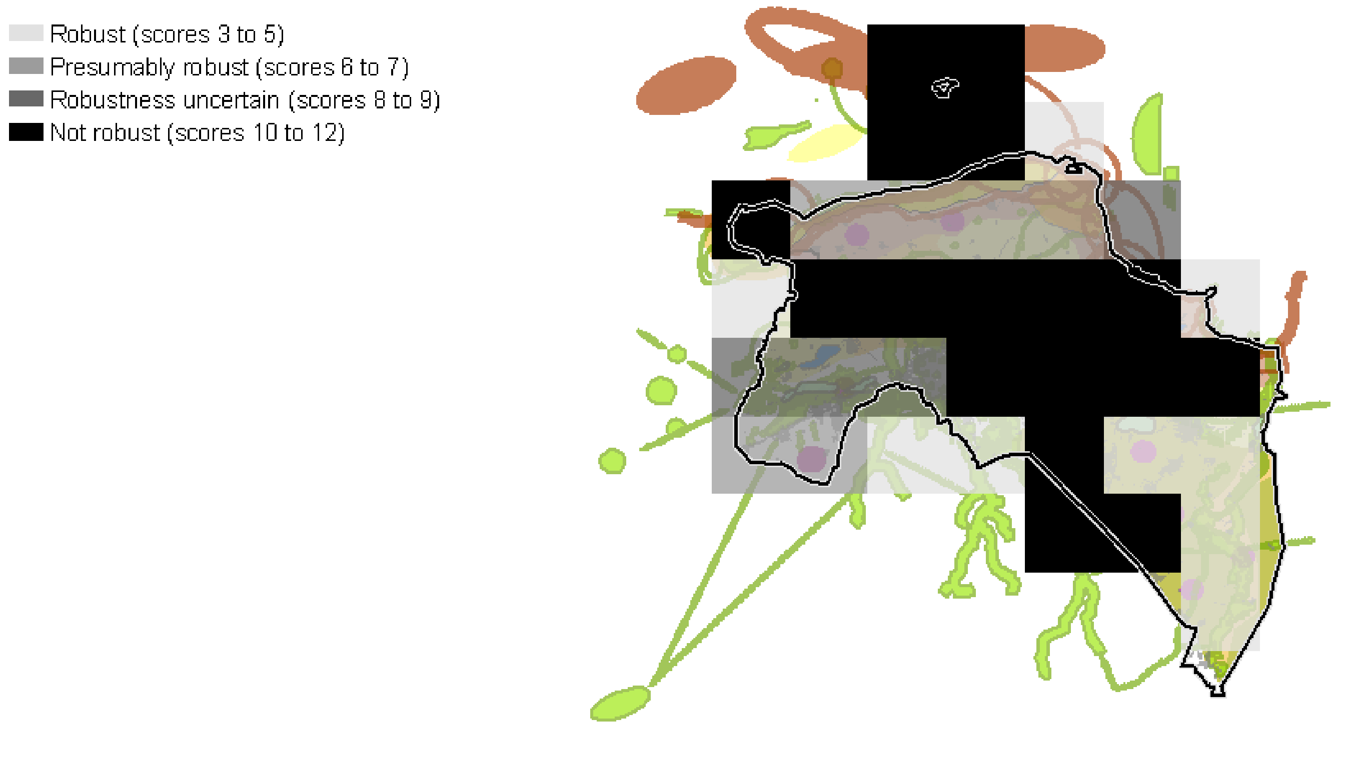

Figure 24: robustness adaptation measures per gridcell

4.2.2. Creating climate proof scenarios

The previously integrated sector-specific adaptation measures have been combined with the solutions to six key problems that were proposed in the participative session. This combination has led to two fundamentally differing scenarios. Both scenarios assume substantial effects of climate change that require drastic measures.

The first scenario ('sustain', see Figure 25) sketches a situation where Groningen will defend itself fiercely against the effects of climate change, even with an increasingly rapidly rising sea level. In this scenario the Wadden system will be sustained by supplementing it with sand and it can maintain its' protective function for the Northern Dutch coast. Next to maintaining the Wadden system, land is cleared along all of the coast for a broad 'dike zone', unbreakable and high enough to withstand the high sea levels and high wave energy of a northwestern storm. The dikes in this zone, and the area in between, will house a newly built Eems Harbour, Delfzijl (both 'old' and 'new') and a combination of the industrial zones of Delfzijl and Eems Harbour.

Behind the dike zone, low lying parts of the province will be heightened naturally by using the deposition of periodical, controlled flooding. The area next to Groningen will be the first area to be heightened. In the central part of the province a public water reservoir will be developed that can supply designated areas with freshwater even during droughts. The agriculture along the coast will produce algae and crops with salt water. The agriculture in the Peat Colonies will grow food crops, energy crops and livestock, while developing `agroclusters' and `sustainable greenhouses'.

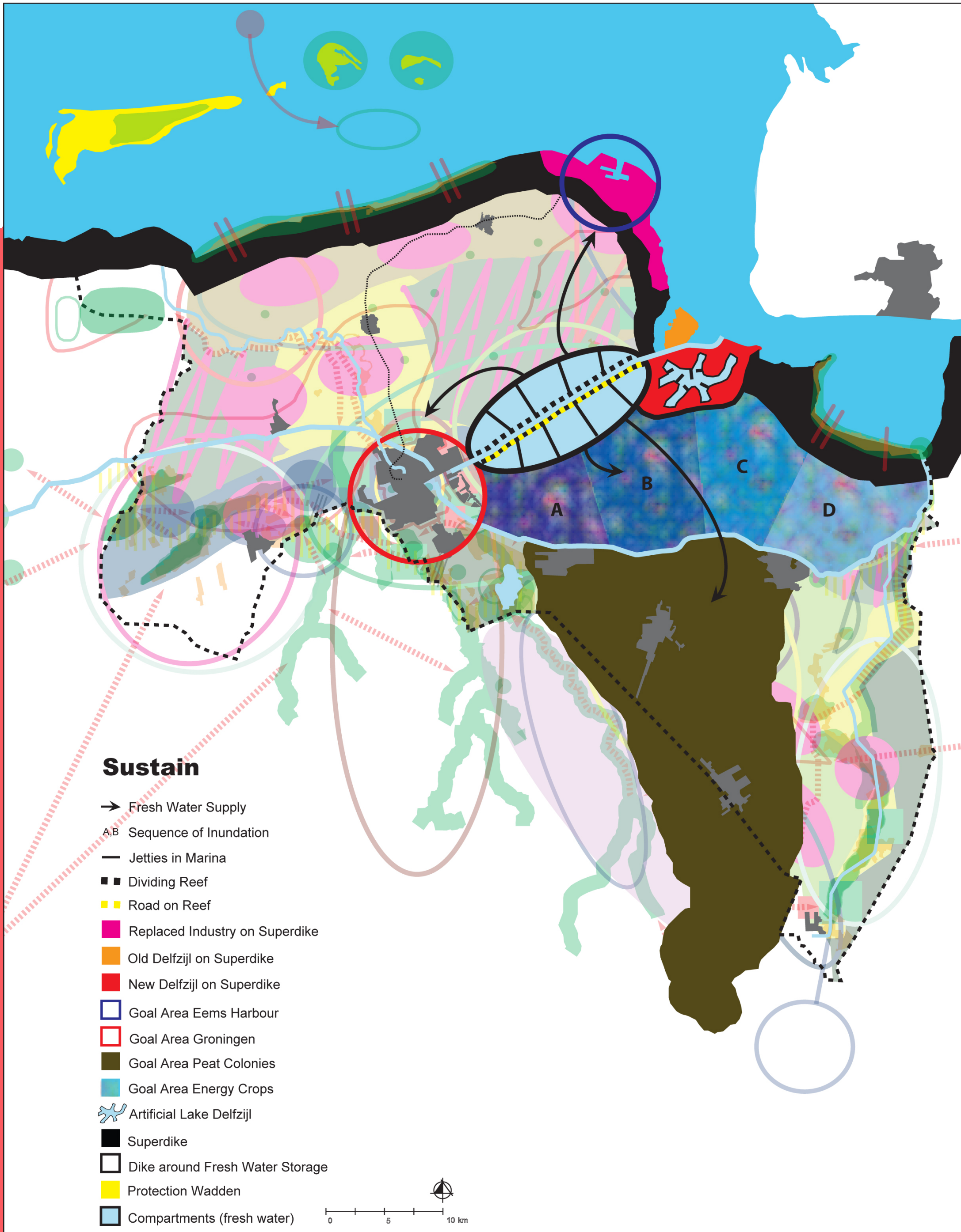

Figure 25: the `sustain' scenario

The second scenario ('give up', see Figure 26) sketches a situation where fighting against the growing sea levels is to no avail, and most of the province floods. In that case the most precious functions of the province should be safeguarded. Residential areas, commercial zones and others functions might relocate to places that are safe from the sea (i.e. all area higher than 5 meters above current sea level). Other, less footloose functions should be made robust enough to withstand the sea (e.g. the Eems Harbour and the Delfzijl industrial zone).

The land that is lower than 5 meter above current sea level will change into a new Wadden system, where new islands, rows of dunes and periodically flooded sandbanks will develop. This new Wadden system will protect the higher lands from the sea. New tidal rivers will appear and form a natural connection with the higher grounds of the Drenthe plateau. This new Wadden system offers new economic opportunities. At open sea, 'sea farms' can be developed. The periodically flooded areas in the system can house agricultures of algae, fish and shrimp. The deposition that this agriculture and controlled flooding will leave can be excavated and turned into glazed bricks in new ovens.

The presented scenarios, 'sustain' and 'give up', offer insight into the far ends of possible climate proof futures of Groningen. Choosing to flood some land, or choosing to give up land altogether, is a choice that decision makers would rather leave alone. These decisions seem extreme - however, it is not impossible that some of the choices that come from these scenarios will have to be made in the next century. It is now uncertain when the situation is dire enough to need decisions as presented here. Furthermore, it is uncertain at what point decisions need to be made to anticipate scenarios as extreme as these. We can only hope that we do not need to make such decisions for years to come. In any case, this report has shown some adaptation measures that might safely be developed right now.

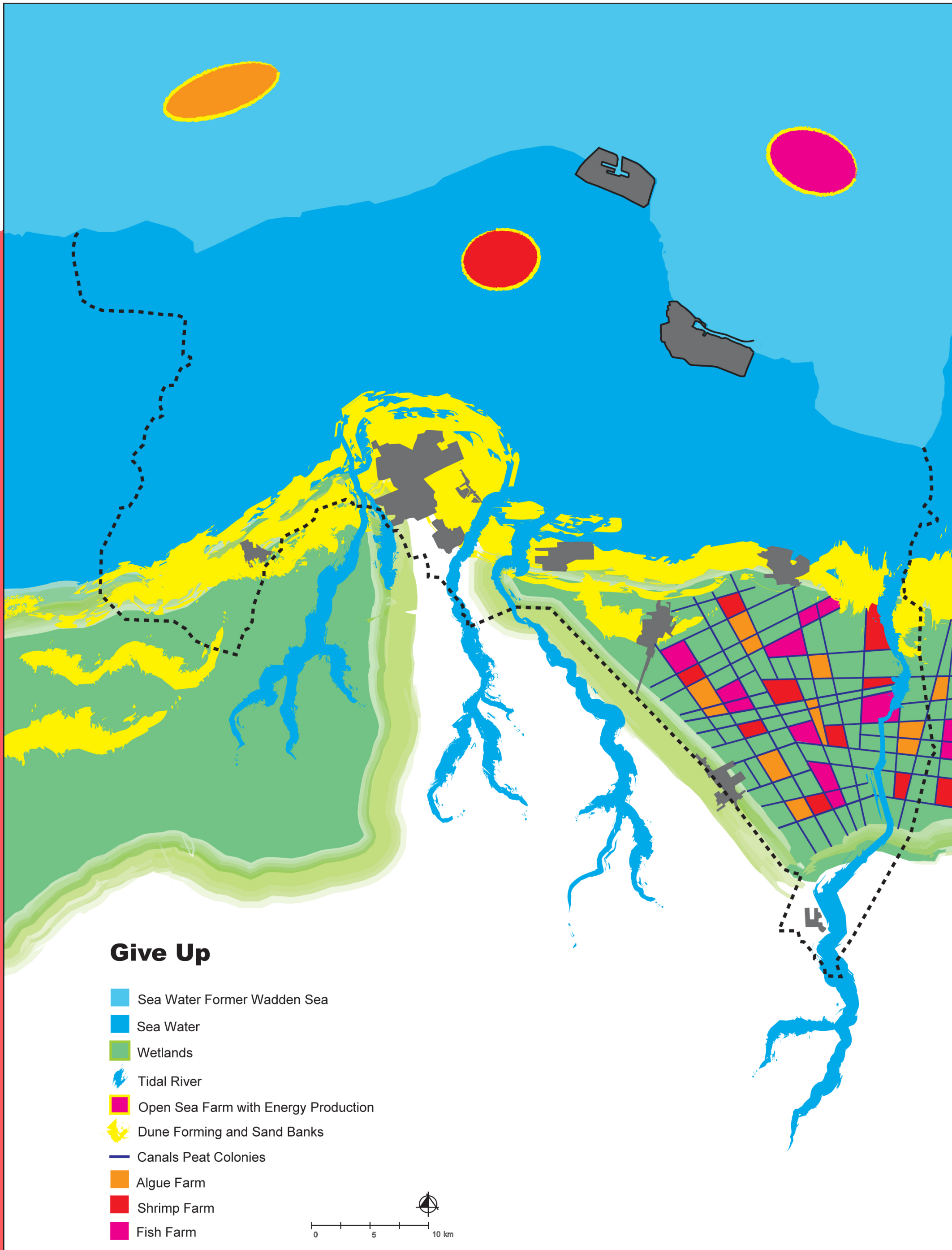

Figure 26: the ‘give up’ scenario

5. Conclusions

The hotspot Groningen process finally led to a large number of maps of adaptation measures for a climate proof Groningen. Some maps showed thoroughly defined adaptation measures, realizable in a short term. Other maps showed roughly sketched long term adaptation strategies. The integrative part of the process integrated these maps with two goals. First, the process meant to explore integral adaptation scenarios for climate proofing Groningen. Second, the process meant to find which adaptation measures are robust, i.e. measures that are applicable in all foreseeable contexts. In this chapter some conclusions on the results will be drawn, followed by some reflection on the methodology. To do this, sector-specific adaptation measures had to be integrated into one map of adaptation measures.

5.1. Integrated sector-specific adaptation measures

An iterative process of defining, locating and combining a score of sector-specific adaptation measures has led to an integrated map of adaptation measures as proposed by experts. At first glance this integration shows a number of important adaptations for Groningen. Amongst these are 1) the impressive amount of land a climate proof coastal protection will need, 2) the amount of measures necessary to maintain the vital economic functions of the Delfzijl and Eems Harbour areas and 3) the role of the lowest central areas in water supply and water storage. Other areas will find new opportunities for energy production and agriculture. According to the specialist proposals, the main urban area of the province does not need comprehensive spatial adaptations for climate change.

5.2. Robust measures

Integrated sector-specific adaptation measures have been combined with the different backcasting scenarios. The gravity of possible conflicts between proposed measures has been scored for each of these combinations. The sum of gravity of conflicts between sector-specific adaptation measures and all backcasting scenarios gives an idea of the amount of robustness of these measures. This analysis has shown that in two areas the proposed adaptation measures are applicable in a broad range of climate change scenarios. These areas are the northern coastal area and the southern Peat Colonies.

5.3. Integral adaptation scenarios

Two integral adaptation scenarios have been explored. This exploration shows that the central climate change problems of Groningen are presumably the risks that might develop because of rapid sea level rise. The scenarios are based on different ways to adapt to these risks. In one scenario all of the province can be saved from the sea (the 'sustain' scenario) while in the other scenario most of the province will have to be surrendered (the 'give up' scenario). Some opportunities and threats are evident from these scenarios.

The resulting scenarios propose that climate change and the likely decline of hydrocarbon fuel availability will offer new opportunities for agriculture in Groningen. A first opportunity comes from climate change. Because of this change, parts of the province will probably lose freshwater supplies. Especially the soil water in some of the coastal areas will turn salt. This makes innovative farming that uses salt water (i.e. production of salt water crops and algae) necessary in some parts of the province. A second opportunity comes from alternative energy sources. Energy crops and wind energy can likely provide farmers in Groningen with new sources of income in the future.

A comparison of adaptation measures and solutions created for scenarios shows that the climate problems of Groningen will accumulate in the lowest areas of the province. The sector-specific adaptation measures propose that these areas should function as water supply areas in dry times and as surplus water storage in wet times. In case of stronger sea level rise, the current protection will not be enough - especially not for these lowest areas. These will have to be heightened, or they will flood.

5.4. Experiences with the integration methodology

The hotspot Groningen process was focused on stimulating creativity and producing innovative concepts for adapting to climate change. The effects of extreme changes in climate and sea level were thought of, rather than modeled. This led to a stream of ideas, concepts and measures drawn on many maps. Such a focus on producing innovation in a preliminary phase can presumably only be reached when giving free rein to participants, without demanding too much in terms of definition or situations. The resulting collection of ideas is on the one hand broad and rich, but on the other hand hard to combine and analyze. A selection had to be made to make combination and analysis possible.

Only adaptation measures of a spatially explicit nature were accepted in the integration phase. This meant that some adaptation measures had to be excluded, while other measures had to be edited to allow acceptance. Eventually, all measures were (to some extent) edited, while some were relocated. This selective step was necessary for a spatial integration of measures.

The amount of overlap between adaptation measures was minimized to reduce possible conflicts between adaptation measures in the integrated map. The resulting integrated map might assume interactions between adaptation measures and land uses that are impossible, while on the other hand it might fail to tackle unwanted interactions. Such mismatches are possible because the spatial properties of accepted adaptation measures were uncoupled from the proposed functioning of these measures. This essentially spatial comparison does not allow for testing functional consistency between adaptation measures and land uses. Only the participants in the process were able to reflect on how land uses and proposed adaptation measures would interact (based on their expertise). More advanced modeling might be possible, where the dependencies and impossibilities between different map elements are made explicit. However, this makes it necessary to define the relations between all provided elements - a difficult task, that did not fit the explorative nature of the process.

Selecting only spatially explicit measures did allow for some analysis and some comparison of otherwise seemingly incomparable qualitative information. The qualitative nature of the provided data restricts spatial analysis possibilities to counting number of units at a give place. It allows the analyst to understand patterns, pressures and possible conflict areas in the data.

5.5. Experiences with using a touch table

A GIS was used for adding and editing information on maps, and a tangible table was used to support the interaction between participants. The GIS was projected on a wall, the tangible table and a computer screen (for moderators). Some drawing was done by two representatives of the groups on the tangible table, while the other participants watched the projections on the wall to follow the progress of the representatives. Very little of the tangible table and GIS functionality was used by the participants: they asked the moderator to zoom in, change tools and change colors. Only graphics were drawn in the GIS. No GIS analyses were used during the session. The found benefits of using the described setup instead of paper maps:

- The onscreen activities were projected on a wall as well. The participants could see what the representatives did on the screen without having to group around the table or a computer-screen. The group would be too large;
- Representatives were able to make changes onscreen on a table. In groups, this is a more convenient position for interaction than sitting behind a computer screen. The representatives could manipulate the GIS on the tangible table, while still being able to interact easily with by-standers;
- Using the GIS allowed the participants to change or delete elements after they added them.

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