Saly, Senegal

CLIMATE RISK OVERVIEW TOOL: MAPPING NATURE-BASED FLOOD PROTECTION OPPORTUNITIES

The planet is facing enormous challenges caused by human activity, increasing the vulnerability of communities and ecosystems to the forces of nature. This is worsened by the effects of climate change, which is threatening the world's coastal defences. Van Oord has responded to these challenges by developing the Climate Adaptation Action Plan. The plan is designed to encourage meaningful dialogue between stakeholders in order to provide ready-to-scale marine solutions that help increase the resilience of the communities and ecosystems of coastal areas.

In 2018, Van Oord marked its 150th anniversary with an international symposium with climate change and the energy transition as major themes. Invited to speak at the symposium was Christiana Figueres, the United Nations' top climate change diplomat who delivered the Paris Agreement in 2015. She gave a powerful speech on the importance of achieving the climate agreements to combat global warming. She emphasised the need for action from both state and non-state actors to limit the effects of climate change, particularly for the world's most vulnerable coastal communities.

Van Oord responded to this call for action by developing the Climate Adaptation Action Plan, designed to encourage dialogue between stakeholders and provide ready-to-scale marine solutions that help increase the resilience of coastal areas, their communities and ecosystems. Our sustainability programme, S.E.A. (Sustainable Earth Actions), focuses on four pillars:

- Enhancing the energy transition
- Accelerating climate action
- Empowering nature and communities
- Achieving net-zero emissions by 2050

The Climate Adaptation Action plan is one of the initiatives under the pillar 'accelerating climate action'. We believe that collaboration with all stakeholders on climate actions is needed to be able to make a greater positive impact.

The pillar 'empowering nature and communities' impacts our day-to-day actions for 'accelerating climate action'. For example, making use of mangrove rehabilitation for flood protection while empowering local communities to create new opportunities for economic benefits and social impact. The involvement of local communities is pivotal in making our marine and Nature-based Solutions (NbS) as effective and sustainable as possible. Our experience and expertise in ocean health, such as restoring marine ecosystems like coral, oyster beds and seagrasses, only developed through the extensive collaboration with local communities and world-renowned research institutions around the globe. The pillar 'achieving net-zero emissions by 2050' also affects which opportunities we invest in for 'accelerating climate action'. On the one hand, we advocate solutions that have a smaller CO2 footprint, for instance by choosing natural materials like sand over concrete and by choosing designs that require smaller equipment and hence less fuel. On the other hand, we advocate solutions that can act as a carbon sink, for instance mangroves are an important opportunity for carbon sequestration (Chatting et al, 2022).

This year, the world's largest humanitarian network, the International Federation of Red Cross and Red Crescent Societies (IFRC) and one of the world's largest and most experienced conservation organisations, the World Wildlife Fund for Nature (WWF) released a report with a call to action (IFRC and WWF, 2022). It urges the private sector to: 'Scale up investment in existing forms of private sector finance mechanisms for NbS. Invest in exploring innovative new finance mechanisms (such as insurance mechanisms) for NbS for climate adaptation and disaster risk reduction, establishing their scale-up potential and feasibility in different geographies.' It advocates a fast track process led by the private sector, in addition to the regular government-led tender-process. Van Oord wants to take the lead in taking action in the private sector of the maritime engineering industry and is dedicated to being a proactive partner in this quest. The launch of our Climate Adaptation Action Plan is a pro-active early stage process that will complement the regular business development process with new projects by exploring new finance mechanisms for delivering our established solutions together with the right partners.

The Climate Adaptation Action Plan consist of three elements (Figure 1). The first stage is to make a **Climate Risk Overview** (CRO). Basically an advanced geospatial multi-criteria analysis, the CRO is a global tool where open source data is mapped onto 10 km segments of the world's coastlines. The overview brings together key parameters, such as populations, low-lying land and expected sea level rise to anticipate the hazard of flooding for all coastlines and societies around the world. Deploying this tool allows us to start and support dialogues with various stakeholders and to focus our efforts on potential climate adaptation projects. Designed to be a fast and intuitive tool for quick selection, the CRO and its information is available for everyone to explore. In contrast to a heuristic bottom-up approach where locations are added to a selection until the selection is large enough for a portfolio of locations, the CRO offers a systematic global top-down approach where locations are dropped until a small enough portfolio of locations is left. For this workflow, the CRO uses readily available global data sources. These sources are often based on satellite data that have some methodical and sensor limitations. Therefore, the numbers shown in the tool are not to be used at face value, but in a relative sense to compare locations. Each selection of a location needs further verification using detailed data sets. The CRO is meant to be used in a cycle back and forth with detailed GIS software. The result is a shortlist of approximately ten potential locations where a climate adaptation project could be initiated. These will subsequently be analysed in the context of the natural and societal systems.

The second element of the Climate Adaptation Action Plan is **Climate Adaptation Solutions**. Using the short list of potential locations created from the CRO, each location is then studied in detail. A system analysis as proposed by the Building with Nature concept (de Vriend et al, 2015) is executed to facilitate maximal synergy with the ecological context. The available Building with Nature solutions, for example permeable dams (Winterwerp et al., 2020) are mapped against the local challenges to select viable solution strategies. This stage requires detailed analyses in dedicated GIS software using a combination of global and local data. This will result in suitable ranges of solutions for each location. Some locations might not be viable and will be dropped at this stage. If too few locations remain, the CRO step will be repeated.

The third step is the **Climate Adaptation Action Coalitions**. After investigating each location with its natural context, each location is analysed in terms of the societal system in which it is located. Just as Building with Nature, this will also be carried out with a range of partners. For this purpose, Van Oord has become an active member of various international groups, alliances and networks, notably Ocean Risk and Resilience Action Alliance (ORRAA). This stage requires detailed societal analyses in using a combination of global and local networks. A site visit to meet local partners is crucial. In addition, after this stage some locations might be found less suitable to pursue for a variety of reasons.

After these three steps of the Climate Adaptation Action Plan are completed, a handful of locations are classified as suitable for further development. At this stage, these potential locations are jointly developed with the commercial department within the dredging business unit of Van Oord as a new project lead that requires follow-up. The three steps of the Climate Adaptation Action Plan will be repeated from time to time to ensure that we continuously investigate and identify potential locations that can be protected from the consequences of climate change. Van Oord is currently in the process of finishing a first iteration cycle. When the next cycle starts, we anticipate adding new data layers to the CRO to detect new business opportunities around the world that were not yet visible.

Climate Risk Overview

The Climate Risk Overview tool has been described by de Boer et al. (2022). Their paper described the basic elements in detail: the systematic global screening grid and the calculation of the number of people exposed to flooding. These aspects are summarised below. Four additional layers

FIGURE 1

The 3 steps of Climate Adaptation Action Plan that are necessary to supply potential projects to our business development.

of the CRO, which were not described by de Boer et al. (2022), will be introduced here: the community aspect via World Bank income level and resilience, and the ecosystem aspect via mangroves and corals.

The site selection and exposure to flooding

For the purpose of screening the entire planet for a combination of parameters, we start our search with the area that is at risk. This is the global Low Elevation Coastal Zone (LECZ), defined as the part of the land that is lower than 10 metres above mean sea level. We used a Digital Elevation Model (DEM) to calculate the global contour of the land 10 metres above sea level. At the sea side, we take the -50 metres depth contour to encompass all marine locations that may act as a source of sediment and could accommodate land reclamations. We used a space filling algorithm to divide the strip of land between these contours into sites of approximately 10 x 10 km² = 100 km². The world's coastline was then used to split each site into wet and dry areas. For the current analyses, we kept only those sites that are at least partially covered with land. The remaining sites are irregularly shaped. The typical size of 100 km² was chosen because it is an upper size at which communities can be informally addressed. It is also the spatial scale of local habitats, which is the typical scale at which geomorphological solutions evolve. This yielded 60,000+ sites worldwide.

The essence of the idea behind Climate Risk Overview is to combine data from a range of different sources from different disciplines for each site. We programmed a range of python modules for different data types. First, detailed grid data needs to be averaged to the sites. This is the case for global digital elevation models with a resolution of 30 m (SRTMv4, NASADEM, ALOS, MERIT), and for population data that is available at 100 m resolution (GPWv4, WorldPop). Second, coarse gridded data needs to be interpolated. Examples of this are the IPCC sea level rise projections. Third, vector data needs GIS software to calculate the overlap area. This is the case for mangrove and coral coverage patches. Also, country data is treated as vector data. Lastly, for point data sources we assigned each object to the nearest site, with a maximum distance. This is the case for the global tide and storm data sets.

Boer et al. (2022) calculated the Extreme Sea Level (ESL) for different scenarios per hotspot and combined that with the local DEM and population data to calculate the population exposed to flood risk for each site. The 2090 scenario with 1/100 year flood exposure was added to the public CRO. With this layer, sites that are prone to flooding can be detected. With the additional layers below, it is possible to filter the sites for the ecological purpose of Climate Adaptation Solutions and for the societal purpose of the Climate Adaptation Coalitions.

Communities: resilience and income level

In order to find those communities that need sustainable climate adaption solutions, we needed a compound measure to detect those sites. The most appropriate measure is the Notre Dame Global Adaptation Initiative (ND-GAIN) index (Chen et al, 2015). It is a compound measure that combines the vulnerability to climate change of a country with its readiness to improve. These two measures are based on respectively 36 detailed and 9 base indicators. The resilience is the readiness minus the vulnerability. The resulting normalised ND-GAIN is a number between 0 and 100, with a higher value being better. Most European countries have values in the range of 60-80, whereas developing countries in Africa have values in the range of 20-30.

A second measure we show in the CRO is the World Bank income level. The World Bank assigns the world's economies to four income groups: low, lower-middle, upper-middle and high-income countries. The split is based on the Gross National Income (GNI) per capita.

Unfortunately, the underlying ND-GAIN indicators are country aggregates, so the ND-GAIN has only one value per country. The same is valid for World Bank data. For large countries, this leads to inherent lack of spatial drill-down resolution in site selection in the CRO. Despite this drawback, this is the best measure available for this purpose.

% Coverage (rounded)	# Number of CRO sites	Mangrove km²
0	54,365	2,892
10	2,814	8,888
20	1,441	9,272
30	990	9,306
40	712	9,372
50	499	9,062
60	347	7,310
70	241	8,462
80	124	4,953
90	43	1,651
100	13	5
Grand Total	**61,589**	**71,172**

TABLE 1

Mangrove distribution over the sites per 10% area coverage.

Ecosystems: mangroves

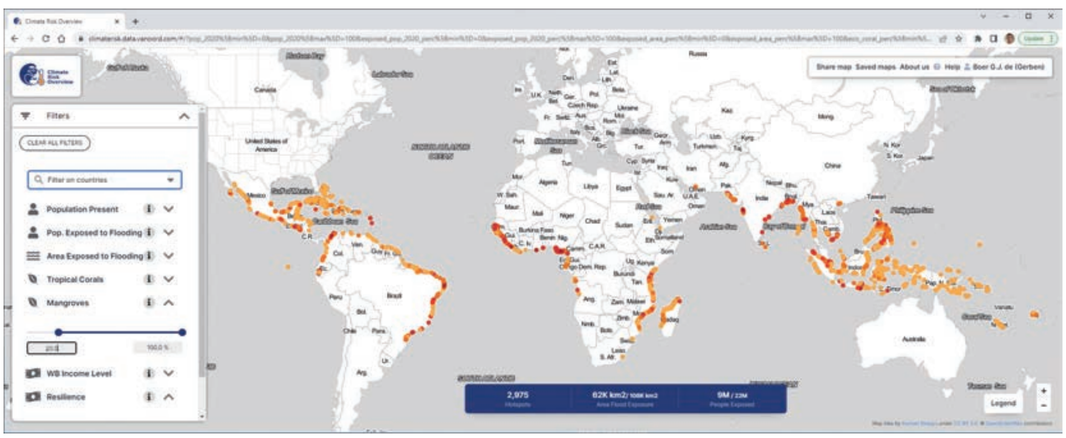
Using the resilience and the income level, it is possible to detect the areas that would benefit most from proactive climate adaptation projects. These are concentrated and located in semi-tropical climates. The most promising coastal ecosystems for climate adaptation solution in those areas are mangroves and corals. For this reason, we prioritised the addition of those two ecosystems to the CRO. We plan to add data from other ecosystems in the future, such as seagrasses and salt marshes. We chose to use the data from Global Mangrove Watch (GMW) (Bunting et al., 2018). GMW has global mangrove cover for 7 years between 1996 and 2016. The data is based on satellite data and has a resolution of 30 m. This data set allows detecting changes in mangroves and classifying each pixel as maintained, lost or gained. To avoid complexity in the early search stage for which our CRO is meant, we chose to process mangrove data for the latest year, 2016. The presence of mangroves shows climatological suitability for mangrove restoration. It is also a base for prevention projects, as the current mangrove deforestation rates are 3.5-8% in Asia (Hamilton and Casey, 2020).

FIGURE 2A-D

The Climate Risk Overview https://climaterisk.data.vanoord.com: (A) 61,022 hotspots from which (B) 27,283 hotspots have <50% resilience, (C) hotspots that also have 20% mangrove coverage and (D) 929 hotspots that also have at least 50% of the population exposed to flood risk.

A

B



C

D

Per site, we calculate the area (km²) of mangroves present and the percentage of the site area that they cover. Table 1 shows that the CRO has 12,324 sites worldwide with mangroves present in them, covering in total 71,172 km². This total number is a little lower than the global area of mangroves as reported by the GMW data processor of 77,000 km² (Bunting et al., 2018). However, a later reprocessing by Hamilton and Casey (2016) shows that the total area of GMW is 69,000 km² for 2014 when using a different definition based on the percentage coverage. We also used percentage coverage in our calculation, so our estimate is close to literature.

Tropical corals

The global tropical corals data set of UNEP et al. (2001) was processed similar to mangroves. The vector data set was used to calculate the area and overlap with our site definitions. Because our site definition includes the underwater foreshore, the CRO does not contain all the world's corals, but only those corals that are in a site that is at least partially covered with land. These are corals that can directly provide ecosystem services to the adjacent areas. This is 6,490 km² of corals of the total world coverage of 284,300 km² (Spalding et al, 2001).

Application

To illustrate the way of working, Figure 2 shows an example drill-down. Selecting a resilience of less than 50% to identify communities that might need assistance, yields 27,283 sites. Also selecting at least 20% mangrove coverage yields 2,975 hotspots. This provides the combined ecological and societal criteria. Finally, we select at least 50% of the population exposed to flood risk, yielding less than 1,000 sites. This number can be further reduced by setting stricter filters, adding other filters or taking other information into account.

Within Van Oord, we have a fully functional extended version of the CRO implemented in our standard business intelligence tool (Qlik Sense). This version differs in three fundamental aspects. Firstly, it is not nearly as polished, user-friendly and fast as the public CRO. Secondly, it is relatively easy to add extra layers because it hardly requires computer programming skills to add new data. This allows us to use the Qlik Sense version as a research and development environment for developing new layers. And thirdly, the data layers in the prototype have not yet passed thorough quality checks and a verification with scientific literature. However, this version does allow us to drill-down further with these draft layers, taking the uncertainties into account. We plan to pass these layers one by one through a quality assurance check and add them to the public CRO. The speed and order of this will be subject to our progress with the Climate Adaptation Action Plan. After each

FIGURE 3

Bacton to Walcott sandscaping (Sand Engine), UK.

FIGURE 4

Hondsbossche and Pettemer sea defence, the Netherlands.

full cycle of the three elements of this plan, a renewed investment effort is made into the public CRO.

Climate Adaptation Solutions

Van Oord has been creating coastal defences across the globe for many years and we are always looking at how we can improve the design and execution of projects. In recent years, we have been more focused on Building with Nature solutions and reducing the impact on the environment. We also see a need from our clients in this direction. Furthermore, it is appreciated when the contractor can bring in their experience and can assist with the design to develop climate adaptation projects in a more environmentally friendly way.

Nature has many ways to defend our coastlines. We can learn from this and are convinced that nature-based solutions will help in tackling societal challenges. When the forces of nature are utilised, opportunities for nature development are strengthened. In turn, more sustainable solutions can be created, adding value to the surrounding area.

The coastal protection solutions can be made from hard elements (grey) or soft elements (green) or a combination of hard and soft elements. Hard structures like revetments, groynes and breakwaters are usually made from rock or concrete precast elements. Sometimes wood is used for groynes. These solutions have the advantage that there are many existing calculating methods to design these works.

The solutions based on soft elements are beach nourishments, dunes, Sand Engines, salt marshes, mangroves and submerged reefs. The advantage of these solutions is that they better fit in the natural environment as natural elements present in the surrounding are used.

The following three examples of coastal protection projects we executed to create value for the environment, economy and society.

To protect the eroding coastline from Bacton to Walcott in the UK (Figure 3), Van Oord created a Sand Engine. To mitigate the eroding coastline threatening infrastructure. The client organised funding from the private and public sector to reinforce the coastline using a new nature-based solution called the Sand Engine (Johnson et al, 2020). The Sand Engine (also called Sand Motor) is a type of beach nourishment where a large volume of sand is added to the coast. The natural forces of wind, waves and tides then distribute the sand along the coast over many years, preventing the need for repetitive beach nourishment.

A great example is the Hondsbossche and Pettemer Zeewering (HPZ) sea defence (Figure 4). Van Oord converted an old hard defence into a soft dune landscape that created more value for the environment and society. The existing dyke was no longer sufficient for future protection. It could not be raised any further within the footprint and therefore the client was open to a novel approach. By using the Building with Nature approach, the level of protection was upgraded with a dune and beach landscape. At the same time, this landscape created a much higher value on nature and recreation purposes (Ecoshape, 2022; Karaliūtė, 2022).

FIGURE 5
Saly, Senegal.

Another example is Saly in Senegal (Figure 5), where the beach had disappeared completely. Houses had been taken by the sea and the tourism industry had completely collapsed. We created a coastal defence over 4 kilometres by protecting the coastline with offshore breakwaters and a beach restoration. As a result, the local fishers now have access to the sea and can store their boats safely in protected calm areas created by the breakwaters. The local economy has recovered as beach tourism started to flourish again.

Climate Adaptation Action Coalitions

Van Oord recognises that the challenges faced and the solutions needed cannot be addressed by us alone. For that reason, we are building a continuously growing network of stakeholders, knowledge institutes, finance institutes and political decision makers. In 2021, Van Oord joined forces with the Ocean Risk and Resilience Action Alliance (ORRAA) and the Global Center on Adaptation (GCA). We also recognise the need to share our solutions and build international networks through participation in events, such as COP26 (UNFCCC Climate Conference) and the UN Ocean Conference.

The global climate crisis can only be solved by collaboration and knowledge sharing, therefore we look to collaborate with various parties from the public and private sector. With everyone working together, all with the same mission, we can accelerate opportunities for scaling up existing and developing new nature-based solutions across the globe to accelerate positive impact for climate adaptation.

To improve on innovative solutions, and ensure longevity and positive impact, collaboration with knowledge institutes like universities and (local) specialists is extremely important. Furthermore, to implement those ideas into designs we need to work together with consultants and clients.

Climate adaption solutions also asks for new financing mechanisms, for different revenues to make the business case and for new structures to bring finance together. For this knowledge and action, input from finance institutes is needed. For example, Carbon Credits and Public-Private-Partnerships (PPP) schemes.

To create added value for the environment, economy and society, it is important to understand the local system and needs from the local stakeholders. A good example of local coalition forming is our approach in Mozambique (Figure 6) where we are engaging with a broad range of communities trying to understand the local needs and explore long-term sustainable solutions together with them.

Conclusions

With the Climate Risk Overview, Van Oord has created a global mapping tool with many coupled data sources that is proving to be an indispensable tool to assist in a dialogue between multidisciplinary stakeholders. It acts as an easy and immediate fact-based sparring partner to test ideas that arise from an individual idea or from a group session. Equally, we also realise that this web tool cannot capture the whole truth, despite our efforts to make it complete. The use of global data sources provides a fair method to compare sites, but also has disadvantages due to the inherent lack of resolution and/or ground truth. After site selection in the tool to a handful of locations (phase 1), we do a detailed study (phase 2) using local data in a GIS system, and a plethora of map thematic web viewers provided by NGOs, research institutes and others. Noteworthy examples are the Ocean Data Viewer (https://data.unep-wcmc.org) of the UNEP World Conservation Monitoring Centre (UNEP-WCMC) where we downloaded our mangrove and coral data, and mapx (https://www.mapx.org) by UNEP/World Bank that shows population and elevations among others. In these web viewers, individual data layers can be analysed in great detail, but these portals are also silos that do not allow for interaction between the layers.

An intended effect of our decision to make the Climate Risk Overview freely and publicly available is that everyone can and should use it, not just the thematic or policy experts in our field. The Climate Risk Overview proved already to be a tool that is so easy to use that it is a powerful tool for the public to explore. We have used it in sessions with both our clients and with students. We hope it will raise awareness for the great challenges that society faces due to climate change and that it might unlock unexpected opportunities.

Before starting with the Climate Risk Overview, we searched the web for existing global screening initiatives that we could join. We found many wonderful initiatives that share valuable data, but most tended to be for a narrow theme. The ones that could accommodate multidisciplinary data, ranging from population to mangroves, tended to be full-fledged GIS systems beyond the reach of the general public. We experienced that making a global multidisciplinary data analysis tool with many diverse layers is a large effort and we are open to partners who want to collaborate with us on the further development of this tool. The Climate Risk Overview is an essential element in the three-pronged approach to delivering our Climate Adaptation Action Plan.

FIGURE 6

Community meeting (Mozambique).

Summary

This article presents the Climate Adaptation Action Plan developed by Van Oord, which consists of three components. The first is the creation of the Climate Risk Overview (CRO). This is a web-based tool that brings together key parameters, such as populations, low-lying land and expected sea level rise to anticipate the hazard of flooding for all coastlines and societies around the world. It allows anyone to find and assess locations based on the number of people exposed to flooding and the presence of mangroves and corals. The combination of these layers is with the aim to help increase the resilience of the communities and ecosystems of coastal areas. The tool is freely available to allow everyone to use it. Van Oord uses an internal version of the tool in standard business intelligence software to experiment with more layers that, following quality checks, will be used to update the public version. Use of the tool internally allows the company to focus its business development efforts in climate adaptation projects.

The second phase is the process of creating Climate Adaptation Action Solutions. This is an experience record of marine and coastal solutions that we and our partners (for example EcoShape) have delivered in the past. The purpose is to have a ready portfolio of options that can be reused across the globe, with the necessary adaptations to the local social and environmental situation. We use this portfolio to assess sites that pop-up from screening with the CRO. Thirdly, we are forging Climate Adaptation Action Coalitions, a global network of partners with a diverse background, with the purpose of creating multidisciplinary teams suited to make convert climate adaptation from a reactive to a proactive field. This step adds a societal filter to the sites from the CRO.

Gerben J. de Boer

After graduating as a civil engineer, Gerben J. de Boer obtained his doctorate in coastal oceanography from Delft University of Technology (TU Delft) in the Netherlands, focusing on the stratification of the Rhine river plume. He worked for over 10 years at Deltares as a consultant on remote sensing, numerical modelling and data management, and was a member of the MODEG marine data export group to the European Commission. Since 2014, Gerben is the manager of the Datalab at Van Oord's Engineering and Estimating department.

Reinout Viersma

Since graduating from TU Delft in the Netherlands with an MSc, Reinout Viersma has worked in coastal protection, land reclamation, ports & waterway and marine construction. He has worked for Van Oord and predecessors for 25 years in various roles in the execution of dredging and marine construction works, including commercial roles on branch offices around the world and as a tender manager at Van Oord's head office working on large complex projects. Reinout currently works as Programme Manager Climate Adaptation, tasked with developing coastal protection to mitigate climate change.

Rachel Terry

Rachel Terry graduated as a Civil and Coastal Engineer with a masters in engineering (Hons) from the University of Plymouth, in the UK. She combines her technical background with a purpose to contribute to making a better world. Rachel gained design engineer experience on projects in the civil maritime industry and operational experience in offshore wind projects. She is currently the head of Sustainability at Van Oord and strives to support the business to translate its capabilities into creating a net positive impact and a sustainable future.

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