**Tecnoambiente - Tradebe in cooperation with the**

**Spanish National Research Center – Institute of Marine Sciences**

**Detailed Proposal for the Thematic challenges 2 and 4.**

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**Summary**
Climate change as well as limited planning of ports, lagoons and coasts have provoked the environmental degradation in West Africa. Apart from the known coastal erosion; the reduced water quality and the poor sediment management, the core issue addressed by the local population is the absence of multidisciplinary cooperation between the stakeholders in-charge. For this matter, a holistic stakeholder mapping is essential as the primary step of the management plan. DAPSI(w)R(m) framework will be applied, such that the drivers, the activities, the pressures, the state of the environment, the impacts and the response are clearly addressed from all the interest parties. Likewise, an effective Integrated Coastal Zone Management (ICZM) with an ecosystem-based approach (EBM) can point the way to tackle current and future issues. The objective of the current proposal is to suggest measures, strictly taking into consideration the necessities of the local population, in order to achieve effective communication and thus, mitigate environmental deterioration. For this matter, phone interviews were performed from the personnel of Tecnoambiente SLU. Planning measures and successful management practices will be adapted to the West African context, addressing the challenges of thematic 2 and thematic 4.

Regarding thematic challenge 2, suggestions include: a gamification approach to increase stakeholder participation; zeolite filtration systems for water treatment and the methodologies of CoastSnap and CoastSat developed by UNSW Sydney to monitor shoreline changes.

As for the thematic challenge 4, recommendations involve: the technology of smartPORT in Hamburg to monitor on-land traffic; the initiative of CleanPort Barcelona to reduce contamination.

## 1. Towards the understanding of the West African way of living

Prior to any major intervention, it is crucial to understand and respect the habits of the population living in the interest area. Phone interviews were performed from the personnel of Tecnoambiente SLU, in order to explore first-hand the African everyday lifestyle. Interviewees included families with and without educational opportunities from Senegal, Ivory Coast, Mauritania and São Tome. The questions were tailored according to the proposed ideas of the current document.

In particular, the questions were:

- In your point of view, what has provoked the environmental degradation of your country?
- Have you ever been involved or informed about potential mitigation projects?
- Would you consider relocating for a better and safer future? And if not, why?
- Do all the family members use smartphones?

These interviews led to the following observations:

- The local population had never been involved to any of the past mitigation projects. However, it was found that the way that the families live, wouldn't allow them to participate either way. This was due to the fact that everyday tasks are being separated within the family; children are in charge of the household necessities, while parents are occupied with economic activities including fisheries, agriculture and selling goods, letting them without spare time;
- There is a lack of trust to external partners. They find the interventions invasive given the connection they have with their land;
- Discussing the idea of relocation three major concerns were arose. The spiritual aspect that everyone has for their region; the fact that their ancestors have been buried to these lands as well as the potential relocation place.

The bottom line was that the fact that they live on a day-by-day basis without being concerned about their future (which explains why they construct their houses on the coast and once they are washed away, they build them slightly further away of the waterline).

## 2. Thematic challenge 2

### 2.1. Project description

Tecnoambiente SLU in coordination with the Spanish National Research Center (ICM-CSIC), proposed the following measures in the Expression of Interest:

1. To increase engagement in all the aforementioned measures: the application of the concept of gamification.
2. To improve water quality: the use of zeolites as a natural treatment for drinking water and the creation of cleaning brigades to collect the debris from the natural environment;
3. To monitor coastal erosion and shoreline retreat: the use of CoastSnap – a technology based on crowd-source data, and the use of CoastSat – for publicly available satellite images, both introduced by UNSW Sydney.
4. To create flood hazard and risk map: the use of IH2VOF/IOLE model developed by IHCantabria;

Further investigation on the model developed by IHCantabria (4) for flood mapping revealed that past data would be needed to calibrate it for the West African context, given that it has been developed for the Spanish coast. Past data are limited making it time-consuming, cost-intensive and thus, was excluded from the analysis for its infeasibility of the given timeframe. Table 1 represents a summary of the stakeholders needed for the aforementioned recommendations, while more extensive approach has been given in section 2.3.

| | Zeolites | UNSW Sydney | | Gamification |
|---|---|---|---|---|
| | | CoastSat | CoastSnap | |
| Residents | • | | • | • |
| Users | • | | • | • |
| Scientists | • | • | • | • |
| Local educators | • | | • | • |
| Regulatory authorities | • | • | • | • |
| Regional Planners | • | • | | • |
| Policy makers | • | | • | • |
| Investors | • | • | • | • |

*Table 1: Stakeholders involved for Thematic 2.*

### 2.2. Tools for stakeholder engagement

Interaction with the, either positively or negatively, influenced actors to the overall benefit of a project requires strategic management. A combination of DAPSI(w)R(m) framework with the application of gamification can lead to an effective mapping of the issues and consequently, increase stakeholder engagement.

DAPSI(w)R(m) approach (Elliott et. al., 2017) consists of the evaluation of the drivers and pressures, the state of the ecosystem and the environment, the impact on human welfare and society as well as the management strategies to mitigate environmental degradation in the West African coast. Fundamental human needs associated with fisheries, agriculture and trading of goods (drivers), lead to population migration towards the coast (activities), adding extra pressure by interrupting the sediment transport, causing poor water quality, extra noise to the system, coastal and marine pollution.

Given the current situation of WA, all the actors need to be involved with a bottom-up approach, to efficiently identify all the components of DAPSI(w)R(m) framework (Figure 1).

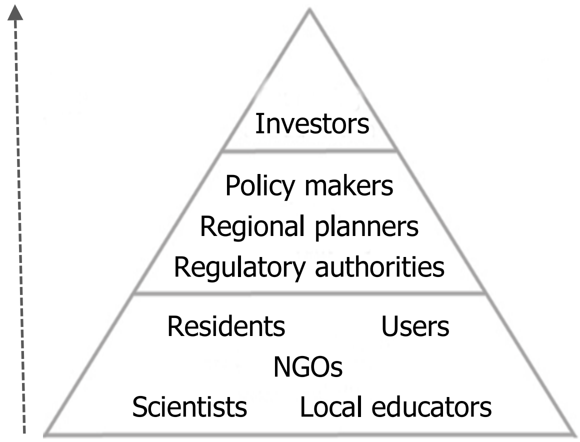


*Figure 1: Suggested stakeholder mapping as a bottom-up approach.*

The above-mentioned phone interviews along with the published material from WGB imparted the effect of poor urban/coastal planning and insufficient stakeholder participation related to WA's environmental degradation. Having identified the root of the issue is of utmost importance and the application of the gamification approach may mitigate it.

Gamification is a game structuring approach used to effectively manage non-gaming issues. It can be applied to any domain in order to increase participation and motivation. Planning a potential port expansion or installing green/gray infrastructures to prevent coastal erosion require the integration of various stakeholders with different interests and benefits. During the phone interviews with West African families it was stressed that most of the times, such projects would not move forward due to the absence of local stakeholder participation and their lack of knowledge of the actual WA situation. Thus, gamification approach can be formed as follows.

Private investors along with scientists will approach local educators and inform them about the potential project. Local educators will, in turn, launch a workshop in order to let the local population know about the future works. During the workshop, as a role-playing game will be developed between the general public and the interested actors. Assuming that most of the audience would own mobile phones, they will start playing, as an ice-breaking form, the "Stop Disaster Game" developed by the UN Office for Disaster Risk Reduction, separated in multidisciplinary teams (i.e. if the topic is related to flooding). Teams with higher score would mean a better communication between the team members, while lower scores may indicate limited communication. Likewise, groups may be mixed again and observe the new results.

Once the audience has warmed up, the role-playing game will be introduced. Given the importance of the land to the West African communities and interests of the investors, the assignment of different roles will increase their engagement and will allow to become more conscious. A board will also be included in order to allow the visualization of the ideas and concerns drawn from the discussion. Private investors and researchers can benefit from this negotiation and re-adjust their plans to the actual needs of the community. Extra points will be given to the ones suggesting feasible solutions related to the topic. Here, it would be interesting to consider a form of interchange and reward. However, to identify the type of reward, further investigation is required; it could be relative to the household activities reflecting the fact that their lives are centered around them.
Figure 2 corresponds to a suggested timeline for the gamification approach. Gamification can be included in the beginning of each project. Years may vary, depending on its application and more on the fact that it is time consuming to conclude to an organized team with all the stakeholders involved.

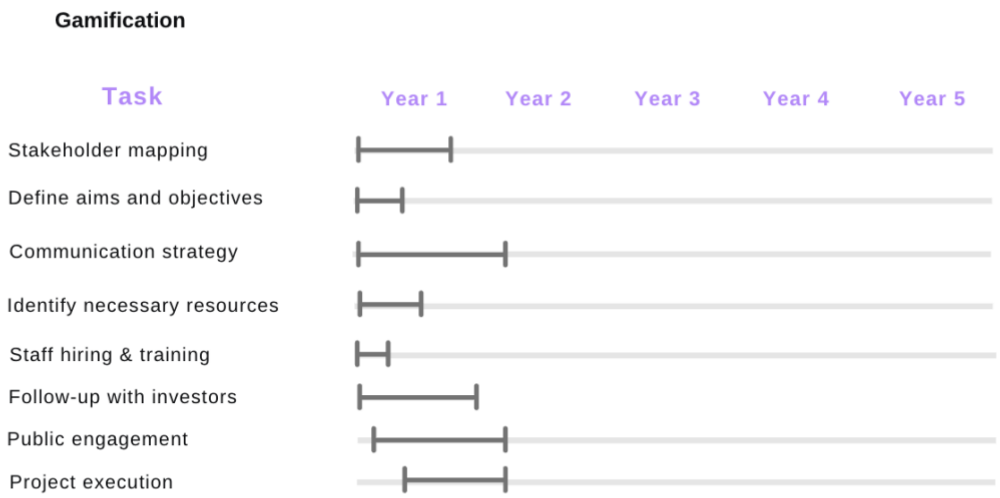


*Figure 2: Workplan and timeline for the gamification approach.*

## 2.3. Tools for water quality

In response to the ongoing water contamination, the use of zeolites can be useful to prevent or limit significant ecological damages of coastal lagoons and coastal areas in relation to the discharge of lagoon to the ocean. Zeolites are a family of hydrated aluminosilicate minerals with a framework structure composed by interconnected cavities occupied by large metal cations and water molecules. This structure gives to zeolites high ion-exchange and reversible dehydration properties. Therefore, they absorb and capture contaminants from the water (i.e., dissolved and particulate metals, sodium, ammonia) into their pores, rather than only capture particles between the grains. Different minerals of the family have the ability to capture different substances. As a reference, natural clinoptilolite is selective for ammonia and heavy metals. Zeolites can also be submitted to regeneration cycles that increase the absorption capacity of these minerals, so that they can be reused time and time again. Apart from natural

zeolites, synthetic zeolites can also be used to reduce water contamination and are highly efficient as they are impoverished of impurities.
The present proposal suggests the development of a pilot project for the application of zeolite filters at Lake Nokoué, behind Cotonou, in Benin. Lake Nokoué is a brackish coastal lagoon characterized by a surface area of about 150 $km_2$, linked in the east to Porto Novo lagoon and connected to the Atlantic Ocean at the south through the 4,5 km-long Cotonou Channel. Lake Nokoué is then nourished at the north by Ouémé Stream and Sô River. Considering these, this coastal lagoon is subjected to strong seasonal variation in salinity and depth (0,4-3,4 m), relative to the predominant flows (Zandagba et al., 2017). The area is characterized by high human pressure because of the proliferation of urban settlements and the growth of Cotonou city just at the south of the lagoon, next to the channel connecting the system with the sea. Domestic and industrial wastes arrive in Lake Nokoué, as well as fertilizers used in the agriculture. In addition, the lagoon has been the direct sink of sewage for years. For instance, in the lake village of Ganvié solid waste, garbage and sewage have been directly discharged into the lagoon. As a consequence, heavy metal contamination has been assessed in the past for the lagoon, as well as excessive levels of nutrients, which usually bring to eutrophication problems (Kaki et al., 2011; Zandagba et al., 2017). The relevance of decreasing the contamination of Lake Nokoué is related to the strict relation with the local community life and economy (fishing, agriculture and drinking water) and to the limitation of ecological damages first in the semi-enclosed system and then at the coastal sea. Taking into account all these observations, this proposal plans to test the effectiveness of zeolites for the purification of domestic water before its introduction in the lagoon at three different strategical points (Figure 3, left): (i) at Abomey-Calavi, at the east side of the lagoon (ii) at the beginning of the Cotonou outlet and (iii) at the mouth of the Cotonou channel. It is assumed that chemistry of lagoon water in these points is quite different, due to the different distance with the contamination sources, the freshwater inlets and the connection with the sea. The selection of the exact location for the installation of the zeolite filtration systems will be established after a baseline survey in order to detect specific sewage with significant levels of metals and ammonium.
For the pilot-project a small shallow well will be dug at any of the three locations, next to a selected African house. The wells will be filled both sides with a bed of gravel, while the middle will be filled with zeolites (for example clinoptilolite) of different granulometry, organized in levels (descendent order, Figure 3-right). Gravel will be used to better preserve zeolites. The idea is to pass domestic water through these wells and monitor the suitability of the system for reducing the concentration of heavy metals and ammonia in the water, before its discharge into the lagoon. To this end, chemical analysis of the domestic water must be done before the entering into the filter system and once out, as well as values of ammonia and metals should be compared. Before developing this pilot project, some experimental filtering studies in laboratory may be conducted in order to select the most suitable conditions for the system.
If the pilot-project gives positive results for the decontamination of waters before their

introduction to the lagoon, this simple system may be applied to the most critical sources of metals and ammonia contamination around the Lake Nokoué and the Cotonou channel.

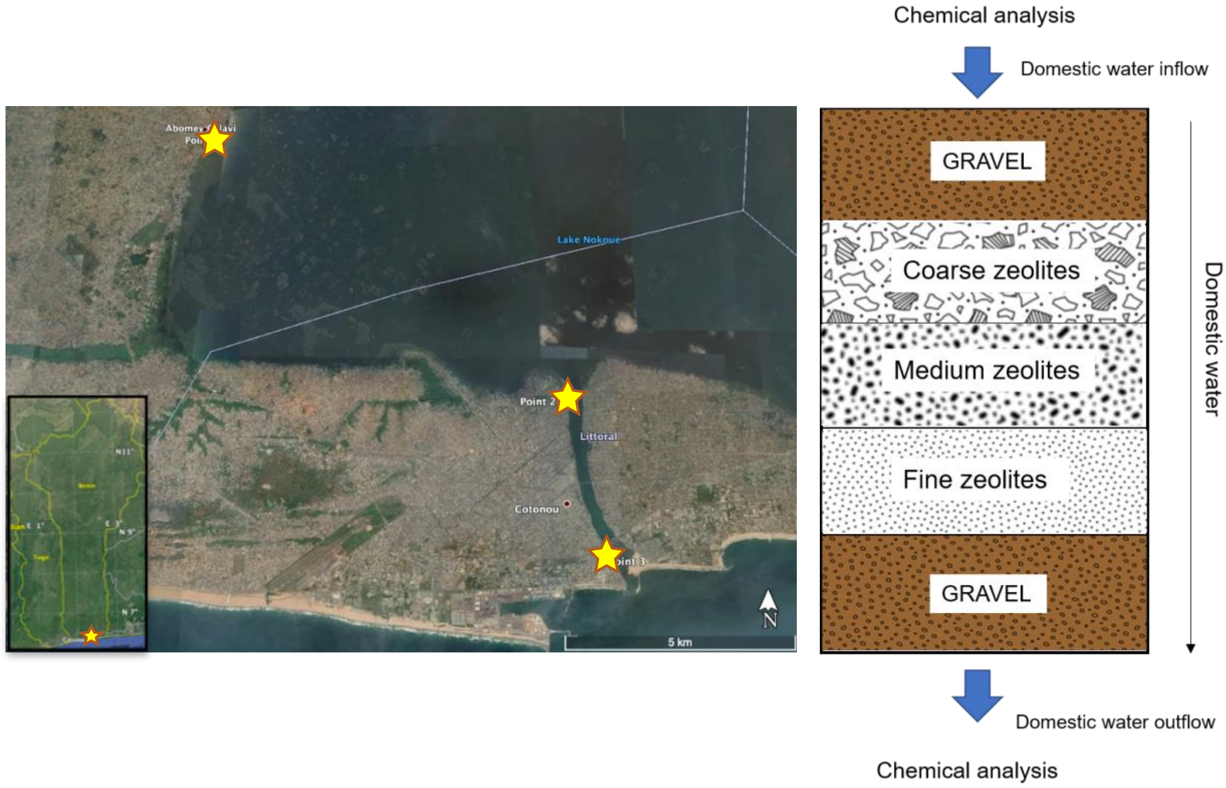


*Figure 3: Possible locations for the pilot project of zeolite filtration (left) and General schematic representation of the zeolite filtration systems (right).*

### 2.4. Tools to monitor shoreline changes

Further involvement of the local population can be achieved with the use of the already developed technology of CoastSnap by UNSW Sydney (Harley & Kinsela, 2017). CoastSnap allows the collection of snaps from the public in order to monitor shoreline changes, significantly important for the implementation of any mitigation project. CoastSnap requires the installation of cradles at a fixed place overlooking the sea, where beach users can deploy their smartphones and take the desired snaps. Alongside the cradles, a visible sign has to clearly present the instructions including the aim of the project, the media that the users can share their images and the hashtags. With the use of these assigned hashtags, they share them through social media platforms where the experts are able to collect and analyze the footage. Here, it is important to make clear how they, themselves, can benefit from this. It is important to consider that their way of living and the limited access to educational resources, does not allow them to see in the long-term.

Figure 4 corresponds to an estimation of the timeline needed for the (pre)planning and execution of both technologies. As per se, post-monitoring of the suggested ideas is necessary in order to evaluate their effectiveness.

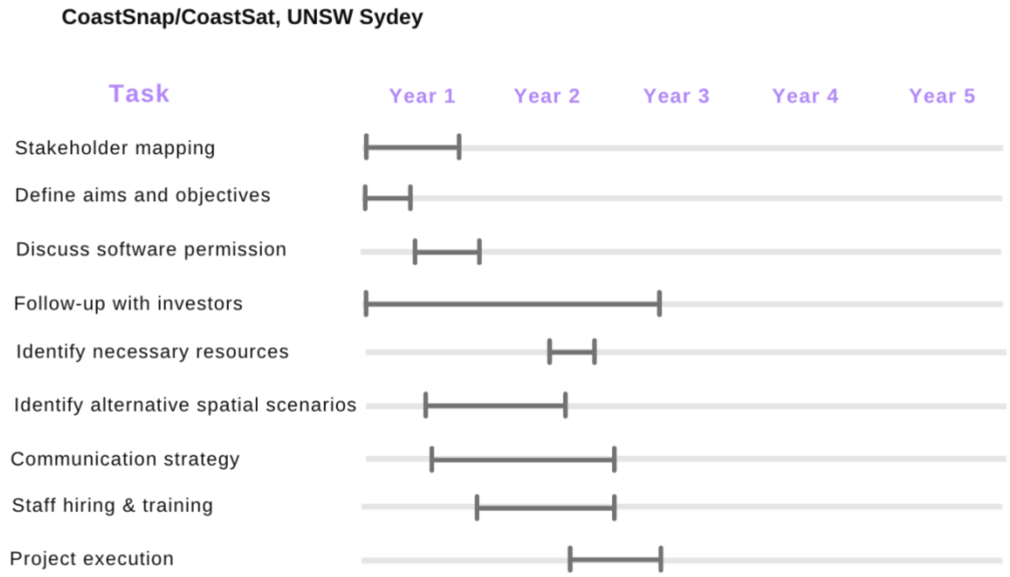


*Figure 4: Workplan and timeline for CoastSnap.and CoastSat*

A pilot study will be released once the permission has been granted from UNSW Sydney. In particular, a fixed place (can be a fence, a balcony of a restaurant overlooking the ocean or a pole) at an elevated viewpoint (>10m) is necessary along with a cradle as the smartphone holder and the sign with the instructions. Examining the West African Coast through Google Earth, it was not possible to identify such points, however, the coast of Cotonou, Benin and the cost of Dakar, Senegal have been considered as a reference. These places are suggested for their touristic potential, to increase attraction and, of course, gather higher amount of information (snaps) in order to build a solid database. Apart from the occasional vacationers, local population will be involved, hence, the extend of use of social media from them will be investigated prior to the project.

The exact point at Cotonou, Benin (6°20′55.12″N, 2°21′55.96″E, Figure 5-top) was chosen taking into consideration the coastal evolution from the historical imagery of Google Earth; in the case of Cotonou the fence at the southern part of the roundabout was placed in 2017 and hasn't moved since then. Likewise, the indicated point for the pilot study at Dakar, Senegal (14°41'58.17"N, 17°28'33.30"W, Figure 5-bottom) was selected due to the fact that the extreme shoreline changes are observed (±10m landward or seaward retreat, according to the historical imagery database of Google Earth) and because it seems to be an entrance to the beach. In case the coasts (Cotonou, Dakar, or other potential fields) do not have such high points, framing towers can be easily constructed from existing materials (i.e. wood, debris, etc.) in a form of monitoring stations.


*Figure 5: Possible locations for the installation of CoastSnap. Cotonou, Benin (top) - Dakar, Senegal (bottom).*

Moreover, a remote alternative, discussed by Vos et al., 2019 from UNSW Sydney, named CoastSat, uses publicly available satellite images (Landsat and Sentinel-2) from Google Earth Engine. CoastSat software has been developed in Python programming language consisting of pre- and post-processing steps. The most important pre-processing includes cloud masking, to reduce the presence of clouds; image sharpening, to distinguish sharp changes in the image and thus, distinguish the shoreline in higher detail. Consequently, shoreline is identified between water and sand where the user can manually digitize it at a reference image and automatically detect at the rest of the frames. As a result, 2D products are generated, with the inputted geographical coordinate system, for each image respectively and the user may accept or reject the digitized shorelines, according to the required level of accuracy.

Both methodologies developed by UNSW Sydney are great tools to monitor coastline changes for policy makers and scientists, involving the local community in the process (in the case of CoastSnap).

## 2.5. Preliminary Environmental and Social Impact Assessment

The Environmental and Social Impact Assessment is related to the possible consequences that the suggested planning measures and management practices may cause, before, during and after their implementation. Potential environmental impacts (Figure 6) are related to air and noise environment, water and agricultural resources, fisheries and ecosystem as well as the socio-economic aspect. In the case of zeolite filtration systems, limited conflicts would arise regarding the generated noise, dust and to the waste that would be generated before, during and after the project. The remaining three suggestions have been included as indirect impacts since they are related to monitoring, flood mapping and stakeholder engagement and they do not directly interact with the ecosystem.

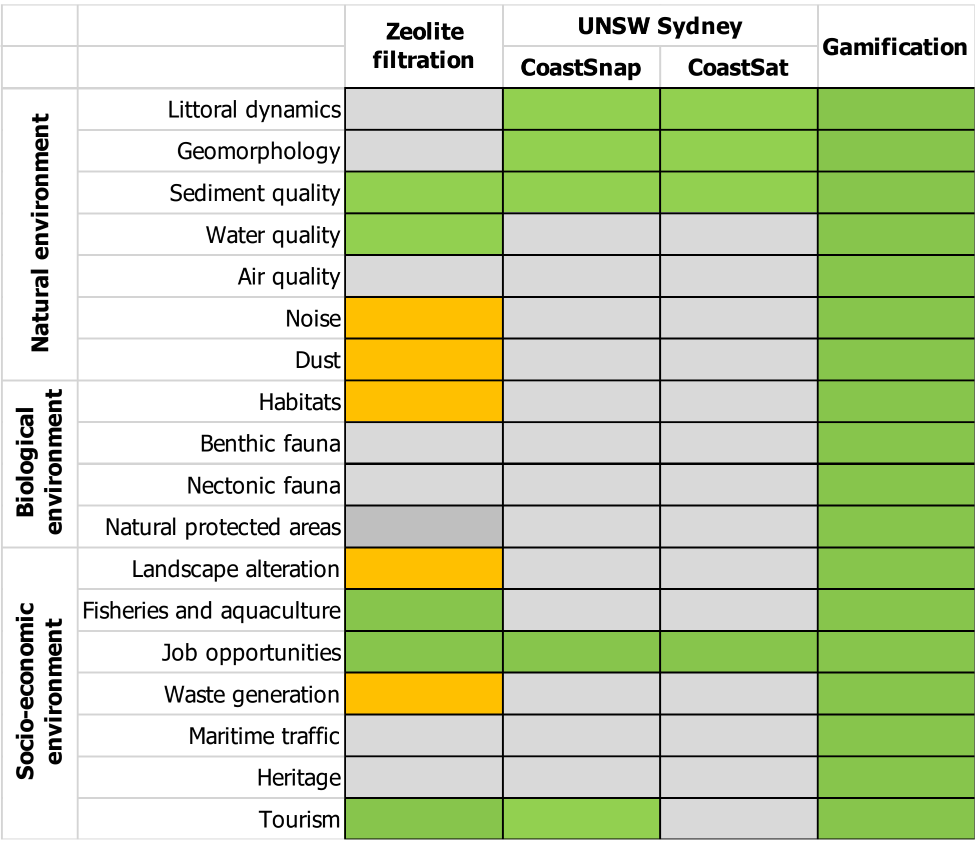


*Figure 6: Environmental and Social Impact assessment for Thematic 2. Colors: yellow: low conflict, green: positive relation, gray: N/A.*

## 2.6. Cost Estimation

Cost estimation has been calculated for the three selected tools, related to stakeholder engagement, water quality improvement (zeolite filtration) and shoreline monitoring

(CoastSnap/CoastSat). The selected tools were analyzed taking into consideration the simplicity of their application in the selected sites, as per being cheaper yet feasible solutions. Table 2 shows a summary of the cost estimation for the different tools in thematic 2:

| Tool | Workforce | Equipment/Materials | Miscellanea | TOTAL ($) |
|---|---|---|---|---|
| **Gamification** | 10000 | - | - | 10000 |
| **Zeolite filtration** | 900 | 900 | 1500 | 3300 |
| **CoastSnap/CoastSat** | 12000 | 500 | - | 12500 |

*Table 2: Cost estimation summary for Thematic 2.*

**Gamification:** This is a common tool for designing, applying and monitoring any of the other tools, and it is basically related to planning process and managing people. The first steps of the workplan (stakeholder mapping) may be conducted by a World Bank technician in collaboration with local staff, in different remote workshops for each selected community. Not a big staff should be needed for the rest of the workplan, and composed by volunteers for each different stakeholder, mainly Government staff (i.e. policy makers), coast users (i.e. fishermen) and resident people, as shown in Figure 1.

Budget estimation for applying the whole process is around 10.000$ considering a work of 200 h for a technical position (50$/h) in managing and training tasks for a specific site. Electronic devices and travel expenses have not been considered.

**Zeolite filtration:** A pilot system will be tested in Cotonou (Benin), at Lake Nokoué, and composed by 3 different microsystems in different sites. The selection of final site for installing the Zeolite filtration will be defined by a baseline survey for detecting some specific sewage (with significant levels of metals and ammonium). Sampling waste waters and analyzing has a specific budget around 1500$. Tests also may be run in Tecnoambiente and ICM-CSIC laboratories free of charge, shipping to Spain may be considered (around 300$). In our laboratories we will do some filtration tests, free of charge, also preparing the construction manual. Construction materials are estimated in around 300$ per system (3), and 300$ (per system) will be used for local workforce.

Total estimated cost for the 3 pilot systems is approximately 3300$. Depending on the availability of Zeolites in the WA countries may be need an extra charge for shipping materials and Customs permits.

**CoastSnap/CoastSat:** Firstly, permission should be asked to the UNSW Sydney for the use of CoastSnap/CoastSat technologies (free softwares). CoastSnap will be installed in two selected beaches (250$/position, including installation on site). Instructions for taking photos will be included in a panel. All permits shall be obtained before installation. Communication of the project may be done through Social Networks.

The main tools needed are the phone cameras of site visitors. Hence, some mobile devices may be asked to different companies, as part of RSC policies and marketing use, to stimulate the public collaboration with the project.

The testing of the system may be done in preliminary steps by a technical position, and after the system is calibrated and fully working some local training will be conducted to scientific public and policy makers, including CoastSat. That part is the main part of the expected cost, assuming a dedication of 300 h for a technical position (40$/h) in testing and training tasks (12000$ budget). Not electronic devices and travel expenses have been considered. Total estimated cost for the systems is less than 15000$.

### 2.7. Concluding remarks

Ideas presented in Thematic 2 described the use of the gamification approach to improve stakeholder participation, CoastSnap and CoastSat to monitor shoreline evolution and the application of zeolite filtration systems to reduce water contamination. Gamification can be applied prior to any of the suggested interventions and monitoring techniques such that, benefits and successful project executions would come to light in long-term. The installation of CoastSnap, require the identification of elevated points (preferably > 10m) in order to have a greater field of view, but also at a place reachable to the users. Moreover, even though CoastSat is an easy to use software, staff training may be time-consuming, depending on their available resources. The use of zeolite filtration systems might pose logistical limitations related to the several chemical analyses of the water at the laboratories

With reference to the suggested workplans and timelines, monitoring, and evaluation of the proposed works were not considered, however, yearly communication with all the actors is strongly proposed to evaluate the progress, conflicts and consult the results with the afectees. The Environmental and Social impact assessments revealed low impact conflicts (zeolites) and potential and indirect impacts in long-term (Gamfication, CoastSnap/CoastSat).

## 3. Thematic challenge 4

### 3.1. Project description

Tecnoambiente SLU, in coordination with the Spanish National Research Center (ICM-CSIC), considered the following successful management practices and lessons learned at the Expression of Interest:

1. The construction of a bypass canal as seen at the Alfacada lagoon and sediment sluicing at Yellow River in China, to improve the sediment management;
2. The development of sustainable urban drainage systems to control flooding considering the applied practices from Denmark;
3. The application of IoT technologies as in the case of the Port of Hamburg, to control the on-land traffic, incidents and to use renewable energy for some port operations;
4. The implementation of sustainable practices influenced by those of the Port of Barcelona related to the reduction of $SO_2$, the monitoring of air-pollution and the minimization of the carbon footprint
5. To take advantage of a population relocation act at the Fiji Islands.

Phone interviews with local African families (as described in Chapter 2), led to the exclusion of the analysis of the creation of a bypass canal (1); the Sustainable Urban Drainage Systems

(2) and the lessons learned from the relocation (4). Despite the fact that the bypass canal can be a powerful tool for reducing the flooding effects in local population living close to the rivers, any civil works proposal applied to an specific site needs a deep study of the real situation and a wider planning analysis in the territory, not supported for this contest. SUDS require solid substrate in order to i.e. test the practice of Denmark "climate-street" (Hoffmann et al., 2015) for the mitigation of flooding. Population relocation is considered infeasible within the given timeframe, considering the spiritual connection of the residents with their land and the concern related to the prospective location and their new economic activities (as discussed in Chapter 2).

The following table represents a summary of the stakeholders (Table 2) needed for the aforementioned recommendations:

| | smartPORT, Hamburg | CleanPort, Barcelona |
|---|---|---|
| Residents | • | • |
| Users | | • |
| Scientists | • | • |
| Local educators | | • |
| Regulatory authorities | • | • |
| Regional Planners | • | • |
| Policy makers | • | • |
| Investors | • | • |

*Table 3: Stakeholders involved for Thematic 4.*

### 3.2. Practices to efficiently manage a potential port expansion – smartPORT, Hamburg

West Africa's economic activities highly rely on the global trade. Current port infrastructures as well as a potential of future port expansion require careful management in order to reduce and limit possible environmental consequences.

Several actors acknowledged the importance of the economic development of the Port of Hamburg and created the smartPORT project (AGT International SmartPort Solution, 2013). The main objective was to optimize the operations regarding land-sea interactions using the power of Internet of Things (IoT) and to enhance resiliency and sustainable development. Regarding the on-land traffic, an application would allow the truck-drivers to track port traffic, suggesting them alternatives routes, possible parking areas and various information regarding the on-going port operations that would influence their route. Additionally, warning sensors through a cloud-based platform, would send information in case of potential incident, as well as, at further stage the sensors would collect data regarding temperature, wind and air-pollution. Likewise, smartPORT initiative seeks to increase port's productivity by minimizing associated costs. It should be noted that converting West African ports to smart ports would require the adequate stuff training in order to support the intelligent infrastructure; this transformation could be a great incentive for the WA generation that have migrated abroad for educational purposes, to return to their home country, apply their gained knowledge and train to the extend-possible the interested residents.

Figure 7 corresponds to the estimated planning and implementation period, considering the requirements of the project. The suggested ideas demand high intervention to the existing port infrastructures and thus the time execution may vary.

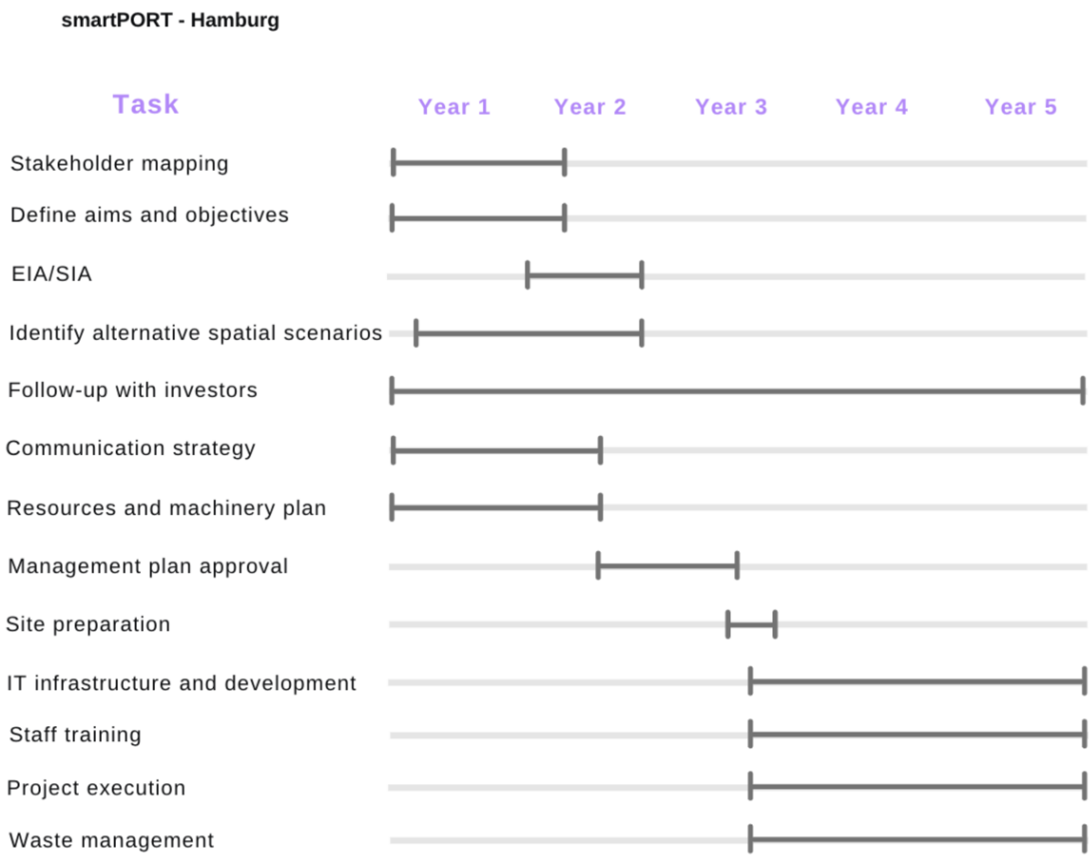


*Figure 7: Workplan and timeline for the transformation to smartPORT.*

## 3.3. Practices to efficiently manage a potential port expansion – CleanPort, Barcelona

Stakeholders interested in the sustainability, have developed green initiatives at the Port of Barcelona. The project Clean Port Barcelona (CLEANPORT Project, 2016), seemed to have significant effects in the reduction of $SO_2$, applying new technologies to the bunkering sectors of the port. They developed a clean alternative maritime system with an on-board gas auxiliary generation with Natural Gas (NG) and LNG (Liquified Natural Gas) through mobile applications and comply with respect to the EU Directives about clean air, sulfur content and port infrastructures. This system has been implemented in the port of Barcelona in relation to the presence of a high number of cruises and ferries that were responsible of sulfur air contamination and particle deposition in districts of the city located next to the port itself. In addition, the on-board installation of the natural Gas generator requires modern vessels and cannot be accomplished in any kind of craft. Modern cruises or ferries do not represent the target ships that usually enter the port of West Africa, making this part of the CleanPort project difficult to be applied to WA reality at this stage of the situation.

Apart from the on-board gas auxiliary generation, the Port of Barcelona has implemented an Eco-calculator to quantify cargo's environmental footprint, that is the $CO_2$ emissions done by the transports of containers around Europe and the world passing through the Port of Barcelona. Introducing in the implemented software the foreland port connected with the Port of Barcelona; the final destination of a container and, when applying, the type of land transportation (rail or road), the calculator provides the results of the carbon footprint for that cargo, as well as of the alternative more efficient transport route that can be contemplated. This allows to question the current maritime cargo routes, trying to find more sustainable alternatives and therefore reconsidering the traffic of commercial ports.

The calculator of carbon footprint from cargo vessels is a system that can be implemented also in the West African ports that are planned to be strongly expanded in the next years, such as for the port of Dakar, in Senegal. This software must be adapted for each specific port, taking into account maritime cargo routes, as well as overland routes to other African sites. Emissions factors for the oceanic transport depend on gross tonnage of the cargo, which is related to TEU through a formula that can be obtained performing a statistical regression of available cargo data. These data on the port traffic can be requested to the Port Authority. Emissions factors must also be calculated for the overland routes, following the formulation model of Barcelona and making changes in relation to the different means of transports employed in Africa with respect to Europe. Once the software is developed, current and programmed cargo routes can be analyzed, and the demand of port expansion reevaluated on the base of the results.

The carbon footprint calculator can be developed also for other ports of Africa in order to compare and integrate the results of different West African ports that are expected to be expanded in the near future. The last aim would be to scale down the future expansion of African ports, increasing the performance of cargo traffic. Evidently, several political and practical factors that can prevent the reduction of port expansion exist and must be taken into account when analyzing the results obtained with the CO2 emission calculator.

Figure 8 discusses the estimated time for the planning and completion of the project.

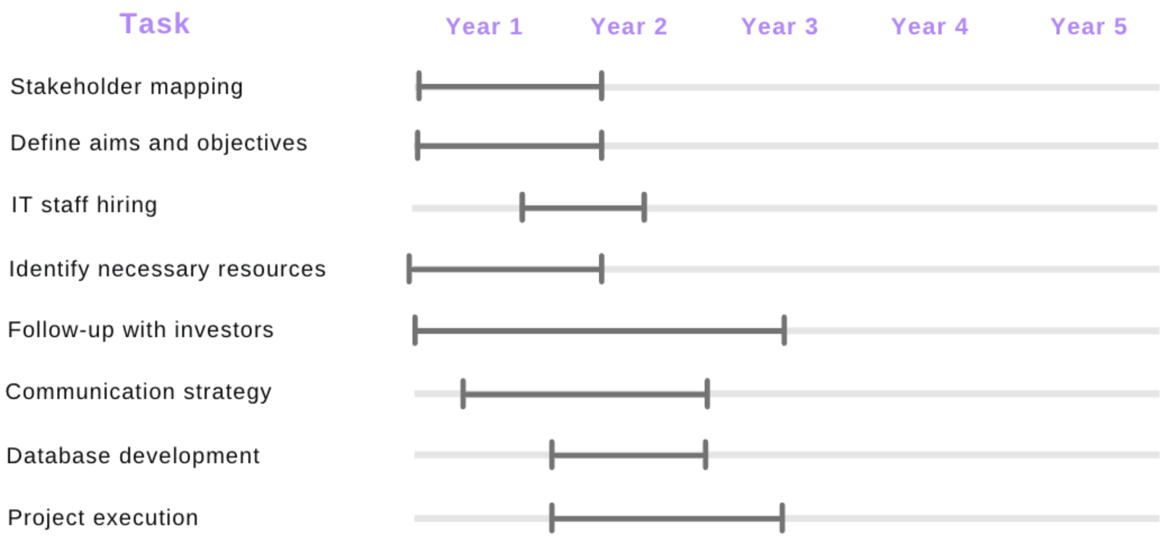


*Figure 8: Workplan and timeline for the implementation of CleanPort initiatives.*

### 3.4. Preliminary Environmental and Social Impact Assessment

The Environmental Impact Assessment is related to the possible consequences that the suggested planning measures and management practices may cause.

To identify the foreseeable impacts caused by the execution of the project, an impact identification matrix has been prepared (Figure 9). This matrix relates the actions that would be taken in case of execution of the project with the potential effects generated during the different steps. Given that both suggested ideas are remote, assessed impacts are presented in a form of indirect and that could be observed in the long-term.  As per se, post-monitoring of the suggested ideas is necessary in order to evaluate their effectiveness.

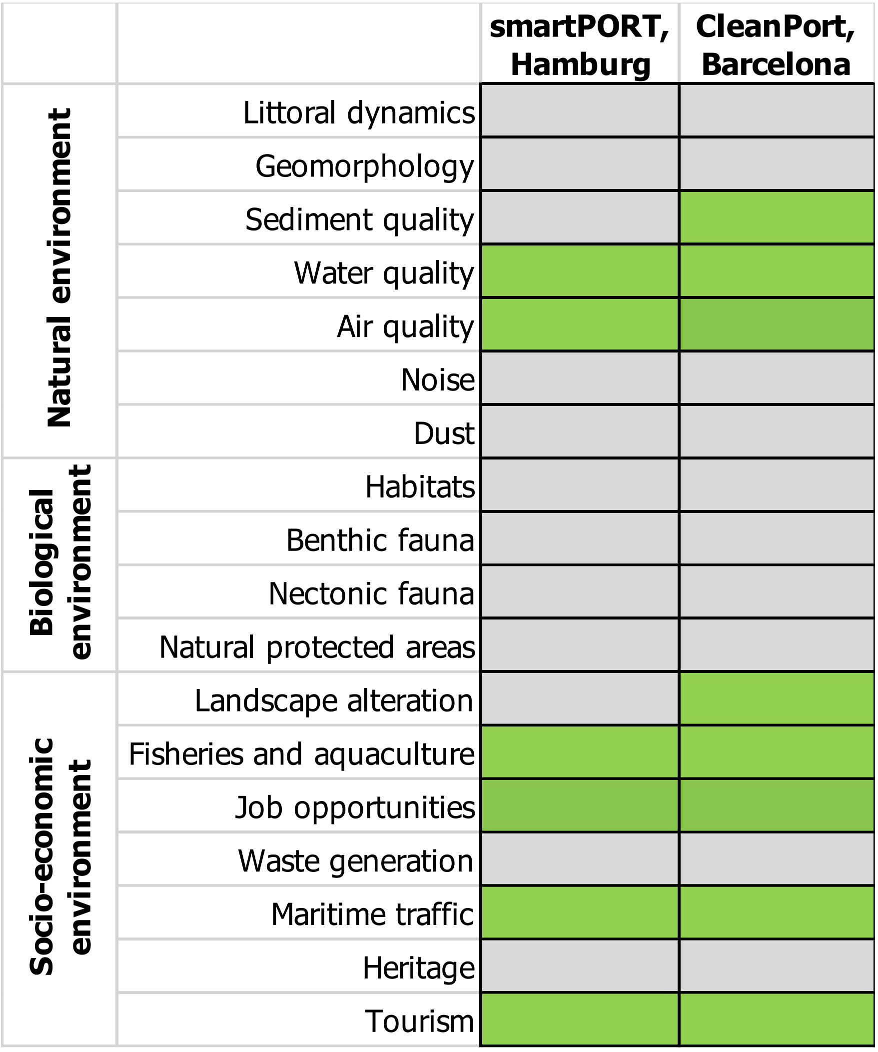


*Figure 9: Environmental and Social Impact assessment for Thematic 2. Colors: green: positive relation, gray: N/A.*

### 3.5. Cost Estimation

Cost estimation has been calculated for the two selected practices, related to improve efficiency in port activity (smartPORT in Hamburg, CleanPort in Barcelona). Table 4 indicates a summary of the cost estimation for the different tools in thematic 4:

| Practice | Desktop works | Site visits | TOTAL ($) |
|---|---|---|---|
| **smartPORT** | 10000 | 20000 | 30000 |
| **CleanPort** | 10000 | 20000 | 30000 |

*Table 4: Table 2: Cost estimation summary for Thematic 4.*

Both **smartPORT** and **CleanPort** practices include basically desktop works related to establish a collaborative network between WA actors (port managers) and the personnel that has driven that practices. A World Bank manager can act as link and supervisor for the

practice's development. Some visits to WA ports and European ports should be needed in order to a better and mutual comprehension of the port status for a better planning.
For the specific practices different Port Managers in WA countries may be selected in order to visit the European ports (up to 5 per each practice). A visit (around 5 days) should be organized to different German and Spanish ports. In the same time some managers in charge of the selected practices and World Bank personnel may visit different target ports in WA. Expenses may be shared for both practices, and specific Lump Sum has been considered.

### 3.6. Concluding remarks

Optimization of the current port infrastructure implementing both plans of smartPORT, Hamburg and CleanPort, Barcelona would overall improve the environmental state of the ports. In particular, these measures are highly suggested for implementation at the potential expansion of the Port in Dakar, Senegal were more job opportunities will rise; private investors will potentially be attracted with these innovative practices as well as touristic sector may be attracted by these advancements. In both cases, limitations are related with the fact that each tool should be developed according to the characteristics of each port. In other words, one calibrated software for the port of Dakar, could not serve the Port of Abidjan, given the different activities.

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## 5. References

AGT International SmartPort Solution, 2013. Optimizing Port Ecosystems with IoT Analytics. Retrieved from https://www.agtinternational.com/wp-content/uploads/2014/10/AGT_AAG_SmartPrt-2_19oct_15.pdf

Bertana A., 2019. Relocation as an Adaptation to Sea-Level Rise: Valuable Lessons from the Narikoso Village Relocation Project in Fiji, Case Studies in the Environment, University of California Press, 10.1525/cse.2018.001701;

CLEANPORT Project, 2016. Retrieved from: http://www.cleanport-project.eu/index.html

Elliott, M., Turner, R. K., Cormier, R., de Jonge, V. N., Borja, A., Burdon, D., & Atkins, J. P., 2017. "And DPSIR begat DAPSI(W)R(M)!" - A unifying framework for marine environmental management. *Marine Pollution Bulletin*, *118*(1–2), 27–40. https://doi.org/10.1016/j.marpolbul.2017.03.049

Harley M., Kinsela M., 2017. CoastSnap community beach monitoring. Retrieved from: http://www.wrl.unsw.edu.au/tags/coastsnap

Hoffmann, B., Laustsen, A., jensen, I.H., Jeppesen, J., Briggs, L., Bonnerup, A., Hansen, L., Sommer, L. R., Rasmussen, J., Andersen, U.R., 2015. Sustainable Urban Drainage Systems – Using rainwater as a resource to create resilient and liveable cities.

Ibáñez C., 2014, Habitat restoration and management in the Ebro delta coastal lagoons, IRTA, Aquatic Ecosystems Program, Sant Carles de la Ràpita. Retrieved from: https://climate-adapt.eea.europa.eu/metadata/case-studies/habitat-restoration- and-management-in-the-ebro-delta-coastal-lagoons

Kaki, C., Patient, G., Nelly, K., Patrick, E., Adechina, R., 2011. Evaluation of heavy metals pollution of Nokoue Lake. African Journal of Environmental Science and Technology, 5(3), 255-261.

Pitt J, Thompson G., 1984. The impact of sediment on reser- voir life, p. 541–548. In: DE Walling, SSD Foster, P Wurzel, (eds). Challenges in African hydrology and water resources, Harare Symposium, July 1984, IAHS-AISH.

United Nation Office for Disaster Risk Reduction, "Stop disaster game" Retrieved from: https://www.stopdisastersgame.org/

Vos, K., Splinter, K. D., Harley, M. D., Simmons, J. A., & Turner, I. L.,2019. CoastSat : A Google Earth Engine-enabled Python toolkit to extract shorelines from publicly available satellite imagery. *Environmental Modelling and Software*, *122*, 104528. https://doi.org/10.1016/j.envsoft.2019.104528

Zandagba, J.E.B.Z., Adandedji, F.M., Lokonon, B.E., Chabi, A., Dan, O., Mama, D., 2017. Application Use of Water Quality Index (WQI) and Multivariate Analysis for Nokué Lake Water Quality Assessment. American Journal of Environmental Science and Engineering, 1 (4), 117-127.