IOSR Journal Of Humanities And Social Science (IOSR-JHSS)
Volume 27, Issue 7, Series 7 (July. 2022) 08-21
e-ISSN: 2279-0837, p-ISSN: 2279-0845.
www.iosrjournals.org

NATURE-BASED SOLUTIONS: an alternative for flood management in Ouémé Basin

Parfait Cocou BLALOGOE
Laboratory of Geoscience, Environment and Applications (LaGEA) / National School of Public Works (ENSTP) / National University of Science, Technology, Engineering and Mathematics (UNSTIM),

Résumé
L'agriculture est la base de la croissance économique, or les terres agricoles subissent de fortes dégradations à cause de l'érosion. De ce fait, l'amélioration des rendements est devenue une préoccupation permanente de tous les acteurs du secteur agricole à travers la protection et la régénération des sols. La présente étude a pour objectif d'acquérir des connaissances sur le processus de mise en place de certains ouvrages antiérosifs pour la protection des terres dans le bassin de l'Ouémé.
Les travaux réalisés dans le bassin de l'Ouémé sont articulés autour de la connaissance des paramètres climatiques de la zone d'étude, des observations, et des enquêtes qui ont permis de collecter des informations auprès de certains acteurs ciblés. La méthode utilisée repose sur : le diagnostic des effets de l'érosion sur les sites, la quantification des pertes de terre annuelles, la mesure des hauteurs de terre apportée ou enlevée.
L'analyse des résultats montre que les aménagements participent d'une façon efficace à lutter contre l'érosion des terres agricoles en améliorant d'une façon considérable les ressources naturelles, notamment la conservation de l'eau et des éléments nutritifs au sol. A cause de leurs pouvoirs de freinage du ruissellement, ils interceptent et retiennent les particules et sont par ailleurs bien appréciés par les populations. Mais malgré cela plusieurs contraintes ont été relevées notamment, les dégâts de la pluie au cours de la réalisation des ouvrages et aussi la réticence de certains producteurs à donner les informations. Environs 88,15 t/ha/an de terre sont perdues sur les sites abritant les diguettes et les cordons pierreux. Le coût global de réalisation de cordons pierreux de 300 m est de 156 000F CFA soit 520 F CFA le mètre linéaire alors que le coût unitaire de réalisation d'un mètre linéaire de diguette est estimé à 1230 F CFA. Ce qui indique que le coût de réalisation de la diguette est plus élevé que celui du cordon pierreux. S'agissant de leur efficacité, le cordon pierreux a entrainé un dépôt de particules de hauteur 4 cm tandis qu'au niveau de la diguette, il a été enregistré 4,5 cm, ce qui prouve l'efficacité de ces ouvrages au bout des épisodes pluvieux des mois de Septembre et d'Octobre (deux mois) totalisant 304,1 mm.
Mots clés : Erosion, Diguette, Cordons pierreux, Bassin de l'Ouémé.

Abstract
Agriculture is of economic growth basis, yet agricultural land is subject to severe degradation due to erosion. As a result, improving yields has become a permanent concern for all actors in the agricultural sector through soil protection and regeneration. This study aims to acquire knowledge on the process of setting up certain anti-erosion works for the protection of land in Ouémé Basin.
The work carried out in Ouémé Basin is based on acquaintance of the climatic parameters of the study area, observations, and surveys that made it possible to collect information from certain targeted actors. The method is based on: diagnosing the effects of erosion on the sites, quantifying annual soil losses, and measuring the height of soil brought in or removed. The results show that the facilities are effective in combating erosion of agricultural land by significantly improving natural resources, particularly the conservation of water and soil nutrients. Because of their runoff braking powers, they intercept and retain particles and are well appreciated by the populations. Despite this, several constraints were noted mainly: rainfall damages during the construction of works, and the reluctance of some producers to provide information. Around 88.15 t/ha/year of soil are lost on the sites hosting the bunds and the stone barriers. The overall cost of constructing 300 m stone bunds is 156,000 CFA francs; that is 520 CFA francs per linear meter, whereas the unit cost of building a linear meter of bund is estimated at 1,230 CFA francs. This shows that the cost of realizing the bunds is higher than that of the stone cordon. As for their effectiveness, the stone cordon resulted in a particle deposit of 4 cm, whereas the dike recorded 4.5 cm, which proves the effectiveness of these structures after the rainy episodes of September and October (two months) totaling 304.1 mm.
Key words: Erosion, bunds, stone strands, Ouémé Basin.

Date of Submission: 09-07-2022 Date of Acceptance: 25-07-2022

I. INTRODUCTION

In recent years, both natural and man-made disasters have marked the world. These led the international community to take this as a major concern. Soils, mainly agricultural ones, are key elements of food security and sustainable agricultural development of societies in a context of adaptation to climate change throughout the world (Ménard, 2018, p36). Unfortunately, these agricultural soils are currently or severely degraded, mainly due to water erosion caused by the rapid expansion of agricultural areas on the one hand, and the increase in extreme rainfall events resulting in uncertain climatic conditions on the other, which accelerates, among other things, nutrient depletion, land degradation, reduction of water infiltration into the soil, and the loss of arable and pastoral land (UNISDR, 2009, pp3-4). It is therefore crucial to reverse the trend of soil degradation so as not to jeopardize the food security of future generations. Indeed, as urban populations grow, ecosystems and the services they provide will be increasingly stretched to the limit (Roberts *et al*., 2012, p46 and Frantzeskaki, 2019, p59). This is particularly true in fast-growing, small- and medium-sized cities that are experiencing rapid, largely unplanned expansion of their urban areas but may have to rely increasingly on watersheds for their water supply.

It is in this framework that the results of the project have been promoted to reduce the risks of this phenomenon, including: "the operationalization of Integrated Water Resources Management (IWRM) through a system of Payment for Ecosystem Services (PES) in the Lower and Middle Ouémé Valley (Benin) of OmiDelta program", implemented by the Center for Research and Expertise for Local Development (CREDEL) in Ouémé Basin. What are the impacts of erosion phenomena on farms in the municipality of Zogbodomey? What types of erosion control measures have been proposed to solve or prevent these phenomena? What are the interests of these developments for farmers? This internship, which marks the end of our License training at the National Water Institute (INE), offers potential for strengthening knowledge regarding the link between theory and practice on water conservation techniques and soils.

Thus, within the framework of this work, we will have to evaluate the effects of erosion on agricultural plots, follow the stages of the realization of dikes, stone barriers, and finally appreciate the effectiveness of the installed works.

II. Materials et methods

2. Materials et methods

Several materials and methods were used in this study.

2.1. MATERIALS

The materials used in this study are presented here and consist mainly of masonry materials and measuring equipment.

2.1.1. Measuring equipments

The measuring equipment consists of:

- Fill-in sheet for data collection ;
- Questionnaire to collect information from affected landowners;
- A-triangle for contour and slope determination;
- Camera for taking field pictures;
- A notebook and pencil to record information.
- A decameter for measuring the dimensions of structures and stakes;
- A metric tape to measure erosion effects ;
- GPS to record the coordinates to make the site map.

2.1.2. Masonry equipments

The masonry material consists of:

- Sand, cement, water for the construction of bunds and stone balls
- Shovel for sand collection;
- Wheelbarrow for transporting sand and stone balls;
- Pickaxe for grubbing and soil removal;
- Cutter to search for stakes,
- Wooden stakes to mark the position of the structures;
- Trowel for consolidation with cement ;
- Hammer for fixing stakes.
- Hoe for making bunds and stone balls.

2.2. Methods

The methodology adopted for this study can be grouped into three (03) phases, namely: the data collection technique (documentary research, fieldwork), the method of processing the data collected and the method of results' analysis.

2.2.1. Data collection techniques

The data collection techniques used are documentary research and fieldwork.

- **Documentary research**

This is essential for data collection (M-O. Safon, 2017, p.4). In this case, it consisted of visiting documentation centers, exploring reference websites and previous documents, dissertations, previous theses available relating to the implementation of anti-erosion measures or CES techniques and the study environment. Interviews were then conducted with staff from the internship structure. Documentary research was carried out on the internet, at Benin Excellence library, at the Hydraulics and Water Management Laboratory, at Faculty of Agricultural Sciences' library, and at Zogbodomey Town Hall.

- **Field Survey**

This step marks the effective presence in the research field. The field survey was rigorously carried out with the beneficiary communities concerned by the said activity and some municipal focal points. Indeed, with the help of these survey sheets drawn up and reproduced in several copies, we approached some young people, landowners as well as resource persons in order to gather the necessary information through interviews. Thus, a sample of respondents made up of three age groups: 18 to 20 years, 20 to 40 years and 40 years was determined. The sampling technique is based on a reasoned choice. To this end, the following criteria serve to choose the target groups:

- be a producer or landowner;
- be at least 30 years old to trace the evolution of the phenomenon over time ;
- live in the commune for at least the last thirty (30) years prior to the investigations;
- belong to village producer groups;
- have a good knowledge of the sector;
- have once experienced the effects of climate hazards in the study area;

As a whole, the sample size is two hundred and fifty-six (256) people/members and the beneficiary communities were interviewed for this study. In addition, a few resourceful, wise and notable were also interviewed.

To carry out these surveys, the data collection tools and materials include the observation grid, the interview guide and the questionnaire. These tools made it possible to collect information using appropriate techniques, mainly:

- the questionnaire survey which collected data from different actors at different levels;
- direct observations based on the practices and methods of carrying out erosion control structures in Ouémé Basin;

2.2.2. Method of data processing

Several treatment methods were used in this study. These concern:

- **Determination of the contour line in the field**

After identifying the site, the slope of the land was determined. This was done with the A-triangle graduated crossbar in percentage (%). The first step is to select the line or direction for which the slope is to be determined in the longitudinal and transverse directions. The two feet of the triangle are then placed on the line whose slope is sought and the triangle is moved in succession by rotating it each time in turn on each foot while recording the indicated percentage. The slope of the land is the arithmetic average of the slope percentages reported. Apart from the A-triangle, stakes and a hammer were also used to fix them (photo 1).

Photo 1 : contour line determination with the A-triangle
***Source**: Blalogoé, november 2021*

Land loss assessment

This step permit to estimate the volume of soil brought in or carried away at each site and be able to assess the efficiency of the structures that will be built. The annual land loss of a site is calculated with the Universal Land Loss Equation (USLE) by Wischmeier. It serves as a guide for the choice of crop rotation, field and land management and is expressed as:

$$A = 2{,}242 \times R \times K \times LS \times C \times P \qquad (1)$$

With:
A: average annual land loss (t/ha/an)
R: potential erosivity index of precipitation (MJ/mm/ha/h/an)
K: soil erodibility index for water erosion (t/ha/MJ/mm/an/h)
LS: slope length and steepness index
C: culture-vegetation factor
P: conservation and development factor
Potential erosivity index of precipitation R

$$\boldsymbol{R = \frac{P_{an}}{2}} \qquad (2)$$

with:
Pan: Average annual rainfall

Erodibility index K

This is the detachment capacity coefficient (erodibility K): the erodibility of soils in Benin had already been the subject of a study by Azontondé (1991, p.57).
Slope length and steepness index (LS)
For a regular slope, Smith and Wischmeier (1962, p.49) established the following relationships from regression of erosion plot results.

$$LS = \left(\frac{\lambda}{22{,}1}\right)^m x\ (0{,}065 + 0{,}045s + 0{,}0065s^2) \qquad (3)$$

With:
s = slope inclination;
L = slope length factor;
λ = length of slope (m) ;
m: exponent, usually 0,5.

Crop factor vegetation C

The cultural practice factor expresses the effect of the soil on the soil slope, it expresses here the effect of crops and cultivation techniques on the erosion rate and allows to compare the impact of different land uses and anti-erosion measures.

Conservation and development factor P

This parameter is obtained from field observations. In this context, the value of P varies according to the sites on which the anti-erosion works are carried out.

Estimate of land brought in and taken away

This step made it possible to assess the quantity of soil brought to the foot of the structure (bund and stone barriers) for a given time. The method consists of considering a linear distance of 50 m and placing five 50-cm stakes 10 m apart into the ground, which made it possible to calculate the height of the soil brought in or removed during the time considered (September and October 2021) by relating the initial height to that measured after the rainy episodes of the months.
Photos 2 and 3 show the process of measuring the soil added to or removed from the dike. It consists of graduating the stakes and driving them into the ground at a given depth. Soil is brought in when we see that the embankment on the stake exceeds the previously notified graduation level and it is removed when the soil is at a lower level than this same graduation. Each measurement is collected to monitor the phenomenon. A graduated ruler is also used for the measurements.

Photo 2 : Measure of soil introduced or stripped at the foot of a bund
***Source** : Blalogoé, november 2021*

Photo 3 : Measure of soil brought in or stripped from the foot of the stone cordon
***Source** : Blalogoé, november 2021*

As part of this research, image processing was used to produce maps relating to the situation/positioning of a climatic phenomenon discussed in the document. The maps were produced using the ARC-GIS software.

2.2.3. Method of results' analysis
The SWOT model was used for the analysis of the results. This model made it possible to determine the strategic options available in a field. Strengths and weaknesses are the internal factors, and the opportunities and threats are the external factors of the model. Figure 1 presents the model for analyzing the issues and challenges of civil protection in Benin.

Internal factors	Strengths	Weaknesses
External factors	Opportunities	Threats

Figure 1: SWOT analysis matrix of civil protection issues and challenges in Benin
Figure 1 presents the SWOT analysis model, which consists of an external and internal analysis, highlighting the positive and negative factors of the entity or system under study.

III. Results

This section presents the different results of the current study.
This section presents the different results of the current study.

3.1 Different types of NFS developed in Ouémé Basin: Municipality of Zogbodomey
At the watershed scale, several initiatives have been undertaken by various actors for water and soil conservation by implementing restoration methods and techniques that are not only adapted to the specific agro-ecological context (rainfall, topography, nature and structure of the soil, nature of the degradation, vegetation cover, influence of the watershed, etc.) but are also feasible and within the reach of the producers and have significant direct effects. Rainwater runoff is slowed down or stopped, which promotes water infiltration into the soil; this is nothing but the desired solution.

3.1.1. Bunds
Dikes are anti-erosion structures that help fight against concentrated erosion. Successively placed at the bottom of the thalweg, the dikes slow down the speed of the water, improve infiltration and encourage the sedimentation of the earth particles carried along, which will then help to fill in the gully. Only the excess water that overflows the height of the device or passes through the spillways is not retained. By intercepting and retaining runoff, the bunds increase water infiltration into the soil, improve soil moisture and to some extent

recharge shallow groundwater. These earthen bunds are very effective in reducing erosion and trapping suspended sediments, which has a fertilizing effect (photo 4).

Photo 4 : Bund made in the village of AGBLATA (Municipality of Zogbodomey)
***Source**: Blalogoé, november 2021*

Photo 4 shows a CES technique of consolidated bunds in the study area to conserve water for crops and reduce water flow to fields in the Basin.

3.1.2. Water reservoir or overburden

This is a water storage Basin aim at storing runoff water at the outlet of a road or on a natural water passage at a low point in order to limit runoff, the overflowing of the watercourse during rainy periods and also to increase the availability of water for agricultural production (market gardening and arboriculture) and fishing. Also, this work contributes to the mitigation of the water deficit created by repeated droughts to reduce the vulnerability of livestock and to a better exploitation/management of pastures as shown in photo 5.

Photo 5 : Water tank built in the village of AVAVI (Municipality of Zogbodomey)
***Source**: Blalogoé, november 2021*

Photo 5 shows an overbanking on land over which a river flows in order to retain some of the water before it reaches the riverbed. Indeed, the construction of a dam requires technical skills, construction materials, a large workforce, heavy equipment and maintenance against invasive plants and silting. For this one, only local labour was used in order to interest them and make them participate in common thing. They will later manage the works carried out all by themselves.

3.1.3. Fascines

Fascines are small, unassuming and inexpensive arrangements. These are linear developments made up of branches that can have different roles: the first is to create an effective brake to reduce flow speeds, they also allow the retention of sediments resulting from erosion, and water infiltration in the calm water zone located upstream of the fascines. They are thus positioned at the foot of slopes with a gradient >5% that suffer from gully erosion, perpendicular to a runoff axis, at the interface between cultivated plot and meadow. Generally, the fascines consist of two rows of willow stakes spaced 0.5 m apart. These piles are 6 to 8 cm in diameter and 1.2 to 1.5 m long. They are driven more than 0.5 m deep into the ground. The whole thing is filled with a local (or other) plant species to a total height of 80 cm, i.e. 50 cm above the ground. In the middle, a trench is dug to a depth of 30 cm as shown in photo 6.

Photo 6 : Fascine made in the Basin
***Source**: Blalogoé, november 2021*

This photo 6 shows a fascine, which is a water and soil conservation technique used on plots of land to slow down run-off water.

3.1.4. Anti-erosion hedges

The hedge is a landscape element which, in addition to its ecological interest, has a real hydraulic interest. It slows down runoff, retains sediments and active materials. Its root system favors infiltration. When well established following a reflection on the scale of the catchment area, they enable the flow of water to be controlled. By physically blocking the water flow and encouraging its infiltration, hedges reduce the quantity of water runoff as shown in figure 7.

Photo 7 : Anti-erosion hedge
Source*: Blalogoé, november 2021*

Photo 7 shows an anti-erosion technique consisting of a row of trees lined up one after the other.

3.1.5. Stone strands

These are structures composed of rubble (large stones) aligned along the contour lines of the concerned land area, helping to reduce water erosion while increasing water infiltration, thus reducing crop water stress in periods of drought where they are mostly effective in areas with high risk of water erosion (photo 8).

Photo 8 : Earth balls used for stone cordons in a field in the village of Koussoukpa (Municipality of Zogbodomey)
Source*: Blalogoé, november 2021*

Photo 8 illustrates the CES technique involving stone bunds in the study area in order to conserve water for crops and reduce water flow to fields in the Basin.

3.1.6. Riverbanks' reforestation

Bank plantations reduce the erosive effects of water currents on the banks, contribute to reforestation and stabilization in these areas in order to reduce silting downstream and the risk of flooding, and also act as a buffer to runoff from the slopes and filter sediments before they reach the river. The quality of the river is thus preserved (photo 9).

Photo 9 : riverbanks' reforestation
Source: Blalogoé, november 2021

Photo 9 illustrates an anti-erosion measure that aims to reduce bank undercutting through reforestation.

3.1.7. Sandbags

These are also anti-erosion devices made up of sand buried in jute bags arranged in one or more rows, perpendicular to the runoff bed. They slow down the force of runoff water and cause slower flow of water downstream (photo 10).

Photo 10 : Sandbags used in the municipality of Zagnanado
***Source**: Blalogoé, november 2021*

Photo 10 shows one of the traditional erosion control practices, namely bags filled with sand and placed on the runoff paths.

3.2. Observations made during the works' construction

During this, it was noticed:

- the use of cement for the consolidation of the embankment;
- the use of earth balls to act as stone barriers due to the lack of stones in the study area;
- the amount of cement applied during the consolidation of the bund to ensure its resistance to weathering and to prevent its destruction by rodent pests to ensure the durability of the bund;
- the creation of earth balls, i.e. a homogeneous mixture of earth, cement and water, due to the non-existence of stones in the study area, which is created to act as a stone barrier against erosion;
- how to use the A-triangle;
- the creation of the balls of the stone cordons, and the notions on the characteristics of these works.

3.3 SFN and runoff reduction in the Municipality of Zogbodomey

It was noted here that the phenomenon of runoff/erosion is present on the different sites and causes several damages including: crop lodging, the deposition of sediment and solid elements at stake on the sites (plastic, pebbles, etc.), and the leaching of the surface layer of the soil. Figure 2 shows the variation in the height of the stakes after two months.

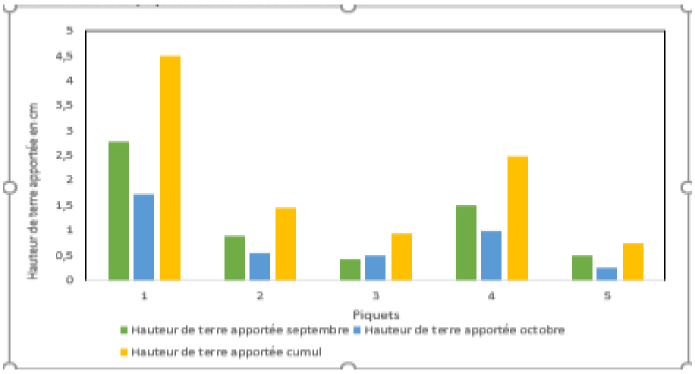

Figure 2 : Height of sediment brought upstream of the dike at the five observation stakes
***Source**: Field survey, november 2021*

Figure 2 shows that September is the month during which there is the most soil input, whereas in October, there is a decrease in soil deposition which can be explained by the low frequency of rainy episodes in October in the region. The accumulation these months made it possible to conclude that there is about 4.5 cm of soil brought upstream of the dike at the end of this period. However, in the case of the stone barriers, the decrease in height was not felt too much because of its filtering effect which consists in slowing down only the force of the runoff. Figure 3 shows the evolution of the height of sediment brought upstream of the stone barrier at the five observation stakes.

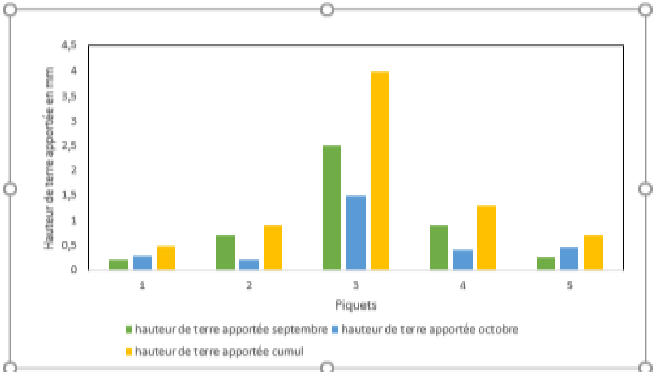

Figure 3 : Height of sediment brought upstream of the rocky spit at the five observation stakes

***Source**: Field survey, november 2021*

Figure 3 also reveals that the excess of soil input is noticeable in September. We also notice that there is about 4 cm of deposited sediment at the end of the measurement period.

After the results' analysis and the observations made on the site, we evaluated the efficiency of the two structures at two levels:

- the resistance of the structures after the rainy events of September and October;
- the presence or absence of sediment deposits upstream.

Thus, we noticed that the structures counter attack the rains of these months. Then, the aim of evaluating the quantity of soil brought upstream of these structures gave a good result, because we recorded about 4 and 4.5 cm of sediment at the initial height of the land upstream of the structure and a reduction of about the same quantity of height of the land located downstream of the structure. Therefore, the role of retaining a significant quantity of sediment is also ensured. This reflects the effectiveness of the structures. These results compared to previous research on the same theme show results that are more or less the same taking into account the technical aspect, and unlike the study area and the density of the rainfall in the area.

3.4 Advantages and disadvantages of NFS in Ouémé Basin

The data collected and the observations made during the work made it possible to identify internal factors (strengths and weaknesses) and external factors (opportunities and threats).

The data collection and field observations also permit to determine the internal factors (strengths and weaknesses) and external factors (opportunities and threats) of the structures built in the Basin. Table I summarizes the SWOT analysis of the facilities in the Basin as follows.

Table I : SWOT analysis of structures in the Basin

STRENGHS	**WEAKNESSES**
Slowing down and braking run-off water Sediment retention available Spreading of run-off water in the Basin Fairly economical works Works achievable with materials easily available in the Basin Soil organic matter supply Non-costly maintenance of such works Water seepage; Groundwater recharge; Contribution to good crop growth in the Basin; Erosion control.	Only on gentle slopes Need regular maintenance; Rainwater filtration Less lasting; Occupation of space on arable land; Refuge for burrowing pests; Possible and impossible submergence in some cases.
OPPORTUNITIES	**THREATS**
Witness site for other structures/institutions/projects implementing Water and Soil Conservation (CES) techniques	Weathering and bushfires; Risk of destruction/degradation by producers during field work; Risk of destruction by transhumant animals; Degradation by the roots of the plants that will grow there Tendency of some structures to sink into the ground when stored sediments exceed the height of the installed structure.

***Source**: Field survey, november 2021*

The table summarizes the SWOT analysis of the installed structures. Following the SWOT analysis, it is noted that these structures contribute extremely to soil water retention, nutrient return to the soil, slope reduction and also provide opportunities not only for farmers but for future projects in this direction. The plots located upstream of the works carried out on the study site benefit from the deposition of sediments, an improvement in the infiltration capacity of the soil and the structural stability of the soil due to the deposition of clayey sediments. On the other hand, those located downstream present a low risk of erosion. The construction of a bund has significant advantages in the protection and conservation of ground water. Indeed, the dikes slow down the flow of water and increase in water infiltration and the sedimentation of sand, clay and organic debris upstream, and protect the production land from being torn up and transported in large quantities of material, while reducing the speed of runoff and increasing water infiltration which will feed the groundwater. These opportunities are pledges that contribute to the extension of the project to other localities. However, there are some weaknesses and threats that may hinder the action of the project. However, weaknesses and threats have also been identified.

4. Discussion

Population growth, increasing industrialization, urban development and rising demand for food and consumer goods have led to massive global changes in land use and land cover, which in turn has led to hydrological changes (Short and al., 2015, p.247; Davies and al., 2019, p.408; Delangue and al., 2018, p.15; Kabisch and al., 2016a and b, p.18; Pontee and al., 2016, p.33; Raymond and al., 2017, p.22). The Nature-based Solutions approach is widely accepted within global policy frameworks, including the European Commission (2015), the Convention on Biological Diversity (2014, p.28), the United Nations Framework Convention on Climate Change (UNFCCC), the United Nations Office for Disaster Risk Reduction (UNISDR), the United Nations Educational, Scientific and Cultural Organization (UNESCO), the World Bank, the Partnership for Environment and Disaster Risk Reduction (PERRC) and the new UN programme for cities - Habitat III.

Nature-based solutions have received increased attention in recent years for their potential to address water scarcity and help achieve the Sustainable Development Goals (SDGs), the Paris Agreement on climate change, the Sendai Framework for Disaster Risk Reduction, the Aichi Biodiversity Targets and other international commitments (Fink, 2016, p.4; Potschin and al, 2018, p.6; BenDor and al., 2018, p.100 and Faivre and al., 2018, p.7).

Zuniga-Teran and al., 2018, p.716; Albert and al., 2019, p.18; Andersson and al., 2018, p.56; Accastello and al., 2019, p.8; have all proposed the use of forests as nature-based solutions to natural water-related hazards. According to these authors, the potential of forest management as a nature-based solution to alleviate some of the problems of urban development must be taken into account in spatial planning and management strategies (Droste and al., 2017, p.318 and Dorst and al., 2019, p.29). Thus, cities will need to take an active role in protecting the water resources on which they depend so as to grow sustainably. In Peru's Pacific Coast Watershed, where about two-thirds of the historical tree cover has been lost (Whelchel and al., 2016, p.142; Haase, 2016, p.292), integrating grey and green infrastructure could reduce Lima's dry-season deficit by 90%, and this would be more cost-effective than implementing grey infrastructure (Huq and al., 2017, p.6). Similarly, restoration of local forests is used in Malaga, Spain, to mitigate flood risks.

Roberts and al., 2012, p.186 and Frantzeskaki, 2019 p.107; proposed nature-based solutions with an application to prescribed burning with a comparison of the effects of periodic prescribed burns combined with grazing and fire on purgative grass communities.

Whelchel and al, 2016, p.146; Rizvi and al, 2015, p.34; Davis and al, 2015, p.2; Van Ham and al, 2016, p.279; Cohen-Shacham and al, 2016, p.78; Song and al, 2019, p.573; Young and al, 2019, p.27, have proposed so many nature-based methods/solutions which consist of actions such as vegetating eroded gully beds to reduce fine sediments in rivers, planting on banks to limit current velocity, developing flood expansion areas to allow the river to overflow, redesigning the river to slow it down, vegetating the slopes of the Basin to reduce and slow down runoff, preserving and restoring wetlands to regulate flooding and finally vegetating and de-silting cities to encourage the infiltration of rainwater. It must be recognized that these are all proposed techniques that have been implemented within the framework of the present study.

The implementation of nature-based solutions also requires advanced understanding of the local environment, both in terms of ecosystems and of the human societies with which they interact (Rizvi and al., 2015, p.42; Diep and al., 2019, p.569; Connop and al., 2016, p.103). Data must therefore be context-specific, but they are not always available. The production of data and the diagnosis of the territory thus represent a non-negligible additional cost, even before decisions are taken.

Conclusion

This study made it possible to make a list of the implementation of anti-erosion measures (CES techniques) in Ouémé Basin. The methodology is based on interviews through questionnaires, diagnosis of the effects of erosion, estimation of the annual loss of soil in the fields, and measurement of the height of soil brought in or removed. Thus, the results show that:

- the average land loss is 88.15 t/ha/year on the different sites, which proves that farmers are really facing the negative impacts of erosion;
- the effective sedimentation of particles upstream of the structures; proving the effectiveness of these works;
- the soil input after two months reached a maximum height of 4.50 cm at the level of the bunds and 4.00 cm at stone barriers' level after approximately 304.1 mm of rainfall.

The study of the anti-erosion works carried out has shown that these facilities contribute greatly to the fight against agricultural land erosion with a high demand. These facilities are naturally integrated into development projects allowing for considerable improvement of natural resources, the overall environment and the landscape are well adapted to the influences of the study area and are also well appreciated by the populations as to their role. The interest of the population in replicating these structures in their fields is also noted. On the other hand, some weaknesses and threats are also noted and may affect the implementation and sustainability of the structures.

References

[1]. Accastello, C., Blanc, S., & Brun, F. (2019). A framework for the integration of Nature-based solutions into environmental risk management strategies. Sustainability (Switzerland), 11(2).

[2]. Albert, C., Schröter, B., Haase, D., Brillinger, M., Henze, J., Herrmann, S., Matzdorf, B. (2019). Addressing societal challenges through nature-based solutions: How can landscape planning and governance research contribute? Landscape and Urban Planning, 182, 12–21.

[3]. Andersson Eric, Borgström Sara, & McPhearson, Timon, 2017, Double Insurance in Dealing with Extremes: Ecological and Social Factors for Making Nature-Based Solutions Last. In Nature-based Solutions to Climate Change Adaptation in Urban Areas Linkages between Science, Policy and Practice (pp. 51–64).

[4]. BenDor T, K, Shandas V, Miles B, Belt K, & Olander L, 2018, Ecosystem services and U.S. stormwater planning: An approach for improving urban stormwater decisions. Environmental Science and Policy, 88, 92–103.

[5]. BRGM, 2018, Modeling of marine flooding in the Camargue - Phase 2. Final report. European Center for Flood Risk Prevention. 2016. "Local authorities facing coastal risks Developing and implementing a strategy to reduce the risk of marine submersion".

[6]. Cohen-Shacham E, Walters G, Janzen C, and Maginnis Stewart, (eds.) 2016, Nature-based Solutions to address global societal challenges. Gland, Switzerland: IUCN. xiii + 97pp.

[7]. Cohen-Shacham Emmanuelle, Walters G, Janzen C, & Maginnis Stewart, 2016, Nature-based solutions to address global societal challenges. In Nature-based solutions to address global societal challenges.

[8]. Connop Stuart, Vandergert Paula, Eisenberg Bernd, Collier Marcus, J, Nash Caroline, Clough Jack, & Newport Darryl, 2015 Renaturing cities using a regionally-focused biodiversity led multifunctional benefits approach to urban green infrastructure. Environmental Science and Policy, 62, 99–111.

[9]. Davies Clive, & Lafortezza Raffaele, 2019, Transitional path to the adoption of nature-based solutions. Land Use Policy, 80(October 2018), 406–409.

[10]. Davis McKenna, Krüger Ina, & Hinzmann Mandy, 2015, COASTAL PROTECTION AND SUDS-NATURE-BASED SOLUTIONS. In POLICY BRIEF. Retrieved from www.recreate-net.eu.

[11]. Davis McKenna, Krüger Ina, & Hinzmann Mandy, 2015. Coastal Protection and Suds – Nature-based Solutions. RECREATE Project Policy Brief No. 4

[12]. Delangue Justine, Teillac-Deschamps Pauline, & Moncorps, Sébastien, 2018, Nature-based solutions to combat climate change and reduce natural risks in France.

[13]. Diep Loan, Dodman David, & Parikh Priti, 2019, Green Infrastructure in informal settlements through a multiple-level perspective. Water Alternatives, 12(2), 554–570.

[14]. Dorst Hade, van der Jagt Alexander, Raven Rob, & Runhaar Hens, 2019, Urban greening through nature-based solutions – Key characteristics of an emerging concept. Sustainable Cities and Society, 49.

[15]. Droste Nils, Schröter-Schlaack Christoph, Hasjürgens, Bennet, & Zimmermann, Hans-J, 2017, Implementing Nature-Based Solutions in Urban Areas: Financing and Governance Aspects. In Nature-based Solutions to Climate Change Adaptation in Urban Areas Linkages between Science, Policy and Practice (pp. 307–322).

[16]. European Commission, 2015, Nature-Based Solutions & Re-Naturing Cities.

[17]. Faivre, N., Sgobbi, A., Happaerts, S., Raynal, J., & Schmidt, L. (2018). Translating the Sendai Framework into action: The EU approach to ecosystem-based disaster risk reduction. International Journal of Disaster Risk Reduction, 32, 4–10.

[18]. Fink, Helen Santiago, 2016, Human-nature for climate action: Nature-based solutions for urban sustainability. Sustainability (Switzerland), 8(3).

[19]. Frantzeskaki Niki, 2019, Seven lessons for planning nature-based solutions in cities. Environmental Science and Policy, 93, 101–111.

[20]. Haase Dagmar, 2016, Reflections on urban landscapes, ecosystems services and nature-based solutions in cities. Planning Theory & Practice, 267–300.
[21]. Huq Nazmul, Bruns Antje, Ribbe Lars, & Huq Saleemul, 2017, Mainstreaming ecosystem services based climate change adaptation (EbA) in Bangladesh: Status, challenges and opportunities. Sustainability (Switzerland), 9(6).
[22]. Kabisch Nadja, & Deutschland. Bundesamt für Naturschutz, 2016b, Proceedings of the European Conference "Nature-based solutions to climate change in urban areas and their rural surroundings": Bonn, Germany, 17 - 19. November 2015:
[23]. Kabisch Nadja, Frantzeskaki Niki, Pauleit Stephan, Naumann Sandra, Davis Mckenna, Artmann Martina, Haase Dagmar, Knapp Sonja, Korn Horst, Stadler Jutta, Zaunberger Karin and Bonn Aletta, 2016a, Nature-based solutions to climate change mitigation and adaptation in urban areas: Perspectives on indicators, knowledge gaps, barriers, and opportunities for action. Ecology and Society, 21(2).
[24]. Pons Pere, Lambert Bernard, Rigolot Eric, Prodon Roger, 2003, The effect of grassland management using fire on habitat occupancy and conservation of birds at a mosaic landscape. Biodiversity and Conservation.
[25]. Pontee Nigel, Narayan Siddharth, Beck Michael W, & Hosking Alison Baptiste, 2016, Nature-based solutions: Lessons from around the world. Proceedings of the Institution of Civil Engineers: Maritime Engineering, 169(1), 29–36.
[26]. Potschin Marion, Kretsch Conor, Haines-Young Roy, Furman Eava, Berry Pam, & Baró Francesc, 2018, Nature-Based Solutions. A Technology Portfolio of Nature Based Solutions, 1–9.
[27]. Puissant Stéphane. & Prodon Roger, 2002, Impact of controlled burning on grasshoppers (Orthoptera) communities: a Pyrenean example. In Fire and Biological Processes edited by L. Trabaud and R. Prodon, Blackhuys Publishers,233-247.
[28]. Raymond Christopher M, Frantzeskaki Niki, Kabisch Nadja, Berry Pam, Breil Margaretha, Nita Mihai Razvan, Calfapietra Carlo, 2017, A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas. Environmental Science and Policy, 77(June), 15–24.
[29]. Reimann Lena, Vafeidis Athanasios Thomas, Brown Sally, Hinkel Jochen, & Tol, Richard S, 2018, Mediterranean UNESCO World Heritage at risk from coastal flooding and erosion due to sea-level rise. Nature communications, 9(1), 4161.
[30]. Renaud, Fabrice G, Sudmeier-Rieux Karen, & Estrella Marisol, (Eds.), 2013, The role of ecosystems in disaster risk reduction. United Nations University Press.
[31]. Rigolot Eric, Lambert Bernard, 2021, Nature-based solutions - Application to prescribed burning. XXXth National Meetings of the Integrated Fire Employment Network, Nov 2021, Valabre, Gardanne, France.
[32]. Rigolot Eric, Etienne, Michel, Lambert Bernard, 1998, Different fire regime effects on a Cytisus purgans community. In Fire Management and Landscape Ecology Edited by L. Trabaud: 137-146.
[33]. Rigolot Eric, Lambert Bernard, Pons Pascal, Prodon, Roger, 2002, Management of a mountain rangeland combining periodic prescribed burnings with grazing: impact on vegetation. In Fire and Biological Processes edited by L. Trabaud and R. Prodon, Blackhuys Publishers, 325-337.
[34]. Rizvi Ali R, Baig Saima, & Verdone Melinda, 2015, Ecosystem-Based Adaptation: Economic Arguments for Promoting Nature-Based Solutions in Response to Climate Change. International Union for Conservation of Nature, 1–47.
[35]. Roberts Debra, Boon Richard, Diederichs Nicci, Douwes Errol, Govender Natasha, Mcinnes Alistair, Spires Meggan, 2012, Exploring ecosystem-based adaptation in Durban, South Africa: "learning-by-doing" at the local government coal face. Environment and Urbanization, 24(1), 167–195.
[36]. Rodríguez José F, Saco Patricia M, Sandi Steven, Saintilan Neil, & Riccardi Gerardo, 2017, Potential increase in coastal wetland vulnerability to sea-level rise suggested by considering hydrodynamic attenuation effects. Nature communications, 8, 16094.
[37]. Schuerch Mark, Spencer Tom, Temmerman Stijn, Kirwan Matthew L, Wolff Claudia, Lincke Daniel, & Hinkel Jochen, 2018, Future response of global coastal wetlands to sea-level rise. Nature, 561(7722), 231.
[38]. Short Chris, Clarke Lucy, Carnelli Fabio, Uttley Chris, & Smith Brian, 2019, Capturing the multiple benefits associated with nature-based solutions: Lessons from a natural flood management project in the Cotswolds, UK. Land Degradation and Development, 30(3), 241–252.
[39]. Song Yinan, Kirkwood Niall, Maksimović Čedo, Zhen Xiaodi, O'Connor David, Jin Yuanliang., & Hou Deyi, 2019, Nature based solutions for contaminated land remediation and brownfield redevelopment in cities: A review. Science of the Total Environment, 663, 568–579.
[40]. Spencer Tom, Schuerch Mark, Nicholls Robert J, Hinkel Jochen, Lincke Daniel, Vafeidis Athanasios T, & Brown Sally, 2016, Global coastal wetland change under sea-level rise and related stresses: The DIVA Wetland Change Model. Global and Planetary Change, 139, 15-30.
[41]. Springgay Elaine, 2019, Forests, nature-based solutions for water management. International journal of forestry and forest industries. Food and Agriculture Organization of the United Nations. Vol. 70 2019/1. ISSN 0251-1053.

[42]. Tour du Valat, Coastal Conservatory, SNPN, Camargue Parc. 2017. Newsletter of the Salins de Camargue Basin and marshes site.
[43]. UNISDR, 2009, UNISDR Terminology on disaster risk reduction. UNISDR, Geneva.
[44]. UNISDR, 2015, Global Assessment Report on Disaster Risk Reduction: Making Development Sustainable - The Future of Disaster Risk Reduction, ONU, New York.
[45]. Van Ham Chantal, & Klimmek Hanna, 2017, Partnerships for Nature-Based Solutions in Urban Areas – Showcasing Successful Examples. In Nature-based Solutions to Climate Change Adaptation in Urban Areas, Theory and Practice of Urban Sustainability Transitions (pp. 275–289).
[46]. Vuik Vincent, Jonkman Sebastian N, Borsje Bas W, & Suzuki Tomohiro, 2016, Nature-based flood protection: the efficiency of vegetated foreshores for reducing wave loads on coastal dikes. Coastal engineering, 116, 42-56.
[47]. Whelchel Adam W, & Beck Michael W, 2016, Decision tools and approaches to advance ecosystem-based disaster risk reduction and climate change adaptation in the twenty-first century. Advances in Natural and Technological Hazards Research, Vol. 42, pp. 133–160.
[48]. Williams Byron K, 2011, Adaptive management of natural resources—framework and issues. Journal of Environmental Management, 92(5), 1346-1353.
[49]. Young Andrea F, Marengo Jose A, Fernando Rodrigues Coelho, Joilson Oliveira Martins, J. O., Scofield, Gerbo Bale, de Oliveira Silva, Claire C, & Prieto, Carina C, 2019, The role of nature-based solutions in disaster risk reduction: The decision maker's perspectives on urban resilience in São Paulo state. International Journal of Disaster Risk Reduction, 39.
[50]. Zuniga-Teran Adriana A, Staddon Chad, de Vito Laura, Gerlak Andrea K, Ward Sarah, Schoeman Yolandi, Booth Giles, 2019, Challenges of mainstreaming green infrastructure in built environment professions. Journal of Environmental Planning and Management. Pages 710-732 | Received 20 May 2018, Accepted 05 Apr 2019, Published online: 12 Jun 2019

Parfait Cocou BLALOGOE. "NATURE-BASED SOLUTIONS: an alternative for flood management in Ouémé Basin." *IOSR Journal of Humanities and Social Science (IOSR-JHSS),* 27(07), 2022, pp. 08-21.