ASSESSMENT OF ENVIRONMENTAL POST DISASTER NEEDS IN DOMINICAN REPUBLIC

Investigation of the impacts from Noel and Olga storms in 2007

ENVIRONMENTAL AND LAND DGRADATION IMPACT ASSESSMENT

Mission report (12-25November2008)

By

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P N U D

SECRETARÍA DE ESTADO DE MEDIO AMBIENTE Y RECURSOS NATURALES

ACKNOWLEDGEMENTS

The evaluation mission was conducted under the auspices of UNEP/UNDP in Santo Domingo in the Dominican Republic, in close collaboration with the Dominican Secretariat of Environment and Natural Resources who provided with technical staff.

The object of the current report is to assess the post recovery situation of the storms, on the basis of field investigations. This report will provide a reference for further actions. It demonstrates major trends that have occurred in key environmental areas-soil, land use and vegetation cover changes, water source sedimentation, institutional structure and policy-in the last 20 years for flood induced land degradation management.

The reporting consultant would like to express his sincere thanks to UNDP and SEMAREN officials for allowing this mission taking place and also for the facilities provided his deed appreciation to members of the field mission who contributed much to the evaluation and whose critical judgement is very relevant to its successful realization. **Luis Reyes Tatis** and **Rafael Rivera** from the Secretariat of State for the Environment and Natural Resources, **Hugo Galarza** (University of Santiago) and **Oscar Valenzuelaga**, Project staff who coordinated the mission and the field study with dedicated commitment. Sincere recognition of the important role played by SEMAREN provincial services San Francisco and Barahona and their technicians, **José A. Hernandez** (Pimentel) and **Ing. Americo Livent**, who kindly accepted to guide the field visits.

SUMMARY

SCOPE, METHODOLOGY AND APPROACH

1. Following the two heavy tropical storms Noel and Olga which hit the country in 2007, The Government of Dominican Republic, represented by its Ministry of Environment (SEMARN), has requested international assistance from the United Nations Country Team to conduct an environmental assessment of damages and needs of areas impacted by the disaster. It also requested support to strengthen local institutions and local capacities to be able to reduce vulnerability to natural disasters in the future.

2. In response to this request, UNDP-UNEP agreed to initiate a joint Project to assist the government addressing the situation. From 09 to 25 November a multidisciplinary mission composed of two international and a national consultants visited the country to assist the government addressing the impacts of the post disasters, under the framework of "**Evaluacion de las necesidades ambiantes post desastres en la Republica Dominicana**" project.

3. The mission was led by Thorsten Kallnischkies. It aimed to assist the government evaluating the post impacts of the damages caused by the two major storms, Noel and Olga which hit the country in 2007, and to proposing mitigation measures and strategy enabling the government to face future flood events.

4. The International Consultant on land degradation and environmental protection assessment, accompanied by a team composed of national counterparts from the Secretariat of the Environmental within the ministry of Agricultural, undertook two week-field visits to Yuna River basin (Cuenca del Yuna) and Yaque del Sur River basin (Cuenca del Yaque del Sur) which were considered as the most affected by the storms.

5. The team had several meetings and discussions with various stakeholders, particularly the population who suffered from the two storms, officials and technical staff of the Secretariat of Environment at provincial and district levels, including ongoing projects and NGOs evolving in the two river basins. Data and information were also collected concerning the occurrence of the floods in the areas, the hydrology network patterns and the river flows in the last 4 decades.

6. In the field, the team undertook a thorough assessment on land degradation issues and impacts, including the major causes and factors (gradient of the slopes, nature of the soil enhancing the inundation impacts in different sites randomly selected on the basis of the recommendations from the stakeholders and the characteristics of the two river basins, Rio Yanu and Rio Yaque del Sur involved. All the sites visited and described are positioned on a map with their respective coordinates (GPS-UTM or geographical coordinates).

7. Understanding the influence of the biophysical patterns (relief, landform units, vegetation cover, etc.) on flood importance and its subsequent impacts on environment and land degradation, was a key issue. As erosion and sediment transport depend on many

factors, particular focus was given to the river basin landform units, soil cover, land use systems, topographical patterns, and the shape of the river valley and the nature of the parent material of the soils bordering the river channel.

8. As it was not possible to assess quantitatively the impacts of the erosion on the sediment transported and deposited over the river edges and bed, soil and water samples were collected for physical and chemical analysis, particularly suspended solid elements.

9. At the end of the mission the consultant attended with the evaluation team a debriefing meeting organized the project team at UNDP office in Santo Domingo, on Monday 24th, November 2008. The consultant presented the findings, conclusion and recommendations of the mission to the participants who acknowledged the pertinence of the conclusions and recommendations. The meeting recommended to highlighting the priority key actions for followed project.

FINDINGS AND CONCLUSION

As for the environmental and socio-economic damages

10. Based on the investigations with the population, it appears that the two storms have had huge environmental and socio-economic impacts in both river basins, with severe damages estimated to hundreds of death tolls, loss of homes and crops and agricultural lands, land and soil degradation, including sedimentation of the river channels, particularly Rio Yuna and Rio Yaque del Sur.

11. From geomorphological and environmental point of view, the Yuna river basin can be divided into three parts: (i) downstream (from Pimentel to the Bay of Samana), characterized by low plain and opened valleys with heavy clayed or loamy soils subject to flood and inundation risks; (ii) medium part (Santiago to Pimentel), characterized by moderate to high altitude with eroded sandy loam and gravel soils along steep slopes down to the river, narrow river channel with more or less vegetation cover; (iii) Upstream (from Santiago to the head of the Yuna river and Camu affluent), characterized by altitude over 1500 m, with hard rocks, limestones and loamy sand and gravel soils well protected by a dense forest. The basin of Yaque del sur river, can alsobe dived into four segments: (i) upstream, characterized by high altitude with dense forest cover and well protected slopes and soil with loamy sand soils; (ii) medium course of the river (from El Higito to Tamayo), characterized by low plains and opened valleys with loamy sand to gravel sandy soils very permeable and with a loose structure, protected by a poor vegetation cover; (iii) the estuary (including the bay of Neyba, Jacquimiyes and Barahona areas), characterized by flood plain and opened valleys, poor vegetation cover on rocky sois and mangrove at the bay shore, densely cultivated with Sugar cane and platano; (iv) western part characterized by the presence of Cabral lagoon and Lake Enriquillo, which were connected to the Yaque river in the tertiary and quaternary, but separated from it during the geological erosion and sedimentation by the end of the quaternary.

12. From socio-economic point of view, the medium courses and the downstream areas are densely cultivated for rice, banana (plantano) and maize for Yuna river, and Banana and Sugar cane for Yaque del Sur. In many cases the river banks are totally cultivated with a very poor soil and water management, thus contributing to aggravate the runoff impacts on land degradation and sediment transport down to the river beds.

As for flood and inundation assessment

13. With regard to their dense hydrological networks composed of many affleunts feeding the two rivers and the steep slopes characterizing the course of the river channel, going from upstream at high altitude (over 2000 m) to downstream at the estuary with an altitude of 3 to 0 m, it appears to the consultant that the two river basins Yuna and Yaque del Sur are prone to flood and inundation particularly in their medium and downstream courses. Indeed, in the rainy seasons, particularly during storms, the rivers flow huge amounts of water provoking, even in normal circumstance, flood and inundation of the low alluvial plain and valleys.

14. As for the contributing factors, the inundation impacts depend on the width and depth of the river channel, the vegetation cover along the river bank, the altitude and the slope gradient of the river course (from upstream to downstream), the shape of the area (watersheed with steep slopes, alluvial low plain, valleys, etc.) and precipitation intensity. These peculiarities are accentuated by agricultural activities characterized by poor drainage networks and which consequently maintain the soils of the large inundable plains and croplands constantly saturated of water.

15. As for the magnitude of the inundation and damages caused, in Yuna river basin has been subject to frequent floods, but Noel and Olga are likely seen as the most devastating in the last two decades. The ample precipitations (1000 to 3000 mm/year) and the high relative humidity of the air throughout all the year are one of the fundamental factors with its geomorphological and physical aspects contributing to reinforce the inundation risks. Indeed, the Yuna river basin constitutes one of the most humid regions of the country and in which the risk of flood is frequent and practically continuous all the year along. It appears to the consultant that the low part of the Yuna River basin suffers more often from the inundation then the medium and upper parts of the basin. Indeed, the flat topography and low level of the plain (less tan 3 meters above the sea level), the low permeability and infiltration of the heavy clay or loamy texture of the alluvial soils and the poor water management, the area remain continuously flood all the year along, even after the crops have been harvested. In Yaque river basin, the inundation affected both medium and low segments of the basin. With regard to the low rainfalls compared to Yuna River (less tan 1500mm), it is likely, apart from the velocity of the water flows due to strong and fast slopes from upstream to downstream, that the inundation has been reinforced by the small size and shalow depth of the river channel shrunk by huge sediments transported by the water flows and deposited along the river bed. Because of these, the river channel is often overflood during rainy season, thus provoking frequent inundations and soil colum collapse. Indeed, throughout

the basin the river bed is filled of sediments (sand and gravel), creating barriers for the water flows and frequent changes of the river course.

16. As for agricultural activities (banana and sugar cane production) taking place throughout the Yuna River basin and Yaque River basin, particularly in the low part (segments iii and iv), they play important role toward flood emphasis and soil erosion and chemical degradation processes.

As for land degradation and soil erosion assessment

17. According to results of many surveys (FAO, 2003 and 1975; Pan-American Union, 1967), many types of soils have been identified in the country. In the two river basins, followings soils were defined: Ferralsols, Oxisoils and Ultisols in the mountain areas, colluvial soils in the bottom of the slopes, Hydromorphic and Alluvisols in the flooded plains and valleys, Fluvisols along the river beds, etc. They have a texture generally (i) sandy to Sandy loam soils, particularly the Ferralsol, Oxisoils, ultisols found in the mountain areas with good drainage; sandy clay soils along the river Bank, loamy sand to clayed loam soils in lowlands and plains with better drainage and clayed soil in the flooded plain and valleys. Most of the recent alluvial soils with a heavy texture (loamy, clayed, etc.) have bad permeability and drainage presenting favourable conditions for the occurrence of floods.

18. The erosion and land degradation are present everywhere throughout the entire river basins, with various types and magnitudes depending on soil nature, the contributing factors and ecological conditions. The most affected areas are deforested and cultivated lands of watersheds with moderate or steep slopes and the river banks with poor vegetation cover, particularly in the medium segment of the Yuna river basin (including Camu river sub-basin) and the entire Yaque River basin, including the derivation or irrigation Canals constructed many decades ago in both basins.

19. In the low part of the river basin, the Yuna river has had an erratic behaviour in its course, due to several factors: (i) Sediment transport and deposits along the water course in Camú which is the most important affluent; (ii) The lithological of the soil parent material and the morphological features of the landform units do not allow the natural control of the river channel and the flood dynamic, as to the high slope gradient from upstream to downstream.

20. In Yaque del sur River basin, erosion and sedimentation are likely common issues found along Yaque del Sur River and in the Lagoon Cabral and Lake Enriquillo areas.

21. The most affected areas are cultivated lands on watershed with moderate or steep slopes and the river banks with poor vegetation cover, throughout the entire river basins, particularly in the medium segment of the Yuna river basin, including Camu river sub-basin, and the entire Yaque River basin, including the derivation or irrigation Canals construction many decades ago. Indeed, agricultural farms are often located along the river bank with total ignorance of the environmental law which limits the cultivable area to a distance of 30 m from the river bank. Evident signs of sheet, rill, gully, and tunnel and river bank erosion are visible throughout the two basins wherever agricultural activities (rice and banana) are taking place. This is due to inadequate land

clearing, agricultural practices, water management systems and the magnitude of the inundation which expose the soils to severe erosion during the rainy season and storms leading to large amount of soil particle loss by sediment transport down to the river.

22. While in both river basins Yuna and Yaque del sur, erosion depends on the geomorphological features of the landscape which enhance the velocity of the water flow and the runoff and the local land use activities, in Camu river sub-basin and Yaque del Sur river basin, erosion process is likely reinforced by the nature of the river bank soil material, mostly sandy with high percentage of gravel (over 50%). The impacts of the degradation are more severe and pronounced in areas with sandy and gravel soil, which is common along the Yaque River and its affluents. In fact, soil with sandy texture and high gavel content hardly resist the pressure of fast water flow. Water infiltration into the soil provoques the collapse of the soil columns of the river banks wit a huge amount of sediments transported down into the river cannel, thus resulting in river bed siltation. All these contribute to fill progressively the river bed, thus creating water overflows and changes in the waterways or inundation during rainy season. This situation has been described by the population as recurrent phenomena in the areas, but Noel and Olga ahve been particularly more severe and devastating more tan waht they have witnessed in the past.

23. Erosion and sedimentation are likely seen as the most important threats to the river and water conservation, and sustainable agricultural development. Furthermore, because of its double effect on sediment transport and siltation of the river bed, as well as on the flood occurence and consequences, land degradation is seen as the main factor to be addressed in order to minimize the impacts of inundation.

PREVENTIVE MEASURES TO BE TAKEN

24. Taking into consideration the fact that the Dominican Republic presents a high degree of vulnerability for the recurrence to hurricanes/storms and flood risks, it is hoped that these evaluation and recommendation below will contribute to providing to the government relevant elements pertaining integrated risks and threat management programme, including mitigation, prevention and reduction of vulnerability. Figure 18 below summarizes the impacts of land and water resource degradation on the environment and socio-economic issues

<u>Flood and inundation control</u>

25. As measures and actions to take to minimizing flood magnitude and its devastating damages, flowing measures are critical to the protection of the river basins:

- It is extremely important that construction of such infrastructures be based on a comprehensive and long term studies which takes into consideration the level and the return period of the higher and devastating water flow.
- To avoid overflow of hydraulic infrastructures and controlling flood and inundation adequate regulation infrastructures must be constructed on the basis based of accurate data and the return period of the highest level of the water flow. To do so, detailed studies must be conducted to collect data on a long series (30-100 years).
- In many places of Yuna River basins and throughout the entire medium and low parts of Yaque del Sur River basin, more civil engineer with a well defined construction work

scheme and repair works, including vegetative protection of the river banks and edges, are very needed to control stream overflow during heavy rains or storm. These will help reducing the vulnerability of areas densely inhabited and threatened by frequent floods, like Jacquimeyes city which is faced with frequent inundations in the last 50 years.

- The country new General Water Law, under development and aiming to establish a scheme to promote a more efficient use of the water, is likely if clearly defined to help improving the water management system. However, SEMAREN and UNDP should work together in the orientation and the preparation of the framework, in order to integrating institutional and operational aspects for the management of two river basins.

Environmental protection

26. Given the threats represented by land degradation and soil erosion on environmental protection, water resource and biodiversity conservation and socio-economic infrastructure viability, following measures and actions should be considered:

- Environment Law enforcement: the current Law 64-2000 which constitute the pillar of environmental protection should be reinforce with a more coherent and realistic regulatory measures for land resource access and management,
- As for confronting flood risks and damages, strengthening the government emergency plan to improve country disaster preparedness tools and management capacities.
- refining or strengthening the Law 64-6000 in order to establish a comprehensive policy regime that will promote sustainable use of the country's natural resources;
- Strengthening of the institutional structure, including local units and local private organizations put in place to manage the environmental sector;
- Promoting incentive law and policy for reforestation and afforestation and integrated soil and water resource management to protect fragile ecological niches such as lagoons, lakes and humid ecosystems of the bay, estuaries and marine coast.

Erosion control and land improvement

27. Preventive and curative measures are essential to minimize environmental and land degradation causes and processes:

- Watershed with steep slopes, fragile soils and narrow river channel must be totally protected against traditional land clearing (slash and burn) and soil preparation practices.
- Farmers should be trained to proven agroforestry technologies (contour band ploughing), alternating cultivated with uncultivated bands (2-5 m of spacing between the bands, depending to the slope);
- To minimize the destructive effect of hillside agriculture, it is essential to improve the traditionally practiced, based on land clearing in removing totally the forest vegetation and slash and burn techniques, through promotion of proven agroforestry technologies in order to keep a minimum rate of forest cover (20%).
- A minimum vegetation cover (15-20%) composed of f trees, shrubs and/or grass, should be systematically recommended to protect the soil against aggressive splash erosion and enable the control of sediment transport;

- Land preparation using heavy machines, such as in the case of intensive irrigated farming, care should be taken in selecting mechanical tools and equipments, in order to avoid soil crumbling or compaction. Mechanical ploughing should be limited to heavy soil texture with low permeability. Sandy soils should never be ploughed; traditional soil preparation using hand tools is enough to improve the soil properties and water infiltration. In general, minimum tillage and best cropping systems should be applied throughout the two river basins wherever agricultural production is taking place.
- Maintain adequate vegetation Cover at a level between 40 to 70% to prevent soil erosion and detachment of soil particles, particularly on steep slope watershed with vulnerable soils permanent vegetation cover should be maintained at levels of 70% and above. To this extent, the followings measures are required: (i) systematic forest cover recovery through plantation or natural regenerating; (ii) on cultivated lands maintaining cereal stubbles and biomass on the soil surface; (iii) avoiding land clearing and cultivation on steep slope watershed.
- Reducing flow velocity (settle suspended particles by using techniques such as (i) roughening soil surface with grassed waterways and grass filter strips; (ii) breaking the slope length with contour drains and ripper mulch lines.

<u>Biodiversity conservation</u>

28. The loss of the biodiversity, deterioration of fragile ecosystems and extinction of some endemic species, constitute serious and inevitable ecological problems to be confronted.

- Involve with adequate responsibilities local NGOs in biodiversity issues, particularly in the most sensitive areas of Samana bay as well as of the Neyba bay estuaries.
- To meet standard norms of biodiversity conservation, a more coherent coordination and support action plan is needed as that could enable to better organize the NGOs and provide them with appropriate training and financial support.
- A participative base-approach is also needed to involve local communities in the management of the biodiversity, as they are at the gateway of the conservation.

PRIORITY ACTION PROGRAMME

29. The protection of the river Banks and bed against erosion/landslides and sedimentation, respectively, should be handled with care in integrated approach with agricultural land use improvement and flood management.

30. As remedial immediate initiatives to undertake in the context of the follow up project, following priority actions are recommended for implementation to improving water and flood management, minimizing environmental and land degradation, including soil erosion control.

<u>Component 1</u>: Land degradation database and information system

<u>Action 1.1</u>: Data and information collecting and management

<u>Action 1.2</u>: Develop integrated environmental and land use information system

<u>Component 2</u>: Promoting best water management and agricultural practices

<u>Action 2.1</u>: Improving agricultural practices

Action 2.2: Improving water and flood management

Component 3: Soil erosion control

Action 3.1: Designing a comprehensive and participative land use panning

Action 3.2: Developing national capacity on erosion causes and factor control

Component 4: Rehabilitation and Protection of the river banks

Action 4.1: Reforestation

Action 4.2: Mechanical works

Contents

ACRONYMS

CEBSE:	-
CEPAL:	-
DIARENA:	-
FAO:	Food and Agriculture Organization of the United Nations
INDRHI:	
NGOs:	Non governmental organization
OEA:	-
SEMAREN:	Secretariat of the Ministry of Agricultural and environment
UNDP:	United Nations Development Programme
UNEP:	United Nations Environmental Programme
USAID:	United States of Agency of International development
USD:	United Stated Dollar
USDA:	United States Department of Agriculture
UTM:	Universal thematic maping

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INTRODUCTION

The current study responds to UNDP/UNEP need for assistance to the Government of The Dominican Republic, upon its request from SEMAREN to address the post impacts of the two tropical storms, **Noel** and **Olga, that hit the country in 2007,** in the basins of Yuna and Yaque del Sur Rivers, considered as the two most affected areas in the country.

Following a rapid appraisal of the events after the emergency phase, the government felt the need to urgently address develop strategies and provide operational, technical and financial means to help the affected population recovering from the damages and consequences caused by the storms and subsequent inundation. The Government of Dominican Republic, represented by its Ministry of Environment (SEMAREN), has requested international assistance from the United Nations Country Team to conduct thorough investigation in the basins of Yuna River and Yaque del sur River and propose solutions for sustainable recovery from the environmental and socio-economic damages, including needs to strengthening capacities of local institutions in order to be enable reducing the vulnerability of people to natural disasters in the future.

In response to this request, UNDP-UNEP agreed to initiate a joint Project "**Evaluation de las necesidades ambiantes post disasters en la Republica Dominicana**" to assist the government addressing the post disaster recovery issues. An assessment mission was organized by UNDP and the project coordination unit in Santo Domingo, composed of a multidisciplinary team to assist SEMAREN and the project coordination team evaluating the damages and post impacts, and to proposing an integrated recovery and development strategy that includes measures and practical solutions in a cost-effective manner, for enabling the government facing future flood events in minimizing disaster risks and the underlying vulnerabilities of the areas and people.

The mission team was led by **Thorsten Kallnischkies**, Consultant ton----, assisted by **Oscar Venezuela**, Project officer. The team visited the project sites (Yuna river basin and Yaque del Sur), from 09 to 25 November 2008. However, as per the TORs and to comply with the specific needs and variances between the profiles defined, the team split into three thematic subteam and worked separately with frequent wrap-ups and exchanges of information and data.

The environmental and land degradation Consultant was assisted by three national counterpart officers, **Luis Reyes Tatis**, **Hugo Galarza**, and **Rafael Rivera**. Emphasis was put on the major damages caused by the storms and floods on the environment and natural resources, including and the underlying root causes contributing to enhance their impacts on land degradation, soil erosion, loss of agricultural lands and socio-economic infrastructures. Preventive measures and priority remedial actions were discussed with the stakeholders with the most environmentally and financially cost-effective concerns.

The present report highlights the findings and recommendation of the mission. It includes the methodology used for the evaluation, the background information, biophysical characteristics of the two river basins, the major findings and priority measures and practical actions recommended for consideration in the formulation and development of the post recovery project.

Chapter 1: SCOPE, METHODOLOGY AND ACTIVITIES

1.1. SCOPE

Land degradation has been likely identified as a serious concern among the major damages from the two storms and that need to be considered in the **post-disaste**r environmental assessment with particular focus. Indeed land degradation and water source (rivers, creeks, lagoons, lakes, etc.) sedimentation are the most pressing problems threatening environmental sustainability and the country development.

It is expected that the consultant undertakes a comprehensive assessment of the post damages on the environment and lands and other natural resources and, most importantly, proposes remedial strategy and practical priority actions to enabling the government overcome the damages and advance in a better management process of flood risks by means of prevention and awareness raising. As per the TORs (annex 1), the specific objectives to achieve are:

- assessment of environmental and land degradation, erosion patterns, landslide issues, sedimentation of the river streams and estuaries;
- diagnostic of the underlying causes enhancing the flood damages, such as deforestation (including upstream of river basins), instability of the riverbanks, sand exploitation, etc.;
- analysis of available flood management plans in the framework of integrated watershed management and environmental impacts from post-disaster recovery projects, including inland ecosystems' biodiversity management, land use policies and practices (Land Use National Plan);
- recommending strategies, measures and priority actions for disaster risk reduction, including institutional and legal capacity building for the assessment of environmental sector;
- propose a draft assessment methodology framework and report of the findings, including (i) damages and major underlying causes and factors contributing to amplifying flood damages, land degradation issues; (ii) priority actions for flood management plan (in the framework of IWRM institutional and legal assessment) and recommendation/implementation of the follow-up environmental recovery projects; (iii) Strategy and measures for disaster risk reduction.

1.2. MISSION EVOLVEMENT AND APPROACH

The mission took place from 14 to 25 November 2008 and was conducted through four steps:

Step 1: preparation of the mission (desk work). This first step was conducted in Montreal before the mission and terminated in Santo Domingo before the field investigations. It consisted to:

- review background information;
- provide UNDP with a list of necessary equipments and materiel for the field activities;
- elaborate an assessment methodology, etc.

Step 2: Inception meetings, contacts and preparation of the field mission in Santo Domingo.

The consultant had several contacts with various stakeholders and meetings with the project team (Project Coordination Unit and UNDP staff), SEMAREN staff and other relevant institutions, technical services and projects intervening in the project areas. He participated at the Inception meeting organized by the project team at SEMAREN with the technical staff.

In preparation of the field mission, the consultant worked with the Project GIS specialist, to review and fine-tune the maps of the study areas and collect other relevant information and documents from DIARENA, before the field trips.

Step 3: Field investigations

This third step is the key of the evaluation and consists of following main objectives:

- site selection and visits to the two river basins (Rio Yuna and Rio Yaque);
- meetings and discussions at provincial, community and site levels with the stakeholders (authorities, population, NGOs, private sector, etc.);
- assessment of flood damages, environmental and land degradation issues, including their impacts on the agricultural production and socio-economic infrastructures;
- recommending practical solutions for recovery and prevention.

Step 4: Information and data compilation and reporting (Santo Domingo & Montreal).

At the end of the field trips, the consultant, in liaison with the national counterpart experts and the two other sub-teams of the mission compiled and synthesized information and data collected, discussed the findings, exchanged ideas and suggestions, and draft the mission report which is part of the full report to be prepared by the team leader.

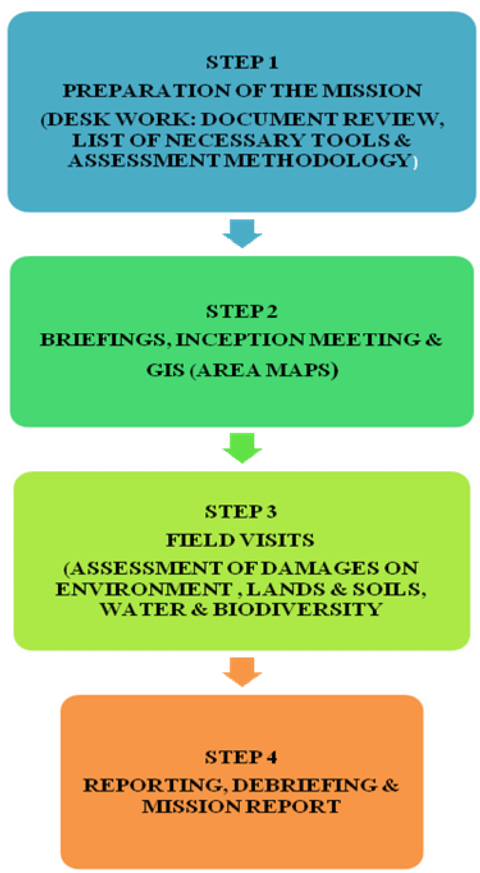


Figure 1: Summary of the sequencial steps of the mission

1.3. ASSESSMENT METHODOLOGY

For the purpose of the current mission and possible future post disaster assessment, UNDP/UNEP and SEMAREN agreed that a comprehensive methodology for integrated environmental and land degradation assessment should be developed and known by the technicians in order to strengthen their technical capacities to face future disaster damages and challenges.

The consultant defined an assessment methodology (annex 2), based on the scope and the specific objectives of the mission and the context of the country. The methodology follows UNEP guideline and those developed by other institutions, like European Union, World Bank, USAID, CEPAL, etc.

The methodology highlights:

- the approach (participatory) and the different steps to follow, as in the below (3.1));
- site parameters to be described and analysed (relief, land forms, topography and units, climate (rainfall patterns and intensities, temperatures, water budget, etc.), soils characteristics (physical and chemical), hydrology networks, vegetation type and cover, etc.))
- main agro ecological zones;
- land occupation and uses,
- erosion forms and sediment types, etc.;
- characteristics of records of the velocity of river flows;
- biophysical and socio-economic parameters to be collected
- site selection and positioning with GPS (UTM or geographical coordinates),
- soil and water sampling, data collection and analysis.

He also provided the project with a list of necessary items and equipments needed for the field assessment, including thematic maps and satellite images.

1.4. ACTIVITIES

The Consultant undertook several tasks: (i) documentation and review of background information (Montreal & Santo Domingo), (ii) contacts and data collecting, (ii) inception meeting, (iv) preparation and fine-tuning the maps of the study area, (v) field investigations, (vi) synthesis and reporting (Santo Domingo & Montreal).

1.4.1. <u>Documentation and background review</u>

The consultant, assisted by the national counterpart team composed of three experts and from the Ministry of Agriculture and Environment and University of Santiago, collected and compiled information from various sources SEMAREN, UNDP, projects, other technical services, internet (document search), etc.

1.4.2. Inception meeting

The consultant had on Wednesday 13th, November 2008 an inception meeting with the governmental representatives from SEMAREN, the three counterpart experts and the Project staff at the SEMAREN office in Santo Domingo. He presented to the participants the context and the objectives of the project, the scope of the evaluation mission, the assessment methodology to be used during the field assessment process, and the activities to be carried out in the field.

Following this presentation, the participants discussed and exchanged ideas and information over the context of the country, the specificity of the two river basins which regard to the damages caused by Noel and Olga. The SEMAREN representative emphasizes the importance of comprehensive evaluation and the need to have a cost-effective assessment methodology and strategy, including key actions to enabling the government to face future storms and inundation situation.

The participants suggested to the consultant and the accompanying team to look at the food risks with regard to land use, water management (existing infrastructures such as derivation canal and irrigation dams, etc.) and agricultural crop failure, while investigating the environmental and land degradation issues.

1.4.3. Training

Due to time constraints it was not possible to organize a training session as recommended by the TORs. Therefore, the consultant and the participants agreed at the inception meeting to consider training issue during the field activities. Whenever and wherever necessary, on job-training was provided to the national team in the field to get them familiarized with the assessment methodology, particularly how to proceed with analysis of landscape and biophysical features and their respective functions within the watershed and the river basin, land and soil degradation assessment and the integrated approach of the natural resource management.

This on-job practical training was repeatedly provided to the national experts in various sites whenever needed and according to changes in the landscape, land use and occupation, the hydrological networks and the type and importance of the damages.

1.4.4. Assessment of the damages on the environment and land degradation

The sub-team visited the two basins of Yuna River and Yaque del Sur, targeting the most affected sites by the disaster. An in-depth assessment was conducted throughout the two river basins with focus on the flood damages and risks, the overall environmental issues, land degradation and soil erosion patterns and sedimentation of the river streams and estuaries, including their impacts on socio-economic infrastructures and the management plans in the framework of integrated watershed management and environmental impacts from post-disaster recovery projects. The team analysed the main underlying causes/factors such as deforestation and inland ecosystems biodiversity (upstream, medium and downstream of the rivers and tributaries), agricultural activities, policy and institutional aspects (land use policies and practices (Land Use National Plan), environmental legal framework, laws and regulatory measures, etc.).

Soil and water samples were collected from some sites were collected whenever necessary throughout the two river basins, for physical and chemical analysis. As for sedimentation, due to lack of appropriate equipment and also time constraints, a broad in-site investigation and estimation of the deposits along the river beds were conducted. Photos were also taken to highlight the impacts of the sedimentation in various places of the river beds. Analysis of the water samples will provide with some estimates of suspended solid elements and photos.

The field assessment followed the approach and different steps of the methodology framework defined for the purpose of the current study. However, as environmental and land degradation studies involve a number of sub-sectors which have wide range of variances, applying a unique or standard methodology is a big challenge as it may not provide all information and data required for action, since each sub-sector may have its own methodology and approach. These variances make it difficult to document precise trends of the various parameters (biophysical characteristics of the sites, vegetation cover changes, land and soil degradation, hydrology aspects, river sedimentation, etc.). As result, the assessment methodology approach has been adapted throughout the study whenever needed. Thus whenever needed, the consultant applied specific methodology and approach for each sub-sectors.

For the better understanding of the influence of the hydrological networks and landscape physical characteristics, inundation and land uses on the dynamic of the sediment transport and deposit along the river bed and to recommending strategic measures for future action and reducing the environmental vulnerability, including changes on the environmental aspects, flood and soil erosion importance. Each river basin was divided into three segments:

- downstream;
- medium stream;
- upstream.

About sixty (60) study sites were randomly selected and localised with their respective coordinates (UTM) using GPS and roughly described (annex 3 & 4). Forty sites were studied in the Yuna River basin and 20 in the Yaque del Sur River basin (figure 2 & 3). In each site, the team assessed:

- inundation status (area concerned, level of the flood, types and importance of the damages, etc.);
- post disaster impacts on the environment and croplands, including socio-economic impacts;
- land degradation and erosion patterns, including the major causes and factors (gradient of the slopes, nature of the soil enhancing the inundation impacts, etc.);
- sediment transport and effects on water source degradation;
- measures and priority actions for recovery and prevention of future storm impacts.

Figure 1 and 2 below shows the study sites in the river basins.

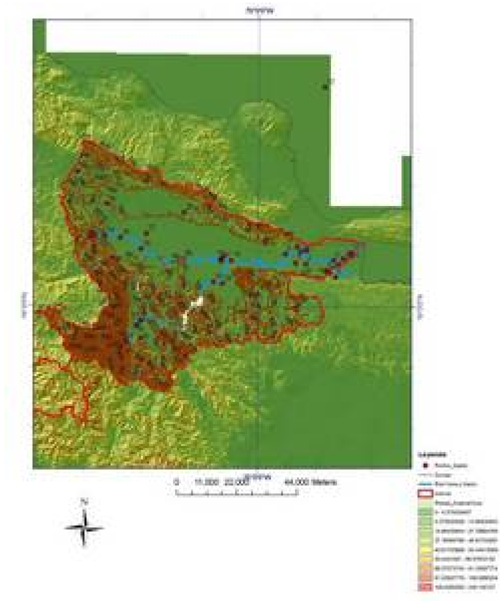


Figure 2: Study site locations in Yuna River basin

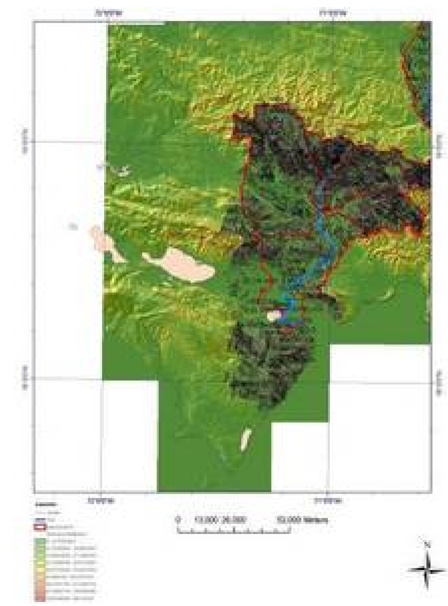


Figure 3: Study site locations in Yaque del Sur River basin

As indicated in section 1.4.3, simultaneous on-job field practical training was provided to technical staff from SEMAREN and the provincial technical services, while assessing the impacts and whenever necessary.

The team met and discussed possible solutions and opportunities for environmental protection and soil and water conservation with the stakeholders, particularly the population in the villages bordering the river and affected by the inundations from Noel and Olga.

All these elements aim at providing objective information for a better understanding of the nature of the damages caused by the storms and the subsequent inundations, their magnitude on the development of the whole basin.

Chapter 2: GENERAL OVERVIEW OF THE COUNTRY PROFILE

2.1. BIOPHYSICAL ASPECTS

The Dominican Republic is located at 19º 00 NR, 70º 40 O and covers 48.730 km2, bordered by the Atlantic Ocean in the northern coast and by Carribbean sea in the southern coast. The country is likely a **cyclones prone zone** with violent hurricanes occurring from July to December.

2.1.1. Geomorphology and pedology

The country is characterized by mountainous landscape with a geological history that goes back to the Secondary era. Until the Tertiary era the mountainous systems formed three islands separated by two marine channels. During the Quaternary era, alluvial materials were deposited and terraces and plains formed in the valleys and the coastal plains, between the present bays of Neyba and the valley of the Cibao.

Several types of landscape units have been identified:

- **Central mountain range** (Cordillera central), with higest picks such as Duarte (3.087 meters) in the central cordillera, Pelona (3.076 meters), Loma Rucilla (3.029 meters) and Yaque (2.955 meters);
- **Northern mountain** range, separating the Cibao valley from the Atlantic coast, with the highest pick Diego de Ocampo (1,220 ms);
- **Eastern mountain range** (Seibo), which is the lowest and smallest mountainous systems;
- **Lake Enriquillo,** in the south-west part, containing saline water. It's the lowest point of the country, with an altitude of -44 meters below the sea level;
- **Peninsula**, in the eastern part, characterized by broad and low plains;
- **South part**, with broad plains, suitable for sugar cane cultivation.

Various soil were described FAO (1975 and 2003) and Pan-American Union (1967) in the country, among which the main classes are:

- ***FERRALSOLS (FAO) or OXISOILS (USDA*)**:** developed in areas with high precipitation and constantly humid microclimate, causing complete mineral weathering, leaching phenomenon or washing of the soluble salts and mobilization of insoluble elements from a horizon to another.

- ***LITHOSOLS (FAO):*** constituted of fragments of rock and stones mixed with soil, without differentiated epidon, found in mountain and hill areas with high slope.

- ***ENTISOLS (USDA)****:* constituted by fine alluvial material deposited with fragments of rock, sand. The profile does not have defined differentiated horizon and limited vegetation and organic horizon. The frequent sub-group found all over the two basins is Fluvents, formed by deposition of materials near the river channel. Its drainage is variable depending on their position with respect to the rivers. Near the rivers the drainage is poor. They are commonly found in the low terraces of the rivers, lakes and lagoons, through all the country. They occupy extensive areas in the Plain of the Yaque del Norte River, Fluvial areas of the Coastal Plain of the Atlantic; Alluvial planes of the Yaque of the South, South peninsula of Barahona, Plain bordering to Cabo Deceit (FAO, 2003).

- **HISTOSOLS (FAO, USDA):** formed in special microclimatic poor drainage condition with water accumulation that prevents the fast decomposition of the fresh organic matter that arrives at the topsoil. The accumulation of organic matter derives from a low micro-organism activity. They occupy the South flank formed by hills and mountains on lime-stones and slates, under 700 to 1400 mm.

- **INCEPTISOLS (USDA)**: mineral soils under a microclimate creating temporary or permanent saturation of pores, diminishing the decomposition of the organic matter and produces ferric iron oxides. This excess of humidity is due to *permanent presence of shallow depth* groundwater or submissive strong oscillation.

- ***MOLLISOLS (USDA)***: soils with dark colour, constituted by a horizon that contains great amount of thick organic matter with a low C/N and strong biological activity.

- ***GLEYSOLS (FAO*****):** characterized by temporary saturation within the soil by groundwater for long enough periods to develop a characteristic gleyic colour pattern. This pattern is essentially made up of reddish, brownish or yellowish colours at surfaces of soil particles (peds) and/or in the upper soil horizons in combination with greyish/blueish colours inside the peds and/or deeper in the soil. Gleysols are also known as Aqu-suborders of Entisols, Inceptisols and Mollisols in USDA Soil Taxonomy, or as groundwater soils and hydromorphic soils. They are found in depression areas and low landscape position (wetlands of the valleys and low flooded plains) with shallow groundwater, and developed on unconsolidated materials, mainly fluvial, marine and lagoon ecosystem sediments of Pleistocene or Holocene.

- ***VERTISOLS (FAO, USDA):*** alternated wet and dry conditions, characterized by high content of expansive clay (montmorillonite) and the faculty to expand and to be contracted, thus causing internal movements in the matrix of the soil which form cracks at the surface of the soil and slickensides, peculiar characteristics of their recognition. The organic matter is bound to mineral particles.

- ***ANDOSOLS*** **(FAO):** found in volcanic areas, etc. These soils are formed over various parent materials: volcanic rocks, metamorphic hard rocks, sandstones, lime stones of coralline origin, etc.

Alluvial soils parent materials are frequent in the flooded plain, the river channel and valleys, while colluvial soils are mainly found at the foot of mountain and hills or at the bottom of steep slope areas. Table in annex 4, summarize the regions where the above defined soils have been identified in the country.

According to the Land-Use (table 1) Capability classification for the Dominican Republic published in 2004 by USAID (1981), on the basis of the 1977 soil studies (OAS, 1967), 12.6% of the Dominican Republic's soils fall into classes I-III. They have good potential for intensive agricultural production and 55% of soils falling into classes VII-VIII, characterized by steep slopes, rocky and shallow depth, with limited potential for forestry or protected areas (table 1). Most of the remaining soils have constraints that limit capability to support crops, but can be used for tree crops (coffee, cacao) and as pasturelands.

Land Class	Km^2	Percentage of National Territory	General Characteristics of Land Class Unit
I	537	1.1	Excellent for cultivation, high productivity potential.
II	2,350	4.9	Very good for cultivation, few limiting factors.
III	3,122	6.6	Good for cultivation, some limiting factors, medium productivity potential with good management.
IV	3,639	7.7	Limited potential for cultivation, appropriate for pasture or perennial crops, with severe limiting factors. Low to medium productivity with management.
V	6,071	12.7	Limiting factors severe, especially drainage. Can be used for pasture, or for rice with intensive management.
VI	5,611	11.8	Cannot be cultivated, except for certain perennial crops (such as coffee), pasture, or forestry. Limiting factors include topography, soil depth, rocky soils.
VII	25,161	52.7	Cannot be cultivated, only appropriate for forestry uses.
VIII	1,202	2.5	Cannot be cultivated, appropriate for protected areas or wildlife uses.
Total	**47,693**	**100.00**	

Table 1: Land Use Capability Classification for the Dominican Republic

Ref: OAS Survey of Natural Resources of Dominican Republic, 1967; *In* **USDA (1981)**.

All these soils are vulnerable to any form of degradation (erosion, landslides, etc.) which can be very severe depending on the surface vegetation cover, with important loss of sediments transported down into the river beds where there contribute to sediment deposits within the river basin. The sandy soil are poor soils and very sensitive to fertility decline. Because of their little productivity, they are often used as grazing lands (FA0, 2003).

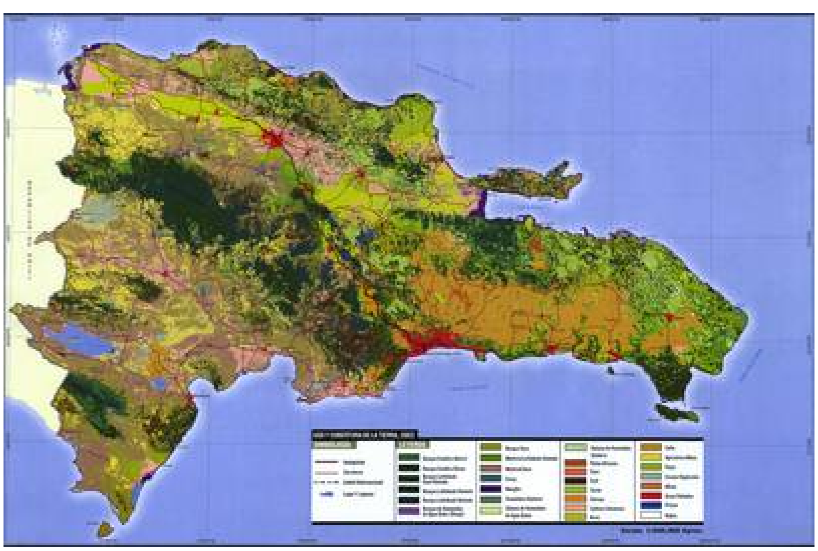


Figure 4: Land occupation map (FAO, 2003

2.1.2. Hydrography

The Dominican Republic has a dense hydrological network that irrigates the territory and re-charges the ground waters. The rivers and their tributaries are of various types with irregular water volume and flows (table 2).

RIVERS	LENGTH (Kms)	BASIN AREAS (km2)	ALTITUDE (m)
YAQUE DEL NORTE	296	7,044	2,580
YUNA	210	5,498	-
YAQUE DEL SUR	183	4,972	2,707
OZAMA	148	2,685	-
CAMU	137	-	-
NIZAO	133	974	2,415
SAN JUAN	121	-	2.460
MAO	105	-	-
ARTIBONITO	-	2,614	-
HIGUAMO	-	1,182	-
SOCO	-	1,051	-
BEAM	-	-	2,320
MIJO	-	-	2,280
GRANDE	-	-	2,280
OCOA	-	-	2.000

Table 2: Main rivers of the country and their tributaries.

Remarque: Data found in the literature show big variance for same river or tributary, depending on the author, thus some data reported here may not be accurate.

The Central mountain range is the hydrographical knot of the country comprising the main 4 rivers of the country, that are: Yaque del Norte River (296 kilometers) and Yuna River (210 kilometers) originated from the northern slope of the central mountain range, Yaque del Sur River (183 kilometers) born from the southern slope, and flow down to Atlantic ocean and Caribbean sea, respectively and Ozama (148 km).

2.1.3. Climate

The country has a tropical climate, characterized by thermal conditions (25 and 30°C) throughout the year in the mountain areas which introduce important modifications in the climatic zones, with cool variant in few areas of the mountainous regions, like Constanza, Jarabacoa and Ocoa, where the temperature can reach 5 °C in winter. It's a monzonic climate type, due to its position in the coastal strip of the Atlantic Ocean and its insular character. The annual rainfall is very variable from one ecological zone to another, ranging from 455 mm in the area of the Lake Enriquillo, to 2,743 mm in the northeast mountainous area of the Central range. The mountain range produces orographic rains influenced by monzónico effect, with a great asymmetry between the slope of windward, more humid, and the one of leeward.

All these expose the country to frequent hit of the hurricanes that are generated in the Atlantic. The rainy season with torrential rains and proneness to hurricane occurrences, result to important frequent earth landslides which are taken place during the rainy season. The tropical hurricanes and other storms are registered mainly between August and October, and affects, particularly, the southwest of the country. The tradewinds of the anticyclone of Azores, the Intertropical convergence zone and occasionally the storms of the Polar front are the ones affecting mostly the country.

2.1.4. Vegetation

The natural vegetation is composed of humid tropical forests (P -1,000 mm), semi-humid forest, savannah, etc. The common species are pine (Pinus occidentalis), Ceiba sp., Mahogany, Acacia sp. Along the coast are characteristic vegetation and mangrove forests in the estuaries (Samana, Neyba, etc.) composed of *Rhizophora mangle* (mangle red), *Racemosa Laguncularia* (mangle white) and *Avicennia germinan,* etc.

The dry zones are generally occupied by shrubs developed in semi-arid areas with high evapotranspiration, while the coastal zones are occupied by various species, such as real palm (hispaniolana Roystonea), coco palm tree (*Plumeriana bactris*) and the guano (*Coccothrinax mountain*),

The country also have many protected areas and 16 national parks covering about 10% of the territory.

All these forests present an extraordinary variety of species, of which many are endemic (40% of the flora) due to their insularity and threatened by degradation.

2.2. SOCIO-ECONOMIC ISSUES

The Dominican Republic has about 9 million inhabitants with a very low annual growth (1.6%), an average density of 180 inhabitants per km², varying between 240 in the South eastern part 57 inhabitants/km² in the south western region. About 60% of the population live in cities.

The economy is based on four major pillars:

- agriculture,
- commercial & agro-industry,
- mining (salt gem, plaster, ferronickel, gold, marble, etc.),

- service sector (tourism and trade). Indeed, after being dominated by agricultural sector until some years ago, the economy relies now mainly on the tourism and trade.

The service sector is the most important contributor to the economic growth, with 58% to the GDP. During the 1990s industry (including sugar production, mining, construction, and utilities) expanded from 26% to just over 32%. Manufacturing, led by the introduction of free zone *maquila* operations, grew at 3.8% per year between 1994 and 1998. Mining also increased substantially over the same period.

However, although only 40% of the population is considered as living in rural areas, agriculture remains the mainstay of the country as more than 70% relies on crop production which provides employments, revenues and food. The production is dominated by sugar cane (main agricultural activity in Yaque del Sur River), orange, citrus and rice (alluvial plain of Yuna), cacao, coffee, tobacco, cotton, vegetable, etc. In the last two decades, agricultural contribution to the GDP dropped from 30% (from 17.5% in 1991 to 12.4% in 1997) to 12% between 1990 and 2004, due to substantially of sugar cane production and process which was the mainstay of the economy. Despite the sector has declined as a whole, there has been modest growth in crop production, due to increase in high-value commodities production (rice, tobacco, industrial tomatoes, and bananas, etc.). The use of processed fertilizers and other chemical inputs to improve production and productivity has expanded in lockstep with agricultural diversification.

Chapter 3: CHARACTERISTICS OF THE PROJECT SITES

The study covers the two river basins (Yuna River basin - Cuenca del Rio Yuna and the Yaque del Sur River basin - Cuenca del Rio Yaque del Sur (figure 5) of the project areas, considered as the most affected by Noel and Olga tropical storms.

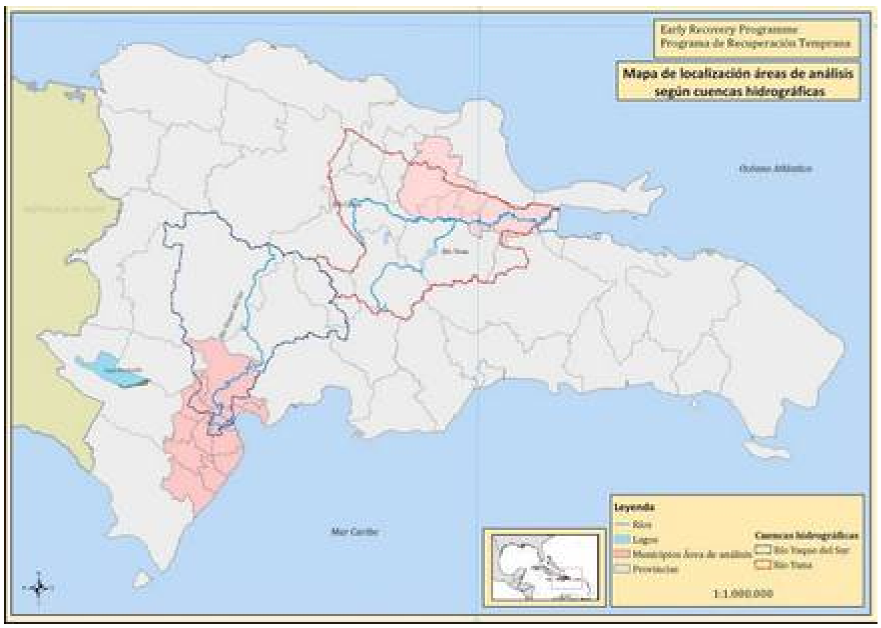


Figure 5: Map of the locations and hydrographic networks of Yuna River and Yaque Del Sur River.

3.1. YUNA RIVER BASIN (Cuenca de Yuna)

3.1.1. Hydrology

3.1.1.1. Main tributaries

Yuna River is the second important (in volume and length) river of the country after Yaque Del Norte, with 210 Kms long and an area of 5,498 km2, 11.6% of the country. The head of the river sources originates from the Central mountain range at an altitude of 1,640 meter high. It extends toward the plain of Cibao and flows down to the Samana Bay at the estuary. This bay is one of the biggest estuaries of the country and in the Caribbean countries (INDRHI, 2006).

From morpho-hydrological and environmental point of view, the Yuna River basin can be divided into three segments:

- **Uupstream** (from Rio Blanco to the head of the Yuna river and Camu affluent), characterized by altitude over 1500 m, with hard rocks, limestone and loamy sand and gravel soils (see 3.1.2) well protected by a dense forest (photo 1).

- **medium stream** (Santiago to Pimentel), characterized by moderate to high altitude with eroded sandy loam and gravel soils (see 3.1.2) along steep slopes down to the river, narrow river channel with more or less vegetation cover (photo 2);

- **Downstream** (from Pimentel to the Bay of Samana), characterized by low plain and opened valleys with heavy clayed or loamy soils subject to flood and inundation risks (photo 3a & 3b).

PHOTO SHEET I: LANDSCAPE FORMS IN YUNA RIVER BASIN

Photo 1: Upstream (La Vega)

Photo 2: Medium stream (Santiago)

Photo 3a: Downstream landscape: alluvial valley   Photo 3b: Downstream landscape (toward estuary)

On its way along downward, the Yuna River is fed by many tributaries and rain water coming from the slopes, thus irrigating the provinces of the Fertile valley of Sanchez Ramirez, Duarte and Samaná and through the cities of Pimentel, Villa Riva and Sanchez Ramirez. The most important tributaries:

- **Rio Blanco**, born in the east of the Cumunuco hill, joining Yuna river at the confluent of the Torito;

- **Rio Tireito, born** in the hill Hunted New in its North part to an altitude of 1800 meters, joining the Yuna River at Guázara, with the Arroyón and the Skinny Toro, as their main tributaries;

- **Rio Blanco:** born in the east of the hill of High Flag , in the National New Valley Park, to an altitude of 2300 meters and joinning Tireo river in the confluent of roundup and flows toward Yuna River;

- **Rio Masipedro**, born in the protected area of the Fogs, receiving in its low part the contributions of the Yuboa rivers and **Rio Maimón,** born in the hill of the northwest, to an altitude of 1307 meters with their main subtributaries, as Rio Yautía, Rio Leonor, thus flowing down to Rio Yuna;

- **Rio Camú:** born in the northeast of the Hill of Cazabito in the Scientific Reserve of Green Ebony, in the Central mountain range to an altitude of 1190 meters, merging with he Yamí River in the town of Bayacanes and with the Yuna River next to the town of Platanal. The camu river receives in its way along the contributions of several tributaries (River Guaigüí, Guarey are located and Yamí, in the low part (**Jima river** (1000 meters); **Licey river** (740 meters); Rio **Cenoví** (680 meters); Rio **Jaya** (400 meters); Payabo river.

3.1.1.2. Water flows

Surveys and measurements have been conducted by INDRHI (2004) in selected survey points of Yuna River and its tributaries since mid-fifties 1956, to monitoring the evolvement of the water flows (table 3) with regard to climatic changes, water uses (agricultural irrigation, drinking water, etc.) and construction of socio-economic infrastructures (derivation canals, dams and aqueducts, etc.).

STATIONS	**AVERAGE FLOWS** (m^3/sec)	**MINIMUM FLOWS** (m^3/sec)	**MAXIMUM FLOWS** (m^3/sec)	**PERIOD**
Yuna	**15,83**	2,42 (1965)	**56,52** (1976)	1962-1979
Maimón	5,15	0,12 (1991)	**40,03** (1988)	1968-2000
Camú-La Bija	**36,23**	2,79 (1975)	**145,88** (1996)	1968-2002
Camú-Bayacanes	4,26	0,74 (1995)	31,07 (1993)	1960-1995
Licey-Orange grove	1,62	0,33 (1977)	22,28 (1981)	1964-1987
Cenoví-Saint Ana	1,31	0,05 (1991)	7,47 (1985)	1982-1995
Maguaca-Cabilma	1,33	0,12 (1994)	11,84 (1993)	1982-1995
Chacuey-Los	1,53	0,37 (1992)	12,11 (1988)	1984-1993
Payabo-Abbess	5,90	0,85 (1987)	22,68 (1983)	1971-1995
Lemon	**102,39**	10,87 (1975)	**374,68** (1981)	1968-2003
Payabo	5,79	0,47 (1977)	22,68 (1983)	1971-1995
Villa Riva	**89,38**	6,08 (1977)	**402,52** (1979)	1956-1992

Table 3: Average annual means, minimum and maximum values of water flows of the Yuna River and its various tributaries between 1956-2003 (INDRHI, 2004)

As shown in the above table 2, the value of the water flow is variable from one location to another. The volume of Yuna in the medium stream is greater than in their high part, due to important contribution from the various tributaries. The highest value are recorded in Vila Riva (89, 38 m^3/sec), Lemon (102, 39 m^3/sec), Camu (36, 23 m^3/sec), Yuna (15, 32 m^3/sec) and Maimon (5,15 m^3/sec).

However, the water flows are in many areas regulated by dams constructed across the river or tributary to control the water flow or by derivation canal for agricultural irrigation purposes. There are six dams constructed and under construction in the Yuna River: Target, Arroyón, Tireíto, Yuboa, Hatillo, Corner and Guaygüí. There also a number of derivation docks within all the river basin that are used for taking aqueducts for urban consumption and secondary channels for agricultural irrigation.

3.1.2. <u>Major soil types and characteristics</u>

Most of same soils described in section 2.1.1 have been identified in the river basin (FAO, 2003; USAID, 2004) to various extent. However, the most representative are in the basin: **Ferralsols/Oxisoils** (photo 4 a & b) in the mountains areas in up-slopes, dominating the hig altitude, **Colluvial soils** at the bottom of the slopes, generally bordering the valley, **Alluvisols** in the flooded plains, **Fluvisols** along the river beds, **Hydromorphic soils** in the lowlands and valleys.

Depending on the area and the nature of the sediments, they have variable texture:

- **soils composed of sand mixed to lot of gravels** in upstream and medium stream along the river banks and fine sand (silt), loam and clay in the lowest parts and the river beds (photo 5);

- **soils with clay and loamy texture**, with poor drainage, occupying the high plain and the valley, with high topography (photo 6);

- **organic acid soils** formed under lagoon or lake systems with clay texture, found in the areas between Cotuí and Cevicos;

- **Soils with plastic clay subsoil** formed on old calcareous limestone material**,** occupying extensive areas in the Eastern Valley of the Cibao, mainly, between the South eastern of San Francisco de Macorís and Villa Riva, with poor drainage. Their profiles show stratified soil layers (horizons) formed from sediments deposited at different periods (photo 7). They are poorly drained and subject to frequent floods due to the area smooth topography, their low permeability and heavy texture. They constitute the most fertile agricultural lands of the river basin, particularly for rice production.

Most of the soils bordering the river banks are sandy clay soils, while those in the alluvial plains are loamy sand to clay soils, and clay loam in lowlands and valleys. The sandy soil are poor soils and very sensitive to fertility decline. Because of their little productivity, they are often used as grazing lands (FA0, 2003).

The flooded plains are characterized by alluvial sediments deposited by the end of Quaternary and recent alluviums. The basin is known as the area including the most fertile agricultural lands of the country (FAO, 2003).

All these soils are vulnerable to any form of degradation (erosion, landslides, etc.) which can be very severe depending on the surface vegetation cover, with important loss of sediments transported down into the river beds where there contribute to sediment deposits within the river basin.

PHOTO SHEET II: SOILS TYPES ALONG YUNA RIVER BANKS


Photo 4: Forest red soils (Ferralsols/Oxisols)

Photo 5: Shallow sandy soil with gravel and stones at the bottom of mountains/hills

Photo 6: Clay loam soil occupying the flooded plains and valleys (Downstream)

Photo 7: Sandy loam soil along the river bank (Downstream)

3.1.3. Climate of the river basin.

The climate is variable, with a very low temperature (zero degrees Celsius) in upstream (hill of High Flag), varying generally between 12 and 31°C (annex--, fig. No 31 and table Not). The rainfalls vary widely from one location to another, between 3000 mm/year and 1000 mm/year.

However, in the south slope of the northern part of the Central mountain range, the situation of the climate is different with high temperatures and less precipitation, causing less vulnerability of the tributaries to flood issues.

3.1.4. Vegetation

From up to downstream, the river is protected by various types of forest with different cover and species (photos 8-10).

The upstream part is well protected by a good forest cover, mainly in the sub-river basins of Maimón, White Stream, Masipedro, Jima, Camu. The forests are composed natural stands and plantations of coffee and cacao. However, the sub-basin of Tireo tributary has a limited forest cover due to important deforestation by intense agricultural activities and logging. In general, most of the tributary sub-basins in the Southern slope of the central Mountain range have poor vegetal cover; thus vulnerable to degradation.

The medium stream is mainly occupied by Savannah dominated by herbaceous and shrubs (Guayabo) performing on rocky materials, gravels soils with fine sandy texture and high permeability. Depending on the topographic characteristics of the sites and the soil depth (deep or shallow soils), they are more or less dense. They are mainly found around Cotuí, the South eastern part of Fantino and San Francisco. Because of their little wood productivity they are mainly used as grazing lands (FA0, 2003).

In downstream, the western portion of the Bay, Río Yuna and Rio Barracote are well protected by dense forests of mangrove (CEBSE, 1993). With 17,6 km long (Sang and Lamelas, 1995), these forests occupie all the western part of the Bay of Samaná, from the town of Sanchez to the south margin of the exit of the Barracote River. The main species are composed and structured, from sea to the earth as follows: *Rhizophora mangle* (mangle red), *Racemosa Laguncularia* (mangle white) and *Avicennia germinans* (mangle black) (Sang et al., 1994).

PHOTO SHEET III: FOREST COVER ALONG YUNA RIVER BANKS

Photo 8: Forest cover protecting the Watershed in Rio Blanco sub-basin (Upstream Yuna River)

Photo 9: Forest cover protecting the watershed in medium stream (Rio Camu)

Photo 10: Flooded plain protected by low forest cover in Yuna River downstream

3.1.4. Socio-economic issues

From socio-economic point of view, agricultural development is the mainstay of Yuna River basin. Agricultural production is based on cereal crop (rice, maize, etc.) and banana plantain widely practiced particularly in the medium and downstream areas.

In the fertile valley in downstream the production tends to be focused on high-value export crops (vegetable, banana, etc.), with special focus on rice (95% of the cultivated area). The valley is also the domain of animal husbandry (cattle ranch) for milk and meat production.

Upstream is an area of influence of small farmers practicing subsistence farming and also tree crop plantations and fruit trees for cash (fruits, coffee, cacao, citrus, orange, avocado, etc.) developed by small/medium private, mainly in the tributary sub-basin, such as in **Licey River**, **Cenoví** and **Jaya**,

In support to irrigated rice production many constructions have been promoted to expand the cultivated area in developing the irrigation networks of canalizations that assure the water control. The area cultivated with rice under irrigation amounts approximately 65,000 hectares (14,44% of the total irrigated land in the country, 450,000 Ha) equipped with a hydraulic in-frastructures that allow adequate irrigation (SEMARN, 2004b mentioned by Valbuena**,** 2007)

3.2. YAQUE DEL SUR RIVER BASIN (Cuenca de Yaque del Sur)

3.2.1. Hydrology

3.2.1.1. Characteristics and tributaries

Yaque Del Sur River is the third river basin of the country and the most important river basin of the southern region. It covers a total area of 4,972 Km2 and flows along 183 km from its birth place in the south slope of the Central mountain range at an altitude of 2,2007meters, up to its exit in the Bay of Neyba (Mar Caribe). The average water flow is estimated to 40m3/sec at Villarpando.

This river basin has steep slope landscapes, with very steep slopes that drain torrential rain water run-off toward the river and its many tributaries, especially in those with poor forest cover (photos). Its principal tributaries are the Rio Saint John (1,654 Km2 of the Saint John and 232 Km2 of the River Millet), Rio Caves (582.1 Km2), Rio Grande (685.46 Km2), Rio Ozama (148 Km) also fed by many sub-tributaries (Isabela, Sabita, Yabacao, etc.).

From geomorphological and environmental point of view, the basin of Yaque del Sur River, can alsobe dived into four segments:

- **Upstream**, characterized by high altitude with dense forest cover and well protected slopes and soil with loamy sand soils (photo 10);

- **Medium stream** of the river (from El Higito to Tamayo), characterized by low plains and opened valleys with loamy sand to gravel sandy soils very permeable and with a loose structure, protected by a poor vegetation cover (photo 11);

- **Downstream** (estuary: including the bay of Neyba, Jacquimiyes and Barahona areas), characterized by flood plain and opened valleys, poor vegetation cover on rocky soils and mangrove at the bay shore, densely cultivated with sugar cane and plantain (photo 12);

- **Lake and lagoon ecosystems**: it's the western part of the river basin which is now disconnected from the main basin of Yaque Del sur, due to sedimentation and separation from it during the geological erosion by end of the Quaternary, resulting to creation of lagoons and lakes. The area is characterized by the presence of Cabral lagoon and Lake Enriquillo (photo 13).

In the medium stream the landscape changes with the slopes at their minim expression and shape meanders which frequently deviates their main beds, up to the exit in the humid and swamp area of the Neyba Bay.

3.2.1.2. Water flows

As per data gathered by INDRHI (2004), the average annual stream flow measured between 1959 and 1982in Yaque del Sur River is 45.3 m3/s, ranging from 18.4 m3/s (1959) to 104.6m3/s (table 4).

YEAR	YAQUE DEL SUR
1959	41.9
1960	67.1
1961	56.6
1962	38.7
1963	41.9
1964	24.7
1965	27.8
1966	29.3
1967	**18.4**
1968	29.3
1969	32.1
1970	103.3
1971	**104.6**
1972	54.6
1973	42.3
1974	35.3
1975	32.6
1976	26.0
1977	20.7
1978	30.5
1979	74.2
1980	37.4
1981	66.6
1982	51.5
AVERAGE	**45.3 (Period)**

Table 4: Variation of stream flow recorded from 1959 to 182 in Yaque Del Sur River.
Source: INDRHI, 2004

PHOTO SHEET IV: LANDSCAPE FORMS IN YAQUE DEL SUR RIVER BASIN

Photo 11: Upstream

Photo 12: Medium stream

Photo 13: Downstream

Photo 14: Lagoon Cabral

3.2.2. Major soil types and characteristics

Same types of soils as in section 3.1.2 are identified in the Yaque del sur River basin, including saline carbonate soils in the lagoon and lake ecosystems and saline marine soils in mangrove areas (estuaries). In general, soils in upstream have a sandy loam texture and covered by a poor forest cover, while those in the medium part and downstream have a sandy to sandy loam texture. Compared to those of Yuna River, the soils are more sandy and developed over mixed parent materials, c**olluviums-alluviums** with a lot of gravels and hard stones (photo 14), occupying the flood plains and the valleys. Thus, they have high permeability and are very sensitive to erosion and vulnerable to landslide (photo 15).

In Lagoon Cabral and Lake Enriquillo ecosystem areas, the soils are mainly saline with high content of carbonates (**rendzines,** photos 16 & 17) in surrounding areas frequently flooded by the lagoon or lake water, due to calcium carbonates produced by solubilisation of calcareous rocks and concentration of soluble salts. In the estuary the saline soils are associated to mangrove ecosystems and sea water (photo 18).

However, soils developed over alluvial materials have usually good fertility and are very suitable for intensive agricultural production, particularly for sugar cane and plantain, such as in the valley of Saint John and Neyba.

3.2.3. Climate

The climate of the region is warm and dry with annual rainfalls ranging from 500 mm to approximately 2,000 mm per year, and a temperature between 26 and 28oC, especially in the areas of Barahona, Neyba, Jimaní, Flints, Tamayo, Vicente Noble, Cabral Craggy rock, where the population is located.

3.2.4. Vegetation

The region is characterized by mountain forests and Savannah with a big diversity in species and height. The main forest vegetation types described are (i) humid mountainous low Forest (bh-MB), (ii) humid subtropical Forest (bh-S), (iii) dry subtropical Forest (bs-S), (iv) thorny subtropical Mount (me-S), (v) dry savannahs and shrubs (photo 19).

The southern and south western margins are occupied by humid savannah composed of palm trees (photo 20), acacias (Photo 21), and other many flood tolerant species, while the lacustrine ecosystems (photo 22) and swamp areas are colonised by mangroves composed of *Rhizophora mangle* (mangle red, photo 23a), *Racemosa Laguncularia* (mangle white) and *Avicennia germinans* (mangle black)(photo 23b).

The area has a rich biodiversity but of which many are endangered by natural and socio-economic activities. Several protected areas and national parks have been created to preserve their biodiversity and the natural resources: (i) José Del Carmen Ramírez, (ii) Juan Bautista Pérez Rancier, (iii) Saw of Neyba, (iv) Martín García Saws.

The lagoon Cabral and Lake Enriquillo bear huge potential biodiversity which play a great role for the livelihood of the communities living in the area, such as Cabral, Cristóbal and Craggy rock.

<u>PHOTO SHEET V</u>: SOILS AND NATURAL VEGETATION IN YAQUE DEL SUR RIVER BASIN


<u>Photo 15</u>: Savannah

<u>Photo 16</u>: Eroded Sandy gravel & stony soil


<u>Photo 17</u>: Saline calcareous soil (Rendzine)

<u>Photo 18</u>: *saline soil* (marine water)

PHOTO SHEET VI: REPRESENTATIVE NATURAL VEGETATION TYPES


Photo 19: Mountainous dry Savannah Photo 20: Wetlands (Palm trees)


Photo 21: Alluvial Acacia woodlands Photo 22: Halophyte plant (Lagoon Cabral

Photo 23: Mangrove vegetation at the estuary of Neyba

3.2.5. Socio-economic issues

The province of Barahona is irrigated by Yaque Del Sur River and its tributaries, including Lagoon Cabral and Lake Enriquillo. It covers a total area of 1.650,49 km2, that's 20% of the country area. The province is constituted by 11 municipalities, Barahona, Cabral, Enriquillo, Paradise, Noble Vicente, etc.

More than half (74%) of the population of the province of Barahona are faced with poverty. The main activities of economic sectors are agriculture occupying 20,2% of the population, Services with 22,0% and trade with 19,0% and occupy more than two thirds of the active population of Barahona. Agricultural production takes place mainly in the Valley of Neyba and is based on, as main crops: sugar cane, plantain, sweet bananas, fruit, etc.

Chapter 4: FLOOD OCCURRENCE, DAMAGES AND RISKS

4.1. Overview of the occurrence and damages

4.1.1. Previous floods and damages

In the last four decades, Dominican Republic has suffered from cyclic hurricanes and tropical storms disasters which caused serious damages on the environment, agricultural lands, forest resources, and socio-economic infrastructures (roads, water dams and canal for irrigation and domestic use, homes, etc.), throughout the country.

To better understand the impacts of Noel and Olga storms and the magnitude of the floods on the environment and land degradation, was studied through field observations and discussions with affected communities, it is important to recall damages caused by previous hurricanes and storms which hit the country in the last 4 decades.

Flood issues and damages due to hurricanes and tropical storm disasters seem to be well known in the country, as recurrent natural catastrophes happening annually throughout the country in the last 4 decades provoked by series of storms of various amplitudes, as reported by various sources (CEPAL, 1998, UNDP, 1998). Since 1930, the country is confronted with many disasters, among the most important are:

- **San Zenón** (happened the 3 of September of 1936 with a balance of 4.500 death tolls, 20 thousands hurt and a number of more than 15 million dollars of estimation of direct losses),
- **Flora** (happened in October of 1963, 400 died and direct losses of more than 60 million dollars),
- **Ines** (29 of September of 1966, 70 died and not less than 10 million direct losses),
- **Beulah** (11 of September of 1967 that affected the province of Pedernales severely and caused severe damages to the agriculture of the South region of the country) and
- **David** (31 of August of 1979, 2 thousand dead people and material damages considered by CEPAL in 829 million dollars that enter losses of heap and production, as reported by CEPAL , 1979).
- **Geoges hurricane** in 1998 left to losses near 2.200 million dollars and 235 registered death tolls, in addition to a high percentage of the population directly affected by the phenomenon (CEPAL, 1998).
- **Torrential rains** in 2003 in Yaque del Norte, Yuna River basins y El Cibao, southwest (Fonds Verretes and Jimani).
- **Hurricane Jeanne** in 2004 with inundation and lot of damages (human, socioeconomic infrastructures and environment).
- **Noel** (Tropical Storms, October 2007);
- **Olga** (**subtropical storm,** 11 and 12 December 2007).

According to UNDP (1998) studies, **San Zenón (1936)**, Flora (1963), **Ine**s (1966), **Beulah** (1967), **David** (1979), **Georges** (1998), are the most devastating hurricanes and storms which had hit the country with severe damages on the environmental and socio-economic issues since 1936. The National meteorological service noted that, since back from 1900, at least every decade the country is hit at less by four devastative hurricanes, as registered since 1960. However, the number of floods has decreased from 39 events in 1978-1987 to 25 in 1988-1997 (PPD/PNUD, 2008).

FAO (2003, 2004) reported important cropland loss by heavy floods in 2003 and 2004, particularly in the river basins of Yuna nearly 2300 ha and 2565 ha, respectively, of agricultural lands and croplands with main crops (1200 hectares of guandul, 5800 ha of maize, 400 ha of red bean, 215 ha of auyama, and 118 ha of onion) were lost. In addition to these damages on agricultural production, the road infrastructure networks were badly affected by the storms with severe erosion of road edges and collapse of bridges. The floods damaged 20 water equipments (aqueducts) in different sectors of the country were reported severely damaged in different sectors.

The table 5 below shows the areas affected by the various floods which hit the country in the last decades.

MAIN FLOODS AND LANDSLIDES THAT HAVE AFFECTED TO THE DOMINICAN REPUBLIC IN THE NINETIES	
30 October of 1990	Santiago Rodriguez (Villa the Almácigos, produce by the River the Almácigos, with destruction of 25 houses)
23 April of 1991	San Pedro de Macorís (District 24 of April, underflow of a gorge who destroyed 15 houses and 7 dead ones)
1992	San Juan of the Maguana (the Bushes of Farfán, underflow of the Yaque River of the South, incomunicando to 10 communities, 3 dead ones)
1993	San Cristobal (underflow of Ríos Nigua and Yubaso, 6 died and destruction of 150 houses)
1993	Nagua (Goatherd, underflow of the River Tío Marcos, 7 died and tens of destruídas houses)
May 1993	Bonao (swelling of the Rivers Leona and Yuna, incomunicando 80 families)
19 August 1995	Santo Domingo (District Mends It, underflow of the Ozama River, destruction of tens of houses and 420 victims
15 November 1995	Neyba (Tamayo, underflow of the Jura River, destroyed 30 houses)
1996-1998	Santiago, San Francisco, Nagua (swellings of Ríos Yaque of the North, Yuna, Stupid, causing more than 2.500 victims)
May 2003	Torrential rains in Yuna, Yaque del Norte, El cibao and Yaque del Sur
15 and 18 September 2004	Yuna River basin, Jimani
2007 (Noel and Olga)	Azua, San Cristobal, Bani, Peravia, Independencia, Barahona and Pedernales, the northern provinces of Espaillat, Salcedo, Arenosa, Montecristi, Santiago, Duarte and Maria Trinidad Sanchez and Puerto Plata

Table 5: Areas affected by various floods which hit the country in the last decades

Source: Closing report of the project "**Fortification of the National Capacity to prevent, to mitigate and to take care of Disasters of Natural or Technological Origin**", September of 1998

4.1.2. Damages by Noel and Olga storms

The Dominican Republic, was badly affected in 2007 by Noel and Olga which provoked heavy rains, floods and mudslides which severely damaged the environment, land and forest resources, agricultural lands, socio-economic infrastructures (road, post harvesting, bridges, canals, homes, etc.) and the potential biodiversity (photos 24-29).

The heavy rains provoked by Noel and Olga storms lashed the Dominican Republic, causing important floods and mudslides. Most of the streets were flooded due to large of water and lack of drainage networks in the cities (photos).

Approximately 24,595 people have been evacuated and 4,929 houses have been affected according to the Emergency Operational Committee (2007). Seventeen (17) were put on alert: Santiago, Puerto Plata, Espaillat, Hermanas Mirabal, Duarte, Maria Trinidad Sanchez, Samana, Montecristi, Valverde, Sanchez Ramirez, El Seibo, Hato Mayor, La Altagracia, La Vega, Montelplata and Monsenor Nouel.

Noel and Olga

In October and November 2007, heavy rainfalls (Noel & Olga) fell across the Dominican Republic, with isolated totals of 10 inches (250 mm) expected, flooding and landslides affecting 80% of the country. Approximately 66,500 people have been displaced of which 23,500 are in shelters and 43,000 are staying with friends and relatives. Approximately 16,700 homes have been damaged. Eighty-four people have died with a further 48 missing as of 5th November.

In addition, there has been severe damage to: (i) Transport infrastructure; (ii) 95% damage to plantain, banana and tomato plantations; (iii) 40% of water supply distribution; and (iv) 60% of 122 aqueducts.

Damage in the country was estimated at $1.5 billion (2007 DOP, $45 million 2007 USD).[29]

Source: http://en.wikipedia.org

River Yuna and River Yaque del Sur are the most affected, particularly extensive areas of cropland especially for bananas, tomatoes, cassava and rice had also been destroyed. Many high risks areas have been severely affected: Espaillat, Salcedo, Arenosa, Montecristi, Santiago, Duarte and Maria Trinidad Sanchez and Puerto Plata, and the southern regions of Azua, San Cristobal, Bani, Peravia, Independencia, Barahona and Pedernales (COE, 2007; INDRHI, 2008).

An estimated 40% of the country's territory was impacted by the storms and heavy floods with approximately 78,752 people affected, 14,997 damaged houses, 1,506 houses affected and 3,185 destroyed, 46 bridges and highways severely affected (40%). According to FAO (2007) the losses in rice and industrial crops (sugar cane) were limited compared to plantain and cassava which were lost up to 80%. In the overall agricultural sector the total estimated cost of the losses amounted USD77,7 million. The small agricultural producers with small incomes have been the most vulnerable. According to CEPAL (2008) the damage on the environment and the agricultural sector are so important that the cycles of farming production recovery will take time to come back to normal.

These damages were believed to be the most important ones in the last decade, more devastating compared to hurricane Georges which damages represented the equivalent of 14% of the gross internal product of the country in 1997.

The signs of these damages and impacts are still visible in the field as noted by the mission team during the investigation, illustrating the magnitude of damages caused particularly on the environment, lands and water and agricultural sector. Indeed, along their 210 km and 183 km long, respectively, the two river basins are affected in their medium and low courses by flood due to the overflow of the huge amount of water drained by the tributaries and the watershed, directly into the rivers, exceeding their capacities of stream flow. It appears to the mission that the flood had affected the low and medium parts of the two basins more than the upper parts, due to the low permeability and infiltration of the clayed soil texture and the poor management of water in the irrigated farms of the plain. The situation is much more marked in the Yuna River basin than in Yaque del sur River basin, due to the presence of large flood plain which soils remaining constantly saturated of water over the year because of their low infiltration rate and accentuated by irrigated agricultural activity mismanagement (Valbuena, 2007).

However, from flood event recurrence point of view, the two river basins are likely too vulnerable to over flow, with regard to their configuration, landscape characteristics and the steep slopes of the watershed.

PHOTO SHEET VII: SOCIOECONOMIC DAMAGES CAUSED BY NOEL AND OLGA STORMS

Photo 24: Street and home flooding

Photo 25: Home destroyed by windstorm

Photo 26: Land degradation: soil block detachment and damaged trees.

Photo 27: inundated farm & Forest in Lake Enriquille

Photo 28: Land degradation: destroyed tree and soil block detachment.

Photo 29: Bridge destroyed by water flow

4.2. Flood risks

Located at the cross-road of Atlantic winds and Caribbean depressions, the Dominican Republic is exposed to intense cyclonal activities and thus threatened annually by unavoidable natural meteorological disasters with of all nature of damage. Many studies demonstrated that most of the hurricanes happening in the Caribbean region have their trajectories passing closely to Dominican Republic and affect the territory, revealing the proneness of the country. According to INDHRI (2007) and CEPAL (1998), every two years the country is hit by hurricane or tropical storm events of moderate to high intensity. As such, it's a hurricane and tropical storms prone country.

Many studies highlighted that the average trajectories of hurricanes in the Caribbean happen very near the Dominican Republic and affect the country every two years. According to meteorological records that go back to 1960, at least four hurricanes hit the country each decade.

Most of the river sub-basins are very vulnerable to flood with their main courses often disturbed by the water overflows happening between October and December each year. Indeed, the area of the Yuna river basin has a humid climate (rainfalls ranging from 1000 to 3000 mm/year) throughout the basin, influenced by orographic rains due to tradewinds that penetrate by the NE and brings high humidity in the North slope of the Central Mountain range, acting like insurmountable screen against humid air masses, thus provoking heavy precipitations.

In order to understand flood occurrences, INDHRI conducted in 2007 studies in various sites along Yaque del Norte River and Yuna River and their respective river sub-basins in simulating different precipitations in diverse scenes taking into account the periods of highest flood return, characteristic parameter of the magnitude and the frequency of occurrence of the hydrological dynamic. This allowed INDHRI to elaborate the scenes of drainage and water flows that define the dynamic of the Yaque Del Norte River and its main tributaries. The hydraulic analysis provided elements for mapping the flood risks zones in all the river basin. The most vulnerable with high flood risks seem to be the sectors in the viscinity of Santiago, including the communities of the low part of the river basin.

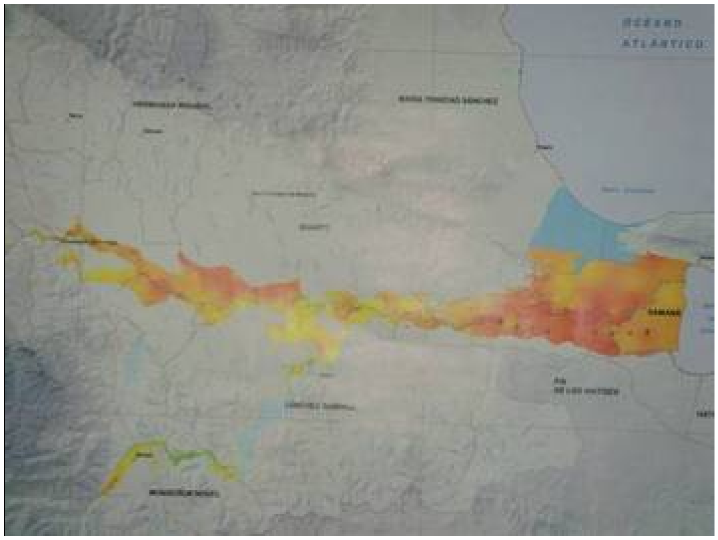


Figure 6: Inundation risks in the Yuna River Basin
Ref: Naional Institute of Meteorology (2007)

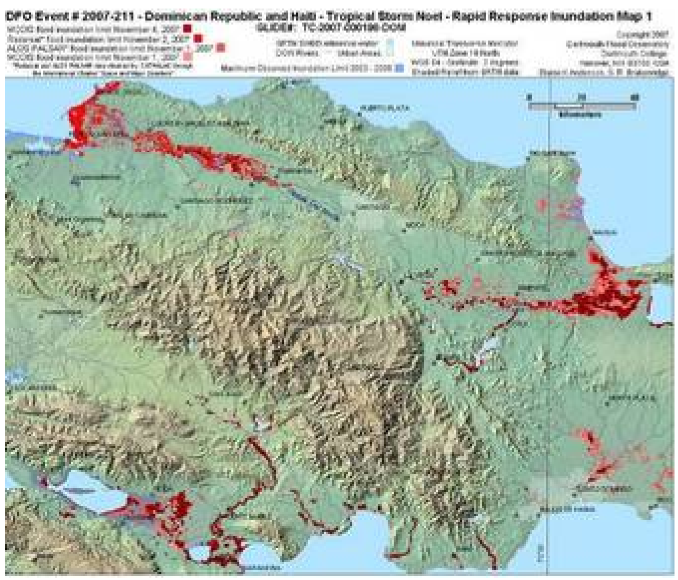


Figure 7: Inundation risks in the Yaque del Sur River basin (INDHRI, 2008)

4.3. Underlying causes contributing to enhance flood

From the field observations and analysis of the past events, the consultant noted that the magnitude of the inundation and subsequent damages don't depend only on the amount of rainwater and rainfall intensity, but also rely on rely a number of underlying factors that contribute to enhance their impacts on the environment and land degradation, such as:

- configuration of the landscape and watershed (topography, slope gradients, shape –open or narrow watershed, etc.);
- agroecological conditions;
- hydrological networks (density of the tributaries, velocity of the streamflow, width and depth of the river channel, etc.);
- soil characteristics (texture, permeability, occupations, etc.);
- land uses;
- vegetation cover;
- water management (infrastructures, etc.);

4.3.1. Landscape configuration and hydrological networks

The two river basins are characterized by various landscape forms (mountains, hills, valleys, flat plains, etc.) and very dense hydrological networks constituted of many tributaries feeding the Yuna River. From the field observations and analysis, the following characteristics and parameters are identified as the most important factors contributing to enhance flood and inundations:

- configuration of the watershed (width-narrow or open shape, depth, shape of the slopes, etc.);
- density of the hydrological networks and velocity of the waterstream flowing down to Yuna, area of the tributary sub-basin and volume of water discharged into the Yuna River, etc.);
- slope gradient of the stream flow, from the upstream (birth place, over 2000 m high) to downstream (exit into the sea, 3-0 m) or the confluence of the tributaries with the Yuna River or Yaque del Sur River which speed up the stream flow, thus provoking overflows and inundations in case of heavy rain such as from Noel and Olga storms (figure 8 & 9);
- presence of important lowlands (valleys, alluvial flop plains, etc.) characterized by flat topography with high vulnerability to flood and inundation (photos 30 & 31).

As for Yuna River, all these factors are exacerbated by its vulnerability reinforced by the amplitude of the precipitations ranging from 1000 to 3000 mm/year and high relative humidity of the air which maintain a positive water balance (rainfall-evapotranspiration) throughout the year. As pointed out by several studies (INDHRI, 2007, 2008; USAID, 1981 and 2004, CEPAL, 1998) Yuna River basin constitutes one of the most humid regions of the country and in which the risk of flood is very high and frequent. With regard to topographical features and the above considerations, the Yuna River appears to be a flood and inundation prone area.

Regarding Yaque del Sur River, the dense tributary networks collect and discharge important volume of water stream (magnitude of 2,000 to 8,000 m3/s) flowing down from up slopes to downstream, enhanced by the high slope gradient (figure 9). Because of the above underlying parameters/factors, particularly the narrowness and shallow depth of the river and tributary channel filled by lot of sediment deposits, any heavy rain provoke overflow of the stream, with as immediate consequences in changing the normal watercourse or discharging the excess of water into the lowlands. It is important to mention that most of the tributaries and even the river in some parts have a very narrow channel filled with a lot of sediments, thus could hardly carry huge amount of water.

It's important to note that in both river basins of Yuna and Yaque Del Sur Rivers, from upstream to downstream the magnitude of the inundation and the damages is variable, depending on the characteristics and the dynamic of the stream flow of each geo-morphological segment. The field observations revealed, while the entire basins are concerned by the flood, the medium part and downstream, particularly the lowlands of the alluvial plains and valleys, are the most affected due to their flat topography and their low slope gradient with the river channel. This has been enhanced by the presence of heavy texture soils with very poor internal drainage (low permeability and infiltration) which amplify water concentration on the soil surface.

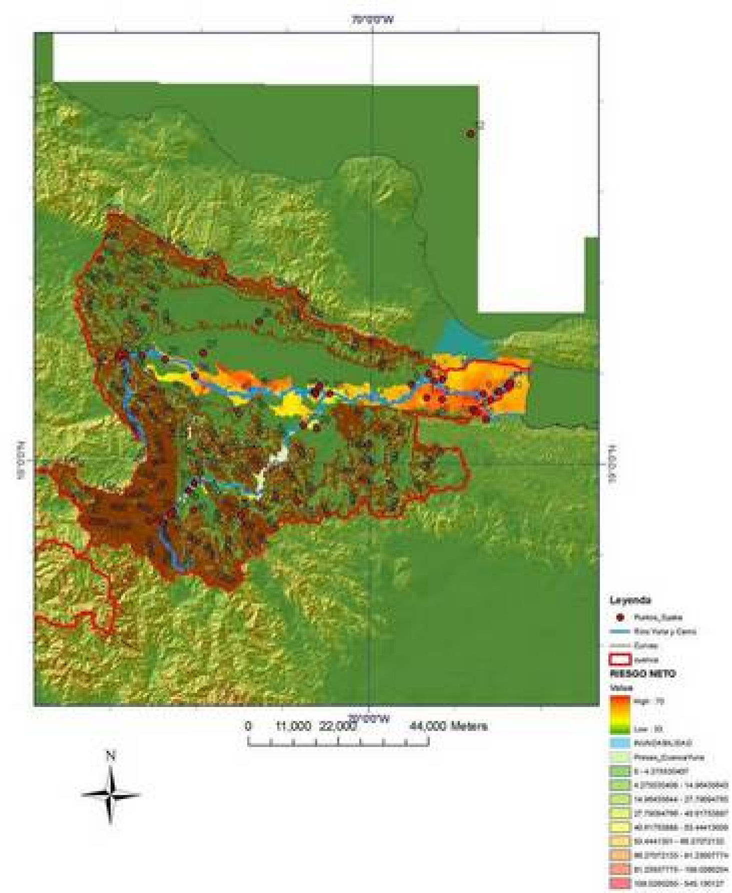


Figure 8: Map of slope gradient and flood risks in Yuna River basin

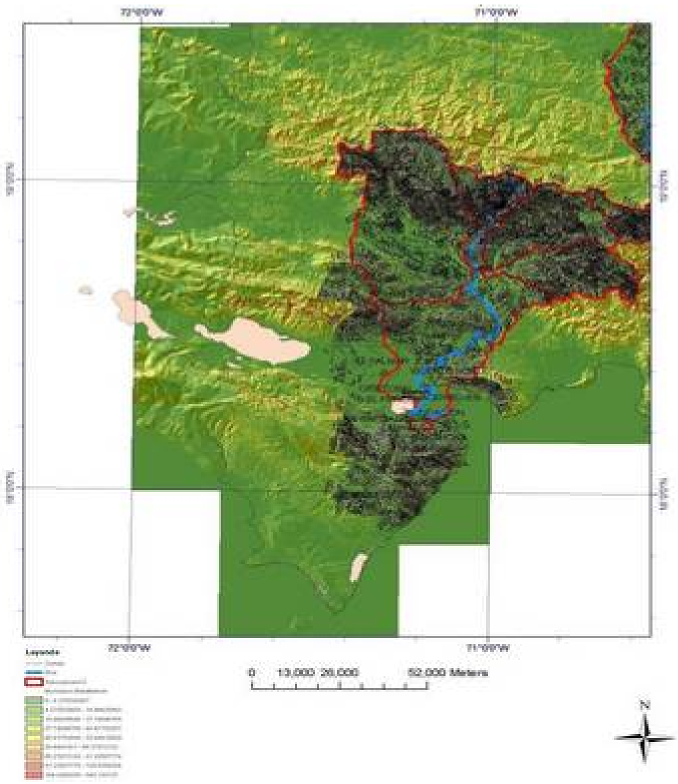


Figure 9: Density of slope gradient in Yaque del Sur River basin

As per studies recently conducted by Reyes-Tatis (2007), there is a decent relationship between the precipitation (minus actual evapotranspiration) and water stream flows, as shown by figure 10 below. The figure also shows that the amount of stream flow is greater in upstream than downstream.

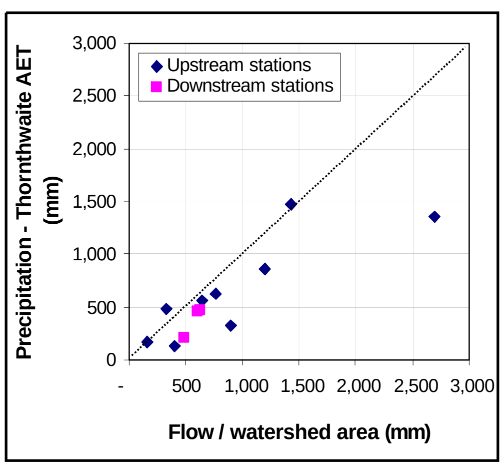


Figure 10: Comparison of stream flow per unit watershed area and precipitations minus actual evapotranspiration, for stream flow of various station locations.

4.3.2. Soil characteristics and drainage

Comparision of rainfalls between Yuna River basin (1000-3000 mm) and Yaque del Sur River basin (450-1500 mm) highlighted that under different climatic zones with high difference of rainfalls, the inundation resulted to more pronounced soil degradation in Yaque Del Sur River than in Yuna river basin.

Soil characteristics have been found of playing a major role on flood and inundation magnitude. Indeed, under humid conditions and flood irrigation like in Yuna River basin, soil with heavy texture tends to be permanently wet or saturated (photos 30 & 31), thus lowering water infiltration and provoking flood during heavy storm. While in Yaque del Sur River basin, the important degradation caused by the storms is enhanced by the sandy soils with loose structure which appears to increase the vulnerability of the soil to erosion by high water infiltration, and soil collapse.

The notion of soil climatic drainage is of great importance in assessing land and soil erosion process. The significance of this notion is that it has impact on soil moisture and on potential flood magnitude. From the collected data, one can estimate the drainage (D), that's the quantity of water which infiltrates into the soil, using the formula known as "Hénin-Aubert" equation:

D (mm) **= YP3/1 + YP2**

Where:

P (or R) = annual rainfalls in mm/an,

Y= @/0,15T-0.13

@ = 0,5 (clay soil) and 2 (sandy ground).

T = annual average température,

From the above equation, we can assume that clay soil has low drainage and is more subject to flood, while sandy soil has good drainage and less subject to flood.

4.3.2. Water management infrastructures

4.3.2.1. <u>Hydraulic infrastructures</u>

The two rivers and their respective tributaries are among the national sources of water for domestic and agricultural uses, industries and hydro-electricity production. For that purposes many hydraulic infrastructures have been or are being constructed in the two basins, such as dams, derivation canals, power plant and water reservoirs (figures 11 & 12).

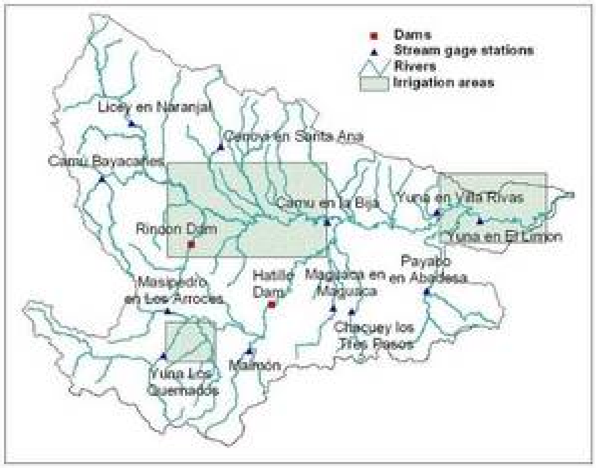


Figure 11: Distribution of hydraulic infrastructures in Yuna River basin

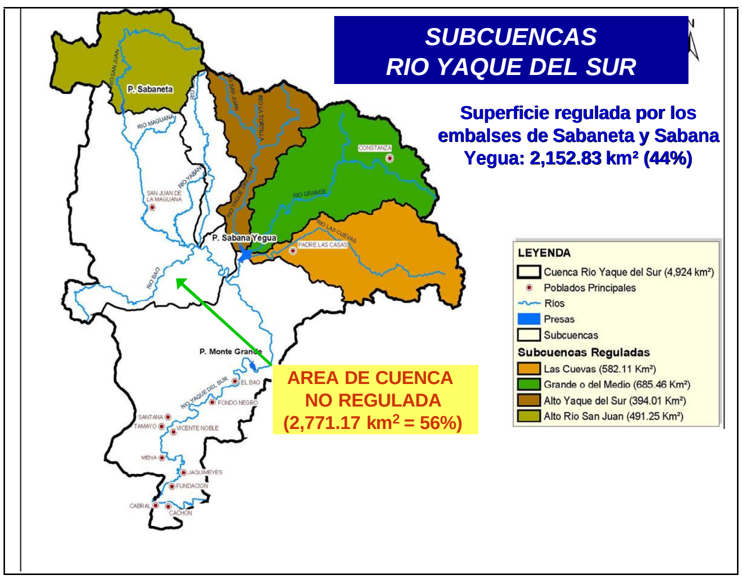


Figure 12: Hydraulic infrastructures regulating water flow in various tributaries of Yaque del Sur River basin

Road infrastructures also play in some case the role of a kind of barrier to the water flow, thus regulating the flood.

All these infrastructures (dams, flood gates, roads, derivation docks and irrigation canal, etc.) are made to, inter-alia, protect against and provide with water for agricultural, socio-economic and industrial uses. Most of them are multi-functions, providing water and electrical power for municipal, industrial and agricultural uses.When the water flow is at its normal or minimum stream flow, they operate like reservoirs for water storage.

However, flooding control has not been always targeted as a defined objective, although all these infrastructures play that role, in regulating the stream flows of the rivers and tributaries. As such, there are many dysfunctions in the management of the infrastructures during heavy rain or storms, as the case with Noel and Olga. It's important to note that their efficiency to controlling floods and inundation depends on the velocity and height of the water flow. Indeed, for instance during Noel, most of dams constructed in the Yuna River basin, including derivation (photo 32) and irrigation canals could not contribute to prevent the cyclical floods in the medium and low parts of the basin. In both river basins, many bridges and roads were destroyed by the waterflow. The excess of the water flows overpasses the road or the dam and provokes inundation which magnitude depends on the configuration of the landscape and the nature of the soil (sandy or clay texture). In Yaque del Sur, due to the configuration of the river channel, the highway going to Barahona and located between Jaquimeyes and the flood plain of Yaque del Sur River basin, could not block the water flow which level reached 1,80m, thus provoking important inundation of the area with serious damages. For this area, discussion with population revealed that in the last 50 years, the population of Jacquimeyes have been affected almost at least once a year by devastating flood. All these are likely the fact of lack of regulation of river stream by the infrastructures constructed along the river, from upstream to downstream.

Noel and Olga

In October and November 2007, heavy rainfalls (Noel & Olga) fell across the Dominican Republic, with isolated totals of 10 inches (250 mm) expected and. The rainfall caused flooding along the Yaque del Norte River, and initially there appeared to be a threat that the Tavera Dam along the river would fail, potentially killing thousands in Santiago Province. Officials instead opted to open all six floodgates at 0400 UTC on December 12, which released about 1.6 million gallons (6.1 million litres) of water into the river every second. The deluge created a 66 foot (20 m) wave of water that caught many off guard due to the time of night and only about 15 minutes to prepare, according to eyewitnesses who criticized the decision; the flooding killed at least 35 people[26] and left homes in seven towns flooded.[27] Two other deaths were reported elsewhere in the country, and more than 34,000 people fled their homes due to the storm; more than 7,500 houses were damaged.[28] Damage in the country was estimated at $1.5 billion (2007 DOP, $45 million 2007 USD).[29]

Source: http://en.wikipedia.org

Furthermore, sediment deposits in the sites of these infrastructures are believed to be big threat to their sustainability as they are continuously filled with lot of silts and clays, thus once clogged they cannot anymore regulate the volume of overflow and resulted inundation. Usually, before the infrastructures are constructed, the sediments are flown toward downstream, but after being constructed all they act like sediment catchments with continuous accumulations on the site, causing their rapid siltation, thus losing their storage and flood control capacities.

PHOTO SHEET VIII: FLOOD CONTROL

Photo 30: Alluvial flat plain permanently flooded

Photo 31: Extended alluvial flat plain permanently water saturated

Photo32: Derivation gate for providing water

to irrigated farms on the valley and alluvial plain.

4.3.2.2. Agricultural activities

Intensive agricultural activities are practiced in both Yuna and Yaque del Sur River basins by small farmers as well as private with as main crops rice, plantain and maize (photo 33 &34) for family consumption and sugar cane and vegetable (photo 35) commercial purpose, mainly in the lowlands (valley, flood plains, etc.). To meet the fast growth of irrigated agricultural land areas, a number of dams, reservoirs and derivation have been constructed in the last 20 years across the rivers and their tributaries to mobilize water resources (table 6).

DAMS	LENGTHS (Kms)	STREAM FLOW (Volume in m^3)	IRRIGATION AREAS (Ha)
Presa de Hatillo (Cotuì)	1,8	710.000.000	12570 (riego yuna - Los Corozos) 25385 (Limón del Yuna)
Presa de río Blanco (Bonao, Rio Yuna**)**		725	
Presa de Tireíto (Las Guáza-ras**)**		340.000	
Presa de Arroyón		3,300	
Presa de Rincón (Rio Jima)		75.5 millones	7,038 (valley of Vega Real)
Presa de Rincón de Yuboa (Bonao**)**	1.32		
Presa de (Guayigá) (La Vega)	parte alta del río Camú	47.5 millones	600
Presa de Pinalito (río Tireo**)**		18.6 millones	
Presa de piedra Gorda (Los Quemados **)**		65.0 millones (3,240 m^3/)	
Proyecto hidroeléctrico Bonito	cota 893 metrros	4.68 millones	
Presa de Masipedro	cota 382.00 metros	5.81 millones	
Presa de El Torito Piedra de Los Veganos	parte alta de la cuenca del río Yuna (493 m)	149,000	
presa de Los Plátanos	cota 295 metros		
presa de Los Limones (río Cenoví, afluente del río Camú**)**	parte baja de la cuenca del río Yuna		

Table 6: Stream flow and irrigated areas in the Yuna River basin

It is believed by many professionals that intensive water withdrawals for irrigation, consumption or industrial purposes may have impacts on water flow in downstream. However, as per table 6 below, withdrawals of irrigation water from Yuna River in the last 40 years did not seem to have affected significantly the river stream, as per comparison of the stream flow between upstream and downstream (table 7).

PARTS OF RIVER	1956	1977	2006
Upper Yuna	6,800	12,000	**27,546**
Lower Yuna	7,500	15,000	**21,429**
Total	14,300	27,000	48,975

<u>Table 7</u>. Irrigated area (hectares) in the Yuna River basin

From the above results and from a separate analysis of trends conducted in stream flow data in the Yuna watershed (FAO, 2006), it appears that there has not been a large change in annual stream flow due to irrigation withdrawals in the watershed. But as pointed out by the authors this does not preclude the possibility that there has been reduction of flows into the estuary during the driest months, especially during dry years, which tend to be the periods when irrigation water use is greatest and also when the estuarine ecosystem is under the most stress.

One of the major problems with irrigation resides in the lack of appropriate drainage networks within the irrigated farms and between the plots and the water mismanagement (photos 36). As result, many farms and soils in the low parts of the river basins remain permanently wet and flooded throughout the year. With regard to the heavy clay and loamy (fine loam) texture the soils have very poor water infiltration, thus any large amount of water drained from the upper part of the watershed or overflew by the river tends to concentrate in the cultivated lands, aggravating the flood risk or magnitude. Indeed, most of the soils of the valleys and flood plains formed over recent alluviums with a heavy texture (loamy, clayed, etc.) not only have low permeability, but a very poor internal drainage, increasing their vulnerable to flood and inundation risks. In addition to this, in low part of the Yuna river basin, the flat topography of the extended valley and flood plain do not ease natural drainage and control of flood dynamic.

PHOTO SHEET VIII: AGRICULTURAL LAND USES

Photo 33: Rice farm

Photo 34: Plantain farm

Photo 35: Sugar cane farm

Photo 36: Irrigated agricultural farm without drainage networks

Chapter 5: ASSESSMENT OF IMPACTS ON ENVIRONMENTAL AND LAND DEGRADATION

As discussed, in section 4.1, the consultant noted serious damages on the environment, agricultural lands, forest resources, and socio-economic infrastructures (roads, water dams and canal for irrigation and domestic use, homes, etc.), throughout the two river basins.

The investigations and discussions with the affected populations, highlighted important damages to environment due to:

- forest destruction by the storms, causing damages to trees;
- deforestation through logging and forest lands conversion into agricultural lands for plantain, coffee and cacao plantations;
- pollution from waste water from houses (sewage water) and drainage water from agricultural lands and contaminated with fertilizers and pesticides;
- erosion and sediment deposit.

5.1. Environmental damages

As pointed out by the study conducted by UNDP (1998) forest cover loss and its subsequent soil degradation has become a big threat to environmental protection over the last 20 years. Despite some evident signs of progress made in the last decade toward afforestation efforts and creation of protected areas, the overall situation is marked by persistent serious problems of degradation of forest cover, due to insufficient control of forest logging and conversion into agricultural land practices and land mismanagement.

In many places along throughout the river basins, it has been observed important forest cover degradation with along soil particles detachment and severe rill and gully erosion, particularly on the hillsides with steep slopes and the margins of the river banks. The medium and upper parts of the two river basins are the most affected, particularly where the forest or woodlands developed over fragile sandy or gravel soils have been cut down. The damages on primary forest and environment caused by the storms and the inundation were estimated to 58 USD/ha-year.

Another threat to environmental sustainability linked to flood and inundations caused by Noel and Olga, including impacts from several previous storms, is pollution from agricultural activities, cities and domestic ewage waters. Indeed, agriculture is likely to be the main land uses throughout the river basins, with particular emphasis on rice, maize and plantain production. In relation to water use, agriculture represents 88% of the total of the demand of water in the country. It’s likely that rapid growth of irrigation in the last 20 years might have reduced in many places of Yaque del Sur River basin the water flows below the environmental stream, with sometimes a total dry out of the tributaries during the dry season, as revealed by field investigations, thus affecting the fresh water quality in the bay shores and the humid habitats of Neyba bay and other estuaries.

Furthermore, intensification of agricultural production goes along with increased use of agrochemicals (fertilizers and pesticides) which is found to be among the biggest environmental threats, as they are true pollutants to water resources and biodiversity. Indeed, in the medium and low parts of the river basins where irrigation is taking place important signs of water pollution in the rivers and some of their tributaries were noted, due to:

- **use of fertilizers and pesticides**: DDT and PCBs, heptclor, clorodane, aldrin and dieldrin), solubilised in the irrigation waters drained from the irrigated rice, banana, sugar cane farms. For instance, in the valley of Low Yuna the main activity is agriculture, specifically rice production, which occupies ninety and five percents (95%) of the cultivateable area. In fact, 46% of the pesticides and fertilizer that are sold in the country are considered to be dangerous highly toxic for the micro-organisms, animal, fish and plants (seaweed). Studies (Rodriguez, 1998) detected agrochemicals components in the weave of oysters that grow in the roots of red mangroves (*Rhyzophora mangle*) in the delta of the Yuna and found that the mollusques of the Samana delta contain pesticide molecules and organic compounds in its weaves. In many cases, as pointed out by several studies (Rodriguez, 1998, FAO, 2006 and 2003, USAID, 2004) it seems that used waters are unloaded to the source from where the same waters have been up taken for irrigation (case of Low part of Yuna and Yaque Del Norte). The re-use of leftover waters of the drainage returned to the channel of the river and again were used to water the cultures in the low part. Indeed, environmental impact produced by industrial and agricultural remainders of the numerous river course networks grows every day, thus constituting themselves in multiple sources and varied forms of pathogenic agents and chemical. In the last decades many rivers, streams and other water sources have disappeared, whereas others have diminished considerably their volume in more of 5º percent, such as the rivers Yuna, Camú, Jaya, Nagua, Licey, Bacuí, Cenoví, Jima, Duey, in the Eastern part and the Yaque rivers of the North, Amine; Mao; Gurabo, Grey hair; Guayubín; Maguaca and Chacuey in its western part, which, almost in their totality, have their contaminated waters to such point they are not even recommended for the irrigation of the parcels bordering to the course of their waters, of which they are tangible examples: Yuna, Camú, Jima, Yaque of the North, amine; Mao and Guayubín (Rodriguez, 1998; FAO, 2006).
- **sewage water from cities and waste waters from mining enterprises**: the study revealed high levels of iron and nickel, with high level of acidity of the water released by the dam/reservoir on Yuna River. In addition, another study found that small drainages under the reservoir have high levels of cadmium, heavy chromium and other metals. Mercury presence in the waters of the Yuna River and the Samana Bay is seen likely as a big threat to the environmental protection and the human health.
- **Secondary and primary soil salinization process due to irrigation mismanagement marine saline water seapage** into the low parts of the river basins (Samana Bay for Yuna River and Neyba for Yaque del Sur) has been also noted another important threat to environmental protection and land degradation which may have been emphasised by Noel and Olga storms and inundation. The mission noted important soil salinization of lowlands (humid forest bordering the mangrove and agricultural lands) in the low parts of Yaque del Sur River basin, particularly in the bay of Neyba and Jacquimeyes, Lagoon Cabral and Lake Enriquille areas.
- **alkalization of irrigated soils due to solubilisation of the carbonate** and groundwater table rise under flood irrigation, maybe another risks threatening the environment in some lowlands of Yalque del Sur river basin (Lake Enriquille and Lagoon Cabral areas), as well as in the medium and low parts of Yuna River basin. However, due to lack of laboratory analysis data, it is premature to confirm the field observations. Soil and water samples are being analysed in Santiago soil and water laboratory.

All these agrochemical pollutants (fertilizers, pesticides, etc.) and waste waters from industries, mining companies and cities, combined to land degradation, sediment deposits and salinisation effects, are seen as increasing threat to environmental sustainability, ecosystems and biodiversity conservation. Indeed, with regard to biodiversity issues, most of biological species and reserves (Idelisa Bonelli de Calventi) and mangrove zones in the shores of Samana Bay (Yuna) and Neyba Bay (Yaque del sur) show signs of high vulnerability to degradation.

5.2. Land and soil degradation

5.2.1. Nature and extent of the degradation

As per field observations and surveys during the mission, the most common and widespread damages affecting the entire basins from upstream to downstream, caused by Noel and Olga are soil erosion and sedimentation of the water courses. These observations are in accordance with findings of many previous studies (CEPAL, 1998, USAID, 1981 and 2004) conducted in the areas to assess the impacts of hurricanes/storms (figure 13) and which targeted land degradation and sediment deposits as the most severe problems threatening the sustainable development of the two river basins.

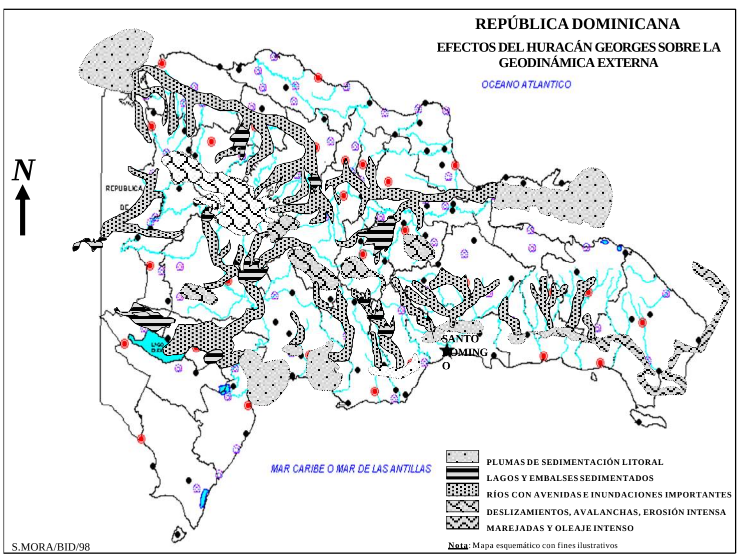


Figure 13: Impacts of hurricane Georges on external geodynamic
Source: CEPAl, 2004

Indeed while in Yuna river basin erosion seems to be pronounced in the medium stream, in Rio Yaque del Sur the entire river banks and the tributaries are severely affected by landslide, erosion and sediment transport and deposits on the river bed, with in some areas changes in of the waterways. All the selected study sites (tables 1 & 2, Annex 3) revealed important soil collapse/landslide at the edges of the river channel and sediment deposits on the river beds (photos) due to water flow an the run-off from the plateau and the high plain.

Furthermore, in addition to water erosion, sand extraction practiced in many places along the medium and low parts of the river valley or bank for home construction is becoming a common concern (photo 35a & b). This activity is practiced without any respect of the regulatory framework and legal measures into place.

Erosion and sedimentation are likely seen as the most important threats to the rivers and their humid ecosystems (lake and lagoon) conservation and sustainable agricultural development. The importance of the degradation varies from one place to another, depending of many factors: forest cover; soil texture; land uses, slope gradient and length, etc.

5.2.2. Soil erosion

Land degradation and water source sedimentation are the most pressing environmental problems threatening the future development of the country. Soil erosion is widespread everywhere throughout the entire river basins, taking place up slope and progressing down slope, at a variant degree depending on the vegetation cover and the topography of the area. It involves two processes: (i) detachment and (ii) transport of soil particles.

The breakdown of aggregates, removal of smaller particles or entire soil layers (soil collapse along the river banks) and poor organic matter weaken the stability of soil structure, thus reinforcing the run-off velocity, sediment transport and water source siltation.

USAID (1981, 2004) identified in the Country Environmental Profile conducted in 1981 and 2004 soil erosion as “the most serious environmental problem affecting natural resources of the Dominican Republic.” According to UNDP the total area of country land classified as eroded, arid or barren had increased by 400%, four times larger than the levels reported in 1980. In the past two decades, the erosion problem continued and, in some senses, became more severe. It was noted that these widespread erosion problems induced soil fertility decline and decreased the life span of critical water reservoirs.

During the field trips the mission noted severe erosion on uplands, but most importantly along the river banks throughout the up and medium parts of the river basin. In the irrigated land, erosion impacts seem to be not apparent in the irrigated farms, but as for up and medium parts, erosion affects mostly subsistence farms and commercial tree croplands (coffee, cacao, etc.) and along the river banks. While on uplands erosion is due by the run-off, along the river banks many processes take place:

- rain water run-off from up slope to down slope toward the river bank;
- infiltration of water at the edge of the river;
- formation of gullies, erosion of soil columns and collapsing
- transport of the sediment down to the river, transport and sedimentation when the stream velocity slowdown
- or by submersion of the river banks by the river overflow, and soil collums (blocks) detachment/landslide by the returning water back to the river after the flood occurrence;
- mismanagement of agricultural lands bordering the river banks.

All these processes resulted to several types of erosion of which the common identified in the two river basins are:

- **Splash Erosion (Rain Drop Impact)**

  Splash erosion is due to raindrop impact, representing the first stage in the erosion process. It was noted particularly in bare soils of soils with low vegetation cover. It results in the formation of surface crusts which reduce infiltration resulting in the start of runoff, observed in some cultivated lands and on sloping lands with sandy loam texture soils.

- **Sheet Erosion**

  Although it is often difficult to recognise, sheet erosion is responsible for extensive soil loss in both cultivated and non-cultivated environments (photo 36). Sheet erosion occurs as a shallow 'sheet' of water flowing over the ground surface, resulting in the removal of a uniform layer of soil from the soil surface. Sheet erosion occurs on sloping land with little ground cover. Under heavy rains and limited vegetation cover the runoff flows down the hill, and washes the soil away and resulting in the breakdown of soil surface structure and in progressive removal thin layers of soil. It mainly occurs when rainfall intensity is greater than soil infiltration capacity (sometimes due to crusting).

- **Rill Erosion**

  Rill erosion appears when the water makes channels up to 30 cm deep and results from concentrates of surface runoff, forming small yet well-defined channels deeper and faster-flowing channels. As the flow becomes deeper the velocity increases detaching soil particles and scouring channels up to 30cm deep. Rill erosion represents the intermediate process between sheet and gully erosion.

- **Gully Erosion**

  Gully erosion is an advanced stage of rill erosion where surface channels have eroded to the point they cannot be removed by tillage operations. It appears under heavy rain when run-off results in deep channels that washes away soil and makes the channels deeper as more soil is removed and flown away by the stream. Gully erosion is responsible for removing vast amounts of topsoil washed away into creeks and streams and irreversibly destroying farmlands, roads and bridges and reducing water quality by increasing the sediment load in streams. The loss of topsoil reduces the amount of area available for farming. Surface runoff, causing gull formation or the enlarging of existing gullies, is usually the result of improper outlet design for local surface and subsurface drainage systems. The soil instability of fully banks leads to sloughing and slumping (caving-in) of bank slopes. Gully formation is too difficult to control if remedial measures are not designed and properly constructed. Control measures have to consider the cause of the increased flow of water across the landscape. In many areas of both river basins and particularly in Yaque del Sur River basin, gully erosion is believed to be a response to changed hydrological conditions. In most cases a combination of approaches, including the use of vegetation, fencing, diversion banks and engineering structures are required.

- **Tunnel Erosion**

  Tunnelling is an insidious form of sub-surface erosion, resulting in considerable damage even before surface manifestations are evident. Tunnel erosion is caused by the movement of excess water through dispersive subsoil. Sheet erosion is often a precursor to the onset of tunnelling. Compacted bare areas generate runoff which flows directly into the subsoil via surface cracks, rabbit burrows, or old root holes. Once formed, tunnels continue to enlarge during subsequent wet periods. Eventually tunnels reach a point where the roof collapses resulting in potholes and formation of erosion gullies. This type of erosion has been witness in the southwestern part of Yaque del Sur River basin, in Lagoon Cabral, Lake Enriquille and located specific river banks along of some tributaries of Yaque del sur.

- **Stream bank erosion**
  It takes place along the river banks when the run-off flows down into the river at the edge of the river bank with abrupt slope gradient and when cropping activities is practiced too close to both stream banks, as the fact throughout the entire river basins wherever agricultural production is taking place. It leads to huge river bank erosion processes. This has been winessed as the most common big problem threatening the environmental protection and sustainable water resource management with regard to the amount of sediments discharged into the river by soil column collapse. Along the river basins stream banks have been eroded by water either flowing over the sides of the stream or scouring at the base, or from run-off overflow. It is aggravated by removal of vegetation, over grazing or cultivation near to the stream banks. Among other damages are: loss of productive farmland, undermining of structures such as bridges, washing out of lanes, roads and fence rows. Poorly constructed tile outlets may also contribute to stream and ditch bank erosion observed in many hydraulic infrastructures and bridges across the rivers. In Yaque del sur, because of the large amount of water flown by the river, many bridges have collapsed, including road damages.

- **Tillage erosion**

  This type of erosion is taking place in agricultural lands due to inappropriate tillage which provokes soil losses and transport by run-off or flood water retreat towards the bottom of the catchment area or river channel where they result to accumulate at the bottom of the rivers, thus causing their progressive silting.

Through all these erosion processes identified in the river basins, thousands of tons of soil sediments are apparently lost from uplands and transported to the river bed and downstream, thus provoking river course and hydraulic infrastructure sedimentation. The most affected areas are (i) the deforested and cultivated lands of sloping watersheds with moderate to steep slopes, (ii) the poorly vegetated river banks and, (ii) cultivated lands, (iv) watersheds with steep slopes (photos 37-43).

<u>PHOTO SHEET IX</u>: SOIL EROSION


a) Sand extraction (Yuna River basin) b) Gravel extraction (Yaque del Sur River basin)

<u>Photo 37</u>: Building material extraction


a) Upland soil erosion upon land clearance b) sheet erosion on smooth sloping land in
b) (Upstream of Yuna River basin) (medium stream of Yaque del Sur River basin)

<u>Photo 38</u>: Sheet erosion


a) Rill eroion b) Gully erosion

<u>Photo 39</u>: Rill & gully erosion


Photo 40: Landslides and soil block detachment, along the river edge


Photo 41: River bank erosion (stream bank erosion) with silt and clay transportation dowward


Photo 42: River bank erosion (soil block detachment and landslide)

Photo 43: River bank soil block detachment and gully erosion

In upstream and medium part of the Yuna river basin, the most affected areas are cultivated lands in Camu river sub-basin, of deforested watersheds with moderate or steep slopes, particularly. Indeed, agricultural farms are often located along the river bank with total ignorance of the environmental law which limits the cultivable area to a distance of 30 m from the river bank. In Yaque Del Sur river basin, soil erosion is widespread throughout the river basin, from up to downstream. Evident signs of rill and gully erosion are visible throughout the two basins wherever agricultural activities (rice and banana) are taking place. This is due to inadequate land clearing and inappropriate practices and management of agricultural lands which expose the soils to erosion during the rainy season with a big sediment loss and transport toward the rivers and downstream, as observed throughout the medium part of Yuna river basin (particularly in Camu river sub-basin) and in the medium and low parts of Yaque del Sur river basin which is likely the most affected by erosion.

While in Yuna river basin, the erosion vulnerably has increased in the last 20 years as consequences of the modification of geo-morphological features due to landscape forest cover degradation and intensification of agricultural production, in Yaque del Sur River basin, erosion is reinforced by the nature of the soil material along the river banks (mostly sandy with high percentage of gravel and stones over 30%), sinuosity of the meanders, the narrowness of the river channel which create overflow conditions during heavy rains and storm with frequent changes of the river bed, thus provoking frequent inundations and river bank soil landslides. All these associated to steep slope gradients which enhance the velocity of the run-off, induce important erosion process, thus land and environmental destruction.

Land degradation is very common in Yaque dels Sur river basin and its tributaries and more marked on fragile sandy loam soils with colluviums and gravels on the plateau and uplands with steep slope and on low plains, along the river beds in the transitional areas of lowlands and valleys. The most vulnerable soils are those bordering the river banks which are frequently subject to landslides or soil block detachment and gully erosion (photos 41 & 42). In fact, soil with sandy texture and high gavel content of gravels and stones hardly resist the pressure of fast water flow, due to their high permeability which provokes important water infiltration into the soil, thus subject to landslides and soil column collapsing with huge amounts of sediments transported down into the river channel toward downstream., thus resulting in river bed siltation.

All these contribute to fill progressively the river bed, thus creating water overflows and changes in the waterways or inundation during rainy season. Flood situation has been described by the population as recurrent phenomena in the areas,

Although the land degradation and soil erosion issues observed in the field results from cumulative effects of the many hurricanes and storms which hit the country in the last 30 years, Noel and Olga have been particularly more devastating to land and environment than what the country has ever witnessed.

5.2.3. Sedimentation

Sediment loss and transport from uplands and deposits over the river beds appear to be a cumulative and continuous process, as the successive series of floods and inundations provoke collapse and landslides of bare and low vegetation cover soils, particularly those with sandy loam texture and gravels of the river banks.

Throughout the basin the water courses are filled with enormous quantities sand and gravel sediments deposited in the river beds, forming larges sand bands across and along the river course, thus creating barriers against the normal water stream (photos 44- 49). In normal conditions, the sediment (suspended solids) rate in the water flow is less than 1.34 g/l (INDRHI, 2006). In case of devastating storm such as Noel and Olga, the rate can increase ten times the normal rate. Nevertheless, a great erosive process and sediment transport take place on a sloppy and poorly forested watershed in case of intense rains with a destructive action due to high velocity of the run-off or in case of inundation subsequent to the rise of the river level. This situation has been described by the population as a recurrent natural threat occurring yearly in the two river basins whenever the river channel overflows due to heavy rain. However, the magnitude of soil erosion and sediment loss caused by Noel and Olga have been particularly severe and devastating in term of land degradation and sedimentation more than what they have ever witnessed in the last past 30 years.

The destructive actions of Noel and Olga have resulted to huge sediment transport by the rivers and tributary water flow. While in the rivers and tributaries the sediment deposits result to formation of sand bands across or along the water course, in lowlands (flood plains and alluvial valleys) sediment deposits constitute thin layers of fertile soil particles (alluviums or **loess**) contributing to improve the soil fertility of the flood plain and valleys with the retreat of the water.

All these contributed to fill progressively the river bed. The river bed being filled regularly with sediments, its drainage capacity is therefore affected with important reduction of depth as the process evolves, thus provoking overflows and inundation in the rainy season. In many parts of the rivers and their tributaries, sediment deposits led to frequent modifications of the configuration and deviations of the water course. In many places, the river beds being filled regularly with sediments, their drainage capacity are therefore affected with important reduction of depth as the process evolves, thus provoking overflows and changes in the waterways and inundations in case of heavy storm. This situation has been described as a normal natural process occurring yearly in the two river basins whenever the river channel overflows.

Other major direct impacts emphasized by Noel and Olga storms and inundations noted in the two river basins is continuous important sediment deposits and siltation of hydraulic infrastructures, such as reservoirs, dams and irrigation canals. Sediment detachment, transport and deposit are seen as major impacts from the storms damages on the environment and represents big threat for the development of the basins as it affected the water availability and quality, including electricity power with regard to the substantial increase of the population demand for domestic and industrial uses. As reported by USAID (2004 and 1981), sedimentation of hydraulic infrastructures was identified as priority concern in the country. The investigations curried out in the context of the CEP in 2004 by USAID (2004) indicated the persistency and the acuity of the problem with a substantial decrease of the storage capacity of most of the reservoirs of the country, particularly in Yuna, Yaque Del Norte and Yaque Del Sur Rivers basins. Indeed, upland erosion and sedimentation of reservoirs in medium and downastream continue to be big challenges for both environmental protection and sustainability of hydraulic infrastructures. Table 8 highlights rates of sediment deposited in reservoirs at different sites of the country.

RESERVOIRS	YAERS OF PERATION	SEDIMENTATION OBSERVED ($M^3/km^2/year$)
TAVERA	20	2,284
VALDESIA	17	3,218
SABANETA	12	1,963
SABANA YEGUA	13	2,644
RINCON	16	4,442
HATILLO	12	4,575

Table 8: Sedimentation Rates in Reservoirs in the Dominican Republic through 1995

Source: UNDP 2000, J. Rodríguez 2001.

According a study from UNDP (2000), the above sedimentation rates exceed what can be expected. The sources of the sediment accumulating in reservoirs include cropland erosion, landslides (many triggered by hurricanes), poor road construction, erosion of riverbanks during floods, and mobilization of sediments deposited over the river beds in the past decades.

Unfortunately, only sporadic studies have been conducted to evaluate soil loss and sedimentation rate of water sources. Studies carried out in different locations by INDRHI (2000) highlighted important loss in water storage capacities of the reservoirs, due to sediment deposits in the sites between 1991 to 1999 (table 9).

DATES	RESERVOIR	WATWER STORAGE CAPACITY (millions of m^3)			LOSS OF WATER STORAGE CAPACITY (%)		
		Active	Dead	Total	Active	Dead	Total loss
Dec-91	Valdesia	130	56	186	11.1	60.7	**26.1**
Dec-92	Sabana Yegua	446.9	33	479.9	9.6	45	**12**
Feb-93	Tavera	165.4	7.6	173	17.1	100	**20.7**
Dec-93	Rincon	58.4	16.1	74.5	15.4	33.4	**19.3**
Apr-94	Hatillo	416	25	441	15.2	10.4	**14.8**
May-99	Sabaneta	65.6	10.9	76.5	10.8	57.6	**17.5**

Table 9: loss of water storage capacities of various reservoir

Source: INDRHI/2000.

As pointed out in the above table 8, sediment accumulation in the (reservoirs principally used for agricultural irrigation) has reduced their total water storage capacities between 12% and 26% of their normal storage volume, in only a 10 years or decade. Since sedimentation is a cumulative process taking place continuously, all the above resulted can be considered as impacts of past several hurricanes and storms among which David and Georges may have played an important role in delivering large sediment loads.

A recent work conducted by Reyes (2004) using ***Burnishes equation and curves*** as reference to estimate the efficiency of reservoir to controlling sediments transport and deposit per unit of area in one year (m^3/km^2/year). The calculation, based on relationships between the bathymetries, annual volumes of run-off, volumes of sediments (cubic metric) or weigh in tons, time to fill the reservoirs (considered as lifetime), gives important erosion rates varying between 4,6 and 8,1 m^3. (table 10).

RIVER BASINS	RESERVOIR VOLUMES	TOTAL (mm³/año)	LIFE TIME (years)	AREA (km ²)	SPECIFIC EROSION (m³/km²/year)	EFFIENCY (Vp /YEAR/Escorrentía) in %
Blanco river	**0.73**	**0.073**	**10**	**203**	**3,596**	**10**
Beam (Tm/Km²/a bati. 1993)	**10.00**	**1.048**	**10**	**260**	**8,065**	**50**
Beam observed erosion Hatillo/Yuna	**10.00**	**0.595**	**17**	**260**	**4,575**	**50**

Table 10: Efficiency of erosion and sediment control in various reservoirs

Figure 14 below demonstrates that the efficiency of sediment control by a reservoir is a function of water storage capacity and total annual run-off.

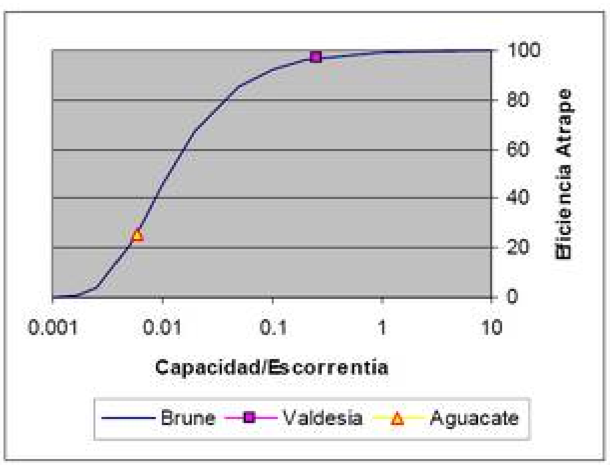


Figura 7 Estimación de eficiencia de atrape de sedimentos (ajuste a la curva empírica de Brune)

Figure 14: Effiency of sediment catchment

PHOTO SHEET X: SEDIMENT DEPOSITS ALONG THE RIVER BEDS

Photo 44: Fine sand sediment deposits

Photo 45: Gravel deposits

Photo 46: Sand bands formed across the river bed

Photo 47: fine sand bands along the river bed

Photo 48: Fine silt sediment transport and coarse sand and gravel deposits on the river

Photo 49: Gravel and stone deposits

5.2.4. Salinization

Land salinization observed in the two river basins, particularly in Yaque del Sur River basin (Bay of Neyba, Jacquimeyes, Lagoon Cabral and Lake Enriquille (photos 50-52) may take place through three processus:

- Saline water introduction by seapage from the sea into the rivers, in case reverse of the normal water stream, in case of rainfall deficit or during the dry season when the river is at its lowest level: case of Samana and Neyba bays;
- Inundation by saline water from salted lagoon and lake systems upon rise of the level of the water table and overflow during storms and hurricanes, such as Noel and Olga: case of Lagoon Cabral and Lake Enriquille in Yaque del Sur River basin;
- Submersive irrigation without adequate drainage systems (secondary salinization): due to excessive amount of water flooding the land and lack of adequate drainage networks provoking rising of the underground saline water table and contact with the irrigation water.

Investigations made by Rodriguez (1998) and by USAID (2004) in many river basins revealed dramatic increases of land salinization, due to the fast growth of irrigated agricultural production under deficient water management technologies. However, the mission did not observed a secondary salinization deriving from irrigation mismanagement, even though there is evident lack of appropriate irrigation and drainage networks in most of irrigated farms. It's important to note that humid conditions and low evapo-transpiration such as in Yuna river basin case, avoid salt accumulation at soil surface by capillarity rise and precipitation at the soil surface, thus limiting land salinization process. Furthermore, salinization maybe limited by the important fresh water flows and the hydraulic and slope gradients from upstream to downstream which maintain the stream flow always towards the sea.

Table 11 below provides with the areas of land affected by salinization in low part of Lower Yaque del Norte, an area where irrigation systems are supplied from already used water for upstream irrigation. It is also an area with insufficient drainage infrastructure.

Location	Not Saline	Slightly Saline	Moderately Saline	Strongly Saline	Very Strongly Saline	Total Hectares
Upper Valley (Santiago–Hatillo Palma	56,167	4,090	3,687	–	3,345	67,289
	84%	**6%**	**5%**	**0%**	**5%**	**100%**
Lower Valley (Hatillo P.– Montecristi	7,520	16,780	6,070	4,275	675	35,320
	21%	**48%**	**17%**	**12%**	**2%**	**100%**
Total	**62%**	**20%**	**20%**	**4%**	**4%**	**100%**

<u>Table 11</u>: Salinization of Soils in the Upper and Lower Yaque del Norte Valley (hectares)

<u>Source</u>: Plan Nacional de Ordenamiento de los Recursos Hidráulicos (PLANORHI), OEA/INDRHI 1993.

<u>PHOTO SHEET XI</u>: PROGRESSION OF SOIL SALIZATION PROCESS & HALOPHYTE VEGETATION

<u>Photo 50</u>: Salt precipitation at the topsoil due to high evaporation (Lagoon Cabral area)

<u>Photo 51</u>: Salt precipitation at the topsoil and progression toward acacia woodlands (Lagoon Cabral) area

<u>Photo 52</u>: Holophyte plantes growing on saline alkaline soils (swamp area of Lagoon Cabral)

5.3. Underlying contributing causes and factors

Land degradation and erosion are closely linked to various factors that are here considered as underlaying factors to the damages caused by Noel and Olga storms: characteristics of the precipitations, soil surface vegetation (mainly forest) cover, watershed slope gradients, land uses, etc. The contribution of all these parameters to erosion process is well demonstrated by the so called Universal Soil Loss Equation (USLE) of Wischmeier et Smith (1978), predicting the long term average annual rate of erosion on a field slope based on rainfall pattern, soil type, topography, crop system and management practices:

$$\mathbf{A = R \times K \times LS \times C \times P}$$

A: represents the potential long term average annual soil loss in tons per acre per year. This is the amount, which is compared to the "tolerable soil loss" limits.

R: rainfall and runoff factor by geographic location as given in (table Anex.4.1). The greater the intensity and duration of the rain storm, the higher the erosion potential.

K: determines soil erodibility factor (table Anex.4.2), or the susceptibility of soil particles to detachment and transport by rainfall and runoff. It represents the average soil loss in tons/acre per unit area for a particular soil in cultivated, continuous fallow with an arbitrarily selected slope length of 72.6 ft. and slope steepness of 9%. Texture is the principal factor affecting K, but structure, organic matter and permeability also contribute.

LS: the slope length-gradient factor represents a ratio of soil loss under given conditions to that at a site with the "standard" slope steepness of 9% and slope length of 72.6 feet. The steeper and longer the slope, the higher is the risk for erosion (table Anex.4.3).

C: is crop/vegetation and management factor, determines the relative effectiveness of soil and crop management systems in terms of preventing soil loss. It‘s a ratio comparing the soil loss from land under a specific crop and management system to the corresponding loss from continuously fallow and tilled land (table Anex.4.4a & 4b).

P: reflects the effects of practices that will reduce the amount and rate of the water runoff and thus reduce the amount of erosion. It represents the ratio of soil loss by a support practice to that of straight-row farming up and down the slope. The most commonly used supporting cropland practices are cross slope cultivation, contour farming and stripcropping (table Anex.4.5).

Each of above factors is the numerical estimate of a specific condition that affects the severity of soil erosion at a particular location. The erosion values reflected by these factors can vary considerably due to the variation of weather conditions. Therefore, the values obtained from the USLE more accurately represent long-term averages. It is important to note that USLE helps predicting the amount of soil loss that results from sheet or rill erosion on a single slope and does not account for additional soil losses that might occur from gully, wind or tillage erosion. This erosion model was created for use in selected cropping and management systems, to compare soil losses from a particular field with a specific crop and management system to "tolerable soil loss" rates. It is also applicable to non-agricultural conditions such as construction sites and other types of lands. A tolerable soil loss is the maximum annual amount of soil, which can be removed before the long term natural soil productivity is adversely affected.

The impact of erosion on a given soil type, and hence the tolerance level varies, depending on the type and depth of soil. Generally, soils with deep, uniform, stone free topsoil materials and/or not previously eroded have been assumed to have a higher tolerance limit than soils which are shallow or previously eroded.

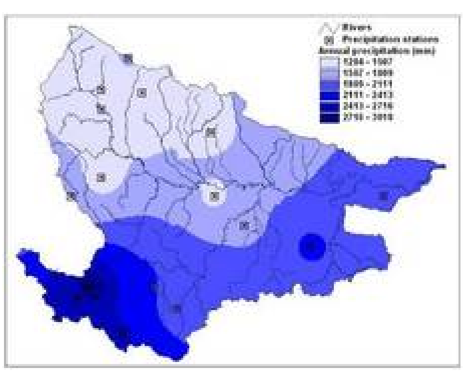
Application of the equation may help estimating erosion impacts on the soil of the country river basins and estimate the potential sediment loss dragged towards the river or the hydraulic infrastructures (reservoirs, dams, hydroelectrical power generation dam. etc.).

5.3.2.1. <u>Rainfall intensity and run-off</u>

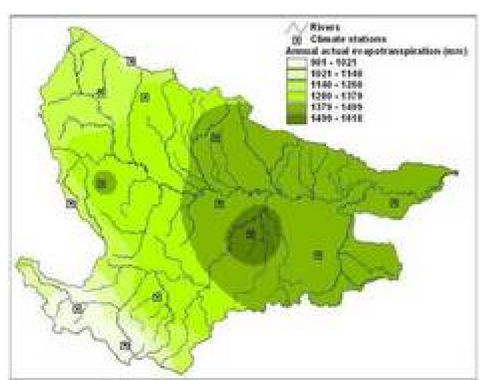
Rainfall and raindrops must be considered among primary factors creating erosion. The impact of raindrops on the soil surface can break down soil aggregates and disperse the aggregate material and the strutural stability. Lighter aggregate materials such as very fine sand, silt, clay and organic matter are easily removed by raindrop splash and runoff water.

Although the erosion caused by long-lasting and less-intense storms is not as spectacular or noticeable as that produced during heavy storms or hurricanes, the amount of soil loss can be significant, especially when compounded over time. Run-off can occur whenever there is excess water on a slope that cannot be absorbed into the soil or trapped on the surface. The amount of runoff can increase if infiltration is reduced due to soil compaction, crusting or freezing. Runoff from the agricultural land may be greatest during rainy season and in case of irrigated lands; due to the fact the soils are usually saturated by the water mismanagement.

Figures 15 and 16 below show distribution maps of precipitations and evapotranspirations recorded by INDRHI in 2003 and 2007 in Yuna river basin and Yaque del Sur River basin, respectively, following the hurricane Jane and Noel/Olga storms. Persistent rains with high intensity caused important soil erosion and damages on the environment, including socio-economic infrastructures.



<u>Figure 15a</u>: Average annual precipitations in the Yuna watershed



<u>Figure 15b</u>: Average annual actual evapotranspiration (Thornthwaite's equation)

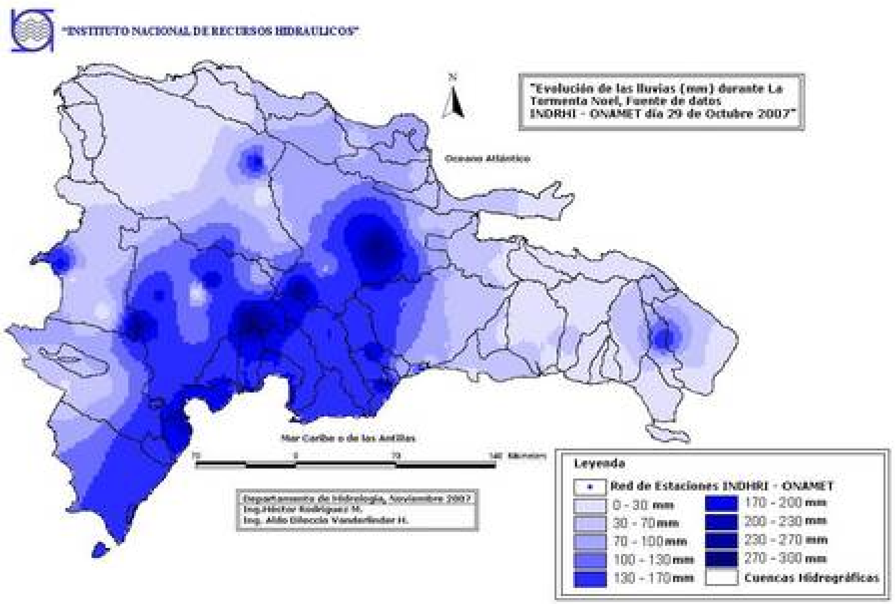


Figura 16: Precipitation map in Yaque del Sur River basin

Source: INDRHI (2008)

The reduction of the soil water infiltration capacity tends to create water saturation conditions, thus provoking flood by water accumulation on the lands, thus contributing to enhance inundation magnitude. Regarding soil degradation, the most important factor enhancing soil erosion is not only the quantity of the run-off, but more importantly the rain intensity (amount of precipitations per hour). Table 12 below provides with data of the precipitations recorded in selected meteorological stations by INDRHI (1993).

STATIONS	DATE (1993)	RAINFALL INTENSITY (mm/hour)	AMOUNT OF RAINFALL PER 24 HOURS (mm/hour)	RETURN PERIOD (Years)
Santiago-Isa	14 November	39,80	**228,8**	**85**
Ramons,	15 November	21,5		**5**
Jarabacoa	14 November	16,2 **22** (David) 7,7 (Federico, 1979) **10 (Allen, 1980)**	**181,4** (28 hours) **371,1** (48 Hours, David) 40 (Federico)-29H **75**	**72**
Slippery	14 November	17,4		**2**
Janey	-	-	113,4	**11**

Table 12: Rainfall intensity, recorded within 1-2 days and return period of the maximum amount

From the results in the above table 12, the high rainfall intensity is obtained at Santiago Isa station with 39.80 mm/hour and the lower intensity recorded at Jarabacoa with 16.2 mm/hour. Their calculated return periods are 85 years and 72 years, against 5 for Ramos and 2 for Slippery for respective rain intensities of 21.5 and 17.4 mm/hour.

5.3.2.2. Soil erodibility

Soil erodibility is an estimate of the ability of soils to resist erosion, based on the physical characteristics of each soil. Generally, soils with faster infiltration rates, higher levels of organic matter and improved soil structure have a greater resistance to erosion. Sand, sandy loam and loam textured soils tend to be less erodible than silt, very fine sand, and certain clay textured soils.

Tillage and cropping practices which lower soil organic matter levels, cause poor soil structure, and result of compacted contribute to increases in soil erodibility. Decreased infiltration and increased runoff can be a result of compacted subsurface soil layers. A decrease in infiltration can also be caused by a formation of a soil crust, which tends to "seal" the surface. On some sites, a soil crust might decrease the amount of soil loss from sheet or rain splash erosion, however, a corresponding increase in the amount of runoff water can contribute to greater rill erosion problems.

Past erosion has an effect on a soils erodibility for a number of reasons. Many exposed subsurface soils on eroded sites tend to be more erodible than the original soils were, because of their poorer structure and lower organic matter. The lower nutrient levels often associated with subsoils contribute to lower crop yields and generally poorer crop cover, which in turn provides less crop protection for the soil.

5.3.2.3. <u>Slope Gradient and Length</u>

Naturally, slope gradient and lenght are two parameters, with soil cover and rain intensity, controlling ersoin process on a given watershed and soil. Steeper the slope of area, the greater the amount of soil loss from erosion by run-off. Soil erosion also increases as the slope length increases due to the greater accumulation of runoff, due to increased velocity of water which permits a greater degree of sediment carrying capacity (scouring).

Landscape and slope effects are characterized by the length of the slope (L) and the gradient of the slope (S), determined by the following formula:

$$L = (x/22,13)^{m}$$

Where,

L = is slope effect on soil erosion

m = B/(1+B) where B = (sinQ/0, 0896)/[3,0 (sinQ) 0,8 + 0,56]; where Q = angle of the talus.

The degree of the slope can be calculated in the following way:

S = 10,8sinQ + 0,03; slope < 9%; S = 16,88sinQ + 0,03; slope > 9% (Fox and Al, 1997).

5.3.2.4. Forest cover degradation

Erosion is closely associated with the vegetation cover, particularly forests and permanent grasses. Indeed, forest cover serves as a natural barrier against the raindrops and run-off in lowering the velocity. As such it controls erosion process. By the same way it because of the barrier it creates, forests can avoid or limit the magnitude of inundation damages. Therefore, any decline in the proportion of the soil vegetation cover, leaves open-door to raindrops, run-off and high flood devastating actions taking place.

Indeed, soil erosion potential is increased if the soil has no or a very little vegetative cover (plants and/or crop residues). Plant (forest, grasslands and crops) and crop residue cover protects the soil from raindrop impact and splash, tends to slow down the movement of surface runoff and allows excess surface water to infiltrate. However, the infiltration rate depends on soil permeability governed by the soil texture and structure. The erosion-reducing effectiveness of soil surface covers depends on the type, extent and quantity of cover. While good soil cover (forests, permanent grasses, etc.) intercepts most of falling raindrops at the surface and control more efficiently soil erosion, poor vegetation covers is less efficient in controlling raindrops, thus leading to important run-off, depending on other factors, like slope gradient and length.

According to USAID (2004), forest cover which was estimated to 70% of the country area before 1980, has gone through big changes in the last two decades through logging and agricultural land conversion by small farm and commercial producers, particularly in steep sloping (photos 51 & 52). As noted in upper part of the Yuna River basin, there is important deforestation and conversion of forest to food crop and tree crop lands (coffee, cacao, etc.), including terracing for hydroelectrical power dam construction, taking place in the upper part of Yuna River and its tributaries (Camu River), resulting to widespread erosion problems and sediment transport down into the Yuna and Camu river beds (photos). This is to critical, as siltation of river beds and the presence of suspended solid may compromise the sustainable conservation of the rivers and the availability of clean water for the population leaving in the area, like La Vega city and others, and also may decrease the life span of critical water reservoirs for hydroelectric generation and irrigation.

Forest cover reduction is also associated with loss of habitats and biodiversity decline, particularly in upstream and dowmstream of both Yuna and Yaque del Sur River basin. However, appropriate measures are being put into place to mitigate the effects and help improving biodiversity conservation.

Table 13 below provides with general data calculated using the USLE (Wischmeier et Smith, 1978) of soil loss according to soil cover and also slope and streaming.

VEGETABLE COVER	SLOPE (%)	STREAM (%)	SOIL LOSSES (t/ha/an)
HERBACEOUS (100%)	36	6,9	0,026

HERBACEOUS (20%)	20	20,0	12,0
NATURAL FOREST	7-15	2,4	0,24
CITRUS FRUITS + MULCHING	7	2,6	4,3
CITRUS FRUITS WITHOUT MULCHING	7	9,2	18,9
CROPS + MULCHING	7	13,9	13,0
CROPS + BARE SOILS OR PASTURES	7	21,0	43,6
BARE SOIL	7	39,0	89,4
NATURAL PASTURES	7	-	5,3

Table 13: Ground losses according to vegetable cover and of the slope of the land

Source: Euroconsul (1989)

Important efforts were deployed by the government to reverse the degrading trend of the forest cover since mid-eighties through which resulted in the 90s (USAID, 2004) to slight improvement in land reforestation and forest cover recovery throughout series of national and local programs have been initiated by the government, such as Quisqueya Verde campaign for reforestation of the 1990s, Plan Sierra's government–private sector efforts to replace annual crops with coffee and promote reforestation and economic development in the north-central portion of the country. Furthermore, important efforts have been deployed by the many NGOs on watershed, soil conservation, and reforestation projects in the uplands of the major river basins, particularly in Yuna River basin. Although, all these and similar previous efforts appear to have important impact on water conservation and on erosion control, they did not help reversing substantially the degrading trends of forest cover and with along erosion phenomena. This situation might probably be due to lack of incentive forest resource management and tree planting policy, encouraging the involvement of private and individuals, including the importance of the damages caused by the recurrent storms and their subsequent inundation on land degradation which in turn also affected forest viability.

5.3.2.5. Land use and Agricultural activities

Agriculture is one of the main factors contributing to aggravate environmental and land degradation, soil erosion and water course sedimentation, including inundation impacts on irrigated lands.

Inappropriate agricultural production systems, through forestland conversion (photo 53-58), soil and water mismanagement and land preparation practices, are among major issues contributing to increase soil erosion vulnerability through destruction of stability of soil structure, thus enhancing the run-off velocity and impacts. Indeed, in the upper parts of the river basins, particularly in Yuna River basin, soil erosion potential is affected by hillside subsistence farming (plantain, cassava, other food crops) and commercial tree crops (coffee, cacao, etc.) through inappropriate tillage operations (traditional or mechanical) provoking destruction of soil structure which results to increase soil erosion vulnerability and removal of fine particles washed out down to the river by the run-off or inundation retreat. As noted in the two river basins, the importance of the erosiondepends on the depth, direction and timing of plowing, the type of tillage equipment. Generally, the less the disturbance of vegetation or residue cover at the soil surface, the more effective is the tillage practice in reducing erosion.

Furthermore, with the expansion and intensification of irrigated farms focused on rice and banana production and high-value export food crops and tree crops (tomato, banana, cassava, coffee, cacao, avocado, etc.) in the last decades, there has been increased land degradation through erosion, salinization and alcalinization. Indeed, about 13% of the Dominican Republic's cultivated land is under irrigation, with particular increase of irrigated area from 178,000 ha to 265,000 ha, between 1980 and 1998 (H. Rodriguez 1998). Much of these irrigated lands are concentrated on the lowlands of flood plains and valleys in the basins of Yaque Del Norte, Yuna, and Yaque Del Sur Rivers.

Indeed, it has been noted that the medium courses and downstream of the two river basins are densely cultivated for rice, banana (plantano) and maize for Yuna River, and Banana and Sugar cane for Yaque del Sur. In many cases the river banks are totally cultivated to the edge of the river, regardless the 30 m distance from the river imposed by the environmental law (64-2000) and with a very poor soil and water management particularly on up-slopes, leaving open door to the run-off and thus contributing to aggravate erosion phenomena. As result a lot of sediment are lost from cultivated lands and transported by the run-off down into the rivers, thus creating critical situation in the protection of the reservoirs and other hydraulic infrastructures.

Agricultural induced-soil erosion continues to be a serious problem, although some relevant measures put into place by the governmental regulatory land use measures. It is critical to determine whether traditional annual cropping systems (shifting cultivation) on hillsides by the small farmers are still actual and really unavoidable. In the same line, it is important to analyse whether the principal source of eroded sediments, or whether landslides, dirt roads, and stream bank erosion are more important at a watershed level.

Another major impact of irrigation noted in the medium part of Yaque Del Sur river basin is the reduction of dry season flows in the rivers themselves due to irrigation diversions, reducing substantially the environmental water flow with dry up of some tributaries. Indeed, water requirements for agriculture, driven mainly by the expansion of irrigation activities, have increased more than threefold to almost 8 million cubic meters per year. The amount of water used for industrial purposes has also risen considerably in response to the growth of light manufacturing. Improving irrigation efficiency to leave enable environmental flow would of great benefit to the environment and conserve aquatic ecosystems and biodiversity.

PHOTO SHEET XI: AGRICULTURAL IMPACTS ON LAND DEGRADATION

Photo 53: Forestlands conversion into agricultural lands

Photo 54: Hillside deforestation and cultivation

Photo 55: Plantain plantation on the edge of the river channel (Yuna River)

Photo 56: Agricultural drainage water into Yuna River (agrochemicals)

Photo 57: Cultivation along the river bank

Photo 58: Cultivated sloping uplands

5.4. Relationships between storm/hurricane effects, land and environmental degradation and socio-economic issues.

The figure 17 below summarizes how storm and induced effects (rain, wind, inundation, etc.) affect the environment, land and water resources and socio-economic issues in the two river basins.

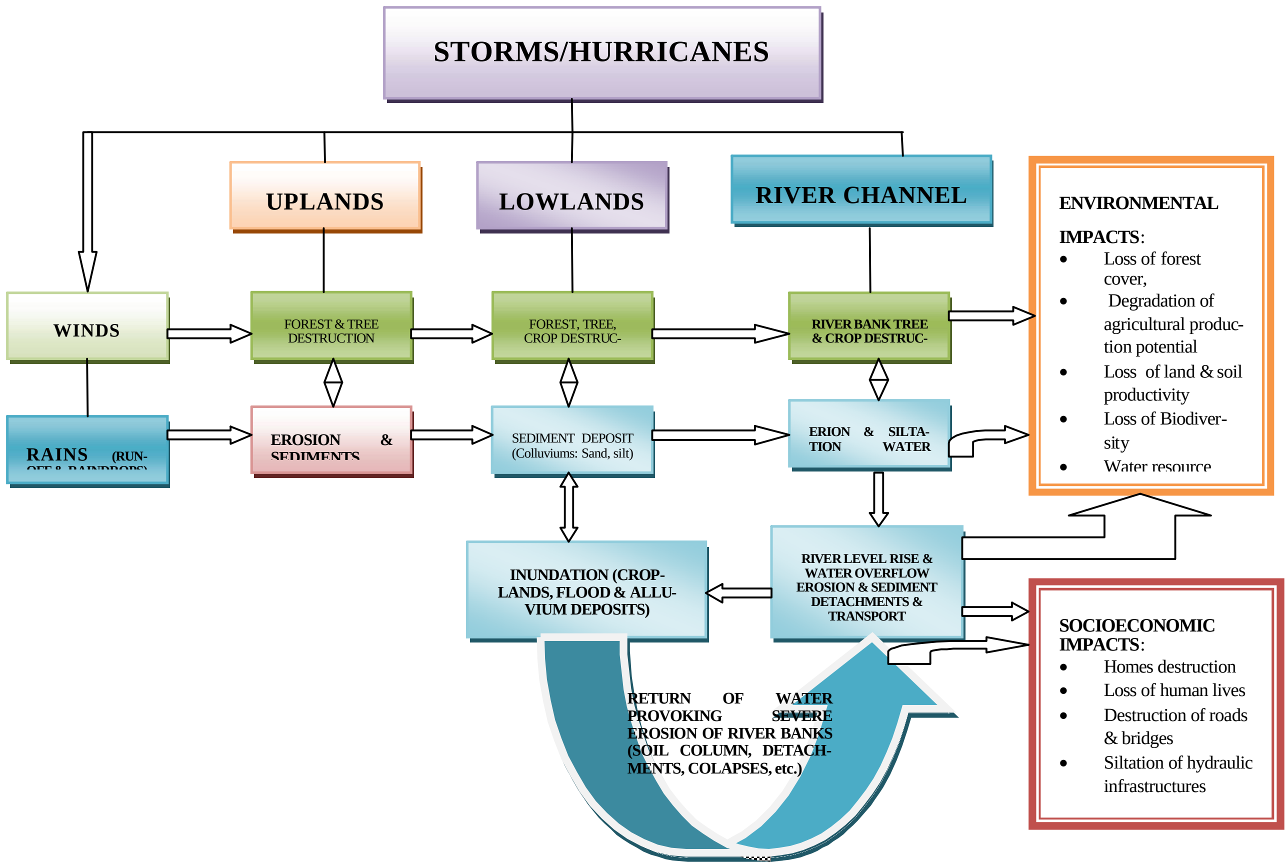


Figure 17: Effects of Storms/Hurricanes on land erosion and impacts on environment and socioeconomic issues.

Chapter 6: CONCLUSION AND WAY FORWARD

6.1. CONCLUSION

The field visits revealed high vulnerability of the two river basins to flood and inundation, particularly in the medium and low parts, due to poor water management in the irrigated farms of the flood plain, their flat topography and heavy soil texture which tend to provoke water accumulation in the area. Along their 210 km and 183 km long, respectively, the two rivers fed directly or indirectly by many respective tributaries receive large amount of water during heavy rains or storms like Noel and Olga, which amply exceed their stream flows and provoke widespread inundation in lowlands throughout the river basins. The damages have been catastrophic throughout the two river basins, with particular emphasis on lands, socio-economic infrastructures and the overall environment, as well as on both revenue generating crops and subsistence crops.

While hurricanes and storms are big concerns for the government to both environment protection and vulnerable population because of their destructive actions, land degradation and soil erosion appear to represent the major threats for sustainable development, with regard to their impacts on habitats and biodiversity, water resource quality and conservation, agricultural production potential and socio-economic infrastructures.

Despite the limitations due to time constraints which did not allow in-depth assessment of the impacts and the fact that environmental and land degradation issues are cross-sectoral and involve various disciplines, the team could draw a comprehensive analysis of the state of the damages in the two river basins and identify the major evolving trends, challenges and key measures and actions to put into place as remedial solutions.

Taking into consideration the fact that the Dominican Republic presents a high degree of vulnerability for the recurrence to hurricanes/storms and flood risks, it is hoped that this evaluation should contribute to providing to the government relevant elements pertaining integrated risks and threat management programme, including mitigation, prevention and reduction of vulnerability. Figure 18 below summarizes the impacts of land and water resource degradation on the environment and socio-economic issues.

Figure 18: Impacts of land and water resource degradation on the environment and socio-economic issues

6.2. FLOOD AND WATER MANAGEMENT

6.2.1. The Facts

Hurricanes and storms constitute the primary natural threats and challenges for the Dominican Republic environmental sustainability and poverty reduction, with regards to their cyclic occurrence and devastating effects on the socio-economic pillars. In the last four decades the country faced several devastating hurricanes and storms among which Flora and Edith (1963), Ines (1966), David (1979), Georges (1998), Odette and Jeanne (2004), including Noel and Olga (2007) are believed to be the most harmful in the history of natural disasters in the country.

Although it is not possible to ascertain it, because of lack of data due to rapid appraisal (time constraint), the consultant thinks that the magnitude of inundation has been more important in Yuna River basin than in Yaque del Sur River basin, because of the presence of extensive flood plains and valleys and particularly the humid meteorological conditions which maintain irrigated lands permanently wet and saturated all over the year (Valbuena, 2007), with less impacts on impacts on environment and land degradation. In Yaque Del Sur River flood have induced widespread soil erosion all over the river basin with a devastating environmental and socio-economic impacts.

As said earlier in the above, although the many hydraulic infrastructures have been constructed in many locations throughout the river basins, they did not play sufficient or efficient role in controlling water over flow and flood, blasting away the false perception that constructing hydraulic infrastructures like reservoirs, derivation canal, docks, suffice to help minimizing flood risks.

Floods noted in both river basins, particularly in Jaquimeyes area, are significant illustration of lack of consideration of a long term rainfall and flood data series analysis, including main technical parameters to orientate the design of the infrastructure that should be constructed. While structural solutions (infrastructure works) have been always emphasized, a little was done towards vegetative protection of the river banks, removing sediments deposits from the river beds, sharpening and deepening the river channel. This has created a false impression of security that may provide people safe occupation of areas and facilitate socio-economic development. As the matter of fact, not only these infrastructures did not avoid the flood risks, they have been themselves severely damaged by sediment deposits, thus lowering their capacities of water storage and flood control (Paoli, C., 2000).

Flood and inundation are likely known in the country as recurrent natural disasters happening often and in a cyclical basis. Increases in population and the development of permanent infrastructure in close proximity to shorelines, however, have made flood a prominent hazard to the country's social and economic well-being, in the border of the rivers and in lowlands which are three meters or less above sea level. Their low elevation makes them particularly vulnerable to storms and changes in river level. The prospect of increase in hurricanes and storm occurrences and global sea level rise, including their potentially catastrophic impacts on inundation of lowlands and environmental degradation, with regard to climate changes, makes flood and flood risk issues the most urgent.

6.2.2. Remedial measures and actions

Indeed, throughout the river basins, many flood gates, earth dikes and walls conceived to control water flow and flood risks or reduce inundation magnitude and damages have been constructed without careful and technically sound studies as needed, causing often more destruction of the infrastructure than expected and the fact they have not been able to control water flow, thus amplifying the magnitude of the inundation.

As measures and actions to take to minimizing flood magnitude and its devastating damages, flowing measures are critical to the protection of the river basins:

- It is extremely important that construction of such infrastructures be based on a comprehensive and long term studies which takes into consideration the level and the return period of the higher and devastating water flow.
- Channelling water flows may avoid inundation if adequate infrastructures are constructed based on accurate data and the return period of the highest level of the water flow. To do so, detailed studies must be conducted to collect data on a long series (30-100 years), covering return periods as calculated in table 11.
- In many places of Yuna River basins and throughout the entire medium and low parts of Yaque del Sur River basin, more civil engineer with a well defined construction work scheme and repair works, including vegetative protection of the river banks and edges, are very needed to control stream overflow during heavy rains or storm. These will help reducing the vulnerability of areas densely inhabited and threatened by frequent floods, like Jacquimeyes city which is faced with frequent inundations in the last 50 years.

- The country new General Water Law, under development and aiming to establish a scheme to promote a more efficient use of the water, is likely if clearly defined to help improving the water management system. However, a comprehensive preventive and remedial measures should be delineated in line with environmental and biodiversity conservation concerns, SEMAREN and UNDP should work together in the orientation and the preparation of the framework, the process can be an opportunity to work out aspects for integration of institutional and operational aspects for the two river basin Management, and also improve the general understanding of potential changes to environmental possible changes.

6.3. ENVIRONMENTAL PROTECTION

6.3.1. The facts

The torrential rains and runoff generated by the development of diverse meteorological turbulences, emphasized by low forest cover and landscape disturbance human-induced factors, are the main causes provoking floods and devastations of the environment, land degradation and socio-economic infrastructure loss. The cumulative damages and impacts caused by Noel and all previous natural disasters have been very harmful to the overall country and particularly Yuna and Yaque del Sur River basins environment and natural resources. Furthermore their impacts have induced dysfunctions in the governmental development strategies and put budgetary pressures on the economy, with as immediate consequences increased poverty at rural level.

Indeed, environmental issues in the Dominican Republic span a wide range: (i) watershed degradation, (ii) soil erosion, (iii) pollution due to fertilizers, pesticides, waste waters from homes and industries (mines), (iv) deforestation and biodiversity loss, (v) land degradation and erosion, including loss of agricultural production potential, etc.

The recurrent situation of storms and floods and their damages to environment, lands and socio-economic infrastructures are closely linked to policy and institutional issues. Although there has been meaningful progress toward environmental policy approach that helped transforming the way natural resources are managed in the country, with the establishment of specific entities to handle environmental issues (INDRHI, Agricultural Secretariat, Forestry Directorate, National Parks Directorate and National Agricultural Council, etc.) persistent lack of coordination was noted in the last 25 years within public institutions involved in natural resources management who tends to operate by parallel functions and with inefficient use of human and financial resources (USAID, 2004). Furthermore, the adoption of Law 64-2000 aiming to improve the governmental policy and with the establishment of the Secretariat of the Environment and Natural Resources, as the single broad entity responsible for environmental oversight and which can be seen as a significant step toward coordinating and strengthening the national capacities, has not been able to reverse the degrading overall situation of natural resources.

Indeed, flood related environmental damages control is confronted with policy and institutional weakness and incoherencies, lack of articulation between interventions of the different institutions constituting SEMAREN and those of the many other stakeholders, particularly the plethora of local NGOs established to deal with specific watersheds, parks, and community areas, environmental education, community awareness, and sustainable management of natural resources, including academic and research institutions.

6.3.2. Remedial measures and actions

Given the threats represented by land degradation and soil erosion on environmental protection, water resource and biodiversity conservation and socio-economic infrastructure viability, following measures and actions should be considered:

- Environment Law enforcement: the current Law 64-2000 which constitute the pillar of environmental protection should be reinforce with a more coherent and realistic regulatory measures for land resource access and management,
- As for confronting flood risks and damages, strengthening the government emergency plan to improve country disaster preparedness tools and management capacities.
- Considering involvement of civil societies and private in the decision-making process and in all relevant sector policy design and implementation;
- To comply with its mandate SEMAREN is forced to develop an open, consensual and participatory policy, based on common interest, strategic alliances between stakeholders and the governmental technical entities, in order to imbue every public and private entity that intervenes in the environment with a sustainable development model that guarantees an adequate quality of life for present and future generations."
- Improving the implantation of the national environmental action plan in backing it with environmental norms, monitoring and evaluation guidelines, including a national environmental education and information system.
- refining or strengthening the Law 64-6000 in order to establish a comprehensive policy regime that will promote sustainable use of the country's natural resources;
- Strengthening of the institutional structure, including local units and local private organizations put in place to manage the environmental sector;
- Promoting incentive law and policy for reforestation and afforestation and integrated soil and water resource management to protect fragile ecological niches such as lagoons, lakes and humid ecosystems of the bay, estuaries and marine coast.

6.4. SOIL EROSION AND SEDIMENT TRANSPORT AND DEPOSITS

6.4.1. The facts

As lessons learned from field investigations, as erosion is a long term process with many off-site impacts on the environment and water resources, it's obvious that damages observed in the field are not the sole fact by Noel and Olga. Indeed, as already said, depending on the type, soil erosion process may take time before becoming apparent. Therefore, the current land degradation and sedimentation of the river beds as well as for the hydraulic infrastructures over the rivers must be seen as results of many years associated and cumulative effects of the many disasters which affected the country in the last decades, dating back since David in 1979. As well for sediment transport and deposit, their impacts are more off-site than on-site. Sediment transport relies on a number of factors, such as the stream flow, the slope gradient, the shape of the river channel, presence or not of barrier across the water course, etc. Depending on these conditions, sediments may travel a short or long distance before being deposited in the river channel or in the hydraulic infrastructures across the river.

As for spatial consequences, it is obvious that soil erosion implications may extend beyond removal of fertile topsoil affecting directly crop emergence, growth and yield on agricultural lands, loss of natural nutrients and use of fertilizers. Indeed, soil erosion affected water quality through sediment deposits, agricultural land potential fertility and natural resource recovery potential. Off-site impacts of soil erosion were less apparent in the upper part compared to medium or downstream parts of the river basins, as eroded sediments are flown from uplands or upstream far away down to the low parts of the rivers, with several potential impacts on the environment, the poor small farmers livelihoods living all the way along to downstream and using the resources (water, soils, vegetation, and biodiversity). Fine clay and iron oxides suspended elements transported by the water flow not only affect the quality of the water, but may accelerate clog drainage ditches (irrigated agricultural lands) and siltation of the reservoirs and also damage socioeconomic infrastructures due to their corrosive action causing oxidation of metal and iron made equipment.

However, due to time constraints and lack of appropriate equipment the mission could not verify in the field how important was the distance to which the sediment are transported, their off-site impacts on agricultural and cropland loss, including impacts on socioeconomic infrastructures and the relationships between erosion processes and sediment loss.

6.4.2. Remedial measures and actions

The matter is of priority concern as the degradation and the sub-sequent impacts are continued process with cumulative impacts, given the close relationships between the natural resource-based economic growth and the country environmental contingencies to meet global requirements against climate changes and for biodiversity conservation and also to comply with local needs. Indeed, in the next decades The Dominican Republic will continue to base its economy on sustainable natural resource management. Consequently, the prospects for rural poor livelihood and national economic expansion are inextricably linked to the remediation of the damages, protection measures, and integrated approach for the conservation and safe use of the natural resource potential.

6.4.2.1. Preventive measures

Preventive and curative measures are essential to minimize environmental and land degradation causes and processes:

- Watershed with steep slopes, fragile soils and narrow river channel must be totally protected against traditional land clearing (slash and burn) and soil preparation practices. Farmers should be trained to proven agroforestry technologies (contour band ploughing), alternating cultivated with uncultivated bands (2-5 m of spacing between the bands, depending to the slope);
- To minimize the destructive effect of hillside agriculture, it is essential to improve the traditionally practiced, based on land clearing in removing totally the forest vegetation and slash and burn techniques, through promotion of proven agroforestry technologies in order to keep a minimum rate of forest cover (20%). Shade coffee holds promise as an option for addressing this problem. Important investments in coffee tree planting could improve

upland watershed protection against excessive run-off and erosion, and in turn contribute to reduce poverty rate at rural level with regard to employment and income generation opportunities.

- A minimum vegetation cover (15-20%) composed of f trees, shrubs and/or grass, should be systematically recommended to protect the soil against aggressive splash erosion and enable the control of sediment transport;
- Land preparation using heavy machines, such as in the case of intensive irrigated farming, care should be taken in selecting mechanical tools and equipments, in order to avoid soil crumbling or compaction. Mechanical ploughing should be limited to heavy soil texture with low permeability. Sandy soils should never be ploughed; traditional soil preparation using hand tools is enough to improve the soil properties and water infiltration. In general, minimum tillage and best cropping systems should be applied throughout the two river basins wherever agricultural production is taking place.
- Promoting at the level of small farmers hoeing using manual tools to break crusting at the topsoil could help to minimizing loss of soil particles and improve soil permeability and water infiltration into soil, thus avoiding high water competition between crops and grasses.
- Maintain adequate vegetation Cover at a level between 40 to 70% to prevent soil erosion and detachment of soil particles. On steep slope watershed with vulnerable soils, such as in north and south parts of the central mountain range from where are born the two rivers (Yuna and Yaque), permanent vegetation cover should be maintain at levels of 70% and above. To this extent, the followings measures are required: (i) systematic forest cover recovery through plantation or natural regenerating; (ii) on cultivated lands maintaining cereal stubbles and biomass on the soil surface; (iii) avoiding land clearing and cultivation on steep slope watershed.
- Reducing flow velocity (settle suspended particles): flow velocity can be reduced by either reducing the flow volume or roughening the soil surface. Increasing surface roughness through the use of grassed waterways and grassed filter strips causes entrained soil particles to fall out of suspension. Flow volume can be reduced by not allowing sheet flow to accumulate. Techniques such as ripped mulched lines and contour drains prevent runoff building up enough volume and speed to detach and entrain soil particles. Therefore, using following measures may help limiting sheet and rill erosion: (i) roughening soil surface with grassed waterways and grass filter strips; (ii) breaking the slope length with contour drains and ripper mulch lines.
- Protecting soil surface from scouring by hardening the surface maybe efficient solution to reduce runoff volume or velocity, through (i) compaction of soil surface, (ii) paving and concrete lining; (iii) rock rip rapping all over the area.

6.4.2.2. Curative actions

Rehabilitation of eroded uplands affected by gully erosion and the river banks affected by soil column collapse and sediment detachments observed throughout the medium part of Yuna River basin and the entire course of Yaque Del Sur River, will require:

- **Reforestation:** when the erosion level reaches the stage of gullies, vegetation cover increase is the most efficient primary long-term action by which gully erosion can be controlled and degrade land rehabilitated. Establishing vegetation on gully sidewalls maybe often difficult in some part of Yaque Del Sur due to the aridity and low humidity and soil moisture stress. Consideration should be given to supplying irrigation to get vegetation established: (i) afforesting all gully erosion areas with rapidly growing grasses; (ii) afforesting sidewalls, surrounding areas and catchment above gully with trees and grasses
- **Engineering**: (i) constructing diversion structures : properly designed and installed engineering structures may be the only means to stop headword advance in many gully system areas; (ii) engineering structures such as soil pins, retaining walls, rock filling and slope grooming may also be required to prevent or control landslips.

6.5. BIODIVERSITY

Environmental and land degradation, including forest resources put biodiversity at a risk, particularly in the vulnerable areas of the river basins, such as estuaries, humid forest or woodlands and lagoon and lake ecosystems. Indeed, wherever land and forest degradation takes place either induced by flood or by deforestation, there has been important biodiversity loss. In both river basins, Yuna and Yaque del Sur, biodiversity loss in the estuaries maybe caused either by presence of suspended solids drained by the river stream flows or used water drained from irrigated farms containing fertilizers or pesticide components, or from mining companies and industries.

The loss of the biodiversity, deterioration of fragile ecosystems and extinction of some endemic species, constitute serious and inevitable ecological problems to be confronted. Many local NGOs have been very proactive in biodiversity conservation in the Samana bay as well as in the Neyba bay and the lagoon and lake systems. However, due to lack of technical capacities and incoherency in their intervention approach, these NGOs have not been successful, putting to integrated biodiversity concerns into the population community resource management. Their activities have been driven by immediate benefits, while biodiversity conservation is a long term action as linked to environment conservation.

To meet standard norms of biodiversity conservation, a more coherent coordination and support action plan is needed as that could enable to better organize the NGOs and provide them with appropriate training and financial support.

A participative base-approach is also needed to involve local communities in the management of the biodiversity, as they are at the gateway of the conservation.

6.6. PRIORITY RECOMMENDED ACTIONS

The protection of the river Banks and bed against erosion/landslides and sedimentation, respectively, should be handled with care in integrated approach with agricultural land use improvement and flood management.

As remedial immediate initiatives to undertake in the context of the follow up project, following priority actions are recommended for implementation to improving water and flood management, minimizing environmental and land degradation, including soil erosion control.

Component 1: Land degradation database and information system

Action 1.1: Data and information collecting and management

The present situation is characterized by lack of accurate data and information on land characteristics, erodibility and vulnerability to degradation and erosion, including organized institutional capacities, more research/investigations must be done towards erosion process causes and factors, types and sediment loss rates, under various land uses, such as agricultural, road infrastructures, dams and water catchments. It is expected through this action to collect throughout the river basins:

- data on land use systems,
- land and soil occupation,
- forest cover,
- landscape features,
- land preparation and cropping systems,
- human settlements,
- Socio-economic activities (agriculture, forestry, fishery, hunting, etc.)
- Hydraulic and economic infrastructures along the river courses;

Action 1.2: Develop an integrated environmental and land use information and monitoring system

This will involve the following:

- Establish GIS unit within the SEMAREN or strengthening capacities of existing structures to be more efficient;
- Develop and disseminate tools for information and data update and sharing among users and professionals, on environmental and land occupation changes;
- Develop a soil mapping and erosion monitoring system complying with international standard and norms;
- Initiate of a long term monitoring of social indicators and environmental keys.
- Define and implement criteria and indicators for environmental risks and threats monitoring and evaluation, including remedial and preventive measures actions.

Component 2: Promoting best water management and agricultural practices

In general, land uses that emphasize perennial tree crops, minimize road construction, and lower population densities in steep upland watersheds are critical to addressing the serious existing soil erosion problems. However, in the context of current difficult economic and demographic situation of the mountainous provinces of Dominican Republic, promoting integrated soil and water conservation practices for hillside uplands agriculture through alternative development opportunities will be a more important asset of any long-term solution.

Action 2.1: Improving agricultural practices

Following activities should be carried out:

- Evaluate current farming systems in hillsides farms as well as in lowlands on irrigated farms;
- Assess the efficiency of the tools used for land preparation, including the traditional practices of slash and burn favoured by small farmers;
- Analyse crop patterns and management techniques.
- Define criteria and indicators for soil and water management, in collaboration with SEMAREN and other related institution's staff members are in the process of developing clear standards and policies for land use planning and watershed management (USAID, 2004).
- Raise awareness and training farmers on best agricultural practices (soil conservation, limited tillage, irrigation and drainage technique, efficient use of fertilizers and pesticides, etc.).

Action 2.2: Improving water and flood management

- Analyse irrigation techniques, with focus on water control and drainage networks with regard to flood issues;
- Conduct a survey of internal drainage to detect the depth of the ground water and develop and implement a drainage networks;
- Analyse the efficiency of hydraulic infrastructures on water and flood control with regard to their water storage capacity, their site and the surrounding landscape features (vegetation cover, slope gradient, soil types, etc.).
- Study opportunity of creating new infrastructures or resizing the existing ones in order to improve their stream flows
- Identify all vulnerable sites and construct diversion structures and retaining walls with a proper design in order to be able to resist high overflows and inundation.
- Develop and implementing a proactive plan of priority action to anticipate flood damages and appropriate remedial measures.

Component 3: Soil erosion control

Regarding Forestry related issues, hillside agriculture in river basin upstream has been traditionally practiced with destructive damages on soil and environment. As a result, many areas have become deforested and unproductive. Development of more improved framework is underway for tree planting initiatives with high priority placed on technical norms and criteria for management plans and timber planting. Forest tree and commercial tree crops (coffee, cacao, avocado, etc.) holds the promise as an option for addressing degradation problem. It is important to support current underway current work to reconciling provisions of the 1999 Forestry Law with Law 64-2000. These will require not only substantial financial support and high investments, but implementation of key actions:

Action 3.1: Designing a comprehensive and participative land use panning

- Improve land use Planning: as land use has not evolved in orderly or planned way in the country (USAID, 2004) in the country, a proactive and participative land use planning initiative, on the basis of clearly defined criteria and indicators, would make a significant contribution to environmental protection;
- Conduct a field survey and a "micro-zoning" of uniform and homogeneous watershed units with a comprehensive management designs. Participative approach would be a far more effective management tool and key asset for integrated watershed management with high value agricultural return.
- Establish operational committee on integrated land use and watershed management or strengthened existing ones, at national level and particularly at the two river basin levels, in order to confront the problems of storm magnitude and environmental and land degradation issues;
- Define and promote participative environmental protection and biodiversity conservation policy framework which considers natural resource sub-sectors as interlinked, and eases accessibility to land resources by smallholder farmers.

Action 3.2: Developing national capacity on erosion causes and factor control

This will involve:

- Undertake in the two river basins an in-depth study on the causes and factors leading or enhancing soil erosion;
- Identify and characterizing the different forms on erosion affecting the upland and the river banks;
- Conduct a survey in downstream to assess off-site impacts of upland sediment transported from upstream to downstream at the estuaries;
- Establish soil erosion map (scale of 1:50,000) highlighting degraded and vulnerable sites along the river banks, using GIS and field control techniques. It would be appropriate to acquire and process satellite imageries (LANDSAT, IKONOS is preferred) of 2007, 2004, 1993, 1979 and 1968.
- Develop and implement integrated soil, water and forest resource management programme framework.

Component 4: Rehabilitation and Protection of the river banks

Action 4.1: Reforestation

The protection of the river banks and beds against erosion/landslides and sedimentation, respectively, should be handled with care in integrated approach with agricultural land use improvement and flood management. This will require following actions:

- Afforestation of all eroded river banks on the basis of the erosion map;
- Revegetalization of all gully erosion areas with fast growing grasses;
- Planning tree and shrubs on the sidewalls, surrounding areas and catchment above gully.

Action 4.2: Mechanical works

This will involve mainly engineering works:

- constructing protection walls and mechanical structures along river banks affected by soil column collapse or detachments;
- engineering structures such as soil pins, retaining walls, rock filling and slope grooming to prevent and control landslips, reinforced with vegetation.

Table 19 below summarizes components, priority actions and activities.

COMPONENTS	PRIORITY ACTIONS	ACTIVITIES
Component 1: **Land degradation database and information system**	Action 1.1: Data and information collecting and management	• data on land use systems, • land and soil occupation, • forest cover, • landscape features, • land preparation and cropping systems, • human settlements, • Socio-economic activities (agriculture, forestry, fishery, hunting, etc.) • Hydraulic and economic infrastructures along the river courses;
	Action 1.2: Develop an integrated environmental and land use information and monitoring system	• Establish GIS unit within the SEMAREN or strengthening capacities of exis cient; • Develop and dissemination tools for information and data update and sharing on environmental and land occupation changes; • Develop a soil mapping and erosion monitoring system complying with intern • Initiate of a long term monitoring of social indicators and environmental keys. • Define and implement criteria and indicators for environmental risks and threa including remedial and preventive measures actions.
Component 2: **Promoting best water management and agricultural practices**	Action 2.1: Improving agricultural practices	• Evaluate current farming systems in hillsides farms as well as in lowlands on i • Assess the efficiency of the tools used for land preparation, including the tr burn favoured by small farmers; • Analyse crop patterns and management techniques. • Define criteria and indicators for soil and water management, in collaborati related institution's staff members are in the process of developing clear star planning and watershed management (USAID, 2004). • Raise awareness and training farmers on best agricultural practices (soil cons tion and drainage technique, efficient use of fertilizers and pesticides, etc.).
	Action 2.2: Improving water and flood management	• Analyse irrigation techniques, with focus on water control and drainage netwo • Conduct a survey of internal drainage to detect the depth of the ground wate drainage networks; • Analyse the efficiency of hydraulic infrastructures on water and flood control age capacity, their site and the surrounding landscape features (vegetation c etc.). • Study opportunity of creating new infrastructures or resizing the existing stream flows • Identify all vulnerable sites and construct diversion structures and retaining wa order to be able to resist high overflows and inundation. • Develop and implementing a proactive plan of priority action to anticipate floo remedial measures.
Component 3: **Soil erosion control**	Action 3.1: Designing a comprehensive and participative land use panning	• Improve land use Planning: as land use has not evolved in orderly or planned 2004) in the country, a proactive and participative land use planning initiative, criteria and indicators, would make a significant contribution to environmenta • Conduct a field survey and a "micro-zoning" of uniform and homogeneous wa hensive management designs. Participative approach would be a far more effe asset for integrated watershed management with high value agricultural return • Establish operational committee on integrated land use and watershed manage

		ones, at national level and particularly at the two river basin levels, in order to magnitude and environmental and land degradation issues; • Define and promote participative environmental protection and biodiversity co which considers natural resource sub-sectors as interlinked, and eases accessib smallholder farmers,
	Action 3.2: Developing national capacity on erosion causes and factor control	• Undertake in the two river basins an in-depth study on the causes and factors l sion; • Identify and characterizing the different forms on erosion affecting the upland • Conduct a survey in downstream to assess off-site impacts of upland sediment downstream at the estuaries; • Establish soil erosion map (scale of 1:50,000) highlighting degraded and vulne banks, using GIS and field control techniques. It would be appropriate to acqu ries (LANDSAT, IKONOS is preferred) of 2007, 2004, 1993, 1979 and 1968. • Develop and implement integrated soil, water and forest resource managemen
Component 4: Rehabilitation and Protection of the river banks	Action 4.1: Reforestation of the river banks	• Afforestation of all eroded river banks on the basis of the erosion map; • Revegetalization of all gully erosion areas with fast growing grasses; • Planning tree and shrubs on the sidewalls, surrounding areas and catchment ab
	Action 4.2: Mechanical works	• constructing protection walls and mechanical structures along river banks affe detachments; • Engineering structures such as soil pins, retaining walls, rock filling and slope trol landslips, reinforced with vegetation.

Table 19: Summary of components, priority actions and activities to be considered for implementation

REFERENCES

DIARENA-CAD-HELVETAS, 2007: Zoning Territorial Municipio de Polo, Provincia Barahona. República Dominicana. Enero 2007.

CONAU, 2008: Evaluación Riesgo de Municipios afectados por Tormenta Noel en la Provincia de Barahona. ABRIL 2008.

CEPAL, 2008 : EVOLUCIÓN DEL IMPACTO DE LA TORMENTA NOELEN REPÚBLICA DOMINICANA. Distr. LIMITADA; LC/MEX7L.853; 39p

CEBSE, 1996: Plan of Handling Integrated for the Region of Samaná. For Center the Conservation and Ecodevelopment of the Samaná Bay and its Surroundings and the for Center Marine Conservation, Samana, Dominican Republic, 90 pp.

CEBSE, 1993: The Pesquería Marina in the Province of Samaná, Dominican Republic: Basic study," for Center the Conservation and Ecodevelopment of the Samaná Bay and its Surroundings and the for Center Marine Conservation, Samana, Dominican Republic

CEPAL, 2008: Evolution of the Impact of the Storm Noel in Dominican lic LC/MEX7L.853 ORIGINAL: SPANISH This document has not been put under publishing revision

CEPAL, 2003: Dominican Republic: Evaluation of the Damages Caused by the Floods in River basins Yaque of Norte and Yuna, 2003 (LC/MEX/L.607

CEPAL, 1998: República Dominicana: evaluación de los daños ocasionados por el huracán Georges, 1998, LC/MEX/L.365, 4 de diciembre

CEPAL, 1979: Dominican Republic: Effects of hurricanes David and Federico in the social economy and conditions (note of the Secretariat), LC/G.1098/Rev.1, October.

FAO, 2003: EVALUATION OF CAUSED DAMAGES PORLAS FLOODS IN RIVER BASINS YAQUE OF NORTH AND YUNA, 2003- LC/MEX/R.852/Add.1, Addendum PROFILES OF PROJECTS

FitzHugh, Tom, Water Budget Analyses for the Yuna River Watershed and Samana Bay. The nature Conservation, 8p

Hernández, René (2000), Medio ambiente, sostenibilidad y desarrollo, en "Desarrollo Económico y Social en la República Dominicana: los últimos 20 años y perspectivas para el siglo XXI," Comisión Económica para América Latina y el Caribe, LC/MEX/R.760, 27 de Julio, pp. XIII-1-XIII-39

Herrera-Colored person, A. 2005: Synthesis of historical biophysic information of the region of Samaná, Dominican Republic. Center for Conservación and Ecodesarrollo of the Bay of Samaná and its Surroundings, CEBSE, Inc. Santo Domingo

Jovel, Roberto y Zapata, Ricardo (1993), Macroeconomic effects of natural disasters in Latin America and the Caribbean, ponencia presentada a la 40º Reunión Norteamericana de la Asociación Internacional de ciencia Regional, Houston, 11 al 14 de noviembre.

Hartshorn, et al. 1981. *The Dominican Republic: Environmental Profile of the Country—A Field Study*. USAID Contract No. AID/SOD/PDC–C–0247.

Herrera-Moreno, A., 2005: Coastal Resources Center, University of Rhode Island, Narragansett, RI USA (2365 kb)

INDRHI, 2006: *The statistics of the water in Dominican Republic*. Santo Domingo. 744p.

INDRHI, 2000: *National Hydrogeological Study*. Santo Domingo: INDRHI.

NDRHI and GTZ, 1993: *Atlas of Maximum Rainfall in the Dominican Republic*. Santo Domingo: INDRHI.

IRG.Ltd, 2001: Dominican Republic Environmental Assessment-USAID/ Task Order No. 841, 80p.

IRG, 2001: Environmental Assessment. International Resources Group, Ltd., USAID Contract No. PCE-I-00-96-00002-00, Santo Domingo, September 2001.

Lamelas, P., 2005: Perfil Socio Económico de las Comunidades de Sánchez, Sabana de la Mar y Agua Santa Del Yuna, Coastal Resources Center, University of Rhode Island, Narragansett, RI USA (3285 kb)

LC/MEX/L, 2004: Evaluation of the damages asionados by the floods in river basins Yaque Of Norte and Yuna, 2003, LC/MEX/L.607, 25 of March of 2004),
LC/MEX/L., 2004: The socioeconomic effects of the hurricane Jeanne in the Dominican Republic, LC/MEX/L.638, 3 November 2004).

Lizardo, M., 2003. National Report: The Dominican Republic. Roles of Agriculture Project International Conference, FAO, Rome, Italy, October 2003

Lizardo, M., and De los Santos, J., 2003: Farming Sector Incentive Framework During the 90s in the Dominican Republic. Roles of Agriculture Project, International Conference, FAO, Rome, Italy, October 2003

Lockwood, H., 2001: Operations and Maintenance Strategy for Community-Managed Rural Water Supply Systems in the Dominican Republic. Environmental Health Project, USAID, 37 pp., October 8, 2001.

Medina, J., A., Núñez, F 2004: Project Yuna River Basin, Phase II. Santo Domingo, Dominican Republic: The Nature Conservancy

Nuñez, F., 2006: Taller de Socialización de los Resultados de la Evaluación del Impacto de La Cuenca del Yuna en la Bahía De Samaná, Febrero, 2006, Coastal Resources Center, University of Rhode Island, Narragansett, RI USA (1018 kb)

Robadue, D., J. Tobey, 2007: Improving Local Community Livelihoods and Strengthening Capacity for Implementing Tanzania's Water Sector Development Strategy, Coastal Resources Center, University of Rhode Island, Narragansett, RI USA (648 kb)

Robadue, D., Tobey, J., 2007: Coastal Resources Center awarded grant for integrating coastal and watershed governance in Tanzania, Coastal Resources Center, University of Rhode Island, Narragansett, RI USA (67 kb)

Rodriguez Taveras, R. I., 2004: Hydroelectric prey and centrals in Republic

Dominican. Santo Domingo: CDEEE, EGEHID, INDRHI.

Pan-American Union, 1967: Recognition and evaluation of the resources naturals of the Dominican Republic. Study for its development and planning. Washington,. 540P.

PRT-PNUD, 2008: Minuta Taller sobre lineamientos técnicos y medioambientales. Barahona 26 Junio 2008.

Pugibet, E., Vega,M., Geraldes, F., 2006: Protocolo de monitoreo a largo plazo, estuario Yuna-Barracote y Bahia de Samana, Acuario Nacional, Santo Domingo, Dominican Republic (1313 kb)

SEMARN-SUR FUTURO-FMAAM-PNUD, 2007: Caracterización Biofísica Actualizada de las Cuencas Altas de la Presa de Sabana Yegua. República Dominicana. Noviembre 2007

SEMARN, 2007: Caracterización Socioeconómica Actualizada de las Cuencas Altas de la Presa Sabana Yegua. República Dominicana. Diciembre 2007.

Tobey, J., Mateo, DeCurtis and A. Ortiz., 2004: Impact of altered freshwater flows to estuaries, Yuna Bay watershed and Samana Bay, Dominican Republic. Unpublished summary, project document.

Tobey, J., 2004: Dimensiones Sociales de la Cuenca del Yuna y el Estuario de la Bahía de Samana, Coastal Resources Center, University of Rhode Island, Narragansett, RI USA (3442 kb)

Tobey, J., 2004: Resumen del Taller: La Influencia de los Flujos de Agua Dulce Desde la Cuenca del Río Yuna en el Estuario de la Bahía de Samaná, Coastal Resources Center, University of Rhode Island, Narragansett, RI USA (1065 kb)

Tropical Research and Development, 1991: Intensive Survey of Rural and Urban Activities Impacting Water and Coastal Resources. Tropical Research and Development, Inc. for USAID/DR, 113 pp., January, 1991.

UNDP, 2008: Informe Sobre Desarrollo Humano. República Dominicana 2008-11-03

UNDP, 2000: *Human Development of the Dominican Republic, 2000.*

UNDP (1998), Fortification of the national capacity to prevent, to mitigate and to take care of disasters of natural or technological origin, Report of the Project, September of 1998.

US Army Corps of Engineers, 2002: Water Resources Assessment of the Dominican Republic Mobile, Alabama, June 2002.

USGS, 2000: *Survey Report, Caribbean District.* San Juan, Puerto Rico.

Valbuena, R., 2007: River basin of the Yuna River. Notes introductorias for the study of the risk by flood

Annex 1

TORs of Land Degradation Specialist

Assessment of Environmental damages and needs in Dominican Republic

1. Background

Within the space of two months last autumn, the Dominican Republic was hit by two intense tropical storms, which brought heavy rains and flooding. Tropical Storm Olga followed shortly after Tropical Storm Noel, which hit the Dominican Republic at the end of October 2007.

In addition to the loss of lives, damage was sustained to the environment and infrastructure, resulting from major rivers bursting their banks, flash floods in vulnerable gullies, landslides, and flooding of low lying areas.

The most impacted areas are located in the two river basins of river Yuna and river Yaque Del Sur. The two storms have killed over 160 people, and more than 130,000 people have now been directly affected, mostly through displacement caused by flooding and loss of shelter. Some 3,500 homes and shelters were damaged, and another 25,000 have had sustained damage as a result of the storms. Extensive areas of cropland especially for bananas, tomatoes, yuca and rice had also been destroyed. This is expected to substantially affect livelihoods, as many of the crops lost were for the financially important export market. According to the ECLAC economic assessment of the disasters, published in March 2008, the environmental damages amount to 116 million of RD$.

The Government of Dominican Republic, represented by its Ministry of Environment (SEMARN), has requested international assistance from the United Nations Country Team to conduct an environmental assessment of damages and needs of areas impacted by the disaster. It also requested support to strengthen local institutions and local capacities to be able to reduce vulnerability to natural disasters in the future.

Beyond the assessment of the environmental damages from the disaster and from the response to it, the report will analyse the underlying vulnerabilities which may have contributed to amplifying the environmental impacts of the disaster. Such a "forensic" review will help targeting the most (environmentally and financially) cost-effective disaster risk reduction measures to be undertaken, in order to minimize these underlying vulnerabilities. The report will therefore recommend measures to integrate environmental concerns into recovery and development efforts.

This environmental assessment project will be realized in the framework of UNDP Early Recovery Programme, with UNEP technical support.

It appeared to the UNEP staff that the most visible environmental impacts from the two tropical storms are:

- Sedimentation of rivers' estuaries which act as "natural dams" at the sea shore in the event of heavy rains and resulting flooding;
- Landslides/land erosion and land degradation with possible link to upstream deforestation;
- Solid waste's improper disposal practices resulting in a significant accumulation of waste materials along the coast and within river estuaries (which may add on the "natural dam" effect);
- Water quality, wetlands and ecosystems' disaster-mitigation services;
- Environmental quality and management of Protected Areas.

Within the space of two months, last fall, the Dominican Republic has been hit by two intense tropical storms, which have brought heavy rains and flooding. Tropical Storm Olga has followed hard on the heels of Tropical Storm Noel, which hit the Dominican Republic at the end of October 2007.

In this framework, the post-disaster environmental assessment requires the participation of a Land Degradation expert. The thematic scope of this expert's assessment should encompass: land degradation; land erosion and landslides; sedimentation of river streams and estuaries; deforestation (including upstream of river basins); riverbanks' stability and sand exploitation; flood management plans in the framework of integrated watershed management; environmental impacts from post-disaster recovery projects; inland ecosystems' biodiversity; land use policies and practices (Land Use National Plan); disaster risk reduction measures; institutional and legal assessment of this environmental sector.

2. Duties

Phase 1: Before the field mission:

1. Review all background information collected from the scoping mission, available on the ftp server set up for that purpose, and from all other possible sources of relevant data.
2. Following this desk study, liaise with UNDP to fine-tune the scope and technical protocols for the assessment.
3. Provide to UNDP the specifications for the equipment needed for the training and the field assessment. Also provide specifications for requesting environmental thematic maps and satellite images to DIARENA.
4. Prepare training agenda and materials for 1-day theoretical training on the scientific protocol for the assessment, and on emergency response to environmental risks, to benefit SEMARN staff.
5. Before training, establish contact with SEMARN staff beneficiaries of the training (contact will be available from UNDP project coordinator), to communicate them the background material they should be familiar with for the training (including for instance UNEP post-Tsunami environmental assessment reports).

Phase 2: Field mission (11 days):

1. Conduct 1 day of training on the scientific protocol that will be used during the environmental assessment of your area of expertise. Liaise with the Water Expert to organize a common session on flood management plans in the framework of integrated watershed management (IWRM). The skills acquired by the trainees during this theoretical session will be implemented in practice with your leadership during the course of the field assessment (as SEMARN staff would accompany you).
2. Utilising the thematic maps you requested from DIARENA and possible other sources of risk mapping data (PPPD), and in conjunction with the advice of local communities' representatives, visit those sites that are of most relevance for the environmental assessment of your area of expertise.
3. Undertake field investigations, including field monitoring, sampling if necessary and photography of these sites, to evaluate the nature and extent of their damages, as well as of their environmental needs for recovery. All sites visited and sampling locations should be geo-referenced by using GPS.
4. Through a "forensic" review, identify underlying root causes of the major environmental damages from the disasters, with the view of proposing practical strategies and measures for disaster risk reduction.
5. In the course of your field assessment undertake the environmental capacities' needs assessment in your sector of expertise, including institutional and legal aspects. (One day for meetings in Santo Domingo has been added for this purpose if this is judged necessary)
6. At the end of your mission, 1 day of closure is planned for debriefing on the field assessment and for completing the training, using practical cases encountered during the field assessment. This second day of training intends to debrief on the scientific protocol used and to discuss long-term environmental management of vulnerable hotspots and disaster risk reduction measures.

Phase 3: After the field mission:

1. Analyse laboratory results if any, and draft your assessment report of the environmental causes, damages and needs in your area of expertise, with a view of proposing practical recommendations for implementing follow-up environmental recovery projects (with a special emphasize towards disaster risk reduction).
2. Development of an environmental database of your area of expertise, incorporating all relevant data and photographs collected during the exercise.

3. Outputs

- Quick desk study: compilation of all relevant background information for the field assessment mission.
- Specifications of needed equipment to be procured by UNDP.
- Specifications for satellite images and thematic maps to be produced by DIARENA.
- Training package including your scientific protocol, previous post-disaster environmental assessment reports…
- Delivery of 2 days of training, one at the beginning and one at the end of your mission.

- Undertake field investigations, and simultaneous practical training in the field for SEMARN staff.
- An environmental damages and needs assessment report for Dominican Republic (in Spanish), that identifies, delineates, and provides practical recommendations for remediation and recovery projects (including for a flood management plan in the framework of IWRM), and supports strategies for disaster risk reduction.

4. Duration and remuneration of the contract

14 days in the time frame from 1 July to 1 September 2008.

14 days at a daily rate of USD

5. Skills and Experience required

- University degree (Masters minimum) in environmental sciences, or forestry, natural resources' management, or geology/hydrology.
- 15 years of experience in environmental management and environmental assessments.
- Fluent in understanding, speaking and writing Spanish.
- Previous experience and familiarity with the United Nations' system will be considered an asset.

Annex 2: ASSESSMENT METHODOLOGY

As per literature review there is no specific defined methodology for storm impact assessment on environmental and land degradation issues. The only specific methodology to address hurricanes and storm damages and impacts is the REA (Rapid Environmental Assessment) developed and used for assessing disaster damages following the disasters.

The methodology described below combines the guideline of REA and specific methodology assessment for environmental and socio-economic impacts and land degradation.

1. OVEVIEW OF RAPID ENVIRONMENTAL ASSESSMENT (REA)

Rapid environmental impact assessment is a methodology "designed for natural, technological or political disaster, and as a best practice tool for effective disaster assessment and management, some weeks after the disaster (within 120 days after the disaster)".

As per definition from Sphere Project (www.sphereproject.org/): "The environment is understood as the physical, chemical and biological surroundings in which disaster-affected and local communities live and develop their livelihoods. It provides the natural resources that sustain individuals, and determines the quality of the surroundings in which they live".

The objectives of REA in Environmental Impact Assessment in Disaster (REA) are:

- tools to identify, define, and prioritizes potential environmental impacts in disaster situations. A simple, consensus-based qualitative assessment process, involving narratives and rating tables, is used to identify and rank environmental issues and follow-up actions during a disaster.

- designed for use during the critical disaster response period, in all types of disaster situations, including natural, technological and political events from when a warning of a disaster is first received until conditions have stabilized, normally within 120 days after a trigger event. This 120-day period provides time to begin an EIA as part of the recovery and rehabilitation process. The REA, besides identifying immediate environmental factors relevant to the relief operations, provides data and insight that can be incorporated into the EIA. The REA should be started as soon as practicable after a warning or start of a disaster. The initial (baseline) assessment should be followed by periodic updates to ensure the REA

The methodology is built around conducting simple analysis of information in the following areas:

- The general context of the disaster.
- Disaster related factors which may have an immediate impact on the environment.
- Possible immediate environmental impacts of disaster agents.
- Unmet basic needs of disaster survivors that could lead to adverse impact on the
- environment.
- Potential negative environmental consequences of relief operations.

However, REA does not replace an EIA, but fills a gap until an EIA is appropriate.

2. METHODOLOGY USED AND RECOMMENDED FOR ASSESSMENT OF ENVIRONMENTAL AND LAND DEGRADATION HURRICANE OR STORM RELATED

2.1. Scope and objectives

The Scope of the assessment is to evaluate damages caused and highlight their causes, factors and underlying factors and issues. It's objectives to:

- Assess the status of the damages caused to various components constituting the environment, as defined above;
- Analyse the context of the occurrence of the disaster, its magnitude, duration and return period
- Assess land degradation and soil erosion status (area concerned, types of degradation, causes and factors, etc.) and evolvement of the erosion process; including their impacts on the overall environment and land uses;
- Propose long term and short term remedial measures and practical mitigation actions to be implemented for rehabilitation and improvement of the situation.

2.2. Assessment Modules

The methodology includes three modules, as follows:

<u>Module 1</u>: Organization of the Assessment

This module deals with organizational issues and aims to identify critical environmental issues related to the disaster from the perspective of providing with appropriate guidelines and services to people or institution for recovery and rehabilitation assistance. It consists in:

1. Collecting background information and identifying assessment participants and key issues to be investigated.
2. Drafting a short context Statement, including description of the phenomena, the amplitude and the main objectives, expected outputs and major threats of Disasters.
3. Proposed a list factors which influence the assessment and the outputs.
4. Ranking issues by importance within each section.

<u>Module 2</u>: Assessment at Community Level

This module aims to identify all major current and future critical issues related to the disaster and which may affect the environment and land uses from community-based perspective and group vulnerability. It consists in:

1. Deciding on what type of information to collect and how relevant is this information to the community concerns and perceptions of environmental and disaster issues.

2. Identifying major stakeholders and categorize them according their socio-economic position and interests
3. Develop a questionnaire for focused discussion, information and data collecting, testing and administering the method in communities.
4. Compile the results of the community level assessment into usable form (a report or completed questionnaire) for each community.
5. If data from other assessments are used, ensure that all the information needed for this module is collected or extracted from existing assessment reports.
6. Complete the Community Assessment Summary Form based on the information collected or drawn from other assessments.
7. Rank the issues by relative importance within each section of the form.

<u>Module 3</u>: Consolidation and Analysis

This aims to analyse and prioritize environmentally-linked issues involving significant immediate and future threat. It consists in:

1. Analysing information and data collected form module 2 at both Organizational and Community Levels.
2. Placing a single list of issues on Issues and Actions table prepared for the purpose.
3. Prioritize the issues, measures and actions to consider for recovery and rehabilitation, on the basis of their impact on environment, socio-economic aspects and people life, welfare and culture.
4. Review the potential environmental impact of the actions and make changes as appropriate.

2.3. Approach

<u>Step 1</u>: The step analyses items specified in Module 1 and aims to the preparation of the mission (desk work). This first step is conducted in office before the field investigations. It consisted to:

- review background information;
- establish a list of necessary equipments and materiel for the field activities: GPS, altimeter, clinometer (SUNTO), folder, measuring tape (10-50 m long), note book, pH-meter, colorimeter, water probe (sediment quantification and water quality estimation), maps (road, slope gradient map, topographical and geographical maps, land occupation, soil maps, geological maps, vegetation maps, land use maps, etc.), etc.
- elaborate an assessment methodology, etc.
- For each component list all of the sources of environmental disturbance
- For each component all the inputs and outputs must be listed, eg, <u>air pollution</u>, noise, <u>hydrology</u>

<u>Step 2</u>: Institutional Level and preliminary discussion with stakeholders, particularly decision-makers and technical department and services, inception meetings, contacts and preparation of the field mission

It's a crucial step as it will condition the overall evaluation process and involves several contacts with various stakeholders and meetings with the decision-makers, the project team (in the case of this assessment: Project Coordination Unit and UNDP staff), the official representative of the government (SEMAREN) staff and other relevant institutions, technical services and projects intervening in the project areas. He participated at the Inception meeting organized by the project team at SEMAREN with the technical staff. The expected outputs are:

- Establishment of thematic maps of the area for use during field visits: a GIS specialist or service is required,
- Undertaking a rapid appraisal mission to the field for confirmation of the map and other relevant data and information;
- Reviewing and fine-tuning the maps of the study areas, as well as information and data collected, and update as appropriate.
- Examine best alternatives intervention approaches or consideration
- List of all issues that may be considered before filed investigation

Step 3: Field investigations

This third step is the key of the evaluation and consists of following main objectives:

General activities

- site selection and visits to the two river basins (Rio Yuna and Rio Yaque);
- meetings and discussions at provincial, community and site levels with the stakeholders (authorities, population, NGOs, private sector, etc.);
- assessment of flood damages, environmental and land degradation issues, including their impacts on the agricultural production and socio-economic infrastructures;
- collect and use quantitative data whenever possible related socio-economic issues.

Environment assessment

- Description of the significant effects on the environment
- Environmental assessment threats
- Importance of forest cover assessment
- Description of landform units and landscape characterization (altitude, slope, area, hydrology network, etc
- Land use and occupation
- Pollution threat and major causes

Land degradation and Soil erosion assessment

- Description and identification of the major soil types and their distribution in the landscape (texture, structure, fertility, organic matter content, surface cover, etc.);
- Analyse soil texture and structure in relation to their erodibility, classification using appropriate soil classification methodologies (FAO, Soil Taxonomy. French, Russia, etc.)
- Analyse water resources management techniques and their impacts on land degradation;
- Assess the importance and manifestation of erosion process in the area, their impacts on environment and other natural resource, including the development potential

- Develop soil vulnerability and current erosion map in highlighting current status, the most degraded areas,;
- Identify and analyse major and underlying causes and factors: agricultural and forestry activities, rainfall intensity, rainfall, topography, slope gradient;
- Identify the most vulnerable segments to be rehabilitated or protected;
- Analyse the country land tenure policy and regulatory frameworks, including customary agreed measures in use at community level;
- Propose remedial measures and priority action programme.

Geology, Hydrology and geodesy

- Description the geomorphological patterns of the area, including land occupation;
- Description hydrological networks with main rivers and important tributaries, in identifying particularly the permanents and those temporally;
- Characterize the major parameters (stream flow, volume of water, slope gradient, influence of saline sea water, quality of water;
- Study sedimentation issues (process, causes, importance, etc.) and the evolvement of the process;
- Propose remedial measures and priority actions.

Biodiversity

- Assessment major threats
- Assess vegetation, fisheries and wildlife, including aquatic and terrestrial species found in the area: number/relative importance, list all those classified by the international threaties (CITES, UICN red book, etc.) as endangered or threatened species
- Assess community needs and profitable relationship between biodiversity conservation and socio-economic development
- Propose improvement or rehabilitation measures and actions to be taken.

Step 4: Information and data compilation and reporting (Santo Domingo & Montreal).

At the end of the field trips, in liaison with the national counterpart experts and the two other sub-teams of the mission:

- compile and synthesize information and data collected,
- discuss the findings,
- exchange ideas and suggestions,
- draft the mission report which is part of the full report to be prepared by the team leader;
- use information ways to avoid negative impacts should be developed
- establish thematic maps (land occupation, degradation and erosion map, intervention map, etc.)
- recommend practical priority and long term actions plan and programme for recovery, rehabilitation and prevention.

Annex 3: Study sites locations

Table A.3.1: Yuna River basin

EVALUATION OF IMPACTS GIVES TO THE STORMS NOEL AND OLGA					
YUNA RIVER BASIN					
	X	**And**	**HEIGHT (MSNM)**	**PLACES**	**OBSERVATION**
1	404894	2120348	11	Villa Rivas	Over the Bridge on Camú river Villa Riva: flood that lasted 30days
2	408643	2117090	4	Payabo river	5 Houses destroyed and plantations of rice totally lost
3	412347	2116736	5	Intersection Car Via of the East	
4	420046	2114315	5	Paraguay	Birth place of river stream the Surrounded one
5	420990	2113564	4	Laguna	Garbage dump of Paraguay
6	423231	2111843	12	Crystal	The skirt of the inudable hill
7	422550	2118096	12	Jurungo	Houses that were affected and are in danger
8	409108	2122900	24	Highway Villa Riva	Alluvial material coluvio where in where the part is inudables flattest
9	424266	2116581		villa Maria - the Races	
10	426349	2118493	5	The Guayabo	Inundable area and cultures (rice) affected by storm. To measures that we approached the opening are more sediments in slope of river and wide one has diminished its.
11	428611	2119969		The Guayabo	Zone where the river was turned aside in 1972 and now is less inundable
12	429005	2120731	1,5	The Guayabo	when the tide raises gives back the water towards the Payabo river until about 7 km. that it makes confluence with Yuna river.
13	419440	2181440	6	The Heron of Sandy	Sliding in slope and removal in mass in shore of river with vulnerable houses
14	412444	2121591		Sandy	Intersection bridge railcar of the east

15	410401	2121168		Aglipo	System of irrigation Aglipo II, slope the eroded river
16	382391	2119812	30	Highway Pimentel - Cocuy	System of culverts dragged by storms
17	381269	2118709	37		Highway that was to change course
18	381426	2118125	35		Erosion of slope of river, with sandy subject to erosion material
19	385012	2118114	42	Confluence Camú - Yuna	Inudable highway
20	328699	2150633	197	Highway Licey - Santiago	
21	339617	2138906	130	Moca highway - Vega	slidings the slope and bridge that was destroyed by storms and is accumulated many sediment in channels
22	333082	2126755	138	Bayacane bridge towards Jarabacoa	In this point the water is clean free of sediments
23	333450	2127632	153	Confluence Bayacane - Camú	Bayacanes contributes many sediments to the Camú
24	334909	2127792		Bridge	Slope eroded by swellings
25	338849	2127261	102	San Miguel community	Meander cut in 1954 to turn aside Camú river, whose community is flooded and used channel as garbage dump and water-drainage of industry.
26	344519	2126431	91	Highway the Fertile valley - San Fco.	The margin of the river broke and flooded and were destroyed several houses.
27	351926	2122283	68	Ranchito bridge - Aloe fibre	Impact on ground and erosion in slope
28	19º14´29¨	70º´2342.56¨	119	Ranchito	
29	19º18´25.83 ¨	70º´15.20.98 ¨	118	Jaya	
30	381728	2109619	38	Maguaca river	Area affected in Platanal-Cotui highway
31	378451	2110298		Pimentel - Cotui	Area affected in Yuna river, is observed many songs rollings and small barren islands of sands and gravel
32	376877	2091851	123	Dominican rosary	Mineral prey of sulphide tail with gold content with considerable value.
33	363108	2088435	117	Maimón river	Area with erosion and slope of affected river
34	351598	2096177	174	Bonao	Flooded area that affected bridge
35	350237	2094520	195	Bonao	Area flooded by storms

36	346406	2089294	258	The Burned ones of Bonao	Wall on Camú river that avoided flood in town constructed after George. Many colluvions are observed.
37	345771	2088739	269	Bonao (work of aqueduct taking)	infrastructure affected by storm
38	344194	2086606	312	Stream wasp	Sedimentario material
39	343886	2086547	315	Stream the Wasp, next to the Blanco river	to the north - the northwest lateral defor-ested by agriculture
40	340510	2087158	827		Imprisoned intersection Target river
41	351472	2089648	203	Juma river	Wall constructed after Storms Noel and Olga, by flood in Town

EVALUACIÓN DE IMPACTOS DA LAS TORMENTAS NOEL Y OLGA					
CUENCA DE YUNA					
	X	**Y**	**AL-TURA(MSNM)**	**LUGARES**	**OBSERVACIÓN**
1	404894	2120348	11	Villa Rivas	Puente sobre el río Camú Villa Riva -La Verde inundación que duró 30días
2	408643	2117090	4	Río Payabo	5 Viviendas destruidas y plantaciones de arroz
3	412347	2116736	5	Intersección Auto Vía del Este	
4	420046	2114315	5	Paraguay	Nacimiento de río arroyo El Cercado
5	420990	2113564	4	La Laguna	Vertedero de Paraguay
6	423231	2111843	12	Cristal	La falda de la loma inudable
7	422550	2118096	12	Jurungo	Viviendas que fueron afectadas y están en peligro
8	409108	2122900	24	Carretera Villa Riva	Material coluvio aluvial donde en donde es inudables la parte más planas
9	424266	2116581		villa Maria - Las Carreras	

10	426349	2118493	5	El Guayabo	Área inundable y cultivos (arroz) afectadas por tormenta. A medidas que nos acercamos a la desembocadura hay más sedimentos en talud de río y ha disminuido su ancho.
11	428611	2119969		El Guayabo	Zona donde el río fue desviado en 1972 y ahora es menos inundable
12	429005	2120731	1,5	El Guayabo	cuando la marea sube devuelve el agua hacia el río Payabo hasta unos 7 Km. que hace confluencia con río Yuna.
13	419440	2181440	6	La Garza de Arenoso	Deslizamiento en talud y remoción en masa en ribera de río con viviendas vulnerables
14	412444	2121591		Arenoso	Intersección puente autovía del este
15	410401	2121168		Aglipo	Sistema de riego Aglipo II, talud el río erosionado
16	382391	2119812	30	Carretera Pimentel - Cocuy	Sistema de alcantarillas arrastrada por tormentas
17	381269	2118709	37		Carretera que hubo que cambiar curso
18	381426	2118125	35		Erosión de talud de río, con material erosionable arenoso
19	385012	2118114	42	Confluencia Camú - Yuna	Carretera inudable
20	328699	2150633	197	Carretera Licey - Santiago	
21	339617	2138906	130	Carretera Moca - La Vega	deslizamientos el ladera y puente que fue destruido por tormentas y ha acumulado muchos sedimento en cauces
22	333082	2126755	138	Puente Bayacane hacia Jarabacoa	En este punto el agua es limpia libre de sedimentos
23	333450	2127632	153	Confluencia Bayacane - Camú	Bayacanes aporta muchos sedimentos al Camú
24	334909	2127792		Puente	Talud erosionado por crecidas
25	338849	2127261	102	Comunidad San Miguel	Meandro cortado en 1954 para desviar río Camú, cuya comunidad es inundada y cauce usado como vertedero y desagüe de industria.
26	344519	2126431	91	Carretera La Vega - San Fco.	La margen del río rompió e inundó y fueron destruidas varias casas.
27	351926	2122283	68	Puente Ranchito - Cabuya	Impacto sobre suelo y erosión en talud

28	19º14´29¨	70º´2342.5 6¨	119	Ranchito	
29	19º18´25. 83¨	70º´15.20.9 8¨	118	Jaya	
30	381728	2109619	38	Río Maguaca	Área afectada en carretera Platanal-Cotui
31	378451	2110298		Pimentel - Cotui	Área afectada en río Yuna, se observa muchos cantos rodados e islotes de arenas y gravas
32	376877	2091851	123	Rosario Dominicana	Presa de cola mineral de sulfuro con contenido de oro con valor considerable.
33	363108	2088435	117	Río Maimón	Área con erosión y talud de río afectado
34	351598	2096177	174	Bonao	Área inundada que afectó puente
35	350237	2094520	195	Bonao	Área inundada por tormentas
36	346406	2089294	258	Los Quemados de Bonao	Muro sobre río Camú que evitó inundación en pueblo construido después de George. Se observan muchos coluviones.
37	345771	2088739	269	Bonao (obra de toma de acueducto)	infraestructura afectada por tormenta
38	344194	2086606	312	Arroyo avispa	Material sedimentario
39	343886	2086547	315	Arroyo las Avispa, próximo al río Blanco	al norte - noroeste laderas deforestadas por agricultura
40	340510	2087158	827		Intersección presa río Blanco-Pinalito
41	351472	2089648	203	Río Juma	Muro construido después de Tormentas Noel y Olga, por inundación en Pueblo

Table A.3.2: Yaque del Sur basin

EVALUATION OF IMPACTS GIVES TO THE STORMS NOEL AND OLGA					
RIVER BASIN YAQUE OF THE SOUTH					
	X	**And**	**HEIGHT (MSNM)**	**PLACES**	**OBSERVATION**
1	257198	2024121	13	Laguna Cabral (Cristóbal)	Inundable area in community of Cristóbal
2	257520	2024230	18	Cristóbal	Area in where flood by Laguna Cabral arrived
3	157103	2023794	17	Canal Cristóbal - wagon Cristóbal	Area where water of natural form to the Cristóbal channel is spilled
4	247051	2029697	18	Canal Cristóbal	In this point the channel was turned aside by breakage. Accumulation of salts
5	225683	2048994	-26	Limit present of Lago Enriquillo	Area where it is the water of the lake
6	215303	2054482	-26	Sulphured (the house of park	
7	265019	2019845	13	Channel of the Yaque river	Gorge that penetrates water from the lagoon to the Yaque river after the storm
8	265077	2020137	7	Course of the Yaque river	In this point the water level of the lagoon is of 9 meters in comparison of the level of the river that has 7 meters
9	265014	2019695		Laguna Cabral (the Rock	Flooded area
10	261761	2011007	523	Gorge the Caves	The water of this gorge goes towards the Cabral lagoon, whose matter coluvio is alluvial
11	261027	2008378		Gorge the Caves	The high part of the area of the river basin presents/displays grass and cultures of subsistence, but it does not contribute sediments to the channel of the river. The impact is in the course of the gorge has slidings.

12	258685	2004101	835	Populated the Auyama de Polo	The stream the Auyama presents/displays many sediments in its channel that are going direct to flood the area of the municipality of Pole in the low part.
13	263179	1980271	7	Enriquillo	In the this pinto channel of the Sito river totally it is settled with great coluviones and trunks of trees
14	263230	1980144	1,5	Mouth of the Sito river	In this point presence of salts does not exist. The channel of the river this upper than the sea which allows the washing of the salts.
15	271179	2026716	25	Jaquimeyes	Area flooded up to three times to the year, exists a measurer of the volume Here to alert to wing population when the water reaches certain levels of height
16	271198	2026915	22	Jaquimeyes	in this point the fine sediments exceed rebuking of the river and this it presents/displays much curvature
17	276020	2019677	3		Saline grounds without vegetation to km. Approximated of the mouth of the river yaque towards the bay. Next to this point we have species of mangle and other species
18	275001	2020069	6	Area under cultures	Around this point we have parcel dedicated to seedtime of cultures (Guandul Cajanus cajan), in where we observed the presence of salts. This area must be evaluated and to eficientizar the water provision to avoid that it increases his salinity.

EVALUACIÓN DE IMPACTOS DA LAS TORMENTAS NOEL Y OLGA					
CUENCA YAQUE DEL SUR					
	X	**Y**	**AL-TURA(MSNM)**	**LUGARES**	**OBSERVACIÓN**

1	257198	2024121	13	Laguna Cabral (Cristóbal)	Área inundable en comunidad de Cristóbal
2	257520	2024230	18	Cristóbal	Área en donde llegó inundación por la Laguna Cabral
3	157103	2023794	17	Canal Cristóbal - carretera Cristóbal	Área donde se vierte agua de forma natural al canal Cristóbal
4	247051	2029697	18	Canal Cristóbal	En este punto el canal fue desviado por rotura. Acumulación de sales
5	225683	2048994	-26	Limite actual del Lago Enri-quillo	Área donde está el agua del lago
6	215303	2054482	-26	La Azufrada (caseta de parque	
7	265019	2019845	13	Cauce del río Yaque	Cañada que penetra agua desde la laguna al río Yaque después de la tormenta
8	265077	2020137	7	Curso del río Yaque	En este punto el nivel de agua de la laguna es de 9 metros en comparación del nivel del río que tiene 7 metros
9	265014	2019695		Laguna Cabral (El Peñón	Área inundada
10	261761	2011007	523	Cañada Las Cuevas	El agua de esta cañada va hacia la laguna Cabral, cuyo materia son coluvio aluvial
11	261027	2008378		Cañada Las Cuevas	La parte alta del área de la cuenca presenta pastos y cultivos de subsistencia, pero no aporta sedimentos al cauce del río. El impacto está en el curso de la cañada tiene deslizamientos.
12	258685	2004101	835	Poblado Las Auyama de Polo	El arroyo las Auyama presenta muchos sedimentos en su cauce que van directo a inundar el área del municipio de Polo en la parte baja.
13	263179	1980271	7	Enriquillo	En este pinto el cauce del río Sito está totalmente sedimentado con coluviones grandes y troncos de árboles

14	263230	1980144	1,5	Desembocadura del río Sito	En este punto no existe presencia de sales. El cauce del río esta más alto que el mar lo que permite el lavado de las sales.
15	271179	2026716	25	Jaquimeyes	Área inundadas hasta tres veces al año, Aquí existe un medidor del caudal para alertar ala población cuando el agua alcanza ciertos niveles de altura
16	271198	2026915	22	Jaquimeyes	en este punto los sedimentos finos sobrepasan el cardar del río y este presenta mucha curvatura
17	276020	2019677	3		Suelos salinos sin vegetación a un Km. Aproximado de la desembocadura del río yaque hacia la bahía. Próximo a este punto tenemos especies de mangle y otras especies
18	275001	2020069	6	Área bajo cultivos	Alrededor de este punto tenemos parcela dedicada a la siembra de cultivos (Guandul Cajanus cajan), en donde observamos la presencia de sales. Esta área debe ser evaluada y eficientizar el suministro de agua para evitar que aumente su salinidad.

Annex 4: Soil class distribution within the natural zones

AREAS	SOILS CLASSES
Valle del Cibao Occidental	Entisol, Aridisol, Mollisol, (Inceptisol)
Valle del Cibao Central	Vertisol, Mollisol, Entisol
Valle del Cibao Oriental	Vertisol, Mollisol, Histosol, (Alfisol)
Llanura del Atlántico	Inceptisol, Entisol, (Mollisol)
Valles Intramontanos	Mollisol, Entisol
Llanura del Caribe	Entisol, Inceptisol, Ultisol, Vertisol, (Oxisol, Afisol)
Llanura de Azua	Aridisol, (Entisol, Mollisol)
Valle de San Juan	Mollisol, Inceptisol, (Vertisol)
Hoya de Enriquillo	Aridisol, Entisol
Península de Barahona Sur	Entisol, Inceptisol, (Aridisol)
Cordillera Central	Inceptisol, (Alfisol, Ultisol)
Cordillera Septentrional	Inceptisol, (Mollisol)
Cordillera Oriental	Inceptisol, Ultisol, (Oxisol)
Sierras de Neiba y del Bahoruco	Inceptisol, (Entisol,)
Sierra de Yamasá	Inceptisol, Ultisol, (Oxisol)
Los Haitises Samaná	Inceptisol, (Entisol,)
Llanura de Miches Sabana de la Mar	Entisol, (Inceptisol,)

Annex 5: Distribution of land uses and occupation

Categorías	Area km^2	% Categoría	% Total
1. Bosque Conífero	**3,025.45**	**22.80**	**6.27**
1.1 Bosque Conífero Denso	1,946.35	14.67	4.04
1.2 Bosque Conífero Abierto	1,079.10	8.13	2.24
2. Bosque Latifoliado	**6,306.27**	**47.54**	**13.08**
2.1 Bosque Latifoliado Lluvioso (Nublado)	1,104.87	8.33	2.29
2.2 Bosque Latifoliado Húmedo	3,151.88	23.76	6.54
2.3 Bosque Latifoliado Semihúmedo	2,049.52	15.45	4.25
3 Bosque Seco	**3,677.39**	**27.72**	**7.63**
4 Bosque de Humedales	**256.95**	**1.94**	**0.53**
4.1 Bosque Humedales Salobres Temporalmente Inundados	19.60	0.15	0.04
4.2 Bosque Humedales Salobres Permanentemente Inundados	192.55	1.45	0.40
4.3 Bosque Humedales de Agua Dulce	44.80	0.34	0.09
Subtotal de Bosques	**13,266.06**	**100.00**	**27.51**
5 Matorrales			
5.1 Matorral Latifoliado	3,033.38	44.54	6.29
5.2 Matorral Seco	3,723.79	54.68	7.29
5.3 Matorral de humedales Salobres	53.10	0.78	0.11
Subtotal de Matorrales	**6,810.17**	**100.00**	**14.12**
6. Sabana			
Sabana de Humedales Salobres	93.28	51.06	0.19
Sabana de Humedales de Agua Dulce	19.79	10.83	0.04
Sabana de Pajón	69.61	38.10	0.14
Subtotal de Sabanas	**182.68**	**100.00**	**14.12**
7. Vegetación de Agua Dulce (Eneal)	**17.47**		**0.04**
8. Escasa Vegetación o Areas Erosionadas	**1,306.44**		**2.71**
9. Areas Agropecuarias			
9.1 Cultivos Permanentes o Arbóreos			
9.1.1 Palma Africana	46.95	1.38	0.10
9.1.2 Palma de Coco	324.93	9.52	0.67
9.1.3 Café y Cacao	3,042.41	89.11	6.31
Subtotal Cultivos Permanentes	**3,414.29**	**100.00**	**7.08**
9.2 Cultivos Intensivos			
9.2.1 Caña	3,681.91	29.94	7.63
9.2.2 Arroz	1,957.49	15.92	4.06
9.2.3 Pastos Intensivos	2,636.26	21.44	5.47
9.2.4 Cultivos Mixtos Intensivos	4,020.54	32.70	8.34
Subtotal Cultivos Intensivos	**12,296.20**	**100.00**	**25.50**
9.3 Agricultura de Subsistencia y Pastos	10,042.90	81.67	20.83
Subtotal Areas Agropecuarias	**25,753.39**	**100.00**	**53.40**
10. Agua (Embalses, Lagos, Lagunas, etc.)	**495.06**		**1.03**
11. Areas Pobladas	**393,64**		**0.82**
TOTAL	**48,224.91**		**100.00**

Annexe 4: Soil erodibility equation parameters

Annex 4.1: Soil erosion reference data

Table 1. R Factor Data

Weather Station	County	R Factor
Brantford	Brant	90
Delhi		100
Essex	Essex	110
Fergus	Dufferin, Wellington	120
Glen Allen		130
Guelph		100
Hamilton	Halton, Hamilton-Wentworth	100
Kingston	Frontenac, Lennox & Addington, Prince Edward	90
Kitchener	Waterloo	110
London	Lambton, Middlesex, Oxford	100
Mount Forest	Bruce, Grey, Haliburton, Muskoka, Simcoe	90
Niagara	Niagara	90
Northern Ont.	Algoma, Cochrane, Kenora, Manitoulin, Parry Sound, Rainy River, Sudbury, Thunder Bay, Timiskaming	90
Ottawa	Dundas, Grenville, Glengarry, Lanark, Leeds, Nipissing, Ottawa-Carleton, Prescott, Renfrew, Russell, Stormont	90
Prospect Hill	Huron, Perth	120
Ridgetown	Kent	110
Simcoe	Haldimand / Norfolk	120
St. Catherines		100
St. Thomas	Elgin	90
Toronto	Metro-Toronto, Peel, York	90
Tweed	Durham, Hastings, Northumberland, Peterborough, Victoria	90
Windsor		110

Note: any other counties not in this chart are assumed to have an R Factor of 90.

Table 2: K Factor Data (Organic Matter Content)

Textural Class	**Average**	**Less than 2 %**	**More than 2 %**
Clay	0.22	0.24	0.21
Clay Loam	0.30	0.33	0.28
Coarse Sandy Loam	0.07	--	0.07
Fine Sand	0.08	0.09	0.06
Fine Sandy Loam	0.18	0.22	0.17
Heavy Clay	0.17	0.19	0.15
Loam	0.30	0.34	0.26
Loamy Fine Sand	0.11	0.15	0.09
Loamy Sand	0.04	0.05	0.04
Loamy Very Fine Sand	0.39	0.44	0.25
Sand	0.02	0.03	0.01
Sandy Clay Loam	0.20	--	0.20
Sandy Loam	0.13	0.14	0.12
Silt Loam	0.38	0.41	0.37
Silty Clay	0.26	0.27	0.26
Silty Clay Loam	0.32	0.35	0.30
Very Fine Sand	0.43	0.46	0.37
Very Fine Sandy Loam	0.35	0.41	0.33

Table 3A. LS Factor Calculation

Slope Length ft (m)	**Slope (%)**	**LS Factor**
100 ft (31 m)	10	1.3800
	8	0.9964
	6	0.6742
	5	0.5362

	4	0.4004
	3	0.2965
	2	0.2008
	1	0.1290
	0	0.0693
200 ft (61 m)	10	1.9517
	8	1.4092
	6	0.9535
	5	0.7582
	4	0.5283
	3	0.3912
	2	0.2473
	1	0.1588
	0	0.0796
400 ft (122 m)	10	2.7602
	8	1.9928
	6	1.3484
	5	1.0723
	4	0.6971
	3	0.5162
	2	0.3044
	1	0.1955
	0	0.0915
800 ft (244 m)	10	3.9035
	8	2.8183
	6	1.9070
	5	1.5165
	4	0.9198
	3	0.6811

	2	0.3748
	1	0.2407
	0	0.1051
1600 ft (488 m)	10	5.5203
	8	3.9857
	6	2.6969
	5	2.1446
	4	1.2137
	3	0.8987
	2	0.4614
	1	0.2964
	0	0.1207
3200 ft (975 m)	10	7.8069
	8	5.6366
	6	3.8140
	5	3.0330
	4	1.6015
	3	1.1858
	2	0.5680
	1	0.3649
	0	0.1386

Annex 4.2: Equation for Calculation of LS (if not using Table 3A above)

LS = [0.065 + 0.0456($slope$) + 0.006541($slope$)^2] x (slope_length ÷ const)^{NN}

Where:

slope =	slope steepness (%)
slope length =	length of slope (ft.)
constant =	72.5 Imperial or 22.1 metric

NN = see Table 3B below

Table 3B. NN Values

S	**< 1**	**1 ≤ Slope < 3**	**3 ≤ Slope < 5**	**≥ 5**
NN	0.2	0.3	0.4	0.5

Table 4A. Crop Type Factor

Crop Type	**Factor**
Grain Corn	0.40
Silage Corn, Beans & Canola	0.50
Cereals (Spring & Winter)	0.35
Seasonal Horticultural Crops	0.50
Fruit Trees	0.10
Hay and Pasture	0.02

Table 4B. Tillage Method Factor

Tillage Method	**Factor**
Fall Plow	1.0
Spring Plow	0.90
Mulch Tillage	0.60
Ridge Tillage	0.35
Zone Tillage	0.25
No-Till	0.25

Table 5. P Factor Data

Support Practice	**P Factor**
Up & Down Slope	1.0
Cross Slope	0.75

Contour farming	0.50
Strip cropping, cross slope	0.37
Strip cropping, contour	0.25

Table 6. Soil Loss Tolerance Rates

Soil Erosion Class	**Potential Soil Loss (tons/acre/year)**
Very Low (tolerable)	<3
Low	3 - 5
Moderate	5 - 10
High	10 - 15
Severe	>15

Table 7. Management Strategies to Reduce Soil Losses

Factor	**Management Strategies**	**Example**
R	The R Factor for a field cannot be altered.	--
K	The K Factor for a field cannot be altered.	--
LS	Terraces may be constructed to reduce the slope length resulting in lower soil losses.	Terracing requires additional investment and will cause some inconvenience in farming. Investigate other soil conservation practices first.
C	The selection of crop types and tillage methods that result in the lowest possible C factor will result in less soil erosion.	Consider cropping systems that will provide maximum protection for the soil. Use minimum tillage systems where possible.
P	The selection of a support practice that has the lowest possible factor associated with it will result in lower soil losses.	Use support practices such as cross slope farming that will cause deposition of sediment to occur close to the source.

Annex 4.3: Example: Calculation of Soil Erosion Using USLE

A =R x K x LS x C x P

<u>Rainfall and Runoff Factor (R)</u>

The sample field is in Middlesex County. Therefore the R Factor is obtained in Table 1 from the London weather station. R Factor = 100

Soil Erodibility Factor (K)

The sample field consists of fine sandy loam soil with an average organic matter content. The K Factor is obtained from Table 2
. K Factor = 0.18

Slope Length-Gradient Factor (LS)

The sample field is 800 feet long with a 6% slope. The LS factor can be obtained directly from Table 3A or may be calculated using the " Equation". The NN value from Table 3B to be used in the "Equation" is 0.5. LS Factor = 1.91

Crop/Vegetation and Management Factor (C)

The sample field was plowed in the spring and grain corn was planted. The C Factor is obtained from the crop type factor (Table 4A) and the tillage method factor (Table 4B).

Crop Type Factor for grain corn = 0.4
Tillage Method Factor for spring plow = 0.9

C Factor = 0.4 x 0.9 = 0.36

Support Practice Factor (P)

Cross slope farming is used on this sample field. The P Factor was obtained from Table 5.

P Factor = 0.75

Therefore,

A = R x K x LS x C x P

= 100 x 0.18 x 1.91 x 0.36 x 0.75

= 9.28 tons/acre/year

Referring to Table 6 in this Factsheet, you will see that this soil loss rate of 9.28 tons/acre/year is in the moderate range and considerably higher than the "tolerable loss level" of 3 tons/acre/year. To reduce the soil losses for this sample field below 3 tons/acre/year we will make the following changes to the above example.

Change tillage method from "spring plow (0.9)" to "no-till (0.25)"
therefore, C Factor (Revised) = 0.4 x .25 = 0.10

The adjusted annual soil loss value is

A = R x K x LS x C x P

= 100 x 0.18 x 1.91 x 0.10 x 0.75

= 2.58 tons/acre/year

Thus by changing the tillage practice, the average annual predicted soil loss for this field is below the "tolerable soil loss" of 3 tons/acre/year.