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MATHEUX (ST MARC) CORRIDOR WATERSHED MANAGEMENT PLAN

FEBRUARY 2014

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PREFACE

This report benefited greatly from the excellent GIS images and maps provided by Emmanuel Pierre (GIS specialist), also notes on the stakeholder workshop by Obenson Louis (Disaster Mitigation Specialist), and by the guidance and unconditional support provided by Mario Kerby, Deputy Chief of Party, and Jean-Robert Estimé, Chief of Party, Feed the Future/WINNER.

The Matheux plan reflects stakeholder concerns including small farmers, technicians, private sector and association representatives, and local elected officials who provided information in field interviews and contributed thoughtfully to the stakeholder workshop (September 2013). The workshop was greatly enriched by special presentations from Wilson Célestin, Professor of Biology at the FAMV and UNIQ, and Daniel Elie, Architect and President of ICOMOS-Haiti.

The cover photo was taken on the road to Ivoire. Unless otherwise identified, all photos were taken by Glenn Smucker.

Glenn R. Smucker
Cultural Anthropologist

ACRONYMS

AF	Agro-forestry
CASEC	Conseil d'Administration de la Section Communale
CIAT	Comité Inter-Ministériel d'Aménagement de Territoire
CNIGS	Centre National de l'Information Géo-Spatiale
CNSA	Conseil National de la Sécurité Alimentaire
DEED	Développement Économique pour un Environnement Durable
DPC	Direction de la Protection Civile
EPA	Environmental Protection Agency (United States)
FAMV	Faculté d'Agronomie et de la Médecine Vétérinaire
FOPROBIM	Fondation pour la Protection de la Biodiversité Marine
MARNDR	Ministère de l'Agriculture, des Ressources Naturelles et du Développement Rural
ICOMOS	International Council on Monuments and Sites
MDE	Ministère de l'Environnement
MICT	Ministère de l'Intérieur et des Collectivités Territoriales
MTPTC	Ministère des Travaux Publiques, Transports, Energie et Communications
PPT	PowerPoint
UEH	Université d'État d'Haïti
UNIQ	Université Quisqueya
USAID	United States Agency for International Development
USG	United States Government
UTSIG	Unité de Télédétection et des Systèmes d'Information Géographique
WINNER	Watershed Initiative for Natural Environmental Resources

TABLE OF CONTENTS

Preface i
Acronyms ii
List of Tables v
List of Figures vi
I. Introduction 1
II. The Matheux Corridor 3
Bio-Physical Overview 6
Protection of Natural Areas 10
Protection of Historical-Cultural Resources 13
III. Hydrology of the Matheux 16
Multiple Watersheds 16
Springs 18
Ravines 19
Irrigation Perimeters 20
Coastal Waters 24
IV. Land Use and Agro-Ecological Zones 27
Land Cover 27
Agro-Ecological Zones 30
V. Planning Priorities and Opportunities 33
Watershed Risks 33
Assets and Opportunities 35
Stakeholder Concerns 37
Planning Priorities 38
Geographic Priorities 39
Mitigation of erosion risk 39
Mitigation of Flood Risk 40

Poverty Alleviation 40
Vulnerability to Natural Disaster 41
Reduced Water Quality and Quantity 41
Degradation of Coastal and Marine resources 42
Governance 42
References 56

Annex I. A Watershed Planning Approach 62
Defining Terms 62
Planning and Implementing a Watershed Approach to Land Management 62
Annex II. Findings from Matheux Stakeholder Workshop 64
Annex III. High Risk Ravines and Rivers 74

LIST OF TABLES

Table 1. Administrative jurisdictions of the Matheux Corridor

Table 2. Population of communes and partial communes within the Matheux corridor

Table 3. Prioritization of biological conservation sites in the Montrouis area based on biological importance and threat levels

Table 4. Area drained by seven priority watersheds of the Matheux

Table 5. An inventory of springs by locality

Table 6. High priority ravines for protective interventions

Table 7. Principal irrigation perimeters of the Matheux corridor

Table 8. Synthesis of Watershed Management Planning for the Matheux Corridor

LIST OF FIGURES

Figure 1. The Matheux and other development corridors in Haiti

Figure 2. Municipal jurisdictions in the Matheux corridor between Cabaret and Montrouis

Figure 3. Soil potential in the area of Arcahaie and Montrouis

Figure 4. Slope categories and erosion risk in Cabaret-Montrouis area

Figure 5. Proposed biological conservaton sites by life zone in Montrouis-Arcahaie

Figure 6. Proposed Arcadins Marine Park including coral (red) and mangroves (green)

Figure 7. Ruins of colonial coffee plantations along the Matheux ridge

Figure 8. Historic ruins of a colonial coffee plantation at Lamothe on the Matheux ridge

Figure 9. Historic ruins of Ft. Drouet on the Matheux ridge

Figure 10. Hydrographic network in the Matheux corridor

Figure 11. Seven major watersheds of the Matheux corridor

Figure 12. Spring fed Dupin irrigation perimeter near the freshwater lake of Bois Neuf

Figure 13. Spatial distribution of small irrigated perimeters in the Montrouis area

Figure 14. Comparison of irrigation perimeters and flood plains of the Matheux corridor

Figure 15. Arcadins coast, Arcahaie plains, Riviere des Matheux (Road to Ti Bois)

Figure 16. Arcadins coast, Quartier de Montrouis, Rivière de Montrouis (Arcahaie & St. Marc)

Figure 17. Agricultural landscape on road to Fond-Baptiste

Figure 18. Land use and land cover in the Matheux corridor

Figure 19. Matheux agro-ecological zones by elevation and cultigen

Figure 20. Watershed Approach: Planning & Implementation

I. INTRODUCTION

Purpose. This document proposes a watershed management plan for the Matheux corridor, the hydrographic area defined by the Chaîne des Matheux mountain range and the Arcadins coast between Cabaret and Montrouis. The purpose of this plan is practical in nature: a tool for shared, sustainable management of natural resources, setting priorities, making decisions and guiding actions for sustainable use of water and the land. The plan is a guiding frame of reference for all residents and institutional actors in the watershed. It integrates upland and lowland areas of the watershed into a single, inextricably linked planning unit.

Watershed approach. A watershed management plan is a tool for land management. As a process, this includes watershed evaluation, building partnerships among stakeholders, and preparing and implementing a watershed plan.[1]

The Matheux watershed management plan described here is one stage in this process. The plan is based on documentary review, baseline diagnostic studies of the Matheux and a participatory process of consultation with watershed stakeholders.

Stakeholders in this participatory process include local elected officials of *communes* and *sections communales*, representatives of central government ministries including Agriculture, Environment and Interior, private sector entrepreneurs including hotel operators along the Arcadins coast, members of grassroots organizations including women's groups, upland farmer associations, lowland irrigation water user associations, fishers in coastal waters and the Etang Bois Neuf freshwater lake, and external donors.

Watershed Diagnostic Studies

1. Identify study area, bio-physical milieu, jurisdictions
2. Water resources & uses, irrigation works, hydrology
3. Characterize socio-economic milieu, demography, land tenure, economic activities, infrastructures & services
4. Identify land use patterns, production systems, revenue generation strategies, vulnerabilities
5. Identify environmentally sustainable value chains, perennials, multi-year crops, value added & non-farm employment opportunities
6. Institutional framework, critical actors, capacity for watershed governance
7. Priorities & prospective interventions
8. Identify information gaps

SOURCE : CIAT (May 2011)

Diagnostic categories and objectives. Categories proposed by CIAT are used here as a guideline for summarizing available information and assessing the condition of the Matheux watershed (see adjoining textbox entitled Watershed Diagnostic Studies). Description of the state of the watershed anticipates land use priorities, zoning and concrete actions for sustainable management of natural, social, economic and cultural resources. In the Matheux corridor this includes upland and lowland agriculture, irrigation systems, protected areas, historical sites,

[1] See Annex I for definition of terms and graphic depiction of a watershed approach.

coastal livelihoods such as tourism and fishing, and fragile marine ecosystems including mangroves, fish spawning habitat and endangered species.

State of the watershed. Watershed diagnosis and planning are defined above all by water resources and the flow of water. Consequently, this requires a clear picture of the overall hydrological system including rivers, tributaries, other water courses, ravines, wetlands, irrigated land, lakes and coastal areas. Water resources also include subsurface water such as mountain springs, and coastal waters encompassed by a ridge-to-reef approach. [2]

A watershed plan should also describe the overall character of the watershed, provide analysis, and define actions, participants and resources needed to implement the plan. This includes special attention to local land use patterns and the impact of local populations. As a corollary, a watershed approach views the local populations as critical stakeholders in watershed management. Therefore, this requires information on the social and cultural milieu, land use, production systems and governance. It also includes description of geo-physical characteristics including slope, rainfall, soil, land cover and biodiversity.

Sequence. The chapters that follow provide summary description of bio-physical and socio-economic aspects of the Matheux watersheds including hydrology, land use and agro-ecological zones.[3] The description also identifies risks, assets and opportunities for watershed management. Finally, the Plan identifies priorities and actions to address these issues, and mechanisms for Plan implementation including governance.

[2] See CIAT (May 2011, pp 6-8), PNUD (pp 10) and Section 2.1 of EPA handbook on watershed management (2008).

[3] Unless otherwise noted, the primary sources for bio-physical and socio-economic descriptions of the area are drawn from baseline studies undertaken by WINNER (Jean, November 2010) and DEED (Pierre *et al*, April 2008).

II. THE MATHEUX (ST MARC) CORRIDOR

Planning area. Defining the limits of a watershed is the quintessential parameter for diagnosis and planning including administrative jurisdictions and geo-physical characteristics. The Matheux corridor lies along a northwest-southeast axis between the high ridge of the Chaîne des Matheux and the Arcadins seacoast of the Bay of Gonave. At its end points, the corridor extends some 60 kilometers from the peninsula of Cap St. Marc to the Cul de Sac Plain, averaging around 25 kilometers in width. The Matheux corridor covers an area of some 1,500 square kilometers. See map below showing the Matheux corridor.[4]

Figure 1. The Matheux and other development corridors in Haiti

Administrative Jurisdictions

Administratively, the Matheux corridor includes portions of two *départements*, five *communes*, 16 *sections communales* and two *quartiers*. Jurisdictions of the Matheux corridor are shown on the Figure 2 map of municipal jurisdictions. These jurisdictions are summarized in Table 1 below. Note that the urbanized *quartier* of Montrouis (St. Marc) is not located within the Arcahaie communal section that carries the same name, and the Cabaret and Arcahaie communes

[4] The Matheux is a strategic zone or "corridor" identified by USAID as a geographic target for funding watershed management activities in partnership with the Haitian government (USG, January 2011).

both have communal sections called Boucassin. Most of the corridor falls within the communes of Arcahaie, Cabaret and portions of three populous communal sections of St. Marc. It also includes portions of two high elevation communal sections of Verrettes (4eme Désarmes, 6eme Terre Nette).

Figure 2. Municipal jurisdictions in the Matheux corridor between Cabaret and Montrouis

Table 1. Administrative jurisdictions of the Matheux Corridor

Département	***Ouest***			***Artibonite***	
Commune	Cabaret	Arcahaie	Croix des Bouquets	Saint-Marc	Verrettes
Section Communale	1ère Boucassin	1ère Boucassin	10ème des Orangers	1ère Délugé	4ème Désarmes
	2ème Boucassin	2ème des Vases		2ème Bois Neuf	6ème Terre Nette
	4ème Fond des Blancs	5ème Délices		3ème Goyavier	
	9ème Source Matelas	6ème des Matheux		Quartier de Montrouis	
		7ème Fond Baptiste			
		8ème Montrouis			
		Quartier de Saintard			

Local governance is the front line for implementing watershed plans including zoning and other tools of watershed management; however, watersheds are geographic areas that do not coincide with local jurisdictions of government. In the Matheux corridor, the sheer number of jurisdictions complicates the task of watershed and land use management. This situation requires inter-communal agreements and collaboration in order to plan and implement a watershed management plan that cuts across the borders of several communes.

Population. The Matheux corridor includes an estimated population of 291,819 which is 41% urban including significant portions of several highly urbanized communal sections (see Table 2 below). Cabaret has a higher rate of urbanization (58%) than other jurisdictions. The portions of three St. Marc communal sections that fall within in the corridor are quite densely populated due in large part to the urbanized character of the Quartier of Montrouis.

Table 2. Population of communes and partial communes within the Matheux corridor

Commune	**Urban**	**Rural**	**Total**
Ouest			
Cabaret	36,120	25,943	62,063
Arcahaie	47,608	70,893	118,501
Croix des Bouquets	--	9,525	9,525
Artibonite			
Saint-Marc	36,161	52,904*	89,065
Verrettes	--	12,665*	12,665
Total	119,889	171,930	291,819

SOURCE: IHSI (2009) projections of 2003 census data by commune and communal section.
*Estimates here include partial communal sections that fall with the Matheux corridor; however, IHSI projections are available for entire communal sections only. .

Bio-Physical Overview

The Matheux region is characterized by a varied and steeply sloped topography. Slope in the area varies from 0 to 60 percent. Elevation of the Matheux range is generally 900 to 1,000 meters with high points attaining 1,200 to 1,580 meters. On the southeasterly and leeward side of the prevailing winds, the high ridge drops rapidly to the Arcadins coastline which runs parallel to the mountains. The area's diverse topography includes two lowland plains (Arcahaie, Pierre Payen), sharply defined gorges and mid-range slopes (Ti Bois, Piâtre, Ivoire), valleys (Vallée de Valodon) and cool mountains at higher elevations (Léger, Fond-Baptiste).

Climate. At lower altitudes the Matheux area is characterized by a semi-arid clime averaging less than 1,000 millimeters of annual rainfall; however, rainfall along the high mountain ridge may be as much as 1,500-2000 millimeters. The average temperature is 28 degrees Celsius. Humid high mountain zones such as Léger, Goyavier, Cuyo and Fond-Baptiste have cooler temperatures. The temperature tends to decline with altitude, dropping an average of 0.75 degrees for each 100 meters of increased elevation.[5]

Seasons. The Matheux area is marked by two major seasons, a May-October rainy season and a November-April dry season. In the humid mountains of Léger and Fond-Baptiste, the rainy season tends to last longer, beginning in March and ending in December. In recent years rainfall has tended to shift due to the heightened frequency of tropical storms such as hurricanes Hannah and Ike (2008) and a tendency for prolonged dry seasons, patterns generally associated with climate change.

Soils. The map in Figure 3 below classifies soils in the Arcahaie-Montrouis area along a continuum from excellent to very limited potential. This technical classification indicates that a majority of soils in the region have limited production potential.[6] Alluvial and basaltic soils in mid to high elevations tend to crumble readily when exposed and are therefore highly erodible on slopes.

The range of soils includes recent alluvial deposits as deep as 4-5 meters in some areas including ravines, alluvial fans and riparian areas near the coast. There are also much older alluvial formations consisting of small pebbles in sedimentary sand or clay. Due to the gravelly texture, the older alluvial soils tend to limit root depth.

Colluvial soils in piedmont areas include sandy and clay loams with variable gravel content. These soils may attain a meter or more in depth, retain water and have good agricultural value. Their moist micro-climate lends itself to plantain production.

Some areas have marl outcroppings promoting surface runoff and gullies. Other soils include sandstone formations, basalt and chalky limestone soils (Ti Bois and Bois d'Orme). Lateritic formations in the upper watershed include red clay trapped in limestone formations of Fond-Baptiste and Léger, also to some extent in Bois d'Orme, Capoul and Ti Bois.

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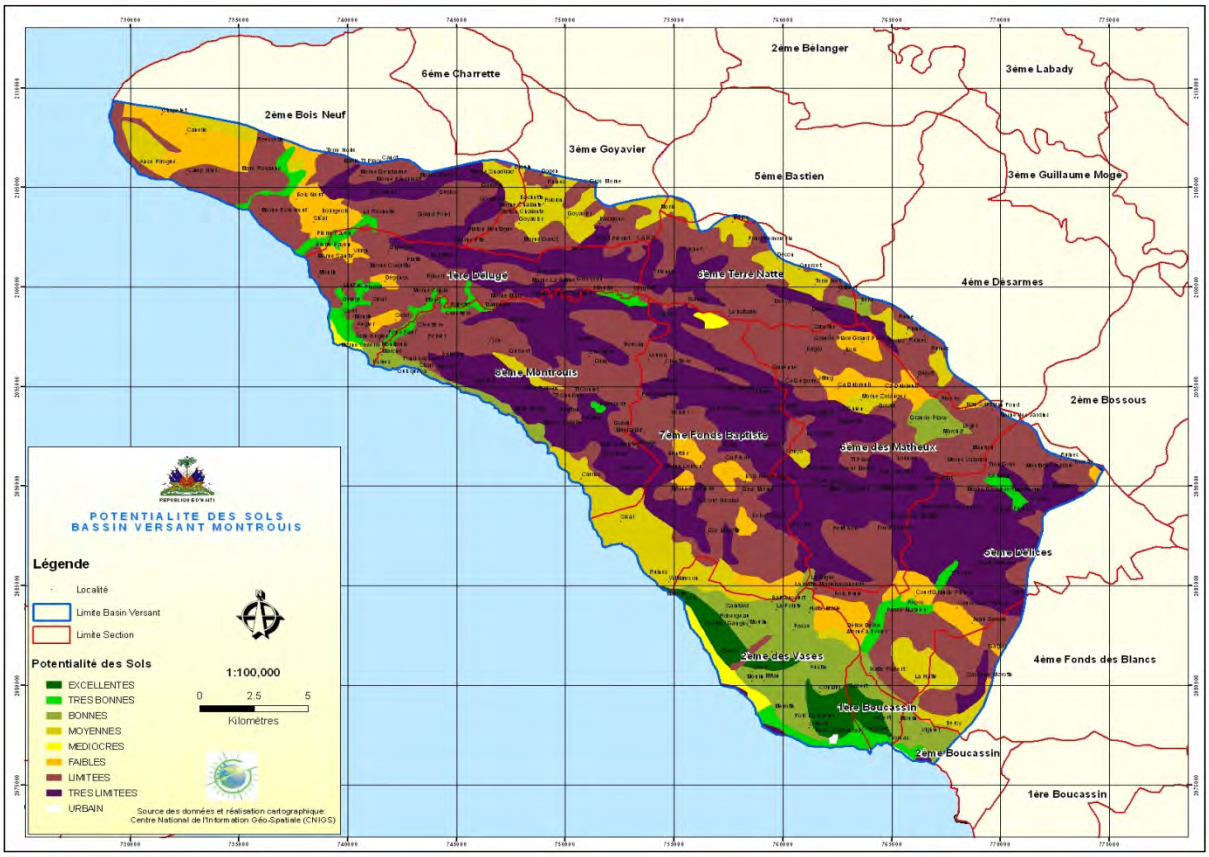
[5] See Pierre (2008, 32) for pluvial data and temperatures. Rainfall data cited are not current and may be shifting due to climate change.

[6] Pierre et al (2008, 42). See map entitled, Potentialité des sols bassin versant Montrouis (CNIGS)

Figure 3. Soil potential in the area of Arcahaie and Montrouis



Slope and risk. Over 60 percent of the Matheux corridor is comprised of 30-60 percent slopes. These upland areas include portions of the communal sections 1e Délugé, 2e Bois Neuf, 3e Goyavier, 8e Montrouis, 6e des Matheux, 7e Fond-Baptiste, 5e Délices, 6e Terre Nette, 4e Fond des Blancs and 10e des Orangers. Slopes under 30 percent comprise less than a third of the land area including coastal areas of Bois Neuf, Délugé, 1e Boucassin (Arcahaie), 1e and 2e Boucassin (Cabaret), 2e des Vases and 9e Source Matelas.

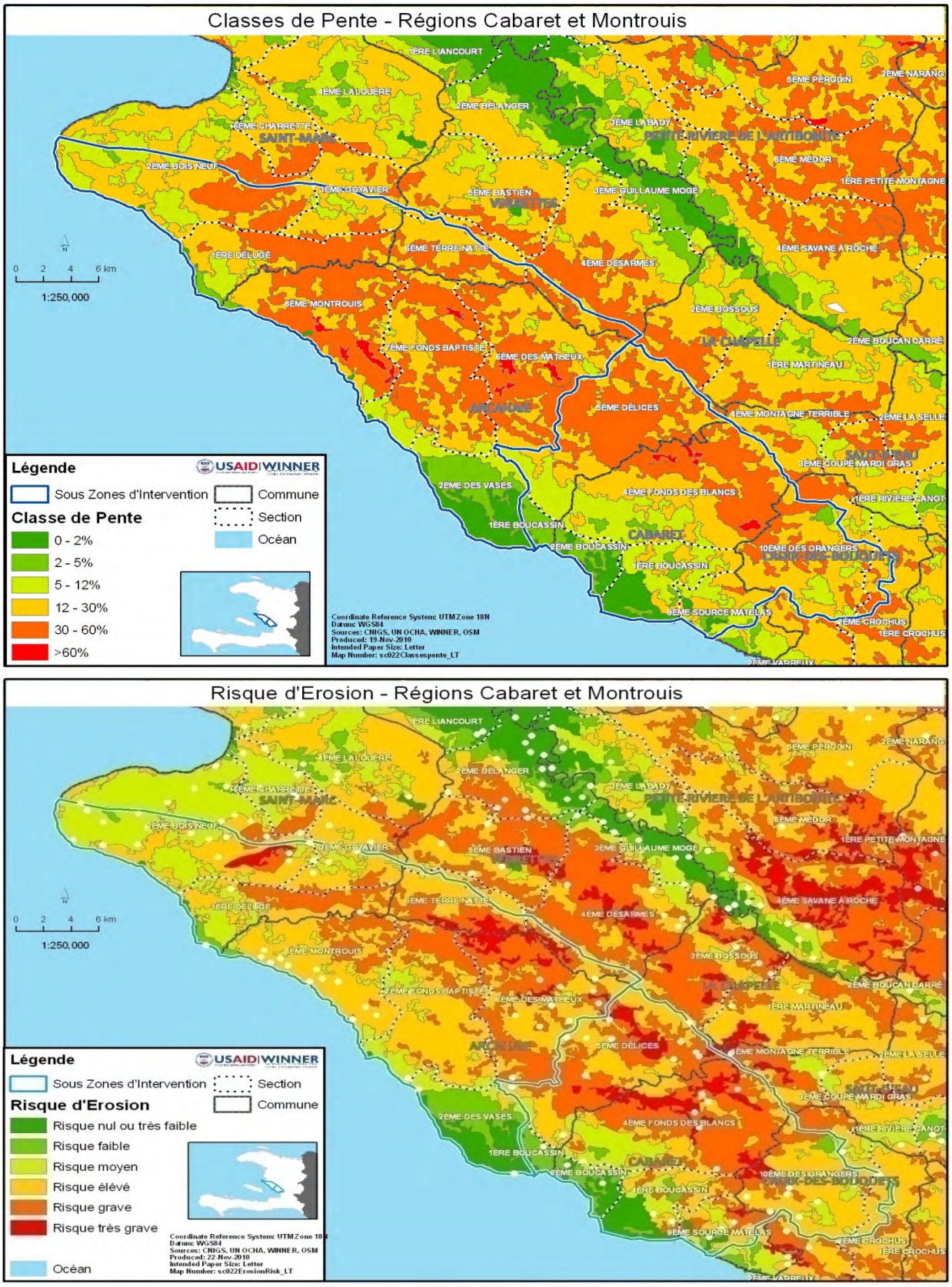
Side by side comparison of slope and erosion risk maps demonstrates that areas of high risk for erosion closely track land forms marked by steep slopes. See slope and erosion maps in Figure 4 below. The predominance of steep slopes is a high risk factor for soil and water erosion in the area, particularly on unprotected slopes lacking permanent vegetative cover. As shown on the map below, more than 85 percent of the Matheux corridor is characterized by high levels of erosion risk.

Risk related to cultivation on slopes is a central element of the Rural Code of 1962. According to the Code, agriculture without protective structures is only allowed on 5 to 10 degree slopes (Article 70). The Code forbids cultivation of annual crops on slopes surpassing 25 degrees in

high rainfall zones (Article 69). It is forbids land clearing on slopes surpassing 30 degrees in arid zones, 40 degrees in semi-arid zones, and 50 degrees in rainy zones (see Article 63).[7] These standards are not reflected in the prevailing patterns of land use and land cover.

[7] Code Rural Dr. François Duvalier, May 16, 1962.

Figure 4. Slope Categories and erosion risk in the Cabaret-Montrouis area



Protection of Natural Areas

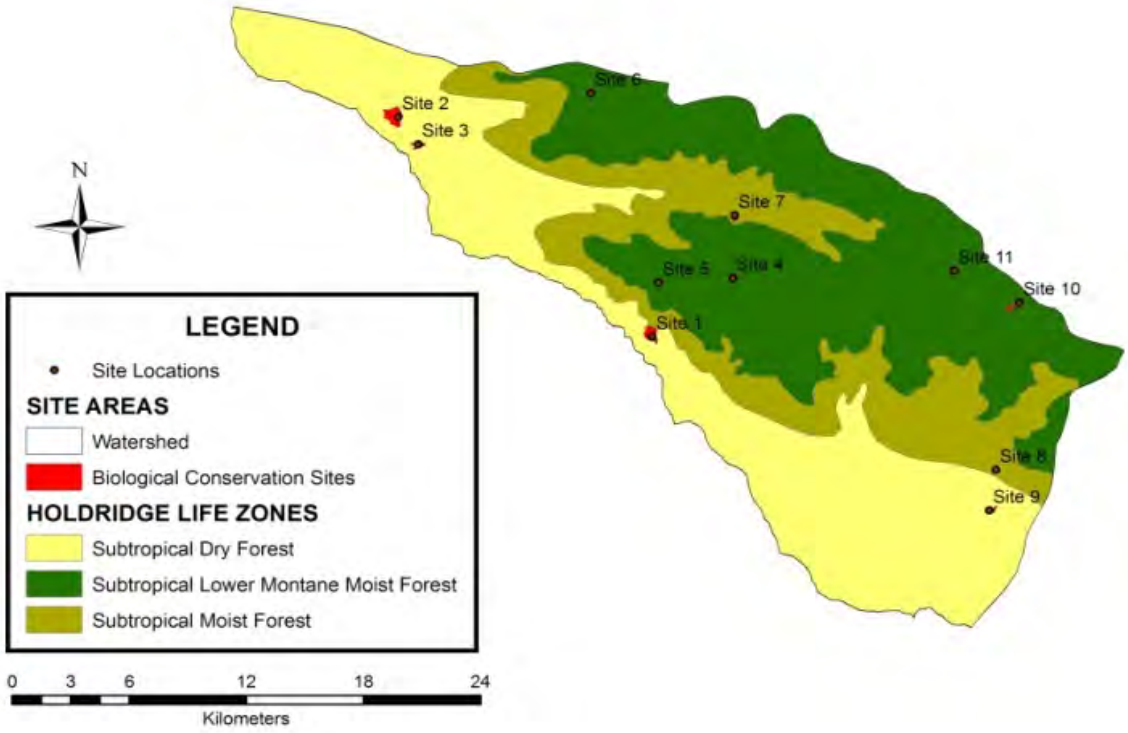
Watershed planning includes protection of natural areas and biodiversity. Specialists in biodiversity have identified a series of significant terrestrial and maritime sites of significant biological interest for conservation.

Terrestrial sites. In 2008, Timyan identified and ranked 11 prospective biological conservation sites in terrestrial areas of Montrouis (St. Marc) and Arcahaie. See the Figure 5 map and accompanying Table 3 below which ranks the sites in order of importance. Three of the sites are publicly owned, one is owned by an institution (Benedictines) and the others are located on privately held land, commonly undivided family inheritance land.

The Timyan assessment ranked each biological site according to its value as a provider of ecosystem services and products including clean water, native species biodiversity and natural buffers to mitigate flooding, erosion and landslides, and prospective economic benefits such as livelihood. The ranking also took into account threats such as fire, disturbance due to agricultural use and grazing, invasive plants and animals, landslides and insecure land tenure.

Ranking of 11 biological sites identified for the area of Montrouis-Arcahaie area is summarized in Table 3 below. The top ranked site is the Etang Bois Neuf (Délugé/St. Marc), a sizeable freshwater lake. This 64 hectare lake includes a significant diversity of waterfowl, aquatic vegetation (*Typhus domingensis*, *Juncus* spp.) and endemic fish, amphibians and reptiles. The lake is fed by the Roseau River and upstream marshes converted to irrigation. The highest threats to Etang Bois Neuf are uncontrolled lake access, over-fishing and hunting; the presence of invasive species such as tilapia, siltation and eutrophication from fertilizers on irrigated lands.

Figure 5. Proposed biological conservation sites by life zone in Montrouis-Arcahaie



SOURCE: Timyan (2008, 5). For life zones see Holdridge (1972). This study only covered the area of Montrouis (St. Marc) and Arcahaie and therefore does not include the Cabaret portion of the corridor.

Maritime Protected Area. See Figure 6 below for a proposed Arcadins Marine Park to ensure protection of endangered species, mangroves, sea grasses and fishing habitat in coastal and maritime areas of the Matheux corridor. The proposed marine park was recommended in a recent national assessment undertaken by Jean Wiener (August 2013).[8] The area of some 78,600 hectares includes the Arcadins coastline, three tiny Arcadins islands and the Arcadins Bank (reefs). It includes mangroves, coral reefs, sea grasses and protected species.

Wiener estimates the annual value of ecosystem services provided by 475 hectares of mangroves in the area to be 200,000 dollars (USD) plus an additional 60,000 thousand dollars for ecosystem services provided by 4,700 hectares of coral reefs. For further detail on the current condition of these resources, see the section on Coastal Waters in the next chapter, which summarizes hydrology resources of the Matheux corridor.

[8] Wiener (2013), Toward the Development of Haiti's System of Marine Protected Areas: An Ecosystem Services Assessment for the Creation of Haiti's System of MPAs.

Table 3. Prioritization of biological conservation sites in the Montrouis area based on biological importance and threat levels

RANK	SITE NO.	NAME	OWNER	WATERSHED
1	2	L'Etang Bois Neuf	L'Etat d'Haiti	Montrouis
2	1	Monastère St. Benedictin	Monastère St. Benedictin	Montrouis
3	10	Nan Montagne	Altius Potine & Desius Dorvilus	Montrouis
4	6	Pic Bachette	L'Etat d'Haiti	Montrouis
5	4	Fond-Baptiste	St. Félix family	Montrouis
6	5	Guibert	Negot Duvelsaint	Montrouis
7	11	Mansou	Cidoine family & Antoine Dorvilus	Montrouis
8	9	Jean Dumas	Fadaël Rosilus	Montrouis
9	8	Tête Source	L'Etat d'Haiti	Montrouis
10	3	Pierre Payen	Jean Michaud family	Montrouis
11	7	La Colline	Elfab Joseph	Montrouis

SOURCE: Adapted from Timyan (2008, 25, Table 1). Site numbers are also shown on Figure 6 map.

Figure 6. Proposed Arcadins Marine Park including coral (red) and mangroves (green)

SOURCE: Wiener (2013, 22).

Protection of Historical-Cultural Resources

In 1789 the colony of Saint-Domingue produced 77 million pounds of coffee, 40% of world coffee production.[9] The humid highlands of the Matheux were one of four major coffee producing zones in colonial Saint-Domingue. CIAT has recently inventoried the ruins of some 28 colonial era coffee plantations along a line clearly defined by the high ridge of the Matheux range. See the map in Figure 7 below which locates these sites at intervals of one to five kilometers along a narrow colonial roadway leading to Saint-Marc along the Matheux ridge. These and other ruins in the Matheux merit recognition as national heritage sites. They include the immense ruins of the Lamothe coffee plantation shown in Figure 8 as well as a chain of forts including Ft. Guibert, Ft. Dèlpêche and Ft. Drouet (Figure 9).

The numerous ruins are an important historical and cultural resource. Their presence points to salient issues for current watershed planning. For example, the ruins today are a potential resource for historical tourism. The high ridge setting for these ruins also offers dramatic panoramic views of the Artibonite Valley, the Arcadins coast, Gonave Bay and the island of La Gonave. The cultural sites should be zoned or set aside as protected areas, each with a simple, site-specific management plan governing use and assuring protection. This would also help to protect the upper reaches of Matheux watersheds.

Secondly, then as now, water was scarce in highland areas of the Matheux. Coffee plantations addressed water shortage by collecting rainwater from impluvia and coffee drying floors (*glasi*). This technology could be restored or replicated as a solution to the longstanding problem of a shortage of water for households in these highland areas. Expanding highland structures for water harvest would also tend to decrease erosion risk.

Thirdly, the decline of coffee and related shade cover over time has tended to expand erosion risk. Nevertheless, the area has a proven capacity for high value coffee and tree production. Therefore, a watershed plan should prioritize the promotion of high mountain areas along the crest for expanded coffee and tree production as sustainable, high value perennial crops.

[9] Elie, Daniel. 2012. Matheux: La Route du Café. Comité National ICOMOS-Haïti.

Figure 7. Ruins of colonial coffee plantations along the Matheux ridge

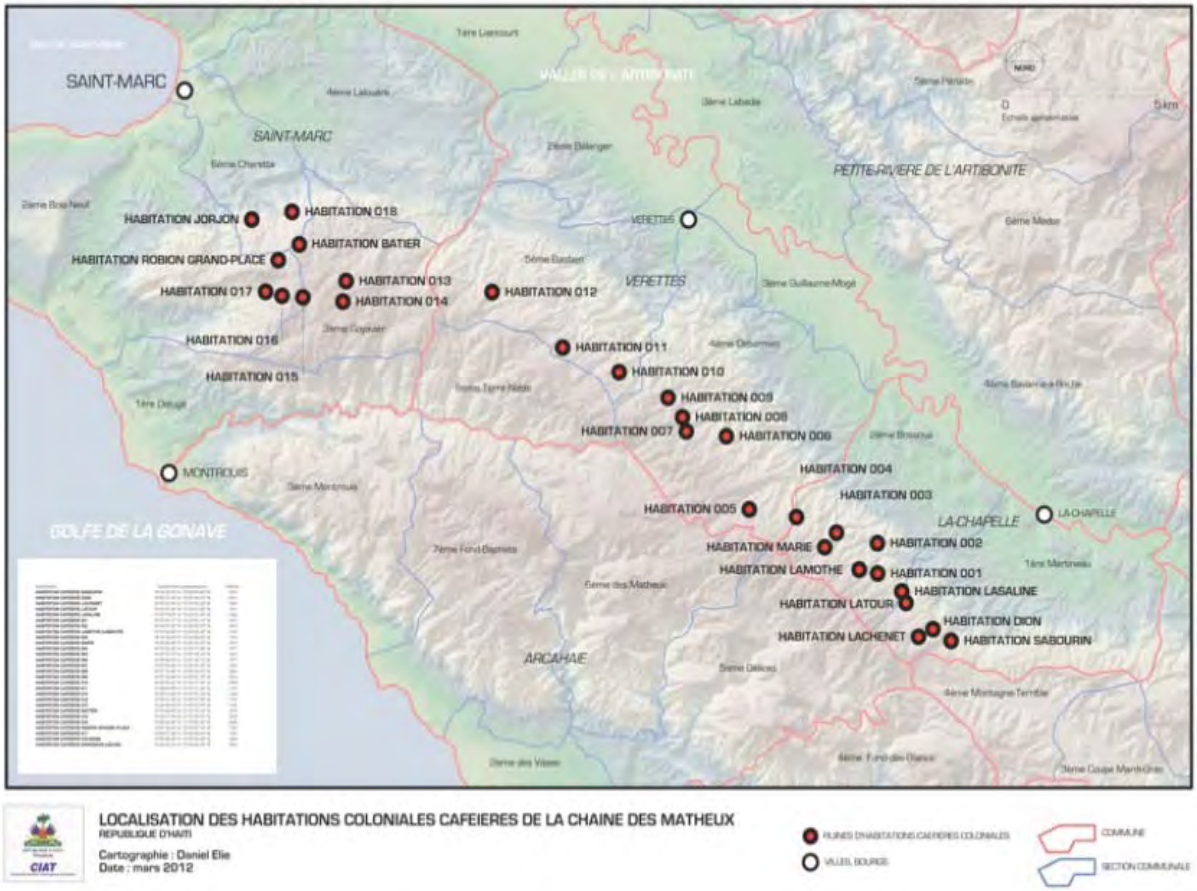


Figure 8. Historic ruins of a colonial coffee plantation at Lamothe on the Matheux ridge

SOURCE: Daniel Elie PPT presentation, September 25, 2012, Club Indigo, Montrouis.

Figure 9. Historic ruins of Ft. Drouet on the Matheux ridge

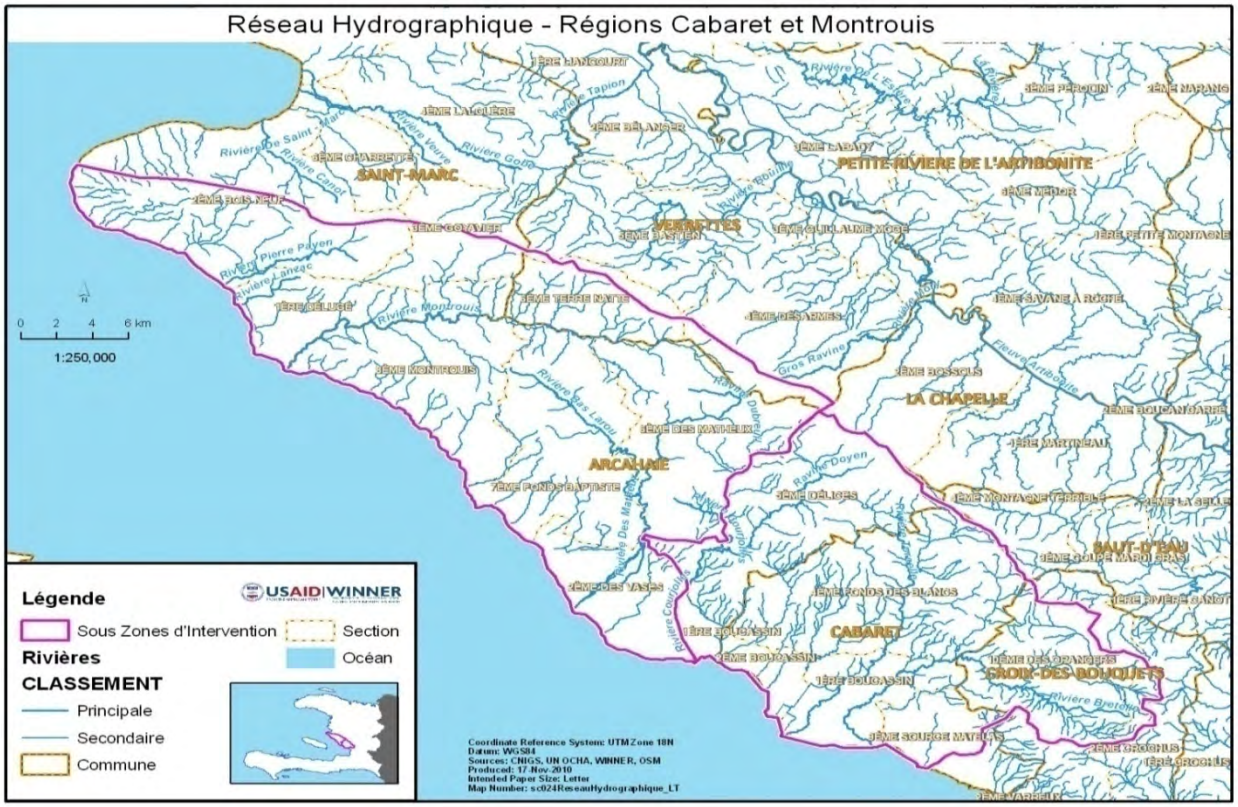
III. HYDROLOGY OF THE MATHEUX

As noted earlier, watersheds are defined first and foremost by the flow of water. See Figure 10 below for the region's network of water courses and major ravines, and Figure 11 for seven major watersheds of the Matheux.

Multiple Watersheds

The Matheux corridor is readily definable as a hydrological zone, but it is not a single watershed. Rather, it is composed of several distinct watersheds with headwaters on the upland slopes of the Matheux range and downstream outlets that flow into Gonave Bay. Given the close proximity of the Matheux range to the coastline, water courses to the sea are numerous but relatively short in length. This configuration lends itself to a ridge-to-reef approach to watershed planning. To some extent, commune borders run parallel to the major watersheds and their ridge to reef configuration. This helps to facilitate watershed planning by communes and communal sections.

Figure 10. Hydrographic network in the Matheux corridor



The corridor's hydrological system includes seven major rivers and sizeable tributaries that flow into these rivers, irrigation perimeters, large ravines with only intermittent or seasonal water flow, numerous smaller water courses, mountain springs, numerous ravines in piedmont and highland slopes, and also river embouchures and coastal waters.

Lakes and wetlands. The hydrology of the zone also features a prominent freshwater lake noted earlier, the Étang Bois Neuf (St. Marc). The Étang Bois Neuf is fed by the nearby spring Source Gadè. The commune of Cabaret includes the lake of Latanier. The high mountain locality of Léger includes a number of small ponds. Such small ponds are sometimes used for water cress or small scale rice production.

Priority Watersheds. In terms of priorities for watershed planning, there are seven major river based watersheds and three sizeable tributaries of note: Pierre Payen, Lanzac, Montrouis, Matheux (including the major tributaries of Ravine Dubreuil and Rivière Bas Larou), Courjolle along with Ravine Doyen as a major tributary, and the Torcelle and Bretelle rivers. These watersheds are clearly identified on the Figure 11 map.

Figure 11. Seven major watersheds of the Matheux corridor

The seven major watersheds vary greatly in size. See Table 4 below for watershed drainage areas: the smallest is the Lanzac watershed (521 hectares) and the largest is Montrouis (16,112 hectares). All have a characteristic shape with broad upland water collection areas draining into a narrow outlet to the sea. In all cases, the river basins in coastal areas include irrigation works located in flood plains.

Table 4. Area drained by seven priority watersheds of the Matheux

Watershed Rivers	Area in hectares
Pierre Payen	2,706
Lanzac	521
Montrouis	16,112
Matheux	7,273
Courjolles	8,256
Torcelle	7,510
Bretelle	9,808

SOURCE: Emmanuel Pierre (GIS based analysis, WINNER, 2013)

Springs

Table 5 below provides an inventory of springs in a number of upland localities of the Matheux. Mountain springs are an issue of special concern to local residents due to their importance as a source of water for household use. There is a higher concentration of springs in the communal section of Fond-Baptiste, an area marked by higher levels of rainfall and somewhat more efficient infiltration than other areas.

In areas with fewer springs, local populations lack access to water for household use and may carry water several kilometers over steep mountain paths. Areas with few springs and a shortage of water include highland communal sections of Terre Nette, Goyavier, 5e Délices and 6e Matheux. These highlands are an agro-ecological zone with high rainfall but few mountain springs. The highland ridge has long been characterized by water shortages for domestic use. The area coincides with colonial era coffee plantations and the remnants of water collection and storage structures noted earlier in the section on historical resources.

Watershed stakeholders in the September 2013 workshop identified water as a high priority for protection and further development, including the capping of mountain springs (see Annex II).[10] The stakeholders identified springs as a valuable natural resource and listed over 50 springs in Fond-Baptiste, Goyavier, Délices, 6ème Matheux and Fond des Blancs (Casale).

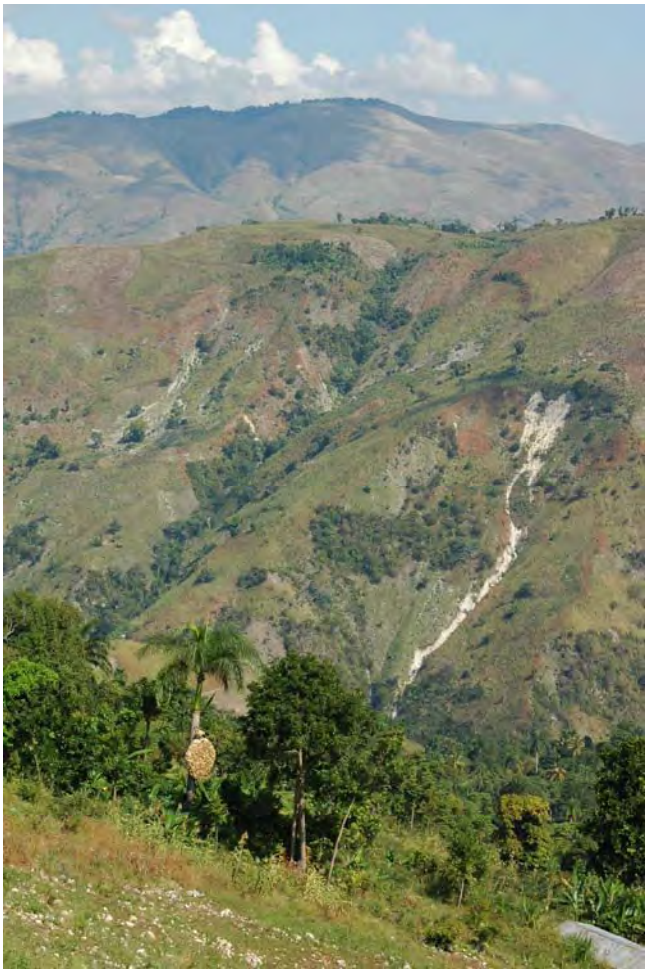
[10] September 25-26, 2013, Atelier d'appui au projet de plan d'aménagement, Chaîne de Matheux, Côte des Arcadins, Club Indigo, Montrouis, USAID/Feed the Future West/WINNER.

Table 5. An inventory of springs by locality*

Locality	Ti Bois	Léger	Digue Matheux	Ivoire	Fond-Baptiste	Piâtre
Springs	7	26	> 3	> 7	15	> 11

SOURCE: DEED baseline study (F. Pierre *et al* 2008, 50).
* This is an illustrative inventory and does not cover all areas of the Matheux
.

Ravines



Numerous ravines on the slopes of the Matheux range and piedmont concentrate surface runoff from the rains while eroding the landscape on steep slopes. Local populations may identify large ravines as a type of public space belonging to no one in particular whereas smaller ravines are more clearly defined as private property belonging to individuals, families or a small number of neighboring landholders. This distinction has important implications for watershed protection: (i) ravine management for flood and erosion control, especially for larger ravines which lend themselves to public works projects, and (ii) smaller, privately held, humid ravines producing high value crops such as plantains.

Table 6 below identifies a series of high priority ravines for conservation treatment to increase infiltration and reduce erosion and downstream flooding. Watershed stakeholders at the September 2013 workshop in Montrouis identified ravines as a significant threat and listed over 100 ravines as high risk priorities for treatment in Fond des Blancs, Fond-Baptiste, Goyavier, Délices, 6ème Matheux, Pierre Payen, Bois Neuf and Délugé.

Table 6. High priority ravines for protective interventions

Communal Section	Ravines
1e Boucassin	Ravine Torcelle
2e Boucassin	Ravine Thomas
4e Fonds blanc	Ravine Dessables, Ravine Gros Trou
9e Source Matelas	Ravines Source Matelas
3e des Vases	Ravine Mitan
5e Délices	Ravine Gros Bassin, Ravine Doyen,
6e des Matheux	Ravine Dubreuil, Ravine la Couline, Ravine Degol,
8e Montrouis	Ravine Bambou, Ravine la Plaine, Ravine Latanier, Ravine Lacombe, Ravine Sibasse, Ravine Rousseau, Ravine Sèche
2e Bois Neuf	Ravine Canelle, Ravine Cannini, Ravine Sèche, Ravine Chapelet, Ravine Bois Neuf,
1e Délugé	Ravine Montrouis, Ravine Saut d'Eau, Ravine Colas, Ravine Mars, Ravine Source
3e Goyavier	Ravine Montagne

SOURCE: WINNER baseline study (Jean 2010, 18).

Irrigation Perimeters

Table 7 below lists the principal irrigation perimeters of the Matheux lowlands. Irrigation works are a high value asset of the corridor. They are concentrated in the lowlands and coastal plains of the corridor. Some irrigation perimeters are plagued by land tenure conflict, for example, Délugé and Lanzac. From a watershed perspective, these irrigation systems are a special category of micro-catchment or sub-watershed. For example, Figure 12 shows the Dupin perimeter in a watershed context, including the upland Doco spring that supplies water to the system.

The Matheux irrigation perimeters are chronically at risk of flooding and a high priority for risk management strategies. Risk mitigation measures required for irrigation works include upstream investment in erosion control, and downstream investment in drainage, riverbank protection and maintenance of water distribution systems.

Figure 13 shows a cluster of smaller perimeters near Montrouis in the northern tier of the Matheux corridor. Nevertheless, perimeters linked to the Matheux and Courjolles Rivers (Arcahaie) in the southern tier are by far the largest irrigation systems in the Matheux corridor, followed by irrigation systems dependent on the Torcelle and Bretelle Rivers of Cabaret.

The Figure 14 maps show irrigation systems and flood plains for lowland areas of the Matheux corridor. Juxtaposition of the two maps demonstrates the intimate correlation between irrigation works and the region's principal flood plains. The irrigation systems also coincide with outlets to the sea for the seven major watersheds shown earlier (Figure 11).

Table 7. Principal irrigation perimeters of the Matheux corridor

Perimeter Site	Area (hectares)	Water Source
2e des Vases & 1e Boucassin (Arcahaie), 1e Boucassin (Cabaret)	6,000	Matheux and Courjolle rivers (Arcahaie), Torcelle and Bretelle rivers (Cabaret)
Délugé	260	Morne Cajean (Source Piâtre)
Montrouis	284	Montrouis River
Lanzac	78	Source Piâtre
Pierre Payen	137	Pierre Payen River
Bois Neuf	231	Pierre Payen River
Dupin	138	Source Doco
Piâtre	370	Source Piâtre, Source Perrier

SOURCE: WINNER baseline study (Jean 2010, 14), V. Joseph (DEED, 2008) and the DEED baseline study (Pierre 2008).

Figure 12. Spring fed Dupin irrigation perimeter near the freshwater lake of Bois Neuf

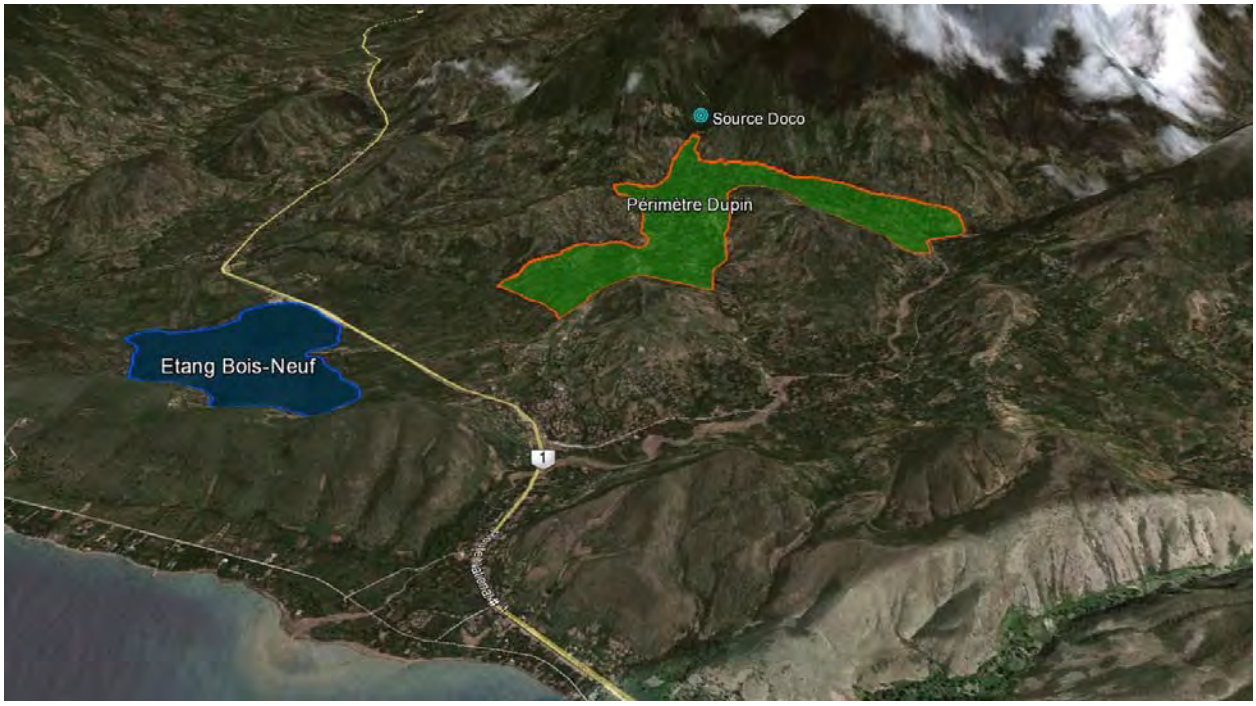


Figure 13. Spatial distribution of small irrigated perimeters in the Montrouis area

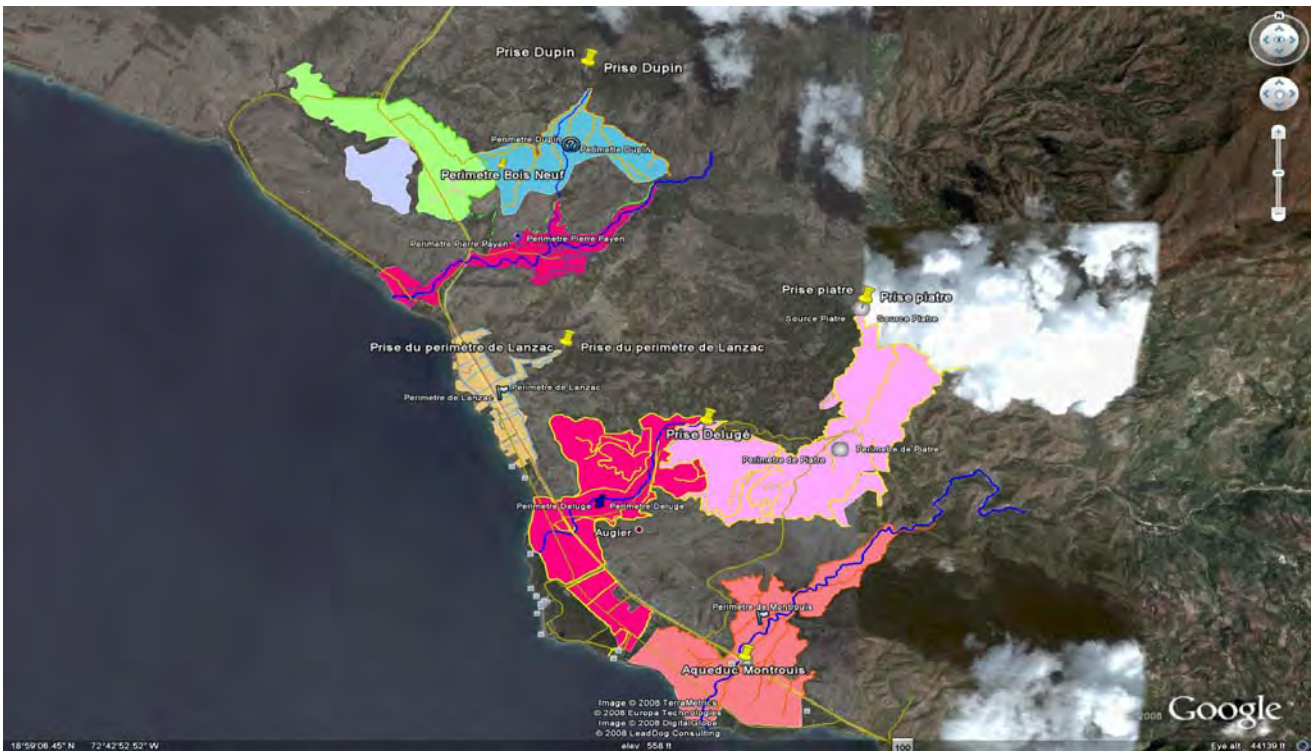
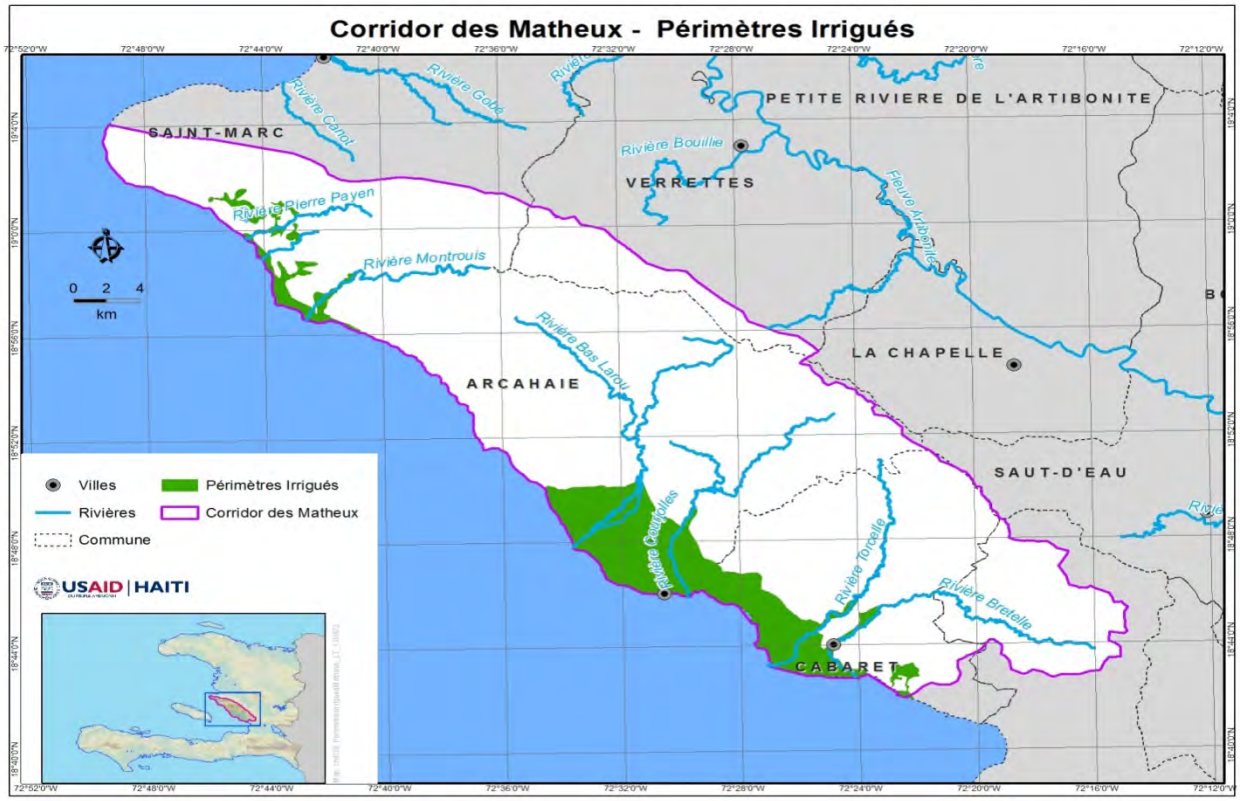
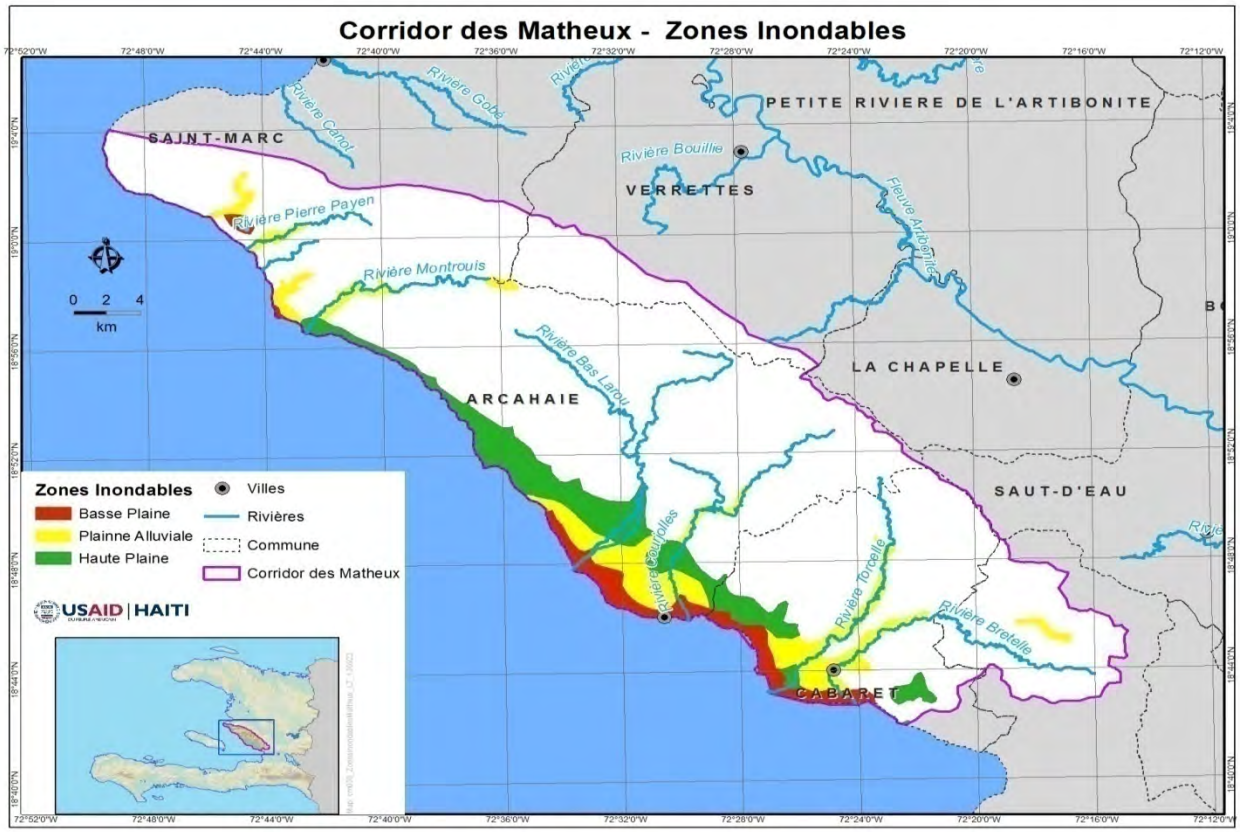


Figure 14. Comparison of Matheux irrigation perimeters and flood plains





Coastal Waters

Biologist Wilson Celestin (2013) noted that Haiti is virtually the only Caribbean nation whose economic development is not oriented to the sea and maritime resources.[11] He further noted that Haiti has significant tourism potential similar to neighboring island countries; however, the development of tourism is unlikely without greater efforts at sustainable resource management, especially coastal waters and the sea.

Tourism. The area from Luly to Montrouis has the largest concentration of hotels of any coastal area in Haiti. Six of the hotels are members of an association of Arcadins hotels. The most significant stretch of sand along the Arcadins coast is 1,500 yards of sandy beach at Club Indigo near the village of Montrouis (Jean 2008).

Coastal resources and risks. An area recently proposed as a Marine Protected Area was shown earlier (Figure 6).[12] The area proposed for protection is directly affected by heavy siltation generated by three of the seven priority watersheds shown earlier: Montrouis, Matheux and Courjolles (see Figures 15 and 16 showing the Matheux and Montrouis rivers).

Endangered species in the area include elkhorn coral, manatees and five species of sea turtles. Mangroves are under threat from agricultural encroachment and the harvest of fuel wood, charcoal production and tannin. Coral reefs are being mined for coral export. The area is overfished, and fisher livelihoods along the coast are increasingly at risk, particularly in Luly.

Mangrove areas of interest along the coast are Bodmè Boula, Mitan and Royale –primarily Red Mangrove (*Rhizophora mangle*), also some Black Mangrove (*Avicennia germinans*) and White Mangrove (*Laguncularia racemosa*). Sea-grasses, mostly *Thalassia testudinum*, are generally in good condition but affected by sedimentation from area rivers.

In sum, primary threats to coastal and maritime resources of the Arcadins are overfishing, unsustainable fuelwood harvest in mangroves, coral harvesting, some near shore sand and gravel mining, marine pollution, invasive species, unsustainable coastal development and the growing effects of climate change.

[11] Presentation by Wilson Celestin at watershed stakeholder workshop, Montrouis, September 25, 2013.
[12] The following discussion of coastal and maritime resources is drawn primarily from Wiener (2008), Assessment of Coastal and Marine Resources along the Arcadins/La Gonâve and Limbé watersheds in Haïti (Coral Reefs, Sea Grasses, Mangroves, and Beaches), and Wiener (2013), Toward the Development of Haiti's System of Marine Protected Areas.

Figure 15. Arcadins coast, Arcahaie plains, Riviere des Matheux (Road to Ti Bois, Arcahaie)

Figure 16. Arcadins coast, Quartier de Montrouis, Rivière de Montrouis (Arcahaie & St. Marc)

IV. LAND USE AND AGRO-ECOLOGICAL ZONES

Land Cover

The following map classifies land cover in terms of the potential for soil erosion and water retention related to different types of land use (Figure 18).[13] This classification is relevant for planning sustainable natural resource management, particularly retention of soil and moisture for sustainable cultivation. Land uses shown include agriculture in flood plains, perennial and annual crops, agroforestry systems and land in fallow.

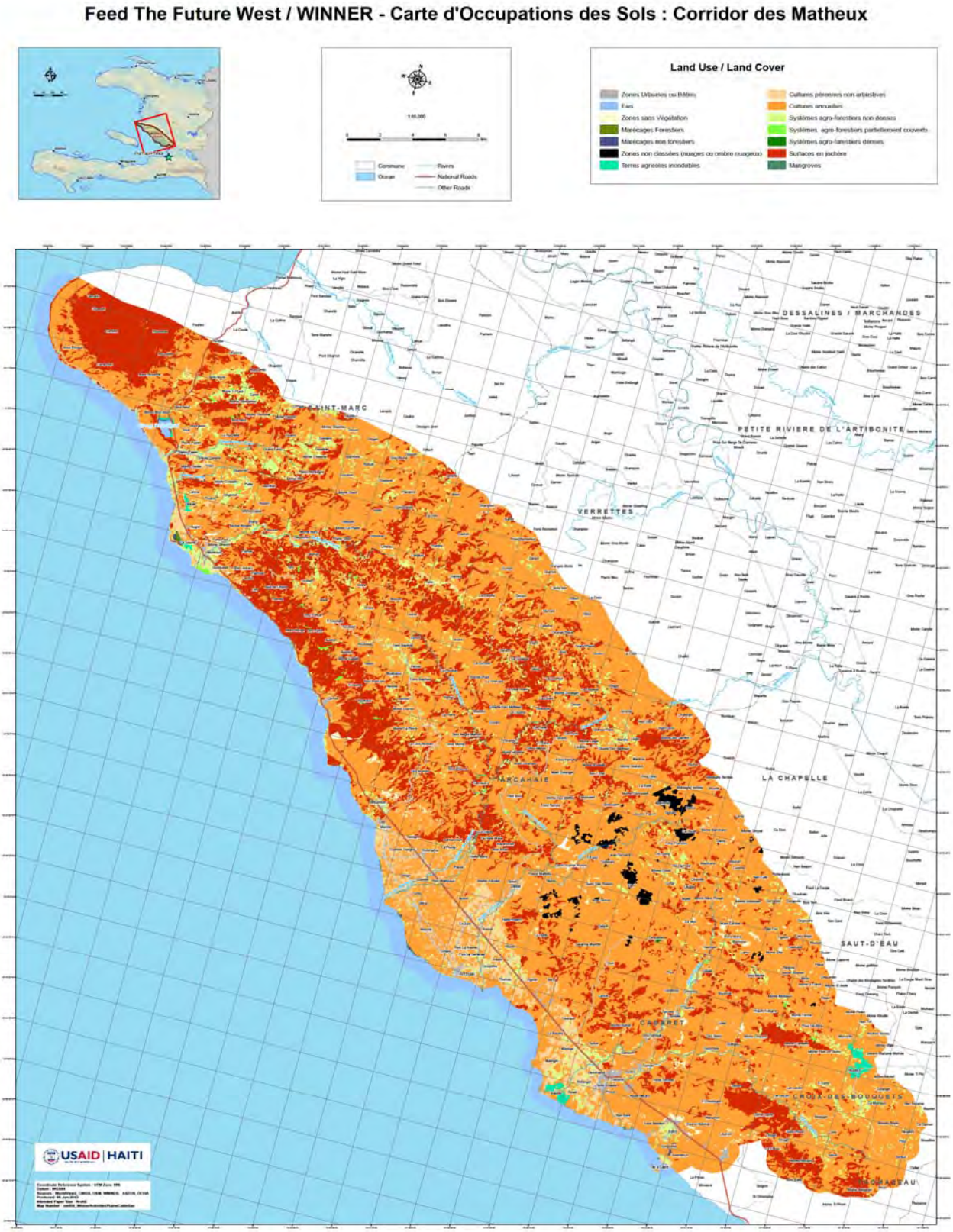
Annual crops are the most common land use shown on the map below. Fallow is the second most common land use shown. The fallow areas tend to be highly degraded and may occasionally be annual cropped when not left in fallow. These areas are also commonly used for grazing livestock especially uncontrolled, open range grazing.

Agroforestry and intensive agriculture are practiced in lowland irrigation systems, narrow strips of riparian land adjoining rivers such as Montrouis and Pierre Payen, piedmont areas such as Piâtre, highland areas of Goyavier, Fond Baptiste and 6e des Matheux, and lowland areas of 1e and 2e Boucassin. There is relatively little land devoted to intensive agroforestry systems. Perhaps 70% percent of the land area is highly degraded.[14] Coastal areas of Délugé, 7e des Matheux and 9e Source Matelas are rocky outcroppings with little or no soil cover. The landscape below shows tree cover related to a house-and-yard compound surrounded by a deforested agricultural landscape devoted primarily to annual crops and fallow (Figure 17).

[13] See White et al (2012, 19-25) for discussion of land use/land cover classification in the Matheux corridor.
[14] Jean (2010, 12).

Figure 17. Agricultural landscape on road to Fond-Baptiste

Figure 18. Land use and land cover in the Matheux Corridor



Agro-Ecological Zones

The classification shown in Figure 19 is based on five agro-ecological zones in the Matheux corridor defined by elevation, slope and crops.[15] Production systems and cultigens include annual crops, grass, bush and tree crops and also livestock. The five agro-ecological zones include sea coastal areas, irrigated plains in lowland areas, semi-arid hills, and dry and humid mountain zones.

Coastal zone. The coastal zone is fairly arid. It includes fishing (Lully, Merotte, Carièce, Bois Neuf, Ravine Sèche, Anse à Pirogue, 87), mangroves and coconuts (Source Matelas and 3e des Vases), grasslands and livestock especially cattle. Sandy soils produce citrus (lime, orange, pomelo (*chadèque*), also pumpkins, pigeon peas, corn, sorghum and especially watermelons.

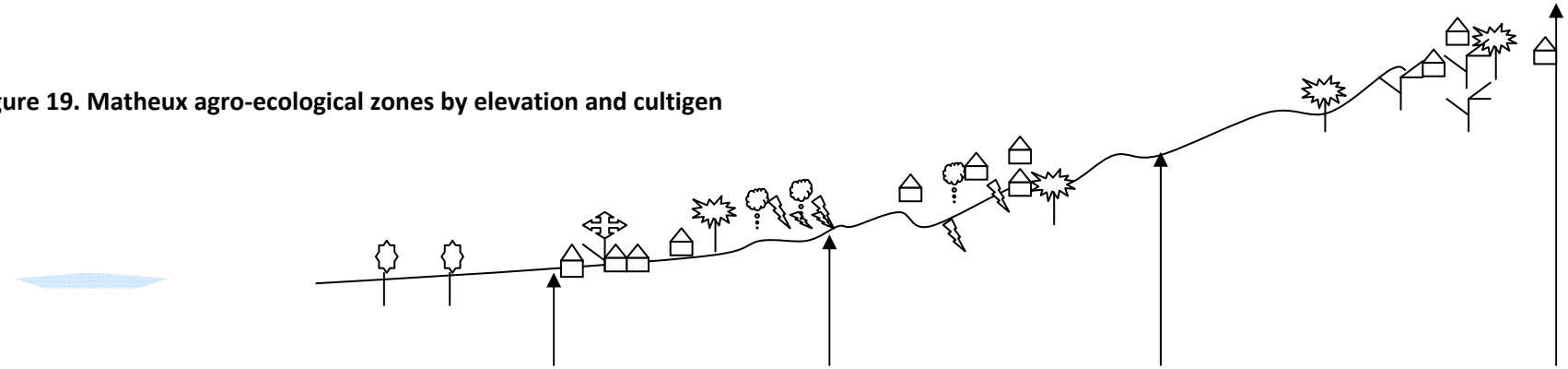
Irrigated plain. As noted earlier, irrigation perimeters cover some 7,000 hectares at lower elevations (5-80 meters) and are a high value asset. The largest irrigation perimeter is in the Arcahaie area. The primary irrigation crops in these clayey soils are plantains, peppers, tomatoes, papaya and eggplant, also beans, corn and manioc, but plantains and bananas are by far the most important especially in Arcahaie.

Semi-arid hills (piedmont). The highly degraded soils of the piedmont (200-700 meters) tend to be sandy clay. The zone produces a range of fruit and hardwood trees including *Prosopis julifora* (mesquite) used for charcoal production, also guava. The zone also includes dry rangeland and livestock, especially goats. The dominant crops are sorghum, corn and beans, and also plantains, especially in humid ravines.

Humid and semi-humid mountains. Aside from lowland irrigation perimeters, the mountainous highlands of Goyavier, 6e Matheux (Léger), Terre Nette and Fond-Baptiste (900-1,600 meters) are the most productive agricultural areas of the Matheux. The clay soils produce a broad range of fruit and hardwood trees. The most important annual crops are beans, corn and congo peas. Beans are a high value cash crop but bean production on unprotected slopes in this highland zone is an important source of erosion. The zone also produces vegetable crops especially cabbage, also yam, i.e., *igname* (*Dioscorea*) and plantains on more humid sites and ravines. The highland zone has proven potential for coffee production and includes coffee groves (Fond-Baptiste), also the ruins of colonial coffee infrastructures as noted earlier.

[15] This typology is derived from a 1999 classification devised by the Coordination Nationale de la Sécurité Alimentaire (CNSA) of the Government of Haiti. Figure 20 is adapted from DEED and WINNER baseline studies (Pierre 2008, Jean 2010).

Figure 19. Matheux agro-ecological zones by elevation and cultigen



Agro-ecological Zones		Coastal Zones	Irrigated Plains	Semi-Arid Slopes	Humid/Semi-Humid Slopes
Altitude		0- 5 m	5- 80 m	200 -700 m	900- 1600 m
Strata	Trees	Mangroves, coconut	Bread fruit, mango, royal palm , Flamboyant, coconut, chêne (*catalpa longissima*)	chêne (*catalpa longissima*), mahogany, acacia, frêne (*Simarouba)*, eucalyptus, coconut, lilas (*melia azedarach*), gommier (*Bursera simaruba*), avocado, trompette (*Cecropia peltata*), mango, royal palm	Sucrin (Inga vera), leucaena, occidental pine, casuarina, chêne (*catalpa longissima*), eucalyptus, bamboo, grevillea, cedar (*cedrela odorata*), capable (Colubrina arborescens, avocatier, tamarin (Tamarindus indica), bread fruit, abricotier
	Shrubs & small trees	Citronnier , chadéquier (*Citrus maxima*), orange	Orange, lime	*Prosopis juliflora*, delin (*Leucaena leucocephala*) , guava, cachiman (*Annona*)	Orange, chadéquier (*Citrus maxima*), lime, guava, cirouelle (*Spondias purpurea*), mortel
	Grasses	Gazon créole	Guinen, chiendent,	Guinen, madan bazin, madan Michel	Guinen, guatemala, elephant, madan bazin
	Practiced	Melon, pois congo, corn, millet	beans, plantain, papaya, pepper, tomato, egg	plantain, corn, millet, taro, mazombel, beans, sweet potato	Beans, corn, pigeon peas , cabbage, *igname* (*discorea*),

Crops			plant, manioc		vegetables, plantain
	Dominant	Melon	plantain, eggplant	Plantain, millet, corn, beans	beans, corn, pigeon peas
Livestock	Encountered	goats, cattle	goats, cattle, horses, swine, poultry	goats, cattle, horses, swine, poultry	goats, cattle, horses, swine, poultry
	Dominant	cattle	Cattle	goats	Cattle
Pedologie	Gravel content	Limited	Very limited	Lilmited to average	average
	Soil type	sandy	clayey	clayey-sandy	Predominantly clay
Sections communales		1e Boucassin, 2e Boucassin, 3e des Vases, Bois Neuf, 9e Source Matelas	1e Boucassin, 2e Boucassin, Montrouis, 3e des Vases, Délugé./Bois Neuf	4e Fonds des Blancs, 9e Source Matelas, 5e Délices, 8e Montrouis	6e Ternette Fond-Baptiste, Goyavier, 6e Matheux, 7e Fonds des Blancs

V. PLANNING PRIORITIES AND OPPORTUNITIES

This chapter identifies priorities and a strategy for watershed interventions and governance in the Matheux. This includes a summary of risks, assets and stakeholder concerns and recommendations (see Annex II). Table 8 at the end of this chapter synthesizes findings and a response strategy and Table 9 summarizes the specific actions recommended to address the watershed management challenges of the different agro-ecological zones of the Matheux corridor.

Watershed Risks

Water is a critical natural resource and the defining element of watershed management. Water is also a significant source of risk and natural disaster. Erosion and flood risk are the dominant themes of watershed planning in the Matheux. Inadequate vegetative cover on steep slopes impedes water infiltration, fosters run-off and causes soil erosion. Erosion upstream contributes to severe flooding downstream.

Normal rainfall tends to be higher in humid upland areas of the Matheux marked by steep slopes. The normal run-off from seasonal rains is presently a high risk factor for natural disaster, especially flooding; however, the risk of severe floods increases exponentially in the wake of severe tropical storms.

Climate change.[16] Increased frequency and severity of tropical storms is an indicator of climate change. The spring and fall rains of 2004 including Tropical Storm Jeanne (September 2004) caused disastrous floods in the Matheux. In 2008 four severe storms struck Haiti within a three week period including Tropical Storm Fay and Hurricane Gustav in August and Tropical Storm Hanna and Hurricane Ike in September. Hurricane Ike inflicted significant devastation and numerous deaths in Cabaret (see Figure 19). In 2012, Hurricane Sandy caused severe flooding in many parts of Haiti including the Matheux coastal zone.[17]

Erosion and flood control structures mitigate the impact of soil erosion on steep slopes, especially for normal seasonal rains; however, the high water volume of severe tropical storms readily overtakes the technical capacity of most upstream conservation measures or downstream flood control structures. Agricultural risk associated with periods of excessive rainfall is further exaggerated by a tendency for extended dry seasons and periods of drought. Changing cycles of rainfall and drought impose a significantly increased risk on rain fed agriculture.

[16] See Leal *et al*, 2009, on climate change issues in Haiti.
[17] See Mike Thompson, "One million homeless' in Haiti," BBC news, Port-au-Prince, http://news.bbc.co.uk/2/hi/americas/7613851.stm and http://news.bbc.co.uk/2/hi/americas/7652075.stm.

Erosion. In the Matheux, the principal causes of vulnerability to erosion are (i) the limited ground cover on steep slopes, (ii) the high proportion of sloped land, and (iii) highly erodible alluvial and basaltic soils on mid and high elevation slopes. Upstream vulnerability is significantly exacerbated by agricultural use of slopes, especially the predominance of annual, weeded crops on unprotected slopes. Farmers and local elected officials point to other common practices that contribute to erosion including tree cutting, the use of fire to clear land and uncontrolled, open range grazing.

Flooding. Stakeholders identify flood risk as the number one environmental concern of lowland urban dwellers and rural agriculturalists. The seven major watersheds (Figure 11) are highly prone to lowland floods, the destruction of riverbanks, heavy siltation, loss of life and damage to housing and other infrastructures. All seven major watersheds include irrigation perimeters in lowland plains, and all are subject to seasonal floods and siltation.

Flooding downstream is intimately linked to the poor infiltration of runoff on steep upstream slopes and ravines; however, flood risk is greatly increased by poor drainage downstream and the heavy sedimentation of riverbeds, canals and coastal waters. Inadequate drainage is affected by uncontrolled mining of construction sand and gravel from riverbeds as well as limestone deposits on slopes and high risk sites along the national road. Flood risk is also affected by uncontrolled harvest of mangroves. Cutting the mangroves undermines their role as a natural buffer against sea surges from severe tropical storms and gale force winds.

Poverty. Poverty is a critical stressor intimately linked to erosion and flood risk. Poverty also leaves little margin for resilience in the face of natural disaster. Despite the high risk of erosion, the deforested slopes of the Matheux do not lend themselves to wholesale reforestation, i.e., transforming whole landscapes into forest cover. The primary reason is that these slopes are not empty lands. They are agricultural landscapes. Most occupants are poor farmers with few options for an alternative, more sustainable livelihood. Given their circumstances, the majority of small farmers are more concerned with managing short term risk than maximizing long term gain. Therefore they tend to rely heavily on erosive, near term annuals such as corn and beans which are widely cultivated on unprotected slopes. Some highland areas are also plagued by longstanding land tenure conflicts (e.g., Fond-Baptiste, Diméran, Piâtre).

In general, farmers retain little economic margin for investing in conservation structures on depleted hillsides without external support. In terms of cost and benefits on highly degraded slopes, the direct tangible benefits of farmer investment in conservation structures may well not be worth the cost. Furthermore, the market for many local food crops does not generate high incentive for conservation investments, particularly since most farmers in Haiti cannot effectively compete with the growing volume of cheap food imports. Farmers also do not generally have access to agronomic services or public investment in conservation practices and structures. In short, rural poverty is a driving force of watershed vulnerability to erosion, flooding and natural disaster. [18]

[18] Some 80 percent of small Haitian farmers fall under the poverty line. For poverty analysis, see MPCE (2004) and Verner (2005). See Pierre (2008) and Jean (2010) for household income data in the Matheux.

Vulnerability to natural disaster. The highest risks are torrential rains, gale force wind and landslides. The most significant impact is severe flooding in irrigation perimeters and other downstream infrastructures, coastal towns and riverbanks. Natural vulnerability is accentuated by human agency including house construction in flood plains, pollution, mining practices and poverty. Weak public services, including organized efforts to mitigate the impact of natural disaster, significantly increase vulnerability to natural disaster.

Reduced water quality and quantity. Despite flood periods of water excess, there is a scarcity of water for household use and irrigation. This is due in large part to the poor infiltration of water on degraded slopes. It also reflects the limited infrastructure for water capture, storage and distribution. Highland springs are not evenly dispersed over the landscape and tend to have a reduced water flow. Along the Matheux ridge, there has been a shortage of water since colonial times when coffee plantations invested heavily in water harvest and reservoirs. A closely related issue is water pollution due to inadequate disposal of human, solid and industrial waste including plastic containers, and motor oil from garages along the national road.

Weak governance. Laws that protect the environment are not well enforced including restrictions on tree cutting, cultivation of steep slopes, the use of fire to clear land, open range grazing, sand and gravel mining and over fishing. Local structures of governance are poorly funded. There is a paucity of public services for water, sanitation and disposal or recycling of human, industrial and solid waste. There is little control over high risk practices such as house construction in flood plains and within irrigation perimeters and drainage infrastructures.

Degradation of coastal and marine resources. Mangroves are under severe pressure due to agricultural encroachment and uncontrolled harvest for poles, tannin, fuel wood and charcoal. This has serious environmental consequences including loss of habitat, spawning grounds, biodiversity and a natural buffer against sea surges. Pollution of coastal waters stems from poor disposal of human, industrial and solid waste, uncontrolled construction along the coastline, near shore sand and gravel mining, and sedimentation from river outlets to the sea. Reduced fish harvest is attributable to over fishing, reduced spawning, excessive siltation, illicit coral harvest and the pollution of coastal waters.

Assets and Opportunities

Agro-Ecological Assets:

- Irrigation perimeters are the area's most productive agricultural asset. There is potential for expanded irrigation in terms of land and water resources.
- There is proven potential for bananas (also plantains) as a high value cash crop, especially in irrigation zones and humid pockets of the piedmont.
- There is proven potential for high value vegetable production in irrigation zones, especially tomatoes, eggplants and beans.
- There is proven potential for high value production of corn in association with manioc in irrigated plains.
- There is proven potential for beans in association with other crops in irrigated areas, also humid and semi-humid highlands if produced sustainably on protected slopes.

- There is proven historical potential for highland coffee production along the old colonial road of the Matheux crest.
- Cool, highland areas of the Matheux also have excellent potential for terraced vegetable production under agro-ecological conditions similar to the Fermathe-Kenscoff vegetable production zone.
- There is proven potential for expanded production of tree and fruit crops, grasses and other perennial and semi-perennial crops on slopes.
- In semi-arid zones such as Ti Bois, agro-ecological conditions favor jatropha production as a source of biofuel.
- Drier low to mid-range areas include tree crops, millet (*pitimi*), grazing resources and sizeable stands of *Prosopis julifora* (*bayahonn*), a sustainable source of fuel wood.

Other productive assets:

- Hotels of the Arcadins coastline are an important asset. They create off-farm employment and are a niche market for local produce, fruit, vegetables and fish.
- Tourism has growth potential in coastal areas and small nearby islands. Tourism assets include beaches, skin and scuba diving, sport fishing and coral reef eco-systems.
- Tourism also has potential in high mountain areas due to a concentration of historical sites, dramatic high mountain vistas, hiking and horseback riding.
- An important asset of the Matheux is the concentration of historical-cultural sites. This includes the ruins of lowland colonial plantations and aqueducts, also numerous sites along the crest of the Matheux including 19th century forts and the ruins of 18th century coffee plantations, impluvia and reservoirs.
- The remnants of colonial reservoirs and impluvia associated with coffee production are also a potential resource and model for water storage in upland zones marked by water scarcity.
- Artisanal fishing remains an important if declining asset in coastal waters and the freshwater lake Etang Bois Neuf.
- Mountain springs, wetlands, ephemeral ponds and freshwater lakes are an important resource for water infiltration and storage, also as a water supply for irrigation.
- Coastal and marine biodiversity, mangroves, sea grasses and coral reefs furnish valuable eco-system services.
- An important asset is local knowledge and experience with traditional agroforestry systems and productive perennials including coffee, fruit and wood trees, native grasses, also some local experience with conservation practices including living hedgerows, ravine barriers, grasses and tree planting.
- The Matheux corridor has excellent transport links to important markets: (1) the newly reconstructed National Road No. 1, which links the Matheux to Port-au-Prince, the country's largest market, also to populous areas of the Artibonite Valley including St. Marc, Gonaïves and the Pont Sondé/La Chapelle road; (2) Montrouis wharfs, which channel a significant volume of boat traffic to the island of La Gonave.
- Sand and gravel mining for construction.

- Productive sites with deep alluvial soils in lowland areas, and humid pockets of fertility in upland areas.
- Local governance assets include disaster mitigation plans for Arcahaie and St. Marc, and a Municipal Investment Plan for Cabaret.
- Local jurisdictions (communes, communal sections) tend to parallel ridge to reef watersheds, a correlation that facilitates watershed planning and implementation.

Stakeholder Concerns

In field interviews and a workshop in September 2013 (see Annex II), stakeholders from all major ecological zones of the Matheux voiced an acute awareness of the two overriding sources of watershed risk: severe erosion upstream and severe flooding downstream. They also pointed to poor governance and the challenge of making a living as crosscutting themes with a significant impact on Matheux watersheds.

Stakeholders identified a series of inter-related risks including uncontrolled grazing (*elvaj lib*), water scarcity for household use in both upland and lowland areas; water shortage, sedimentation and poor drainage in irrigation perimeters; water pollution and sedimentation in coastal waters, and growing problems with the disposal of liquid and solid waste, especially in urbanized lowlands and the coastal littoral. Workshop participants pointed to the increasingly destructive impact of torrential run-off on riverbeds, riverbanks, agriculture, houses and other infrastructures in lowland river basins.

In terms of response, stakeholders expressed a desire that local elected officials and development projects use a participatory approach and consult regularly with the local population. Participants had a clear sense of priorities regarding ravines and the need to construct ravine barriers, cap and protect springs, create special land use zones, protect cultural and natural assets, re-profile river beds to improve drainage, protect river banks near lowland urban populations and irrigation works, and protect the Arcadins littoral.

Mountainous areas. Stakeholders identified deforestation, erosion, drought, ravines, landslides, uncontrolled grazing (*elvaj lib*) and mono-crops as significant risks in upland areas of the watershed including 5e Délices, Fond-Baptiste, Goyavier and 6e Matheux. They also took note of the effects of climate change and pointed to the destructive impact of insects in field gardens.

Proposed solutions included anti-erosion structures on slopes and ravines, improved governance, increased services from the Ministry of Agriculture, employment alternatives to marginal agriculture, and stronger peasant associations. Priority sites for protection included highland areas of 4e Fond des Blancs, 7e Fond-Baptiste, 3e Goyavier, 5e Délices, 6e des Matheux especially high risk ravines, springs and historical archaeological sites along the Matheux ridge.

Lowland risks. Severe flooding is far and away the preeminent environmental concern of lowland residents and agriculturalists. Stakeholders noted the increased risk to productive agricultural land, housing and infrastructure, also the siltation of irrigation systems in flood plains along major waterways of Montrouis, Arcahaie, Cabaret, Pierre Payen, Lanzac, Délugé and Saint-Marc. Other environmental risks included solid waste management, water scarcity for

irrigation, unregulated quarrying of sand and gravel and uncontrolled house construction in lowland agricultural areas and along the coast. Stakeholders from these areas also noted the scarcity of water for household use and irrigation.

Priority interventions included riverbank protection, removal of silt from drainage canals, ravine protection, active enforcement of laws, riverbank protection, re-profiling of riverbeds to improve water flow, tree planting, erosion control structures, regulation of sand and gravel mining including riverbeds, zoning restrictions on construction in order to protect lowland agriculture and irrigation, protection of historical sites, capping of springs and improved services from the ministry of agriculture.

Coastal areas. High risks include sedimentation, water pollution, uncontrolled house construction in coastal areas, unsustainable and declining fish harvest, and destruction of mangroves and fish habitat. Solutions proposed include soil conservation, reduction of weeded crops on upland slopes, regulation of sand and gravel mining, re-profiling of riverbeds, tree planting, regulation and zoning of house construction, enforcement of restrictions on free range grazing, pollution controls, the recycling of plastic, non-polluting disposal of motor oil and human waste, protection and replanting of mangroves, alternatives to unsustainable agricultural practices, fisheries regulation and establishment of marine protected areas.

Governance. Workshop participants included local elected officials. These participants concluded that watershed governance requires the full involvement of local elected officials and a participatory approach rooted in partnership between local associations and local elected officials. This also requires the political will to enforce existing environmental law, including the 1962 Code Rural, the issuance of municipal ordinances and citizen willingness to comply with these requirements. Participants recommended that permissible field crops be matched to slope and zoning requirements, and that issuance of construction permits require compliance with watershed rules and zones. They recommended that local elected officials use local networks, including locality based CASEC assistants, to raise awareness and promote compliance including restrictions on open range grazing, tree cutting and the use of fire to clear land.

Planning Priorities

Priorities flow from the following premises (see Table 8 synthesis below):

- All Matheux watersheds require significant investment in erosion control upstream and flood control downstream.
- Watersheds in the Matheux are framed by a mountain range that runs parallel to the Arcadins coastline. Given these parameters, watershed planning requires a ridge to reef strategy for managing the flow of water.
- Sustainable production strategies upstream should privilege perennial crops over annual weeded crops on unprotected slopes.
- Production strategies downstream should serve to displace production pressures on upland slopes, increase employment opportunities and utilize sustainable modes of production such as irrigation agriculture.

Geographic Priorities

In principle, all Matheux watersheds should be protected and managed in a sustainable manner; however, the first order of priority is the seven watersheds identified in Figure 7: Pierre Payen, Lanzac, Montrouis, Matheux, Courjolle, Torcelle and Bretelle. All are river based watersheds with lowland irrigation works. These irrigation perimeters are the most productive agricultural assets in the Matheux corridor.

Due to the larger size of their irrigation perimeters, the highest priorities for protection from flood risk are the Matheux and Courjolles watersheds (Arcahaie) followed by the Torcelle and Bretelle watersheds of Cabaret. This also coincides with the highest priority for flood risk to local populations including urbanized areas of Arcahaie, Cabaret and the national road.

To protect high value coastal assets related to beaches, eco-tourism, fishing and biodiversity, the high priorities are Montrouis, Matheux and Courjolle watersheds due to heavy river siltation in coastal waters.

In terms of erosion risk, the most vulnerable communal sections are the highlands of 6e Matheux, 8e Montrouis, 7e Fond-Baptiste and 5e Délices (Arcahaie), 6e Terre Nette (Verrettes), and 4e Fond des Blancs (Cabaret).

Mitigation of erosion risk

As a guiding strategy the focus of intervention should be (i) upland slope stabilization with special attention to ravines and springs, (ii) expansion of perennial crops on slopes, (iii) setting aside protected areas.

Slope stabilization. Target high risk slopes, ravines and micro-catchments. Targets should be developed via a participatory process of land use planning and mapping at the most immediate, local level (e.g., a particular ravine, spring, irrigation perimeter, micro-catchment area, or a historical-cultural site). Focus on critical micro-catchment basins, springs and ravines, emphasizing treatment of contiguous parcels to maximize impact.

Construct ravine barriers. Stakeholders identified high-priority high-risk ravines in areas where they live (see Annex II). The Municipal Investment Plan for Cabaret targets 27 million gourdes for watershed protection including ravine barriers in 2e Boucassin and 4e Fond des Blancs (Bretelle and Torcelle watersheds).[19] The Plan de Contingence de St. Marc identifies high risk ravines and rivers for protection in the communal sections of Délugé, Bois Neuf and Goyavier. The Plan de Contingence for Arcahaie identifies high risk ravines and rivers in the communal sections of Boucassin, des Vases, Délices, Matheux, Montrouis and the *quartier* of Saintard (see Annex III).

[19] Commune de Cabaret, 2001, Plan d'investissement municipal.

Perennials

- *Perennials in lieu of annual crops on unprotected slopes*. Promote expansion of perennial crops on slopes including agro-forestry, fruit trees, grasses, wood and energy trees, grasses and forage crops. Prioritize productive niches and income generating perennials.

Protected Areas

- *Site protection:* Set aside and protect special sites including springs, biodiversity assets and cultural-historical sites (see Chapter IV). See Annex II for stakeholder identification of sites that merit protection.
- *Site planning*: Springs and other special sites should be the focus of site-specific protection plans devised by local elected officials in consultation with neighboring populations.
- *Enforcement*: CASEC and commune authorities should actively enforce environmental provisions of the rural code including prohibitions against fire, uncontrolled grazing and tree cutting, and protection of springs.

Mitigation of Flood Risk

Risk mitigation measures include efforts to control erosion and increase water infiltration, as noted earlier; however, downstream investments should focus heavily on improved drainage including canal and river dredging, re-profiling riverbeds and stabilizing river banks, especially in flood plains near irrigation perimeters and urban populations.

Flood control should also include the following:

- restoration and expansion of the mangrove buffer against sea surges,
- environmental assessment and regulation of sand and gravel mining, especially high risk sites including riverbeds and quarries near roadways or drainage canals,
- proper drainage of secondary and tertiary roadways,
- regulation of coastline development including housing and waste management.
- zoning to protect drainage infrastructure and limit construction in flood plains and irrigation perimeters.

Poverty Alleviation

The response strategy is to promote sustainable agriculture in both highlands and lowlands, expand downstream employment including irrigation and tourism, and take advantage of transport linkages to urban markets via the national road, especially Port-au-Prince, also boat traffic to La Gonave. Irrigation in lowland areas is the corridor's most productive asset and a high priority for increased investment, increased production and employment. Promotion of sustainable agriculture will require increased overall investment in the agricultural sector including extension services.

Perennial crops on slopes. Build on traditional knowledge of agro-forestry including highland coffee production under shade along the Matheux crest. Improve grass and forage for sustainable grazing and dairy production. Expand fruit and wood tree production including energy trees. Expand grass and forage production for sustainable grazing and dairy production.

Tree crops can be far more productive than annual crops on slopes; trees also tend to become increasingly valuable over time. Recent economic analysis indicates that market demand for tree crops in Haiti is the highest it has been in over 30 years, especially urban markets for high calorie fruits such as avocado, mango, breadfruit, cashew, *quénèpe* and tamarind. There is also strong market incentive for wood products.[20]

Coastal assets and tourism. Tourism related employment can be expanded through increased sale of locally produced products, enhanced eco-tourism in coastal and marine areas, and the development of tourism related to cultural and historical sites and the Matheux crest.
Coastal and marine resources of the area require a sustainable management regime to protect the ecosystem, the livelihoods of fishing communities and the potential for beach and eco-tourism on the Arcadins coast. Creation and effective management of an Arcadins marine park would help to protect endangered species, mangroves, sea grasses and fishing habitat.

Étang Bois Neuf. This freshwater lake is a high priority for improved protection and management with a view to improved water quality, sustainable management for fish production and irrigation, and protection of biodiversity.

Vulnerability to Natural DisasterS

Clearly the first priority is to address erosion and flood risk as noted earlier. The primary source of natural risk is severe flooding. Mitigation of natural disaster requires improved local governance and the strengthening of local capacity for response to severe tropical storms, including implementation of disaster mitigation plans for Arcahaie and St. Marc, and investment in environmental protection as proposed in the Cabaret Municipal Investment Plan. Cabaret also needs to develop a disaster mitigation and response plan.

Reduced Water Quality and Quantity

The overall strategy is to reduce runoff and improve drainage, as noted earlier, also to cap and protect mountain springs, improve water distribution infrastructure including irrigation systems and ensure proper disposal of human and other forms of waste, especially in urbanized areas. The Cabaret Municipal Investment Plan targets solid waste disposal as a high priority.[21] Pollution and solid waste disposal are also featured elements of the St. Marc and Arcahaie disaster mitigation and risk management plans.

[20] See Bellande, 2009.
[21] Cabaret (2011, p. 24), Plan d'Investissement Municipal, "Gestion des déchets solides dans les zones urbanisées et le centre ville."

A high priority for highland residents is access to mountain springs and improved capacity for water harvest and storage.

- *Protect springs*. All springs should be actively protected. Trees or other permanent ground cover should be planted above springs. Prohibitions on cultivation, tree cutting and grazing above springs should be enforced in keeping with the Code Rural. The Cabaret municipal investment plan inventoried 32 priority springs in 2011. See Annex II for stakeholder priorities regarding protection of springs.
- *Capture water runoff in holding ponds and cisterns.* Expand upland water harvest capacity and storage including household impluvia and reservoirs, also renovation of colonial water storage structures along the Matheux crest in a manner consistent with standards for historic preservation and tourism.

Degradation of Coastal and Marine resources

Strategic responses include erosion control to reduce sedimentation of coastal waters, zoning and regulation of coastal development, regulation of fisheries and mining, fisheries extension services, protection and expansion of mangroves, improved water and sanitation services, and improved disposal of solid and industrial waste.

An Arcadins Marine Park should be created to protect endangered species, mangroves, reefs, sea grasses, fishing habitat and the valuable ecosystem services provide by these resources.

The nearby Etang Bois Neuf is a freshwater lake and a high priority for protection and management as a biological conservation site. It is also a source of fisher livelihood and water for irrigation. To protect water quality in the lake and coastal waters, nearby irrigation perimeters should use organic fertilizers and compost.

Governance

Watershed planning has limited value unless implemented. This requires watershed governance. A watershed plan has national, regional and local frames of reference. It is legitimized by national policy on watershed management, but the front line for implementing watershed management plans is local.

Watershed governance requirements include a framework for ongoing upstream and downstream consultation, implementation of local land use zones, establishment of protected areas including both natural and cultural sites, development of local micro-catchment plans centered on irrigation works, springs, ravines and protected areas, and strengthened enforcement authority for plan implementation. Actions include commune level adoption of zones and management plans, regulation of coastal and marine resources, management of natural and cultural protected areas, issuance of municipal *arrêtés* and construction permits, and active law enforcement.

Policy framework. Matheux watershed management planning is consistent with policy guidelines of the Government of Haiti and the Inter-Ministerial Committee on Land Management

(CIAT).[22] In addition to CIAT guidelines, other GOH provisions for watershed governance include the 2005 decree on the environment and the 1999 watershed policy of the Ministry of Agriculture. The 2006 decree on local government and decentralization provides for environmental action plans at the commune level. As noted earlier, the 1962 Code Rural includes erosion control measures and regulates tree cutting, land clearing and seasonal crops on slopes.[23] In the wake of the 2010 earthquake, CIAT established watershed planning and governance as a land management priority, and inter-sector coordination around high priority environmental stressors including severe flooding, deforestation and soil erosion.[24] In short there is ample legal and policy provision for watershed planning and management in Haiti, including decentralized watershed governance.

Central governmental support for local plans. Access to central government services are required to facilitate local watershed management, e.g., civil protection services (DPC), agriculture and fisheries extension (MARNDR), construction standards and approvals (MTPTC) and heightened support for decentralized governance (MICT). The Ministry of Environment and the Parliament are important actors for norms and standards, and for legal protected area status of an Arcadins Marine Park or the freshwater Etang Bois Neuf.

Grassroots as frontline for watershed interventions. Watershed planning requires a top down overview for diagnostic purposes, defining objectives and prioritizing broader scale interventions; however, Plan implementation requires direct action at the local level including high priority sites, micro-catchment basins, communal sections and communes. The present watershed plan characterizes the Matheux watersheds in terms of assets and risk. It summarizes priorities and proposes guidelines for response; however, implementation requires direct action on the ground, building from the bottom up.

The front line for plan implementation is the local population and local elected officials and jurisdictions (see Annex II for stakeholder views on watershed governance). This requires a participatory approach to watershed management and joint action by public officials and the local population. It also requires the political will to enforce existing environmental law, including the Code Rural.

Tools of local watershed governance. Tools of local governance for plan implementation include the issuance of *arrêtés* and zoning restrictions, e.g., restrictions on housing in flood plains, irrigation perimeters or the coastal littoral. For example, the commune of Arcahaie has issued *arrêtés* reinforcing prohibitions on tree cutting and open range grazing.[25] The issuance of construction permits (*permis de construire*) is presently used by communes to collect taxes. It should also be used to enforce restrictions against construction on fragile sites. Another tool is communal disaster and risk management plans. For example, contingency plans for Arcahaie and St. Marc identify flooding as the number one risk in lowland areas of the Matheux.

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[22] See the following publications of the Comité Inter-Ministeriel d'Aménagement de Territoire (CIAT): *Propositions de politique pour la gestion des bassins versants* (June 2011), *Guide méthodologique pour les études de diagnostic des bassins versants* (May 2011), and *Méthodologie de délimitation cartographique des bassins versants* (October 2010).
[23] See Articles 63-71 on erosion control, Articles 76-80 on riverbank protection (Code Rural, 1962).
[24] CIAT, 2010, March 2010, Haiti Demain: Objectifs et Stratégies Territoriales pour la Reconstruction.
[25] See Arcahaie *arrêtés* of December 12, 2012.

Communes may also decree environmental and zoning plans and enter into inter-communal agreements for watershed protection. The latter is important as watersheds and governmental jurisdictions are not coterminous. Nevertheless, Matheux area watersheds tend to run parallel with commune borders due to ridge to reef configurations for both communes and watersheds (See Figure 11). This facilitates watershed planning and enforcement by communes of the Matheux including ongoing upstream and downstream consultation.

Zoning. Stakeholders propose zoning and the creation of protected areas as tools of watershed planning (See Annex II). Stakeholders prioritized restrictions on house construction in flood plains, the coastal littoral, irrigation perimeters and drainage canals; also protective status for coastal and marine resources of the Arcadins, cultural-historical and pilgrimage sites, mountain springs and the Etang Bois Neuf.

In the Matheux, zoning plans should be prepared for each communal section. Zoning regulations should require watershed-sensitive construction of housing and other infrastructures, protection of agricultural zones including irrigated plains, planting trees and other perennials on steep slopes, protection of natural forest and existing tree cover, and protection of riverbanks and the coastal littoral.[26]

Micro-catchment plans. Watershed interventions should build on the most local feasible level of planning and governance in keeping with principles of subsidiarity.[27] As a priority, watershed interventions should focus on the development of micro-catchment plans centered on irrigation works, springs, ravines and protected area. A watershed approach to managing irrigation perimeters, for example Dupin, lends itself to participatory management of a micro-catchment basin, including upstream protection of the primary water supply, a mountain spring, in addition to water distribution and drainage downstream, which are traditionally the primary roles exercised by water user groups. In effect, the production values of irrigation perimeters can serve as incentive for organizing users around protection of the water supply upstream as well as flood risk downstream.

[26] As reference see zoning plan for the Cul-de-Sac including the following zones: urban areas, agricultural zones, steep slopes for reforestation, protected areas (D. Deslorges and E. Pierre, May 2013, WINNER).
[27] Subsidiarity is defined here as solving a problem at the level of the smallest or most local unit capable of handling the problem (see Millon-Delson, 1992).

Table 8. Synthesis of Watershed Management Planning for the Matheux Corridor

Risks & Constraints	Impact	Causes	Productive Assets	Response Strategy	Actions
1 Soil erosion on steep slopes	Poor water infiltration. Flooding. Loss of soil fertility. Increased vulnerability. Increased poverty	Inadequate ground cover on slopes: -monocropping, especially beans -annual weeded crops on unprotected slopes, -fire to clear land, -over grazing, -unsustainable tree harvest	Banana/plaintains in humid ravines. Agroforestry. Highland coffee. Terraced vegetables. Fruit & wood trees. Grasses. Prosopis julifora (*bayahonn*) for sustainable fuelwood harvest.	Slope stabilization. Expand perennial crops. Establish & maintain protected areas.	Promote farmer expansion of perennial crops: agroforestry, coffee, fruit, grasses, farm forestry, energy plantations, grass & forage crops. Construct ravine barriers. Terraces on productive slopes. Cap/protect springs with trees, ground cover, grazing control. Capture water runoff: impluvia, holding ponds, reservoirs. Prohibit land clearing by fire, free range grazing, unauthorized tree harvest.
2 Severe flooding in lowland plains and coastal areas	Destruction of riverbanks, agriculture, irrigation, housing. Siltation of canals, rivers & coastal waters. Water pollution. Loss of fish habitat & reefs.	Erosion, ravine runoff upstream. Poor water infiltration. Poor drainage. Torrential rains. Ravine runoff. Mining of sand, gravel, riverbeds.	Hotels, tourism, beaches, diving, reefs, sport fishing, artisanal fishing. Mangroves, reefs, seasgrass, biodiversity. Flatlands/iirrigation perimeters. Sand & gravel mining. Bananas, coconuts, fruit trees, vegetables.	Decrease runoff. Ensure adequate drainage. Stabilize slopes, riverbanks, ravines. Protect irrigation. Regulate coastline & mining. Restore mangroves.	Erosion control (see above). Riverbank works to protect roads, irrigation, urban populations. Expand drainage capacity, dredge canals, reprofile riverbeds. Proper drainage of roadways. Regulate sand/gravel mining of hillsides & riverbeds. Expand mangrove buffer.

Risks & Constraints	Impact	Causes	Productive Assets	Response Strategy	Actions
	Increased poverty & vulnerability.	Mangrove harvest.	Grazing.	Create land use zones	Regulate coastal littoral including housing and waste management.
3 Poverty	Unsustainable agriculture on slopes. Unsustainable wood harvest. Overfishing. Mangrove habitat destruction Pressure on resource base. Increased vulnerability to disaster.	Few alternatives to marginal agriculture & fisheries Inability to compete with int'l markets. Cost/benefit constraints to farmer investment. Land tenure constraints. Few public services or agricultural & fisher extension services. Paucity of investment in agriculture or fisheries	*Irrigation agriculture* - banana cash crop - vegetables. *Highlands* - coffee - terraced vegetables. *Coastal/marine diversity* - Hotels & tourism - fishing. *Water resources* - rivers, springs, wetlands - Etang Bois Neuf *Perennial crops* - wood & fruit trees - grasses/forage - agroforestry *Transport links* - national highway - La Gonave wharfs. Concentration of historical	Promote high value perennials & agroforestry Expand irrigation production & employment Target agricultural niche markets, hotels, tourism Leverage transport linkages to markets.	Improve & expand irrigation perimeters. Expand tourism (coast, mountains, historical sites). Promote high value tree crops, perennials, agroforestry, coffee. Improve forage resources, grazing, dairy production. Provide agricultural & fisheries extension services including production credit. Recycle merchantable solid waste, plastics.

Risks & Constraints	Impact	Causes	Productive Assets	Response Strategy	Actions
			sites. Sand/gravel mining.		
4 Vulnerability to natural disaster	Severe flooding. Loss of life, land, livelihood & infrastructures. Water borne disease. Increased poverty.	*Highest natural risks*: torrential rains, cyclones, landslides. *Behavioral*: erosive practices, housing in flood plains, pollution, weak governance, poverty.	Disaster mitigation plans for Arcahaie & St.Marc. Municipal Investment Plan for Cabaret.	Strengthen local capacity for disaster mitigation & response. Mitigate erosion and flood risk (noted earlier)	Strengthen disaster response capacity in local jurisdictions. Develop disaster mitigation and risk plan for Cabaret. Implement house construction & zoning standards. Expand mangroves as buffer against sea surges. Collect & recycle solid waste; manage human waste.
5 Reduced water quality & quantity	Scarcity of water for household use and irrigation. Polluted water.	Erosion, flooding, sedimentation. Poor water infiltration and drainage. Poor capacity for water storage & distribution.	Rivers, freshwater lakes, springs, wetlands, ephemeral ponds; coastal waters. Irrigation perimeters, wells, cisterns, impluvia, remnants of colonial reservoirs. Hydropower plant	Reduce runoff & siltation. Improve drainage Protect springs. Improve water distribution Increase water	Stabilize slopes & riverbanks. Dredge canals & rivers, re-profile riverbeds. Cap & protect mountain springs. Improve irrigation water infrastructure, integrate drip irrigation.

Risks & Constraints	Impact	Causes	Productive Assets	Response Strategy	Actions
		Reduced flow of upland springs. Poor disposal of human & industrial waste.	(Piâtre). Fishing & marine resources	harvest & retention. Improve drainage. Improve sanitation.	Sanitary disposal of human waste. Expand water harvest & storage capacity in upland areas Protective status, mgmt plan for Etang Bois Neuf water quality. .
6 Degradation of coastal & marine resources	*Habitat Loss*: - decreased fish harvest, - destruction of spawning grounds & endangered species *Increased flood risk* *Marine pollution* - water borne diseases, - damage to reef & sea grasses - damage to fisheries - reduction of value of coastal resource for tourism - loss of	*Destruction of mangroves*: - agricultural encroachment, - uncontrolled harvest of tannin, fuelwood, charcoal, - loss of buffer against sea surges - improper disposal of human, industrial & solid waste. -destructive Coastal development - sedimentation - near shore sand & gravel mining	Coastal tourism, beaches, diving, coral reefs, sport fishing, artisanal fishing Mangroves. Sandy soils conducive to citrus, coconuts, grasslands, melons. Transport links to markets: - coastal hotels - boat traffic to La Gonave markets. - National highway access to urban markets north & south Ecosystem services from mangroves, reefs, sea grasses.	Erosion control Regulation of coastal resources. Regulate fisheries Improve water, sanitation, solid waste disposal services	Erosion control noted above. Zoning restrictions on housing and other coastal developments. Protect/re-plant mangroves. Require fishing licenses, define catch quotas & periods of non-fishing Restrict riverbed and near shore mining of sand, gravel & coral. Non-polluting disposal of motor oil, human waste and plastic; recycling of plastic containers. Prioritize sanitation services to coastal urban populations. Protect Etang Bois Neuf as a high priority biological conservation site

Risks & Constraints	Impact	Causes	Productive Assets	Response Strategy	Actions
	Biodiversity - reduction in value of ecosystem services *Diminished fisher livelihood*	*Pressure on resource* - over fishing, - river siltation - coral harvest, - pollution			Create Arcadins Marine Park to protect endangered species, mangroves, reefs, sea grasses, fishing habitat, ecosystem services.
7 Weak governance	Land/water pollution. Water borne disease. Reduction in irrigable land. Degradation of coastal resources. Heightened vulnerability in flood plain.	Poor disposal of human, industrial & solid waste. Few public services, especially water & sanitation. Unplanned urban growth. Poor law enforcement.	Disaster mitigation plans for Arcahaie & St.Marc. Municipal Investment Plan for Cabaret. Local jurisdictions as frontline for sub-watershed management.	Create regulatory framework including land use zones. Establish natural protected areas & cultural sites. Develop local micro-catchment plans focused on the protection of specific irrigation perimeters, springs, ravines & protected areas. Strengthen local authority for watershed management & enforcement.	Adopt communal watershed management and zoning plans. Implement watershed and disaster mitigation and management plans Prepare disaster mitigation plan and civil protection structure for Cabaret. Regulate coastal & marine resources. Legally protect and actively manage natural & cultural sites. Issue/enforce municipal *arrêtés.* Issue construction permits guided by zoning restrictions. Enforce the law including prohibitions on tree cutting, grazing,

Risks & Constraints	Impact	Causes	Productive Assets	Response Strategy	Actions
				Establish framework for ongoing upstream downstream consultation & coordination.	& land clearing by fire. .

Table 9. Specific actions recommended for different agro-ecologiocal zones

Agro-ecological zones	Watershed management issues	Causes	Response	Actions
Coastal zone	*Habitat Loss*: - decreased fish harvest, - destruction of spawning grounds & endangered species *Increased flood risk* *Marine pollution* - water borne diseases, - damage to reef & sea grasses - damage to fisheries - reduction of value of coastal resource for tourism - loss of Biodiversity - reduction in value of ecosystem services *Diminished fisher livelihood*	*Destruction of mangroves*: - agricultural encroachment, - uncontrolled harvest of tannin, fuelwood, charcoal, - loss of buffer against sea surges - improper disposal of human, industrial & solid waste. -destructive Coastal development - sedimentation - near shore sand & gravel mining *Pressure on resource* - over fishing, - river siltation - coral harvest, - pollution Poor disposal of human,	Erosion control Regulation of coastal resources. Regulate fisheries Improve water, sanitation, solid waste disposal services Regulate coastline and mining Restore mangroves Establish & maintain protected areas.	Adopt communal watershed management and zoning plans. Implement watershed and disaster mitigation and management plans Erosion control activities. Zoning restrictions on housing and other coastal developments. Protect/re-plant mangroves. Require fishing licenses, define catch quotas & periods of non-fishing Restrict riverbed and near shore mining of sand, gravel & coral. Non-polluting disposal of motor oil, human waste and plastic; recycling of plastic containers.

Agro-ecological zones	Watershed management issues	Causes	Response	Actions
		industrial & solid waste. Few public services, especially water & sanitation. Unplanned urban growth. Poor law enforcement.		Prioritize sanitation services to coastal urban populations. Protect Etang Bois Neuf as a high priority biological conservation site Create Arcadins Marine Park to protect endangered species, mangroves, reefs, sea grasses, fishing habitat, ecosystem services. Implement house construction & zoning standards. Expand mangroves as buffer against sea surges. Collect & recycle solid waste; manage human waste.
Irrigated plains	Destruction of riverbanks, agriculture, irrigation, housing. Siltation of canals, rivers & coastal waters.	Erosion, ravine runoff upstream. Poor water infiltration. Poor drainage.	Decrease runoff. Ensure adequate drainage. Stabilize slopes, riverbanks, ravines.	Adopt communal watershed management and zoning plans. Implement watershed and disaster mitigation and

Agro-ecological zones	Watershed management issues	Causes	Response	Actions
	Water pollution. Severe flooding. Loss of life, land, livelihood & infrastructures. Water borne disease. Increased poverty.	Torrential rains. Ravine runoff. Mining of sand, gravel, riverbeds. Land tenure constraints Paucity of investments in agriculture *Highest natural risks*: torrential rains, cyclones, landslides. *Behavioral*: erosive practices, housing in flood plains, pollution, weak governance, poverty.	Protect irrigation systems. Expand irrigation production & employment Target agricultural niche markets, hotels, tourism Leverage transport linkages to markets.	management plans
Semi-arid hills (piedmont)	Soil erosion Unsustainable agriculture on slopes. Unsustainable wood harvest.	Erosion, flooding, sedimentation. Poor water infiltration and drainage. Poor capacity for water storage & distribution.	Promote high value perennials & agroforestry Install greenhouses with vertical and protected agriculture Create regulatory	Promote farmer expansion of perennial crops: agroforestry, coffee, fruit, grasses, farm forestry, energy plantations,

Agro-ecological zones	Watershed management issues	Causes	Response	Actions
	Pressure on resource base. Increased vulnerability to natural disaster.	Uncontrolled harvest of fuelwood	framework including land use zones. Develop local micro-catchment plans focused on the protection of specific irrigation perimeters, springs, ravines & protected areas. Strengthen local authority for watershed management & enforcement.	grass & forage crops. Construct ravine barriers. Terraces on productive slopes. ground cover, grazing control. Capture water runoff: impluvia, holding ponds, reservoirs. Prohibit land clearing by fire, free range grazing, unauthorized tree harvest. Expand the implementation of greenhouses on terraces
Humid and semi-humid mountains	Soil erosion Unsustainable agriculture on slopes. Unsustainable wood harvest.	Erosion, flooding, sedimentation. Poor water infiltration and drainage. Poor capacity for water storage & distribution. Reduced flow of upland springs. Uncontrolled harvest of fuelwood	Slope stabilization. Expand perennial crops. Promote agro-forestry Install greenhouses with vertical and protected agriculture Establish & maintain protected areas.	Promote farmer expansion of perennial crops: agroforestry, coffee, fruit, grasses, farm forestry, energy plantations, grass & forage crops. Construct ravine barriers. Terraces on productive slopes. Cap/protect springs with trees,

Agro-ecological zones	Watershed management issues	Causes	Response	Actions
			Create regulatory framework including land use zones. Establish natural protected areas & cultural sites. Develop local micro-catchment plans focused on the protection of specific irrigation perimeters, springs, ravines & protected areas. Strengthen local authority for watershed management & enforcement.	ground cover, grazing control. Capture water runoff: impluvia, holding ponds, reservoirs. Prohibit land clearing by fire, free range grazing, unauthorized tree harvest. Expand the implementation of greenhouses on terraces Revitalize coffee production

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NOTE ON DOCUMENTATION. *Documentary studies of the Matheux corridor include significant material from the earlier USAID/DAI-DEED project as well as FtF West/WINNER. The most important recent diagnostic studies are the Land Use/Land Cover (LULC) map of the Matheux corridor (January 2012), the closely related land classification report for land categories shown on the LULC map (January 2013) and the WINNER Matheux baseline study of the watershed (November 2010).*[28] *It is also useful to consult the earlier DEED baseline study (Pierre, 2008*[a]*) which covers much of the same material as the WINNER baseline including grassroots organizations and producer groups.*[29] *DEED also issued a set of watershed based plans for soil and water conservation, including maps of five sub-watersheds in the Matheux corridor (September 2010).*[30] *Another report of interest from the DEED era is the Timyan (2008) identification of 11 biological conservation sites worthy of protection in the Montrouis area. DEED also issued special reports on labor dynamics and opportunities for upland reforestation in the region.*[31]

[28] WINNER (January 5, 2013), Carte d'Occupation des Sols: Corridor des Matheux; M. White *et al* (2012), 2012 Land Use/Land Cover Classification.
[29] The DEED baseline study includes a separate volume on local organizations (Pierre, 2008[b]), Diagnostic des organisations du Bassin Versant de Montrouis.
[30] DEED issued a similar report for Limbé (2010[b]), including a plan map for each of 5 subwatersheds.
[31] Smucker (2009) on labor dynamics, and tenant farming and opportunities for reforestation (2010).

Annex I. A watershed planning approach

Defining Terms

Watershed: *Area of land that contributes runoff to a lake, river, stream, wetland, estuary, or bay*.[32] The notion of watershed includes micro-catchments such as ravines and small waterways that lie within Haiti's 30 largest watersheds and 24 major sub-watersheds.[33] In the mountainous terrain that defines most of Haiti's land mass, major watersheds and sub-watersheds are generally demarcated by highland ridges and a primary water course. Most of the island nation's primary water courses flow into rivers and coastal waters.

Watershed plan*: A strategy for assessing and managing information regarding a geographically defined watershed.* [34] A watershed plan describes the character of the watershed, provides analysis, and defines actions, participants and resources needed to implement the plan.

A watershed approach*:* The geographic focus on watersheds establishes a flexible framework for managing water quality and quantity within targeted drainage areas, an inclusive approach that supports environmental protection, economic development and quality of life. The watershed approach devotes special attention to the impact of local land use patterns. As a basic premise, a watershed approach views local populations as the critical stakeholders in watershed management. Management actions should also be supported by sound science and appropriate technology (EPA handbook, 2008).

The watershed approach is hydrologically defined, geographically focused and community based. It includes all stressors and all stakeholders including public and private sectors, and strategically addresses priority water resource goals.

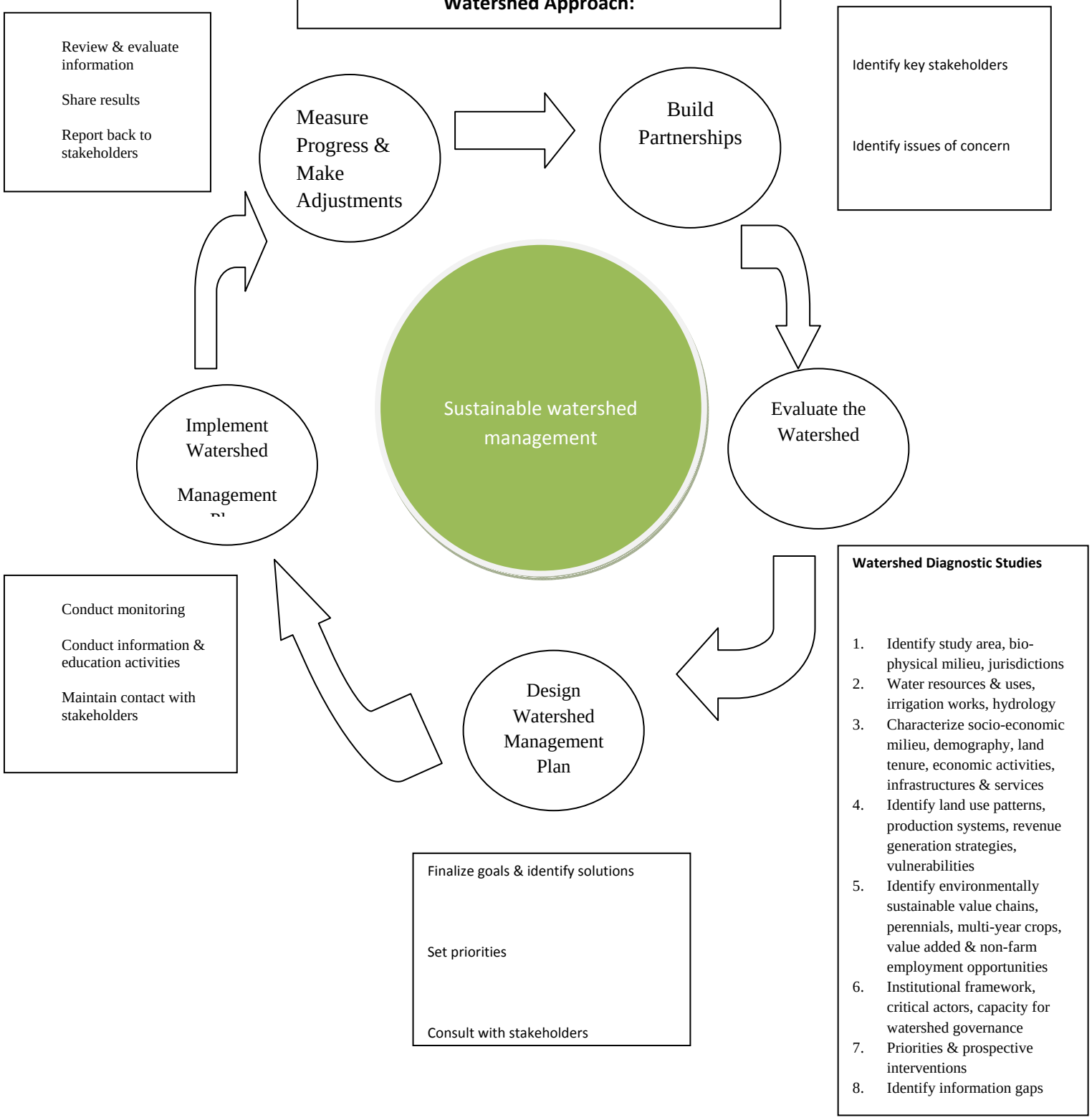
Planning and Implementing a Watershed Approach to Land Management

See Figure 20 below for graphic presentation of different steps in a watershed approach.

[32] See Section 1.1 of the EPA handbook on watershed planning (2008).
[33] The figure for watersheds is drawn from UTSIG analysis (2001) and Smucker et al (2007).
[34] See Section 2.1 of EPA (2008), and CIAT (May 2011, pp 6-8).

Figure 20

Watershed Approach:



SOURCE: Steps in watershed planning adapted from EPA (2008), section 2-6. Textbox for Watershed Diagnostic Studies drawn from CIAT methodological guide for watershed diagnostic studies (May 2011).

Annex II. Findings from Matheux Stakeholder Workshop

Watershed Management, Matheux Range, Arcadins Coastline

September 25-26, 2013

The purpose of this workshop was to ensure stakeholder participation and elicit concerns and priorities for watershed management in the Matheux corridor. Participants included 40 people from Matheux communes, resource persons for special presentations, and staff members of the USAID-Feed the Future West Project (WINNER/Chemonics). Stakeholders present included representatives of grassroots organizations – small farmers, women's groups, irrigation water users, fishermen, also disaster and risk management committees, mayoral and communal sectional councils (CASEC), the Ministry of Agriculture, non-governmental organizations and private sector businesses. Most Matheux communal sections shown in Table 1 of this report were represented, particularly for the communes of Cabaret, Arcahaie and Saint-Marc.

In addition to WINNER staff, resource persons for the workshop included Daniel Elie, architect and specialist in Matheux colonial ruins (ISIOMOS), Wilson Celestin, biologist and university professor (UEH, FAMV, UNIQ) and Glenn Smucker, cultural anthropologist and consultant for watershed planning. WINNER Agr. Marie-Pascale François St. Martin served as workshop moderator. Mario Kerby and Dorine Jean-Paul made presentations on recent efforts at watershed planning and zoning in the Cul de Sac; Daniel Elie on cultural resources in the Matheux (historical archaeological resources), Wilson Célestin on coastal and maritime aspects of watershed management and Glenn Smucker on the concept of watersheds and priorities for the Matheux.

Participants worked in small groups and made recommendations on the following topics:

- Identification of watershed risks (threats) and prospective solutions in mountains, plains and coastal areas of the Matheux
- Identification of high priority microcatchments, ravines, natural and cultural resources for protection or improved management
- Issues of governance in watershed management

Group 1

Watershed risks and threats in mountainous areas

- Deforestation (5e Délice)
- Erosion (Fond-Baptiste)
- Drought/floods (Goyavier)
- Lack of infrastructure (roads)
- High risk ravines (6e Matheux)
- Landslides
- Uncontrolled grazing by goats (*elvaj lib*)
- Climate change
- Insects in field gardens

Proposed Solutions

- Structures to protect the environment, vegetative and mechanical structures, ravine barriers
- Foster economic alternatives to agriculture in rural areas
- Strengthen peasant associations
- Raise consciousness on the destructive impact of deforestation
- Provide agricultural extension services to peasant farmers
- Ensure participation of local population in new development activities
- Improve local governance, more contact by local elected officials with local constituents (CASEC/ASEC)
- Protect/develop sites for ecotourism, sports, patron saint festivals (*fèt chanpèt*)
- Provide micro-credit services for agriculture
- Promote alternative cooking fuel (LP gas)
- More effective NGOs

Priority Sites For Protection

4e Fond des Blancs

- *Ravines* : Ti Rivyè, Ti Ravin (Pikas a lacho), Badagok, Ravin Nan Plas, Gran Bare, Baban

7e Fond-Baptiste

- *Ravines*: Demes, Gibè, Boukan, Louis, Elie, Kolonbye, Kounol, Andro nan Dilèt, Maya
- *Springs* : Sous Maryan, Louis, Elie, Dagon, Dilèt, Demes, Katiren, Robert, Ravin Sèk, Gwoton, Desab, Boukan Karem, Gran Ravin, Kadouya, Boujèt, Gran Chemen, Zile, Doko, Goben

3e Goyavier

- *Ravines* : Mabou, Lestable, Lapre, Jojon, Dogen, Remon, Toukoukou, Tikwakon, Valmon, Ponyes, Makari, Klavi, Pina, Giyen, Fon Roc, Sou Ka, Fon Travès, Fon Pierrot, Majorel, Fon Lazen, Chan Klote.
- *Springs*: Jojon, Gaspa, Bali, Militon
- *Cultural sites*: Lapre ruins, Robyon, Batye, Klavi, Pina
- *Productive assets*: cabbage, potatoes, coffee

5e Délice

- *Ravines* : Robino, Marchan, Baro, Kay Boule, Matiyen, Donyen, Michel Bassia, Matinet, Bazin, Tibwa, Belvi, Dipie, Lachenen, Gran Oge, Dekouve, Devanbare, Gran Rivry, Diveret, Kachet
- *Springs***:** Jon Bin, Gran Fon, Barvo, Pie Tonsin, Belvi, Donyin Lachennin, Machan, Konoye, Dipil, Basia, Bazin, Grandnvir, Diveret, Pas Matie, Dekouvet, Levek Petifon
- *Cultural sites***:** Fo Douet, Djon

6e des Matheux

- *Ravines* **:** Mouvriye, Savann Chwal, Lameri, Sous Blan, Bwa Jazon, Fosten, Valadon, Dejadin, Santony, Batolnaen, Kabouyak, Manso, Chola, Belvi, Fonferye, Ilen, Lourou, Gojan, Omelis, Fondyab, Twoukoukou, Planton Granbi, Grenad, Zalarou, Batfou, Demon
- *Springs* **:** Nansous (Nantika), Gransous, Lakansyel, Domalfini, Larivye, Sous Tlen, Nan Platon, Sous Zekle, Sous Delpech, Dlo Ontre, Sous Valadon, Sous Fonrandol, Nan Banbou, Paskontre
- *Cultural sites***:** Anro Siriz, Fort Dèlpêche
- *Production assets:* fruit trees, yanm ginen, tomatoes, bananas (*fig banann*)

4e Fond des Blancs

- *Springs***:** Sous Rezen, Kasany, Baban
- *Cultural Sites:* Nan Mazi, Siloye

Digue Matheux (plains area, Arcahaie)

Risk/threat:

- River destruction of agricultural land
- Sand siltation of irrigation system
- Deforestation of river basin and watershed

- Disease affecting banana/plantain production (Sigatoka, rot)
- Mono-culture
- Courjolle River, upstream erosion, downstream floods, destruction of field gardens, high risk of flood disaster in lowland population centers
- Montrouis River, significant threat to people and institutions downstream, threatened OSAPO dispensary below Gwo Monn

Solutions

- Riverbank protection with gabions
- Technical and economic assistance to farmers and traders

Productive assets : Moringa, Moringa processing, nursery

Priority sites for protection

Flood protection :

- Digue Matheux : La digue (dike, protective wall)
- Digue Boby (Arcahaie)
- Digue Torcelle (Cabaret)

Cultural assets :

- Fort Gibè
- Fort Dèlpêche and Elie
- Prison Demès

Group 2

Watershed risks/threats in lowland plains

Risks due to hurricanes and heavy rainfall. High risk of flooding in plains areas of Montrouis, Arcahaie, Cabaret, Pierre Payen, Lanzac, Délugé, Saint-Marc. Listing of areas subject to flooding:

Cabaret

- Rivière Bretelle flood risk: left bank from Delbo to Prens, Do Monn Duklo to marketplace and Fovo,
- Rivière Torcelle flood risk : Kazal to the coast, Boyel, Maling
- Ravine Maneg (Levek), Ravine Brely-Becy

Arcahaie

- Ravin Toma, Kay Madanda to the coast, Toma
- Rivière Courjolle, from Matye to town
- Rivye Mitan, Bula Boule to Ba Mitran
- Rivière Matheux, Guiton, Nan Roch.

Montrouis

- Rivière Greso, flood prone from Bwa Blan, Ti Kouyo, Nan Dokte to the coast
- Ravin Ti Montay, Nan Sodo to Rivière Montrouis
- Ravin Boy, flood risk to portions of Délugé

Délugé

- Rivye Delije, Dejans to the coast

Lanzac

- Rivière Lanzac, Ravine Silfa, Ravine Sameon
- Ravin Balanyen to Batado, Paokèt to Lakil

Pierre Payen

- Rivye Rozo, Dukaso, Grilanfon, Korido to the coast
- Ravin Bedenn, Ravin Gede, Ravin Fon Pak, Ravin Chen Kaka

Saint-Marc (Maya-Dupin)

- Ravin Trilou Laza to Ravin Doco, Ravin Foulatann, Ravin Madan Baboket, Bwablan

Bwa Nef

- Ravin Lagon, Distile

Other environmental risks/threats

- Environmental degradation
- Deforestation
- Absence of local authorities
- Cholera
- Uncontrolled grazing (*elevaj lib*)
- Poor management of solid waste
- Violence and land conflict
- Scarcity of potable water in plains areas
- Scarcity of water for irrigation
- Sand and gravel quarries and mining
- Rural-urban migration from mountainous areas to the lowlands, house construction in lowland areas competing with agricultural use

Solutions

- Enforce existing laws, enforce Rural Code
- Job creation
- Riverbank protection
- Improved canal drainage, clean canals (siltation)
- Build gabions in ravines and along river banks
- Clean out river beds to improve water flow : Torcelle, Bretelle, Montrouis, Pierre Payen
- Plant trees
- Education, raise consciousness on the environment
- Construct rock barriers, terraces on slopes, ravines
- Promote alternative cookstoves
- Build feeder roads from rural areas to the national road
- Regulate mining of rocks and sand for construction
- Zoning restrictions, regulate construction, protect agricultural zones
- Protect historical archeological sites (colonial ruins)
- Cap springs
- Agricultural ministry (MARNDR) should provide agronomists for peasant farmers
- Promote local associations

High priority microcatchment areas for protection

- Mountain springs and ravines in Kazal and Bon Blan (Cabaret) and 5^{e}/6^{e} communal sections of Arcahaie
- Ravines that cause flooding in the 4th, 5th and 6th communal sections of Cabaret

High priority ravines for protection

- *Cabaret* : Cour Kenep, Ravin Redout, Ravine Des Duclos, Dal Milye, Cour Kenep, Dos Duklo, Zeklus, Teleco-Sabourin, Maitou
- *1e Section* : Ravine Gros Cheval, Manegue, Beay, Bodri, Nan Brike, Ravine Gros Cheval, Labrodrie
- *9em Seksyon*: Dede, Titanyen, Lafito, Ti Jaden, At Gerard.
- *2eme Section :* Rivière Torcelle, Rivière Bretelle
- *Arcahaie* : Vignier, Toma, Ravin Mitan
- *Délugé* : Ravin Bringo, Dejan, Malerich, Boy, Soufo
- *Pye Payen*: Loulou, Bebare, Te Blanch.
- *Maya-Dupin* : Ravin Doko, Nanpire, Dupin, Mangou
- *Montrouis*: Ravin Seradot, Katnet, Moulin Sur Mer, Lahat, Soudal

Other priorities for protection

- Mines, sources of sand (white, black), gravel, river stones, clays including Morens (Casale)
- Touristic sites
- Infrastructure (roads)
- Etang Bois Neuf (Montrouis)
- Kay Piat hydro-electric plant (Délugé)
- Fort Nan Bural (Belanger)
- Moulin Dubuisson
- Fort Douet (4e section, Cabaret)
- Kay Ena (highest mountain peak)
- Telecommunication site at Samourin (Cabaret)
- En bas Fort
- Colonial mill (Torcelle, Source Mitan
- Colonial and religious sites: Pierre Payen, Délugé, Lakou Gede, Jean-Michel, Roseau
- Cap springs: Bayelle, Belanger, Sous-Ray, Source Puante, Source Carrefour Damien

Group 3

Watershed risks/threats in coastal areas

- Sedimentation
- Water pollution
- Uncontrolled house construction on the coast
- Unregulated fishing
- Insecurity

Solutions

Measures in response to sedimentation:

- Soil conservation
    - living hedgerows and anti-erosion structures on the contour,
    - non-erosive agricultural practices,
    - no weeded crops on steep slopes,
- Regulate sand and gravel mining,
- Reprofile river beds,
- Reforestation,
- Regulate uncontrolled house construction,
- Control free range grazing

Measures in response to pollution

- Use organic fertilizer (compost),
- Recycle plastic,
- Non-polluting disposal (burial) of motor oil (garages)

Measures in response to uncontrolled coastal house construction:

- Establish zone restrictions on uncontrolled construction of slum housing,
- Sanitary protection of rivers, springs,coastal waters
- Laws on reforestation,
- Subsidize propane gas for cooking,
- Legislation to protect and replant mangroves,
- Recycle plastic bottles as construction material,
- Create alternative employment

Measures in response to fishing

- Fisheries regulation,
- Require fishing licenses,
- Define catch quotas for strategic fishing sites,
- Define and enforce periods of non-fishing,
- Establish corps of fishing agents to enforce fishing regulations,
- Legislation to prevent destruction of mangroves
- Create marine protected areas

High priority ravines and water courses to protect

Bercy, Mitan, Marie Gerbo, Seche, Rousseau, Lourou, Ti Godet, Madame Baboket, Lagon, Distrile, Jeanton, Perisse, Source Cadnette

Reprofile riverbeds: Rivières Bretelle, Courjolle, Montrouis, Délugé, Lanzac, Pierre Payen

Tourist sites to protect

- Côtes des Acardins
- Les ilots arcadins
- Etang bois neuf
- Bendene
- Source Mayar
- Source Lazar
- Fatima
- Piâtre
- Dorzer

Groupe 4

Watershed governance: How to implement watershed plans and zoning

Direct involvement of local elected officials and associations

Direct involvement of local communities with elected officials

Roles to be exercised by local elected officials:

- Consciousness raising on environmental problems
- Issuance of municipal ordinances (*arrêtés*)
- Enforcement of laws on the environment
- A participatory approach is essential
- For zoning, identify appropriate spaces for contruction, forest, agriculture, acceptable cultigens for each type of space
- Name CASEC assistants (*èd kazek*) for each locality (*abitasyon*). In communal sections, local CASEC assistants chosen by localities are very important for ensuring local compliance with established principles
- Support local authorities in decisions they make for the benefit of the community at the level of commune and communal section.
- Correct authorities when they are off target, support (accompany) them when they make decisions in the interest of the commune/section communale

Concrete measures

- Require communal issuance of construction permits (permis de construire),
- Require communal/sectional authorization for tree cutting,
- Prohibit uncontrolled free range grazing (*elvaj lib*),
- Actively enforce the law on the environment,
- Issue municipal ordinances,
- Raise consciousness of local population

Level of community involvement

- Comply with the law, zoning and other principles of environmental protection
- Support/accompany local officials in their decisions
- Support/allow the application of such decisions
- Provide advice/feedback to local officials

Annex III. High Risk Ravines and Rivers

Saint-Marc

Ravines	**1ère Section Délugé**
Ravine Cola, Ravine Mars, Ravine Source, Ravine Montagne	
Rivières	
Rivière Lanzac, Rivière Montrouis, Rivière Pierre Payen, Rivière Délugé	
Ravines	**2e Section Bois-Neuf**
Ravine Sèche ou ravine Neuve, Canelle, Camp Nini, Chapelet, Gardère	
Rivières	
Rivière Lamerc, Canot, Pierre Payen	
Ravines	**3e section Goyavier**
Ravine Fond Roc, Pouriesse, Fond Pierrot, Pina, Fond Banyen, Mabou SOURCE: Deslorges, September 2012. Profil de la Commune de St. Marc. Atelier d'élaboration du Plan de contingence communal. Comité Communal de la Protection Civile de St. Marc.	

Arcahaie

Rivière Courjolles, Ravine Thomas, Ravine Bercy, Ravine Vinier	**1e Boucassin**	.
Rivière Matheux, Ravine Mitan, Ravine Matheux, Ravine Lourou	**des Vases**	
Ravine Sèche, Ti Sous, Grande Rivière de Montrouis, Rousseau	**Montrouis**	
Riv. Donyen, Matinèt, Françoise, Gen Blòd, Basya, Bawo, Robino, Jean Dumas, Riv. Cachette, Gauthier, Bellevue, etc.	**5e Délices**	

Riv. Dubreuil, Roberjo, Forondel, Valadon, Grenade, Couleuvre, Dupin, Bòdpè, Godfoy, Dego, Gwo Kan, Nan Barre, Dlo Kontre	**6e Matheux**
Ravine Makercy	**Saintard**

SOURCE: Deslorges, Decembre 2011. Profil de la commune de l'Arcahaie. Atelier d'élaboration du Plan de contingence communal.