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ENVIRONMENTAL VULNERABILITY IN HAITI

FINDINGS & RECOMMENDATIONS

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FINDINGS & RECOMMENDATIONS

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PREFACE

The assessment team for this report is deeply appreciative of the time and enthusiasm shown by all those interviewed in the field, the stimulating questions and comments by workshop participants in Petion-Ville and Washington, and the special support provided by Julie Kunen, USAID/Washington, Dana Roth, US Forest Service, and Lionel Poitevien and Ben Swartley of the USAID/Haiti Mission.

This report will be available in both English and French. The cover photograph of the Roseaux watershed in Grand'Anse was taken by Joel Timyan. Authors can be contacted as follows:

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EXECUTIVE SUMMARY

This report was prepared in response to a Congressional directive that, "after consultation with appropriate international development organizations and Haitian officials, organizations and communities, the Administrator of the United States Agency for International Development shall submit a report to the Committees on Appropriations setting forth a plan for the reforestation of areas in Haiti that are vulnerable to erosion which pose significant danger to human health and safety." This launched an iterative process that has encompassed analyses and consultations, and follow-up recommendations.

BACKGROUND

For this report, which contributes to furthering the response to this mandate, USAID contracted a multi-disciplinary team of experts to assess environmental vulnerability in Haiti. The assessment team has interpreted its scope broadly to include not only vulnerability to erosion but also an array of land use practices and related concerns, such as better management of critical watersheds, improved rural livelihoods, sustainable forest management, and reduction in the vulnerability of the Haitian populace to natural disasters such as floods and hurricanes.

METHODS

The team was composed of nine international and Haitian specialists with advanced degrees in cultural anthropology, natural resource management, agronomy, GIS analysis, public health, and biofuel technologies. Five team members are well known Haiti specialists with extensive field experience in research and program implementation. To carry out its study, the team consulted widely with the government, the private sector, major international donors, and grassroots organizations. In May 2006, the team carried out two weeks of fieldwork in Haiti. The team presented its preliminary findings for feedback and discussion at workshops in Haiti (July 2006) and Washington (August 2006). An earlier study, which reviewed Haiti's public sector capacity for natural resource management and disaster preparedness, and current activities of other major environmental donors in Haiti, laid the ground for the present report.

TRENDS

Natural Disasters

Haiti has long been vulnerable to tropical storms and hurricanes; however, in recent years, the country has been afflicted by a significant increase in severe natural disasters. The country lies on the primary pathway of tropical storms that originate in the Atlantic and strike Caribbean islands every hurricane season. Despite the destructive power of gale force winds, loss of human life from tropical storms in Haiti is due primarily to severe flash floods in eroded watersheds that wash down on poor riverine and coastal floodplain communities. Haiti's disastrous floods of 2004 in Gonaïves and other areas serve as a warning of major threats to densely populated districts of Port-au-Prince and other major coastal cities.

Population

Haiti has a youthful and rapidly growing population which is increasingly clustered in urban areas. Based on the census of 2003, Haiti's current population is estimated at 8.4 million people. The annual population growth rate is 2.5 percent per year and women average 4.9 children. At present rates, the Haitian population will grow to 10 million by 2010, an increase of 19 percent in just four years. Haiti's mountainous agricultural base has long surpassed its carrying capacity and cannot support this rate of population growth.

Rapid Urbanization

Like other countries in the region, Haiti is experiencing rapid urban growth, but not urban job creation. On the contrary, since the early 1980s, the Haitian economy has been marked by a long-term pattern of negative growth and increased poverty. As in sub-Saharan Africa, Haiti is experiencing "premature urbanization" — the agricultural sector is not productive and urban areas are not generating economic growth. Despite these economic conditions, Haiti's overall rate of urban population growth is 3.63 percent compared to 0.92 percent in rural areas. Port-au-Prince alone is growing by 5 percent annually, and 40 percent of Haiti's population lives in urban settlements, including shantytowns in coastal flood plains such as Cité Soleil in Port-au-Prince, Raboteau in Gonaïves, and La Faucette in Cap-Haïtien. The Port-au-Prince metropolitan area now comprises one-fourth of Haiti's entire population. Given the sheer scale of settlement in coastal flood plains, predicted deaths due to catastrophic flooding in Port-au-Prince would far surpass all other disasters in Haiti's meteorological record.

The high rate of population growth and rapid urban expansion do not allow aquifers and floodplains to function as natural storage and filters particularly during flood conditions. Due to unplanned urbanization, hard surfaces caused by anarchic construction methods prevent the infiltration of surface water required to recharge the country's most important aquifers, located in the major plains of Cul-de-Sac, Gonaïves, Léogane, Les Cayes and Cap-Haïtien.

FINDINGS AND RECOMMENDATIONS

Root Causes of Environmental Disaster

The assessment team has concluded that the root causes of environmental disaster in Haiti are acute poverty, rapid population growth and unplanned urbanization. In the short term, it remains critical to convert hillsides to tree-based perennial agriculture; however, the team's most important recommendations are for long-term actions that fall outside the realm of traditional soil conservation and reforestation efforts.

First, prospects for reduced vulnerability to natural disaster in Haiti are very limited in the absence of broad based economic development. In the long run, it is imperative to generate a large number of permanent long-term jobs and viable alternatives to farming the country's hillsides. This objective could be facilitated, for example, by US legislation

favoring trade policy to support the assembly industry in Haiti and also the export of high value fruit crops[1].

Second, an environmental management plan geared to mitigate environmental vulnerability must integrate demographic parameters and take steps to alleviate population pressure by providing access to voluntary family planning information and services. This argues for a national effort (building off current mission and donor efforts) to integrate voluntary family planning service provision with the protection of vulnerable watersheds, economic growth activities, and mitigation efforts in urban flood plain communities.

Hillside Agriculture

The present assessment shows clearly that the future of Haiti does not reside with intensively-managed hillside agriculture. The country's steeply sloped agricultural plots require substantial investments to keep soil, water and agricultural inputs in place. Hillside farmers have long farmed Haiti's slopes; however, these slopes were never suited to annual agriculture and most farmers cannot afford the cost of installing and maintaining appropriate agricultural practices. There is also no evidence that either the Haitian state or donors can afford the high investments required to make hillside agriculture productive on a sustainable basis. Therefore, despite our best efforts, most Haitian landscapes will never consist of an ideal of hillside farms meeting high standards of soil and water conservation, mixing perennial and annual crops, benefiting from profitable marketing strategies, attaining adequate rural incomes, and providing equitably for upstream and downstream users alike. There will undoubtedly be sites where something close to this ideal model can be achieved, but these will be islands in the overall landscape.

Rather, the primary "natural" resource to be managed in Haiti is the intellectual power and work ethic of the Haitian people. Dysfunctional economic and political structures have prevented Haitians from exploiting their individual capacities. In the long run, Haiti must develop non-agricultural economic motors in secondary cities throughout the country, with improved education feeding employees into those businesses. Instead of succeeding though natural resource management projects, it is more likely that improved watershed management will eventually be achieved when the rural population leaves mountainous regions and finds alternate employment in lowland areas, coastal cities and beyond — the Puerto Rican model. Unless the current hillside population density decreases significantly, reforestation in the sense of reestablishing the previously-existing forest will never be possible.

Watershed Interventions

In the near term, landscape restoration is urgently needed in selected watersheds. This will buy time for longer-term efforts to boost broader economic growth, family planning, improved education, and good governance in secondary cities. Up to now, there has been no precedent in Haiti for successful interventions at the level of whole watersheds;

[1] This legislation has now been adopted.

success has been achieved at localized or pilot scales. Nevertheless, to effectively reduce vulnerability, interventions must engage a critical mass of farmers and affect the preponderance of slopes within watersheds. The challenge, therefore, is to scale up interventions in scattered plots and isolated ravines, and promote alternatives to erosion-intensive agriculture on Haiti's slopes. This includes increasing the proportion of the landscape devoted to perennial crops rather than erosion-intensive annual food crops, off-farm employment generation including transformation of local agricultural products, and generally shifting agricultural pressures away from slopes onto more intensively cultivated lowlands and other sites less vulnerable to erosion.

Valuable lessons have been learned from the successes and failures of previous projects in Haiti, especially in the areas of tree culture and marketing of agroforestry products. When properly targeted and implemented, project interventions on slopes can speed landscape restoration, restore the functions of ecosystems, mitigate poverty, and slow the anarchic population growth of Haiti's cities. Using a participatory methodology, watershed management plans should be prepared for whole watersheds and should include identification of assets as well as high risk sites within watersheds. This process should include the direct participation of local farmers and other watershed stakeholders including local government.

Conversion of hillsides to tree-based perennial agriculture should be undertaken in a context of national planning that takes food security into account as well as the capacity for urban centers and lowland agricultural zones to absorb significant increases in population. If grain and pulse production were to decline due to the widespread conversion of slopes to tree crops, Haiti would become even more dependent on food imports. Therefore, complementary improvements in flatland agriculture are needed as well.

Watershed Vulnerability and Prioritization

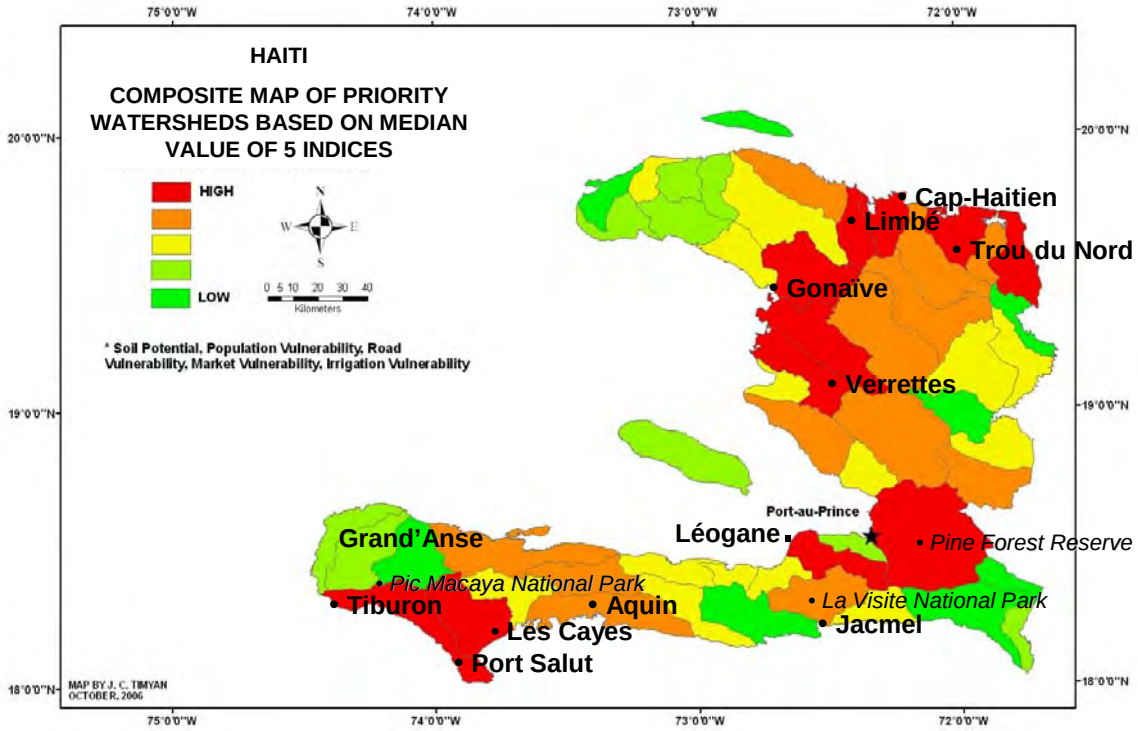
There is little chance of reducing vulnerability to natural disaster unless the interventions encompass whole catchment areas and incorporate ridge-to-reef planning. To be effective, interventions must be part of an integrated approach, directly linking natural resource management with other pertinent sectors such as early warning, urban planning, reproductive health, and job creation programs. To be sustainable, watershed interventions must be rooted in participatory approaches with local levels of government, grassroots organizations, and resource user groups.

Given the overwhelming challenges, it is imperative to establish priorities and make choices based on reliable data and careful analysis of risk and opportunity Prior to the present study, Haiti's watersheds had never been compared and ranked quantitatively in terms of their vulnerability to loss of human life, productive infrastructure, soil potential, or erosion risk. Therefore, the assessment team used geographic information systems (GIS) analysis and hazard mapping to develop an unprecedented new tool for (i) ranking the relative vulnerability of Haiti's watersheds and (ii) establishing priorities to mitigate risks of natural disaster and promote economic growth (please see map below that identifies priority watersheds). The team's vulnerability analysis of Haiti's 54 major watersheds identified four *thematic* clusters of high priority watersheds:

- Port-au-Prince. There is virtually no chance of diminishing Haiti's vulnerability to severe flooding without mitigation efforts that target densely populated urban neighborhoods. The Port-au-Prince metropolitan area has far and away the highest potential for loss of life and infrastructure if a disastrous flood occurs. This is due to the sheer density of people living in the metro region, many in floodplains. Therefore, a task force is urgently required to create flood maps of high risk zones of the Port-au-Prince metropolitan area. A programmatic response should be firmly rooted in partnerships with neighborhood groups. The sheer scale of investment and organizational effort required to alleviate flood risk in the Cul-de-Sac watershed that encompasses Port-au-Prince will undoubtedly require a multi-donor strategy rather than reliance on a single donor.

- Secondary Cities (Les Cayes, Trou du Nord and Jassa, La Quinte-Gonaïves, and Cap-Haïtien). This cluster links high risk to population and infrastructure with high production potential. Therefore, program interventions in secondary cities and their rural uplands should emphasize economic development along with natural resource protection and disaster preparedness. The Inter-American Development Bank and USAID job creation programs are already active in Les Cayes, Gonaïves, and Cap-Haïtien.

- High Mountains and Protected Areas (Grand'Anse, Rivière Jacmel, and Fonds Verrettes). The highland forests of these watersheds exercise a critical hydrological



function as headwaters of more than a dozen rivers and have global significance for biodiversity. According to recent reports, the Grand'Anse region has become the country's principal source for the unsustainable harvest of wood charcoal. Therefore, this cluster links very high erosion risk with the region's high frequency of hurricanes and the opportunity to conserve Haiti's most significant protected areas, Macaya and La Visite National Parks and the Pine Forest Reserve. Watersheds in this cluster would benefit from the development of a national heritage strategy together with the Haitian government and international NGOs, including co-management with local user groups and the promotion of ecotourism.

- Manageable Size, Donor Absence and Vulnerability (Trou du Nord, Momance-Léogane, Limbé, Tiburon/Port-Salut, Aquin/St. Louis du Sud). This cluster overlays manageable size with the absence of other donors whose efforts have instead targeted the lower Artibonite and some of the larger secondary cities. Watersheds in cluster 4 are conducive to ridge-to-reef management plans encompassing both urban and rural sectors, and the income-generating capacity of local producer groups.

In sum, the USAID/Haiti Mission cannot directly intervene in all 54 major watersheds of Haiti. Therefore, it should devise a near term strategy for interventions in high priority watersheds. In general, prioritization should target high risk sites and link early warning systems with watershed interventions, including best management of natural buffering systems such as highland forests, the estuaries of mangroves, and coastal wetlands.

Prospects for Biofuels in Haiti

Charcoal and fuelwood currently provide 75 percent of Haiti's energy consumption. Given the importance of these products, the assessment team was asked to make recommendations regarding improved biofuels and biofuels management as an element of watershed management. The team recommends expansion of bio-energy crops including wood and oil bearing plants in response to viable markets, and incorporation of such crops on slopes and in soil conservation structures where feasible.

Future efforts should promote sustainable planting and harvesting of trees for charcoal and other wood products. Measures to increase the supply of fuelwood should include farm-site tree planting, more efficient carbonization, and massive diffusion of more efficient cookstoves, including more efficient charcoal stoves. To support these efforts, it is also important to advocate for a national strategy on sustainable charcoal production.

Production of oil bearing crops in drier agricultural zones may be used to reduce soil erosion and improve watershed management; however, at the present time these crops and their markets are not well established. Therefore, the Mission should closely monitor liquid biofuel opportunities and work with local stakeholders to define an action plan for pilot efforts in this sector.

CONCLUSION

A USAID strategy for intervening in high priority watersheds should be just one element of a long-term multi-sector strategy for major investments in economic development and off-farm employment in secondary cities, small towns, and flatlands. In order to have a discernible impact, there should be a significantly heightened level of inter-donor collaboration at policy levels as well as the targeting of field interventions. Also, Mission programming should make use of other US government resources in addition to USAID expertise in urban planning, environmental management, coastal and marine resources, and disaster preparedness.

For such an approach to be effective, the US government should make a long-term commitment to poverty alleviation and to interventions in critical watersheds. An effective strategy will require seamless continuity of funding at major funding levels going well beyond scattered projects and intermittent three to five year project cycles. This will require a major commitment on the part of the US government, as well as an enabling political environment in Haiti.

I. INTRODUCTION

This report presents findings and recommendations of a USAID-funded policy study undertaken to define program interventions to reduce Haiti's vulnerability to natural disaster and to improve management of watersheds and erosion-prone hillsides. Hurricanes and tropical storms have long been the primary causes of natural disasters in the Caribbean. In the spring rains of May 2004, more than 2,000 people died due to tropical storms and severe flooding in the Haitian mountain towns of Fonds-Verettes and Mapou, and the neighboring town of Jimani in the Dominican Republic. A few months later in September 2004, flooding related to the passage of Tropical Storm Jean killed more than 3,000 Haitians in Gonaïves and Port-de-Paix.[2]

This policy study was undertaken in response to a Congressional directive. In the 2005 Appropriations Bill, Congress directed that USAID develop "a plan for the reforestation of areas in Haiti that are vulnerable to erosion which pose significant danger to human health and safety." USAID has interpreted this mandate broadly to include better management of critical watersheds, improved rural livelihoods, sustainable forest management, and reduction in the vulnerability of Haiti's populace to natural disasters such as floods and hurricanes.

In order to identify the most effective interventions in these sectors, USAID conducted an initial assessment of current and past watershed management activities in July 2005.[3] This assessment identified environmental stabilization activities that have improved the condition of vulnerable hillsides and rural livelihoods. The key to these successes was the use of market-based incentives that connect soil and water conservation measures to improvements in farmer incomes.

Subsequently, between November 2005 and September 2006, USAID commissioned a somewhat broader overview of environmental vulnerability including (i) a background analysis of environmental risks and opportunities in Haiti, [4] and (ii) the present report of findings and recommendations for alleviating Haiti's environmental vulnerability. The background analysis reviewed Haiti's environmental policy and legal framework, and public sector capacity for natural resource management and disaster preparedness. It also reviewed current activities of other major environmental donors in Haiti including The World Bank, the Inter-American Development Bank, the European Union, and the Canadian International Development Agency. Background analysis took special note of the Interim Cooperation Framework (July 2004) established by donors and the Interim Government of Haiti (2004-2006) in the months following the fall of Aristide (February 29, 2004).

The assessment team conducted its background analysis prior to the February 2006 election of President René Préval and the establishment of a new government in May 2006. The 2004 Interim Cooperation Framework established by donors with Haiti's

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[2] See Potter *et al.*, (2004) and OCHA Situation Report (2006).

[3] *Agriculture in a Fragile Environment Market Incentives for Natural Resource Management in Haiti* (July 2005), Glenn Smucker, editor, and Gardy Fleurantin, Mike McGahuey, and Ben Swartley, USAID/Haiti Mission.

[4] *Environmental Risks and Opportunities in Haiti A Background Analysis* (October 2006), Glenn Smucker, editor, Marc-Antoine Noel, and Jean-André Victor.

Interim Government was scheduled to end in September 2006. After the election of Préval, a new donor conference was held in July 2006. At that point donors attending the International Conference for the Economic and Social Development of Haiti pledged an additional $750 million of assistance to Haiti, and the Interim Cooperation Framework was extended to September 2007. Consequently, the assessment team updated its background analysis to take into account the evolving political and policy environment, including the newly elected government of René Préval and the new donor conference.

The present report is based on an overview of critical sectors that have an impact on Haiti's vulnerability to disaster, including watershed management, disaster preparedness, sustainable forest and parks management, urban planning, population and health linkages, institution-building and policy reform, the use of biomass for energy, and markets for agroforestry products. The report's findings and recommendations are designed to inform USAID efforts to develop a watershed strategy and define interventions that are (a) likely to be effective, (b) able to produce impact at a broad scale, and (c) within the Agency's manageable interest.

To carry out its study, the assessment team consulted widely with a broad range of stakeholders inside and outside of government including grassroots organizations. As a culminating phase of this consultation process, the team presented its principal findings and recommendations at two stakeholder workshops, one in Port-au-Prince (July 20, 2006) and the other in Washington (August 2, 2006). Workshop presentations included opportunity for questions and discussion of the issues raised by workshop presentations. The workshops also served as a forum to test the team's findings in response to stakeholder concerns and feedback. These concerns have been taken into account in the chapters that follow. Some workshop discussants and presenters contributed to workshop presentations but are not listed here as authors.[5]

Stakeholders participating in the two workshops included the US government and other donors including CIDA, The World Bank, and the Inter-American Development Bank, Haitian government representatives including the Ministers of Agriculture and Environment and representatives of other Haitian government agencies and ministries (Ministry of Interior, Directorate of Civil Protection, Bureau of Mines and Energy), Haitian and international non-governmental organizations, representatives of the Haitian business sector, women's groups, peasant organizations, and ordinary citizens.

The following chapters track the panels and themes presented in the two recent workshops. This includes an overview of population, health and the environment in Haiti (Heather D'Agnes and Scot Tobias), practical approaches for intervening in watersheds based on lessons learned from earlier efforts along with new developments of special interest (Mike Bannister and Yves Gossin), and priorities for public policy and for ranking the relative vulnerability of critical watersheds (Joel Timyan and Ronald

[5] Gael Pressoir, plant geneticist, served as a discussant at both the Haiti and Washington workshops, and Andy White, forest economist, at the Washington workshop. In Washington, Rochelle Rainey presented findings on population, health, and the environment, based on the chapter co-authored by D'Agnes and Tobias. Haitian co-authors for the team's background analysis, Marc-Antoine Noel (agronomist) and Jean-Andre Victor (environmental lawyer), also made presentations at the Haiti workshop.

Toussaint). A brief final chapter draws on earlier sections of the report and synthesizes key elements of an emergent strategy for mitigating natural disaster in Haiti's watersheds.

In the early stages of this assessment, high level representatives of the Haitian government asked the team to assess prospects in Haiti for liquid biofuels including plant oil and biodiesel. The team responded in keeping with its mandate to take into account the concerns of critical stakeholders. Therefore, this report also includes a chapter that explores prospects for biofuels in Haiti (Marc Portnoff).

The role of biofuels (including wood charcoal) in donor environmental strategies remains controversial in Haiti. This is due in part to environmentally destructive aspects of charcoal as the predominant cooking fuel in urban Haiti. In addition, current controversy over prospects for new biofuels stems from recent trends for high fuel costs. This has generated high levels of enthusiasm for liquid biofuel alternatives such as biodiesel, although there is little experience with it in Haiti. At the present time, promotion of liquid biofuels as an element of USAID/Haiti strategy remains exploratory and is not a near term option for large direct investments. The Mission's near term planning does include initiatives to improve charcoal efficiency and sustainability. The Mission's longer term strategy may also support pilot efforts and continued monitoring of liquid biofuel opportunities in Haiti, including prospects for private-public partnerships.

Some of the findings in this report reflect natural resource management (NRM) themes and recommendations already presented in earlier studies, particularly the July 2005 report noted earlier, *Agriculture in a Fragile Environment: Market Incentives for Natural Resource Management in Haiti*. This is hardly surprising due to inescapable recurring themes that emerge when confronting the persistent dilemma of how to make an impact in Haiti's highly degraded watersheds. One persistent dilemma, for example, is the difficulty of scaling up from scattered farm plots in order to treat entire slopes or whole watersheds with erosion control measures or market-oriented perennial crops.

So what is new in the present report? The assessment team consulted with a much broader range of stakeholders, including interlocutors outside of the usual network of environmental partners.[6] Secondly, the team used GIS analysis to quantify and rank all of Haiti's major watersheds in terms of their vulnerability to severe flooding. This type of science-based ranking has never been done before and is an unprecedented new contribution. Third, this study takes note of current new developments that show promise, e.g., business partnerships between small peasant farmers and affluent private sector interests, and new evidence of landscape level changes in tree cover due to peasant tree gardens cropped for sustainable charcoal harvest.[7] Fourth, this assessment takes special note of highly stressed mangrove ecosystems and estuaries as an important target for flood control and protection of livelihoods in river delta areas. Finally, this report recognizes new biofuel trends in the world, and examines prospects for biofuel in Haiti as an element of watershed strategy.

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[6] This process also included extended conversations with representatives of both the outgoing Interim Government and the newly elected government of President Préval.

[7] This pattern of market-oriented tree cropping and these particular sites were originally established by small peasant farmers under the AID funded Agroforestry Outreach Project of the early 1980s.

II. POPULATION, HEALTH, AND THE ENVIRONMENT

by Heather D'Agnes and Scot Tobias[8]

Calamities from extreme weather highlight how environmental hazards combine with socioeconomic conditions to magnify the threat of disaster for tens of millions of people in both the developed and the developing world. In an attempt to understand the full range of factors that affect Haiti's growing vulnerability to severe storms, this chapter links population and health trends with the environment as pivotal factors that greatly exacerbate the effects of natural disasters. The present chapter also briefly examines health problems of indoor pollution due to the use of firewood and wood charcoal as cooking fuel.

Policymakers and practitioners routinely assert that high population growth and rapid urbanization increase the negative effects of natural disasters; however, these declarations rarely lead to effective action since standard responses to natural disasters focus on short term alleviation of immediate distress. A long-term approach should examine the relationship among natural disasters and development patterns, population growth, spatial distribution, and the underlying rationale for demographic behaviors. This type of analysis generates recommendations that address structural issues rather than short-term remedial actions.

HAITI'S DEMOGRAPHIC PROFILE

Haiti has a youthful and rapidly growing population with an increasing tendency to cluster in urban areas. A recent census by the Haitian Institute of Statistics (IHSI) estimates Haiti's population at 8.4 million.[9] The annual population growth rate of 2.5 percent per year is higher than previous estimations; women average 4.9 children. Population growth results exclusively from childbearing since Haiti's net migration rate is –1.3 migrants per 1,000. It is estimated that the Haitian population will grow to 10 million by 2010, an increase of 19 percent in just four years.

This growth rate is striking since the average life expectancy was 53 years in 2006, 51.9 years for males and 54.6 years for females. Haiti's health indicators are the worst in the western hemisphere with an annual death rate of 12.2 deaths per 1,000 population, infant mortality at nearly 72 deaths per 1,000 live births, a maternal death ratio of 523 women per 100,000 live births, and an HIV prevalence rate of 4-5 percent of the total population (UNFPA, 2006). This further demonstrates that high fertility is the primary cause of burgeoning population growth.

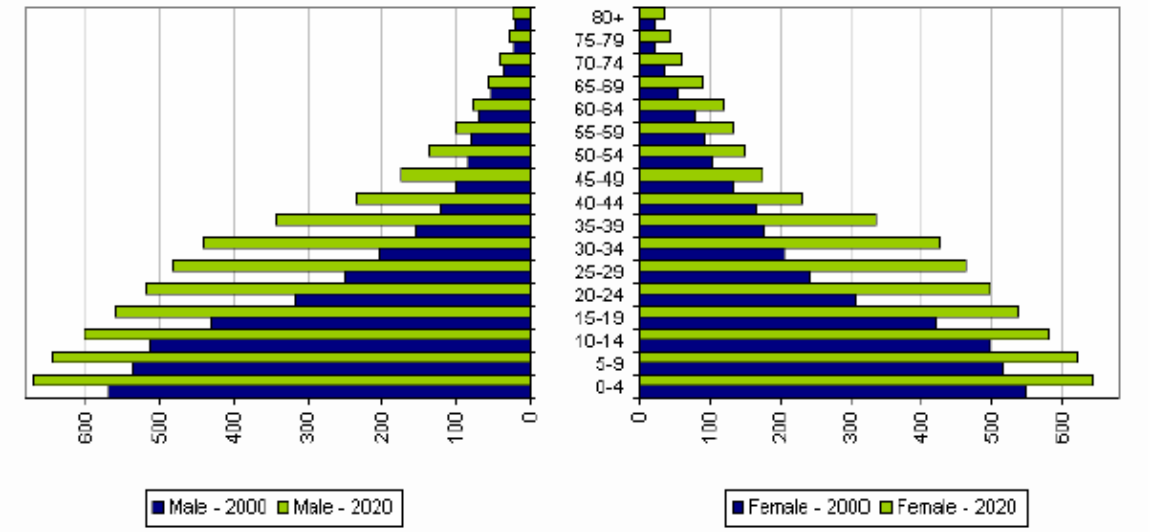
In addition, Haiti's population is increasingly dense and concentrated in urban areas. Haiti is the western hemisphere's second most densely populated country with 302 persons per square kilometer, trailing only Barbados (UNFPA, 2006). With an urbanization ratio of 40 percent, a growing proportion of Haiti's population now lives in urban settlements including shantytowns in coastal flood plains such as Cité Soleil and La Saline in Port-au-Prince, Raboteau in Gonaïves, and La Faucette in Cap-Haïtien. The

[8] Rochelle Rainey also contributed to this chapter and presented its findings at the Washington workshop.
[9] The 2003 census is Haiti's fourth, following those of 1950, 1971 and 1982.

country's high urban population growth rate of 3.63 percent and low rural population growth rate of 0.92 percent reflects high rates of migration from rural to urban areas (UN Habitat, 2001). The Port-au-Prince metropolitan area alone, including seven neighboring municipalities, now comprises more than one-fourth of Haiti's population. This reflects an urban growth rate of five percent annually between 1982 and 2003 in Haiti's most urbanized *département* (Ouest). Consequently, an estimated 62 percent of all urban dwellers in Haiti live in the metropolitan area of Port-au-Prince (IHSI, 2003).

Haiti's population will continue to grow rapidly due in large part to its high population momentum. Population momentum refers to the percentage of the population that has not yet had children but will eventually add to the population through reproduction. In Haiti, 50 percent of the country's population is under the age of 20 (see Figure 1). Haitians are sexually active in their teens; the median age of sexual debut for women is 18.2. In addition, 31.3 percent of women age 20-24 give birth before the age of 20 (ORC Macro, 2000). As a result, the higher the percentage of people age 20 and under, the larger the population growth will be. Therefore, Haiti's population will continue to grow – even if the fertility rate over the next few years begins to decline. For a graphic representation of past and projected population growth by age, see Figure 2 on the next page.

Figure 1: Current and Projected Population by Age and Sex (in thousands)



SOURCE: United States Census Bureau (BUCEN), International Programs Center. International Database.

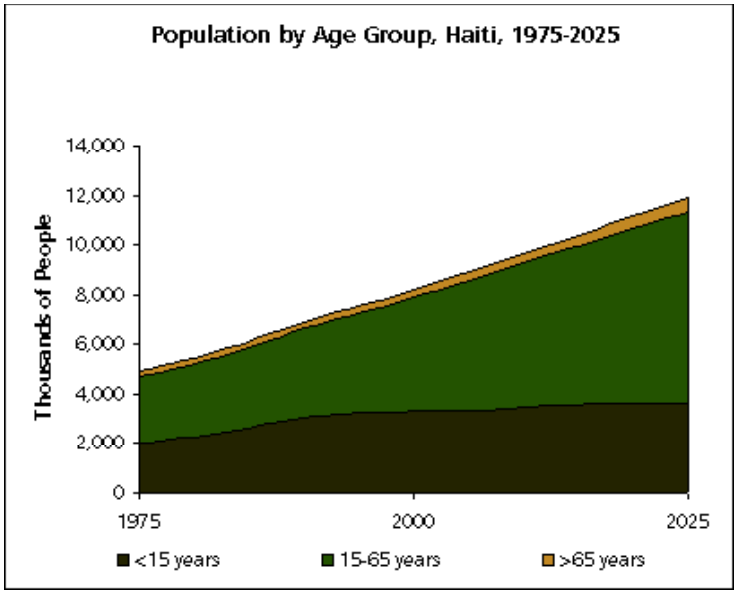
FACTORS INFLUENCING POPULATION GROWTH

Lack of access to family planning

There is scant data on access to family planning services and information in Haiti; however, data gathered by the Haiti Demographic Health Survey (DHS) in 1994/5 and 2000 demonstrate a clear lack of sufficient family planning services (see Table 1). Contraceptive prevalence rate is low at 28.1 percent for all methods of family planning and 22.8 percent for modern methods. Expressed desire for family planning services exceeded availability of those services; 56.9 percent of married women want no more

children and 39.6 percent of women express an unmet need for family planning. In addition, women only want an average of 3.1 children but end up having 4.7 children.

Figure 2. Haiti's Projected Population by Age



Source: World Resources Institute

One reason for the high unmet need for family planning is that Haiti's reproductive health services are primarily health centers and district hospitals clustered in urban areas (see Table 2). Thus, a large percentage of the population lacks sufficient access to outlets for family planning. Due to the limited distribution network, the population depends largely on permanent to semi-permanent family planning methods such as female sterilization and Norplant implants rather than shorter-term family planning commodities such as pills and condoms. This inhibits the ability of many women, especially rural women, to space the births of their children without eliminating the ability to have more children.

Table 1. Key Family Planning Indicators

FERTILITY INDICATORS	1994/95	2000
Total fertility rate (children per women)	4.8	4.7
Percent (%) of teenagers who have begun childbearing	14.5	18.0
Fertility preferences		
Percent (%) of married women who want no more children	52.5	56.9
Percent (%) of married women with an unmet need for family planning	44.5	39.6
Mean ideal number of children	3.3	3.1
Family planning use indicators		
Percent (%) of married women currently using any method of family planning	18.0	28.1
Percent (%) of married women currently using any modern method of family planning	13.2	22.8
Other proximate determinates of fertility		
Median age at first marriage for women age 25-49 (years	20.8	20.5
Median age at first sex for women age 25-49 (years)	19.0	18.2

Source: ORC MACRO, 2006. MEASURE DHS STATCOMPILER. May 29 2006. http://www.measuredhs.com

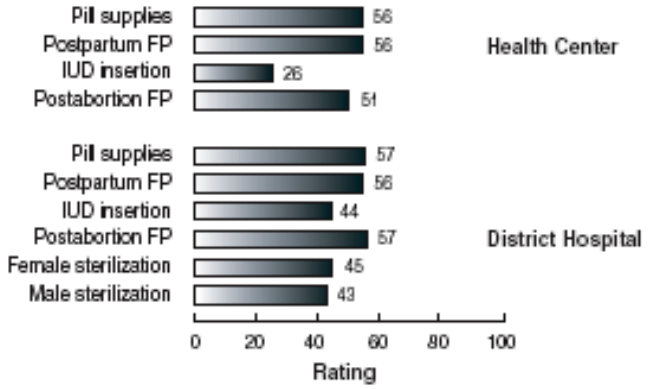
Table 2. Percentage Distribution of Current Users of Modern Methods by the Most Recent Source of Supply according to Method

Source	Contraceptive Method				
	Pill	Implant	Injectable	Condom	Female sterilization
Public sector (hospital and health centers)	21.9	21.9	24	4.5	55.5
Private medical sector (hospital/clinic, health centers, physician, pharmacy)	41.2	45.7	25.8	37.4	23.4
Mixed sector medical sector (hospital/clinic, health center, family planning clinic)	24.3	32	39.4	4.8	18.1
Noninstitutional medical sector (mobile clinic, health agent/promoter, midwife)	8.4	0	10.3	1.1	0.3
Other informal sector (store, market, acquaintances)	4.2	0.0	0.5	51.3	0.0

Source: *Studies in Family Planning*, "HAITI 2000: results from the demographic and health survey," 2003**.**

Unfortunately, family planning services in Haiti tend to be poor in quality. Based on the Maternal and Neonatal Program Effort Index (MNPI), Haiti received a low overall ranking of 49 out of 100 for family planning services provided at health centers and district hospitals (Bulatao and Ross, 2002; Ross, Campbell, *et al.*, 2001). Figure 3 shows individual ratings for family planning services provided at health centers and district hospitals. Both health centers and district hospitals received relatively high ratings for pill supplies (56 and 57, respectively) and postpartum family planning (both 56). Male sterilization (43) was the lowest-rated service for district hospitals, whereas IUD insertion was the lowest for health centers (26).

Figure 3. Provision of family planning services at health centers and district hospitals in Haiti



Impacts of Poverty on Access to Family Planning

High population growth is particularly acute among the poor. The 2000 DHS demonstrates that fertility levels differ significantly among social groups, with the poorest sectors showing much higher levels of fertility. These fertility patterns reflect the fact that limited

availability of family planning and health services in Haiti has the severest impact on poor women. Women frequently bear full responsibility for all family-related decisions and concerns but have the least capacity to exercise their reproductive preferences. Women from the lowest socioeconomic level in Haiti have twice as many children as they would like to have. Their inability to exercise their reproductive rights is the starting point for a vicious circle centered on the intergenerational transmission of poverty. Poor women have limited information and resources to limit the number of births. Forced to rear many children, these women have greater difficulty in obtaining paid employment, leading to a lower per capita income for their families. During emergency situations and disasters, such inequities become more acute.

Current USAID Efforts in Access to Family Planning

USAID funds several projects to provide support to family planning programs in Haiti. In particular, USAID is reinforcing the capacity of institutions nationwide to deliver clinical family planning methods. Anticipated results are increased access to and use of modern and natural family planning services and related maternal health care, and strengthened quality of essential maternal and neonatal care. Reproductive health services are closely integrated with HIV-related activities under the President's Emergency Plan for HIV/AIDS Relief (PEPFAR). [10]

Between 1995 and 2000, a USAID-funded project operated by Management Sciences for Health (MSH) and its partners established an NGO network (34 members) to streamline services, deliver a minimum package of services, and develop strategies to inform and educate the public. This network has had a significant impact. Between 1997 and 1999, use of modern contraceptive methods increased from 15.7 percent to 25 percent at project sites; “three plus” prenatal visits increased from 44 percent to 61 percent; and the number of trained personnel attending deliveries increased from 63 percent to 79 percent. The appropriate use of oral rehydration therapy (ORT) and full immunization also improved significantly in project areas.

HEALTH SERVICES, POVERTY, AND VULNERABILITY

Environmental Health Services

Following natural disaster, any affected population requires shelter from the elements and access to clean water, proper sanitation, and energy sources. The number of people put at risk by interruption of water and sanitation service due to natural disaster can easily be three or four orders of magnitude greater than the number of people killed or injured by that same disaster. Provision of environmental health, water, and sanitation services in the absence of a natural disaster is complex and requires coordinated efforts by national government ministries, local government units, civil society, and the private sector. When these institutions and their coordination are weak, the systems and infrastructure for these services are particularly vulnerable to disruption due to natural disasters.

[10] Principal contractors are Johns Hopkins Program for International Education in Gynecology and Obstetrics, the Futures Group, Management Sciences for Health (MSH), and Population Services International.

In the case of reproductive health services, natural disasters can accentuate reproductive health needs by intensifying the inability of couples and individuals to exercise their reproductive rights due to:

- Deterioration of health services
- Difficulty in access to services as a direct consequence of disaster
- A shift in medical priorities away from reproductive health services

Natural disasters also tend to increase the incidence of sexual abuse, sexually transmitted diseases, unwanted pregnancies due to the poor conditions in shelters, and the vulnerability of minors separated from caretaker adults. For example, the 3,000 deaths attributed to Tropical Storm Jeanne in Gonaïves (2004) generated a sizeable number of orphaned children.

Overall, fertility tends to decrease in times of crisis, but fertility later tends to increase along with recovery. Experiences of war, famine, and other disasters clearly demonstrate this trend. Recent data from a 2001 survey show that fertility in Honduras for the period 1999-2001, after a period of recovery from Hurricane Mitch, were much higher than projected (ASHONPLAFA, & CDC, 2002).

Population Trends, Poverty, and Vulnerability

Links between population trends, poverty, and degraded natural resources are the central feature of Haiti's vulnerability to tropical storms. Growing rural poverty is the dominant precipitating factor behind the country's rapid rate of urbanization. High rural-urban migration is motivated largely by the search for employment and access to schooling. Rapid urbanization has severely aggravated the impact of natural disasters in Haiti, especially among the poor, and has imposed heightened pressures on the environment.

The urban poor in Haiti often have no choice but to occupy the least-valued plots of land in disaster-prone areas such as riverbanks, unstable hillsides, deforested lands, or fragile catchment areas. In general, the densely populated slum districts of Haiti's coastal cities are located to a large degree in flood plains.[11]

These populations are highly vulnerable to disease and natural disaster. Upland soil erosion causes massive deposit of solids in lowland floodplains, overwhelming the capacity of both natural and manmade drainage systems. Downstream flooding creates breeding grounds for insect vectors. Flooding also mobilizes pathogens in human feces and other solid waste deposited on the ground. Public systems for the handling and disposal of human waste are virtually non-existent. Open pit latrines, field defecation, and use of "scandal bags"

> "...poverty and population pressure force growing numbers of poor people to live in harm's way — on flood plains, in earthquake-prone zones and on unstable hillsides."
>
> - Kofi Annan, 1999

[11] Chapter IV addresses this issue in more detail with a view to prioritizing interventions in order to mitigate the effects of natural disaster.

or “flying latrines” are common solutions to human feces disposal, especially in urban districts with few or no public services. The impact of flooding on these open sanitation systems has the effect of contaminating every surface touched by floodwaters. Overall, large urban areas in Haiti tend to be more hazardous than sparsely populated rural areas because of their population size and the potential scale of damage.

Disasters, although terrible in their impacts, often “wipe the slate clean” with respect to reconstruction. An important opportunity exists after disasters to rebuild in a more responsible and sustainable manner, as has happened to some extent in Gonaïves. Communities can be planned, and drainage and transportation systems designed that will increase resilience to natural disasters.

HOUSEHOLD COOKING FUEL AND INDOOR AIR POLLUTION

Globally, about 2.4 billion people rely on inefficient and highly polluting biomass fuel — mostly wood, animal dung, and crop wastes — for everyday household energy needs (IEA 2002; Smith, Mehta, and Feuz 2004). The majority of households using solid fuels burn them in open fires or simple stoves that release smoke into enclosed areas. The resulting indoor air pollution (IAP) comprises a variety of health-damaging pollutants, including particles, carbon monoxide, and carcinogens, and is a major threat to health, particularly for women and young children, who may spend many hours close to the fire (Smith 1987). Every year, 1.5 million people die from inhaling indoor pollutants that often exceed accepted guideline limits for outdoor air; in the case of fine particles, the limit is exceeded by 100 times or more (Smith *et al.*, 2004; WHO, 2006).

Children and women are disproportionately affected with nearly 800,000 deaths annually attributable to indoor air pollution occurring among children under five years of age, and more than 500,000 such deaths occurring among women (WHO, 2006). This issue is inextricably linked to poverty, as it is primarily the poor who rely on solid fuels and inefficient stoves, and many are trapped in this situation. Health and economic consequences contribute to keeping them in poverty, and their poverty stands as a barrier to change (Bruce *et al*., 2006).

In Haiti, the standard charcoal cook stove burns inefficiently with little ability to control air or conserve heat.[12] In addition to the burden that this reliance on biomass puts on Haiti’s tree cover, cooking with charcoal and firewood on crude stoves has a significant adverse impact on human health in Haiti. It has been estimated that the average life span in Haiti is shortened by 6.6 years because of the impacts of indoor air pollution caused by indoor burning of biomass (United Nations, 1998). Acute Lower Respiratory Illness (ALRI), the global number one killer of children under five years of age is also the number one killer of under-fives in Haiti — with ALRI mortality estimated to be more than 40 percent (Fenand *et al*., 2005). This mortality burden is undoubtedly related to the massive use of biomass as cooking fuel. It is common to have outside cooking shelters separated from living quarters in Haiti; however, cramped households in densely

[12] The most commonly used stove consists of a charcoal pan on three legs, and the pan has holes in the bottom for air and for ashes to drop. The cooking pot sits on top of the charcoal pan quite close to the coals.

populated urban neighborhoods are strongly affected by the use of smoky fuels in enclosed areas.

In addition to the negative health effects, use of solid biomass fuel has important environmental consequences. Many low income urban populations rely on wood charcoal for cooking, and the production of charcoal can place severe stress on forests, particularly if the charcoal production technology is inefficient. Reliance on wood fuels may contribute significantly to deforestation when linked to population pressure, poor forest management, and clearance of land for agriculture and construction materials. Reduction of tree cover tends to increase distance traveled to obtain wood and can result in the use of freshly cut (green) wood, dung, and twigs, which are more polluting and less efficient.

Most households in Haiti rely on local biomass for cooking fuel (ECVH 2003, ESMAP 2005). Furthermore, most wood harvest in Haiti is for cooking fuel, primarily for charcoal in urban areas and firewood in rural areas. The high and growing demand for wood-based cooking fuel in Haiti has had significant environmental consequences. Wood charcoal and fuelwood markets, including prospects for sustainable charcoal harvest in Haiti, are discussed in more detail in Chapter V.

Efforts to introduce improved cooking systems in Haiti include locally manufactured adobe stoves, hand-crafted and mass produced stoves constructed of metal, and solar cook stoves. Improved cook stoves have made only minor inroads due to their high cost compared to traditional Haitian charcoal stoves, and also the expense and difficulty of constructing adequate chimneys for indoor use. Traditional Haitian cook stoves are cheaper to acquire but less efficient in the use of energy. Among the urban poor, cash shortage and rising fuel costs commonly result in cooking fewer meals, perhaps only one per day, and also unhygienic “cold” storage and consumption of previously cooked food.

Large scale use of improved cook stoves in Haiti could have a significant impact on the scale of tree harvest as well as human health, particularly under-five mortality. Due to prospective savings on fuel, economic incentives exist to acquire improved cook stoves, especially in urban households; however, the majority of urban households cannot afford up-front acquisition costs for improved cook stoves. There are also culinary preferences for cooking over charcoal rather than other fuels.

RECOMMENDATIONS FOR ACTION

Macro-Level Recommendations

Any serious effort to mitigate Haiti’s environmental crisis must directly address Haiti’s dominant population trends — rapid population growth and rapid urbanization, especially the anarchic growth of Port-au-Prince. This argues for a national effort to reduce population growth and mitigate environmentally destructive patterns of urbanization.

There should be a major effort to promote widespread use of improved cook stoves that direct less smoke into enclosed cooking areas and consume less fuel, especially in Haiti’s rapidly growing urban neighborhoods.

Other Recommendations

Family planning services should be directly integrated with other program interventions to protect watersheds and other natural resources. Family planning should be linked to the management of watersheds, protected areas and forests, and conservation of mangroves and other coastal resources. There is growing evidence that programs linking natural resource management with health and family planning provide substantial value (Pielemeier, 2005):

- Health and family planning services may serve as an important entry point for conservation and natural resource management activities. Integrated programs build positive relationships with communities, and local commitment to land use planning and management of protected areas.

- Integrated programs result in increased participation of groups traditionally marginalized or left out in both health and natural resource management projects. They are more likely to increase male involvement in family planning and health activities, female involvement in natural resource management activities, and increased participation of adolescents of both sexes in natural resource and reproductive health behavior change activities.

- Environmental health services (water and sanitation) may serve as the "entry point" for other family planning interventions. These activities gradually open the door to family planning among conservative rural communities that are traditionally hard to reach.

- Population-health-environment projects have shown themselves to be both cost-efficient and effective. A large number of NGOs have demonstrated that they can successfully implement integrated programs with the positive effects of expanding target audiences, reducing operating expenses, and fostering community goodwill and trust.

Policy and donor attention to the linked population and environment dimensions of natural disasters should be strengthened.[13] These issues are intrinsically linked in both urban and rural settings, but programs are generally designed as stand alone environmental management or reproductive health programs.

- The supply chain for family planning products should be strengthened: Links between vulnerability to natural disaster and population can be used to promote equal access to family planning services for all Haitian populations. Community-based social marketing and distribution networks can increase access to family planning services and boost the contraceptive prevalence rate of modern methods.

[13] See Chapter IV for other recommendations on disaster preparedness in addition to family planning services.

- Local population risk analysis should be undertaken for more effective targeting: Analysis of vulnerability should take note of population density and distribution to determine numbers at risk, and age structure to determine young and older segments of the population that may be at greater risk.

- Targeting the rural poor: High priority should be given to the provision of family planning services for populations living in fragile upland zones of critical watersheds.

- Targeting the urban poor: This population tends to live in neighborhoods that are more vulnerable to natural disaster, as well as to sexually transmitted infections and HIV/AIDS.

- Targeting youth (ages 13-20): Youth are an important population due to Haiti's high population momentum, young average age of sexual debut, and promotion of social and political stability.[14] Communication campaigns that integrate environment and population messages make family planning information and services more acceptable to youth.

- Improved information management and communication about population and environment drivers of disaster. Researchers need to more effectively communicate the importance and economic benefits of disaster mitigation to educators, journalists, advocacy groups, and local communities — emphasizing the role of population, health, and the environment.

Improved cook stove efficiency and behavior change for better health should be promoted.

- Improved cook stoves should be promoted and made accessible to the poor.

- The economics of mass-produced cook stoves for urban areas should be studied as a basis for promoting private sector marketing of stoves that consume less fuel and direct less smoke to indoor areas.

- Behavior change campaigns should be undertaken to reduce the exposure of children and women to smoke from biomass cooking fires.

- Women should be integrated into the design and execution of any behavior change or appropriate technology intervention that involves cook stoves.

[14] In the 1990s, countries in which young adults made up a large proportion of the adult population (40 percent or more) were more than twice as likely to experience an outbreak of civil conflict (Cincotta et. al, 2003).

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III. INTERVENTIONS IN WATERSHEDS

by Mike Bannister and Yves Gossin

BACKGROUND

This chapter considers agricultural practices in watersheds that have shown potential for reducing erosion and vulnerability to flooding both inside and outside of small farm plots. The scope of the analysis is broader than a discussion of trees and soil conservation practices; these are only a part of several models executed over the last several decades along with others presently evolving or proposed for implementation. This chapter is based on recent field visits, experience working on projects since 1981, and review of project documents. It reviews models for intervention as well as individual plot practices, and then makes recommendations about the scale and type of interventions USAID might consider. The following discussion begins by considering the longer-term future of hillside land use in Haiti and some assumptions that guide the assessment and recommendations.

Intensive Hillside Agriculture Is Not the Future

This assessment is based on the assumption that the future of Haiti does not reside with intensively managed hillside agriculture. Although it makes a good painting, a future ideal will not be attained wherein most Haitian landscapes consist of hillside farms conforming to high standards of soil and water conservation, mixes of perennial and annual crops, profitable marketing strategies, and whole watershed planning based on equity between upstream and downstream users that result in the provision of environmental services and an adequate rural income stream.

There will be sites where something close to the ideal model can be achieved, but these will be islands in the overall landscape. The main reasons are the following:

- It is prohibitively expensive and risky to do hillside agriculture “correctly” on a severely degraded resource base.
- Switching completely away from annual cropping in favor of tree-based cropping will not be culturally acceptable to most farm families.
- Demographic trends and farm plot sizes are not favorable.
- The majority of small farmers on Haiti’s slopes do not seek to attain this objective.

Steep topography means extra investments must be made to keep the soil, water, and agricultural inputs on the plot. Although Haiti had rich hillside soils in the past, the current degraded condition of these soils means that to improve yield and make agricultural systems sustainable, a substantial investment is required to improve soil stability and fertility. Most farmers cannot afford the cost of installing and maintaining appropriate practices. The Haitian state can’t afford it and neither can donors. For example, the five-year budget for an upcoming IDB/MARNDR agricultural

intensification project is $25 million (Horton *et al*., 2005). The project area covers about 18,000 hectares of agricultural land and about 10,000 farmers. Projecting this cost per hectare ($1,389/ha) over the hilly 70 percent of Haiti, it would cost $2.7 billion to treat the entire country.[15]

The percent of rural family income derived from agriculture is less than 50 percent and is probably decreasing (Horton *et al*., 2005). Rural populations already migrate to cities and overseas, but continued growth of rural populations has the effect of decreasing average plot size beyond the point where small hillside plots are economically viable. Rural families are investing heavily in schooling, and generally preparing their children for non-agricultural futures.

In some rural areas, there are local labor shortages due to cross border migration of young men seeking work in the Dominican Republic. There are also farm labor shortages in areas where NGOs have established a large number of elementary schools. This is reportedly the case, for instance, in the Maissade area. Labor shortages are another constraint to intensifying agriculture on slopes.

In sum, the protection of downstream infrastructures from environmental damage will require far more than promoting labor intensive mixed agroforestry systems on hillsides to produce food crops. In many cases, a more cost effective hillside farm strategy would be to promote tree crops on slopes, i.e., stands of trees, including fruit trees, which require fewer labor inputs than annual food crops.[16]

In the near term, it is critical to convert hillsides to tree-based perennial agriculture; however, substantial conversion of hillsides to tree-based perennial agriculture should be undertaken in a national planning context that takes food security into account as well as the capacity for urban centers and lowland agricultural zones to absorb significant increases in population. If grain and pulse production were to decline due to the widespread conversion of slopes to tree crops, Haiti would become even more dependent on food imports. The problem with being a net food importer is that, if China becomes a net grain importer, as is predicted, then the worldwide grain surplus will not meet projected needs (López *et al*., 2001).

Regarding urbanization, the traditional model experienced by North America and Europe pushed people away from the countryside by mechanizing agriculture, and pulled people into urban areas by offering jobs and wages. Haiti, as in Sub-Saharan Africa, which has the world's highest rate of urban migration, is not following this pattern. It is experiencing what the UN-Habitat calls “premature urbanization” — the agricultural sector is not productive and the urban areas are not generating economic growth. Instead, crop failure, natural disasters, and conflicts are forcing people to flood into towns and cities.[17]

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[15] Proceedings of a workshop on watershed management (MARNDR, MPCE, MICT, MDE, 2000) contain an estimate of the cost of watershed management of $500 to $700 per hectare. Even at $700 per hectare, the total cost of a national effort would be still be about 1.4 billion dollars.

[16] The distinction here is between *agroforestry systems* that are inherently interactive, such as living hedgerows in close proximity to annual food crops, or shade overstory for shade loving crops, versus *tree farming* whereby trees are managed as a crop or planted as an orchard.

[17] http://news.bbc.co.uk/2/hi/science/nature/5054052.stm..

In the end, the primary "natural" resource in Haiti is the intellectual power and work ethic of the Haitian people — and Haitians have these in abundance. Dysfunctional economic and political structures prevent them from exploiting their individual capacities. In the long run, Haiti must develop non-agricultural economic motors in secondary cities throughout the country, with education through university level feeding employees into those businesses. Rather than succeeding though natural resource management (NRM) projects, it is more likely that proper national watershed management will eventually be achieved because forests regenerate over time as the rural population leaves the mountainous regions and finds alternate employment in non-agricultural endeavors in secondary cities, the capital, and elsewhere — the Puerto Rican model. This spontaneous reforestation (Rudel *et al*., 2000) is distinct from the various tree distribution projects done in Haiti which have improperly been described as "reforestation." Unless the current hillside population density decreases significantly, reforestation in the sense of reestablishing the previously existing forest will never be possible.

It Is Worthwhile to Do Project-Based Activities in the Short and Medium Term

In spite of macro-level constraints requiring long-term investment, micro-level interventions and shorter-term treatment of watersheds are still needed for landscape-level restoration. It is in fact imperative to target high priority watersheds in order to mitigate the heightened risks of natural disaster. Chapter IV assesses the relative vulnerability of Haiti's watersheds and proposes a strategy for prioritizing program interventions in watersheds and other fragile landscapes such as mangroves.

When properly targeted and implemented, project interventions on slopes can speed landscape restoration, restore the functions of ecosystems, mitigate poverty, and slow the anarchic population growth of Haiti's cities. This buys time to boost broad-based economic growth, universal education, and good governance in secondary cities. Lessons have been learned from the successes and failures of previous projects; these are discussed in the next section of this chapter. Case studies demonstrate that project interventions can transform local landscapes, increase farmer income, and positively influence agricultural practices. In particular, there have been important successes in promoting tree culture and marketing. These successes can be used as models for projects with broader watershed protection objectives.

NATURAL RESOURCE PROJECT MODELS

Since the 1950s there have been several programmatic trends in conservation and agricultural extension, and new ones are evolving.[18] Several models are described briefly in this section, followed by a summary of lessons learned. Newer natural resource projects draw lessons from several of these models, and there appears to be a recent convergence of project design elements.

[18] See Smucker *et al*., 2005, *Agriculture in a Fragile Environment*.

Landscape Engineering

From the 1950s to the 1970s there were bilateral projects with the Government of Haiti using an approach commonly described as "*équipement du territoire*," a landscape engineering strategy. These projects were done on both private and public lands using a top-down management approach to cover large, contiguous areas with conservation structures. Soil conservation was considered to be a strictly technical problem to be solved by engineers installing mechanical structures, mainly rock walls and contour canals, using paid (cash or food for work) labor. Neither land tenure nor the interests of peasant landowners were taken into account.[19]

In many cases this resulted in very expensive rock walls constructed on infertile, steep, and droughty garden plots. The cost of installing the structures was many times greater than the value of any added increment of crop yield due to these conservation effects. In general this model is noted for its unsustainability and its near total lack of upkeep of the structures, most of which eventually disintegrated. This model should be discarded; although, there were some limited positive results derived from teaching farmers certain techniques or introducing tree species.

Civic Infrastructure and Job Creation

Job creation projects that became widespread during the middle 1990s share certain characteristics with the landscape engineering model in that public works projects were accomplished with paid labor. Some of these projects made a serious effort to respond to the specific needs and local characteristics of rural localities, for example, the rehabilitation and expansion of irrigation works operated by grassroots water user organizations outside of Mirebalais. Others merely served as a pretext to distribute salaries for political reasons and had no lasting results. In the future, job creation projects will be required as a needed element of watershed management, especially for infrastructure repair and treatment of water courses, but such efforts must fit within an overall strategy so that resources are used efficiently.

Plot-Based Models

Beginning in the 1980s, donors funded agricultural extension projects through grants and cooperative agreements directly with NGOs. They specifically sought a greater understanding of peasant farming systems and tried to design field approaches accordingly. Programs emerged which engaged in tree planting and many other types of soil conservation techniques beyond the rock and canal structures favored previously. Fund management was often done by a large international NGO acting as an umbrella agency, receiving funds from the donor and in turn administering smaller agreements with local NGOs or farmer groups of various sizes and strengths.

Some projects concentrated their activities in smaller regions while others spread out over larger areas. The basic unit of work within the NGO or community-based farmer

[19] In 1982, one of the authors of this report spoke to a project officer supervising one of these projects near Les Cayes, who said the project just "marched imperialistically across the hillsides" with its interventions, and sometimes the landowners were not even present when work was being done on their land.

organization (CBO) was the farmer work group, and project interventions were offered from a basic list of contour and gully soil conservation practices, tree planting, crop seed improvement, fruit tree grafting, marketing, and institutional strengthening activities. Extension agents were selected by the contracting groups from within their own members; these were trained by project technicians and acted as liaisons between project staff and participating farmers.

These projects were not designed to cover whole watersheds. Farmers did not treat all of their plots, which varied in their slope, distance from the residence, security of access, soil fertility, contribution to household economy, and other factors. The principal reason farmers chose not to treat all plots was undoubtedly the high threshold costs for doing so. Treating degraded hillside slopes "correctly" was beyond the means of most farm families. Significant landscape-level changes did occur in some regions due to plot-based project interventions, and three such case studies are presented later in this chapter. This was an interesting period because new technical approaches and new partnerships between technicians and farmers were developed, and the implementing agencies attained greater understanding of peasant farming systems. Nevertheless, the plot-based model, although useful, was not designed to solve the fundamental problems of watershed protection.

Watershed-Based Strategies

The stated focus of these projects is the watershed, or more realistically, a portion of a watershed. This focus defines the geographic limits and the intended type of outcomes, which are primarily environmental and intended to benefit the broader society by reducing the damage to infrastructure. Paradoxically, design of watershed projects is often based on lessons drawn from plot-based projects where the objectives are mainly concerned with increasing agricultural income rather than producing environmental benefits for downstream users. Resolving the differences between these contrasting objectives will be crucial to designing an effective watershed project. The technical approach and outreach, funding and benefit-flow mechanisms vary across projects.

Much debate has taken place in Haiti about watersheds, especially since the release of a report by Löwenstein (1984) on the deteriorating condition of the Macaya watershed; however, no satisfactory watershed-level solution has yet evolved, even though some interesting results were obtained along the way. For example, the USAID-funded ASSET project (see timeline below) worked for three years in the Grise/Blanche watersheds and was designed to work at a landscape scale (Israel *et al*., 2001); however, the project did not

Timeline of Selected USAID Projects	
1981-1989	AOP — Agroforestry Outreach Project
1990-1991	AFII — Agroforestry II
1992-2000	PLUS — Productive Land Use Systems
1997-2002	ASSET — Agriculturally Sustainable Systems & Environmental Transformation
2000-2007	HAP — Hillside Agricultural Program

have a major effect on flooding, sedimentation, or water supplies in the lower watershed. This was due largely to the project's limited scale of operation in the upper watershed.

In general, evaluation of watershed projects points to the importance of designing approaches that consider charcoal markets, animal markets, infrastructure, household water supply, and appropriate social structures. Most importantly, building local social capital needs to be taken to a new level when considering watershed-level interventions. It is imperative to consider off-farm externalities and build new social links that protect the interests of participating farmers whose long history of economic and social disadvantage has led to the creation of their present systems. These persistent systems will not readily be put at risk.

Market-Driven Models

This approach seeks to augment small farmer income by developing or improving marketing links for agricultural crops. The objective of the marketing strategy is to assist farmers to generate sufficient profits to cover their normal agricultural expenses plus the additional expenses required to invest in better germplasm and soil and water conservation. In other words, the intent of project designers is for marketing to drive improved natural resource management.

A market driven strategy was introduced in the Productive Land Use Systems project (PLUS)[20] and then substantially expanded by the Hillside Agricultural Program (HAP) since 2001. The HAP project included natural resource management components in the early years, but specific NRM interventions were eliminated in 2003 due to funding cuts. HAP marketing activities have successfully created new opportunities for tree crops (coffee, mangos, and cacao) that have benefited farmers by boosting farmgate sale prices. This may have had a positive effect on the environment, but the project has not tracked the effect of marketing on NRM. Furthermore, HAP promotes improved marketing opportunities for a given crop regardless of where it is grown, so the effects are not concentrated nor do they consider whole farming systems and their impacts on the watershed. The narrow scope of marketing projects limits their ultimate effect on natural resource management. Nevertheless, marketing is a key consideration and must be central to future watershed projects (see "Tree Products and Trade" later in this chapter).

Cross-Border Model

There is no typical cross-border agroforestry project model, as only two examples of this kind of project were encountered. For example, Floresta is an NGO that operates in both Haiti and the Dominican Republic. Floresta Haiti plans to operate a trans-border project together with Floresta Dominican Republic in the area of the Pine Forest and Fonds Verettes.

Another cross-border NGO is AgroAction Allemande, an agroforestry project that mainly follows the PLUS plot-based model, including timber tree and fruit tree distribution, top grafting, crop seed improvement, agroforestry on plots, gully protection, marketing,

[20] PLUS, Productive Land Use Systems project, 1992-2000 (see Table 1).

institutional strengthening of local farmer organizations, and concentration in particular regions (AgroAction Allemande Haiti, 2005). AgroAction Allemande goes beyond PLUS in that it has sites in the Dominican Republic (DR), does well-capping in the DR, sponsors technician cross-frontier visits, and has compiled a cost benefit analysis of activities in both countries.[21]

In this aerial view, the border between Haiti (left) and the Dominican Republic (right) is clearly delineated.

There is a historical cross-border labor flow (in one direction) and an active trade in animals and other products (in both directions). Tree-based or perennial crop markets that could be exploited include charcoal and wood products, tamarind, and pigeon pea, among others (see information on trade with the Dominican Republic in "Tree Products and Trade" later in this chapter).

One recent study reports that an estimated 50,000 tons of charcoal transit annually into Haiti via Malpasse-Fond Parisien (ESMAP 2005, 10). According to a Dominican-based project officer of the Pan American Development Foundation (PADF), Haitian farmers presently cross the border to harvest wood on the Dominican side, and the effects of this practice can be seen on aerial photographs as deforested wedge-shaped patterns (see Figure 1). The extent to which Haitians are engaged in cross-border charcoal harvest requires further verification; however, growing demand for charcoal suggests there may be opportunities to improve watershed management by using the market as an incentive for tree planting and sustainable harvest strategies, including tree planting on both sides of the border.

New Mutual Interest Coalitions

These models are of particular interest because they reflect a new realism on the part of the elite and business classes: difficult problems can be solved by inter-class collaboration in which all parties benefit. These projects are characteristically based on an economic engine with attendant financial and marketing plans, social development, and a concern for appropriate natural resource management. Assessment team members met with the principal directors of four examples of this model:

- The Haitian Environmental Foundation (HEF) is promoting a project in collaboration with Ateliers École de Camp Perrin and Coopération Française in the area of

[21] The cost of this project over four years (2002-2005) was 933,285 euros ($1,200,233 at June 2006 exchange rates).

Montrouis. This is a collaboration of farmers, agro-industry investors, the agricultural ministry, and the tourist industry.

- Gregory Mevs, a leading Haitian industrialist, has a 200 hectare block of land formerly in sugar cane.[22] The land abuts the Cite Soleil slum district, and the landowner was confronted with the prospect of losing control of his land through occupation by squatters. An objective of this project is to prevent squatters from building on the land by creating a business partnership geared to make money for small farmers working the land, as well as the landlord. The business partnership is based on raising organic bananas for export. Mevs calls this partnership a "productive alliance," and it has social development as well as business objectives.

- Paul Duret (head of Agricorp SA and a former Minister of Planning) is a central figure in two emerging projects with farmers near the Forêt des Pins (pine forest reserve), one centered on dairy production and the other on sawmill operations.

- The Haitian NGO, Caribbean Harvest, is operating a project near Archaie in a mountain village called Ti Bwa. A focus of interest is the production of biodiesel fuel from *Jatropha curcas*. Project personnel have written two proposals ($366K and $600K) to fund this activity. The objective is to create a profit-making enterprise that benefits small farmers.

USAID should encourage these types of projects in targeted watersheds because they are based on economic enterprises that generate employment, and they focus on perennial crops. These initiatives are also potential models for a long-term strategy.

Participatory Local Community Development

Recent assessments conclude that assisting solely in the agricultural domain will produce very limited results in improving natural resource management (GRAP 2003, Horton *et al*., 2005, MARNDR/World Bank 2005). The argument is that farmers will not be able to fully participate in watershed management until their more basic needs have been met. Integrated rural development is not a new concept, having been done in Haiti since the 1970s or earlier. A well-established and a relatively recent example are cited here.

The Mouvman Peyizan Papay (MPP) directed by Chavannes Jn-Baptiste is a well known example of integrated rural development. The outreach approach used by MPP is based on a nine-year cycle of interaction with small groups of farmers who share labor. This includes three years of building soil conservation structures, three years of consolidation of structures, and three years of work on income-generating activities. Soil conservation in ravines is given priority. Local tree nurseries operate for three years during the soil conservation consolidation phase, and the farmers plant trees to strengthen those structures. Income generating interventions include agricultural credit, workshops teaching transformation of crops, sugar mills, and cooperative selling of *kleren* (sugar cane liquor), fruit preserves, and peanut butter. Certain products are raised for the Dominican markets including mangos, cashews, guavas, pigeon peas, tamarind, goats,

[22] This cane land was formerly a large plantation operated by the Haitian-American Sugar Company (HASCO).

and guinea fowl. MPP also works with farmers on small irrigation systems, family water cisterns, and public works job creation projects such as road repair, ravine control, and tree plantations to protect springs, in addition to plot-based activities.

A another recent example is the Association des Planteurs de Vallue (APV), an NGO established in 1987 in the Petit Goave and Grand Goave watersheds. The association operates a primary school, builds and repairs roads, constructs peasant housing, has built a community market and cistern, caps springs, and operates a health center that has a resident doctor, two health agents, and a peasant health committee. Women's groups make and market fruit preserves and peanut butter, and girls learn embroidery and clothing. Animals, the primary source of revenue, are picketed and not allowed to graze freely. The association provides veterinary services and promotes ecotourism. Youth learn how to make steel sculpture and metal *recho mirak* ("miracle stoves"), i.e., improved charcoal stoves. The association operates a tree nursery including fruit and timber species, and promotes soil conservation (rock walls, grass hedgerows) and tree planting. This activity has reportedly lessened the pressure that hillside agriculture exerts on the watershed.

The concept of "social engineering" or local participative community development is discussed in a CIDA report (GRAP 2003). The authors recommend a model of long-term, demand driven, participatory and locally managed community development including involvement of local and state government and entrepreneurs. The report recommends bridging the gap between environmental and socioeconomic approaches. The focus of these projects is the general wellbeing of rural people rather than environmental protection, although environmental benefits are a by-product.

Mixed Models and the Convergence of Ideas

Based on recent field visits and document review, there appears to be a convergence of ideas regarding natural resource project design. This convergence appears in reports on project design, watersheds, and rural development. An inter-ministerial workshop on watershed management recommended that a multi-sector support unit be established for each watershed, noting that watershed management requires good local governance and diagnostic studies (MARNDR, MPCE, MICT, MDE, 2000).

A recently published diagnostic exercise on rural development states that for the short and medium term, it is important to support the agricultural sector as the indispensable engine for rural growth, and it calls for a multi-sector approach to rural development, notes that each region of the country has its own characteristics and requires its own development strategy, emphasizes the importance of social capital development (farmer groups), and recommends fruit tree crops, especially those with a high market value for both export and regional markets, including niche markets (MARNDR/World Bank 2005). It recommends tree crops that lend themselves to production in close association with other crops important to farm families. The report also recommends re-establishment of MARNDR field stations as support centers for regional agricultural development, promotion of regional development plans, promotion of small

producer/buyer alliances, and payment to farmers for environmental services (MARNDR/World Bank 2005).

Existing and proposed natural resource projects (e.g., the IDB/MARNDR Ennery-Quinte Agricultural Intensification Project; Horton *et al*., 2005) include several common elements:

- Working through local farmer organizations and NGOs
- Promoting soil conservation structures on hillsides and in ravines
- Distributing wood-producing tree seedlings
- Top grafting fruit trees and growing/grafting fruit trees in nurseries
- Improving marketing opportunities
- Strengthening grassroots organizations, including administrative skills
- Concentrating activities in geographic regions
- Public works interventions (large check dams, irrigation system and road repair, etc.) that support watersheds through job creation methods

Lessons Learned

Current donor initiatives suggest that lessons learned from different approaches are coming together in a new model. New elements, such as mutual interest coalitions between farmers and businesses and an emphasis on marketing, are presently a part of the mix. Although there appears to be a convergence of ideas regarding the design of watershed management projects, there are still unresolved issues such as how to make payment for environmental services, how to coordinate several sector activities in the same watershed, and how to ensure long-term commitment.

A few lessons learned from the models cited above are listed below; others based on experience with particular agroforestry and soil conservation techniques are presented later in the chapter. *There have been some successes; however, an important finding is that no project has ever succeeded in treating whole watersheds in Haiti*.

- Plot-based projects can have a positive impact in concentrated areas, but plot-based NRM is unlikely to result in the treatment of all areas of a watershed.
- Watershed projects cannot succeed by concentrating only on engineering solutions. A mixed model and innovative approaches are needed because contiguous areas that need to be protected are not all reachable with a single approach.
- Working through local NGOs, grassroots organizations, and farmer labor groups can be effective, especially if trust is built based on long-term relationships.

- Local NGOs and peasant organizations have become stronger institutions due to the long-term association with projects and training for institutional strengthening.

- Linking social scientists with farm technicians is an effective program strategy.

- Successful project implementation requires participatory strategies that ensure ongoing input from farmers and field staff.

- Regional infrastructure projects using paid rural labor need to consider how other on-farm projects operate so that payment for one kind of activity does not jeopardize farmer commitment to others.

SOIL CONSERVATION AND AGROFORESTRY TECHNOLOGIES

This section is organized by practices that conserve soil and water and provide economically useful products to farmers. These are the physical structures that have been shown to function, in certain situations, from a technical standpoint. The difficulty lies in their application and on-farm adaptation, and how they fit into the development model used to support them. The general kinds of agroforestry and soil conservation techniques are described below, followed by a discussion of their relative costs, benefits, and risks to farmers.

Linear Structures with Plant Material

Contour structures have been promoted by development projects since the 1950s. A UNESCO project in the community of Marbial paid people to plant sisal (*Agave sisalana*) on the contour to control soil erosion in the early 1950s, and a FAO project near the town of Les Cayes in the late1960s promoted contour hedges of napier grass (*Penisetum purpureum*), lemon grass (*Cymbopogon citratus*), vetiver (*Vetiveria zizanioides*), and guinea grass (*Panicum maximum*).[23] Farmers were paid stipends based on the number of hedges installed. They were not always appropriately designed and did not last.

LIVING FENCES

Living fences are not strictly soil conservation structures, but they are traditional agroforestry practices very common in Haiti (Ashley 1986). They function as boundary markers, protection against trespassing animals or people, decoration, and sources of useful products. In many cases, several types of plants are seen in the same living fence. They commonly contain succulent euphorbs having milky, poisonous sap that can be used to brand livestock, or medicinal plants such as the *Jatropha curcas* (see photo on the following page). The presence of jatropha in traditional living fences is an advantage to projects seeking to develop biodiesel plantations.

[23] G. Brice, personal communication, 1998.

Creation of boundary markers with living fences, such as this fence made of *Gommier* and *Jatropha curcas*, is a common practice in Haiti.

RANPAY

Mintz (1962) noted that Haitian farmers have been building seasonal crop residue barriers staked roughly on the contour to harvest water and soil since the 1950s. These structures, known as *ranpay* in Creole, are still commonly built in many parts of the country. They last only a single planting season. Some farmers say that stover barriers provide habitat for rats and insects, and so they prefer to burn the crop residue. Traditionally they were built roughly on the contour, positioned by eye. Some projects have modified them by using an A-frame level to get a better approximation of the contour and by covering the crop residue with soil in an attempt to reduce the insect and rodent habitat. A further development was to build the improved *ranpay* and then direct-seed a perennial crop or tree into the structure in order to convert to a contour hedgerow. The advantage of *ranpay* is that it is well known to farmers and costs little to build in the traditional way. The disadvantages are that it needs to be re-built every year and can harbor pests.

HEDGEROWS

Hedgerow intercropping is an agroforestry practice consisting of closely planted and regularly spaced rows of fast-growing trees or shrubs together with short cycle agricultural crops cultivated in the alleys or spaces between the hedges. The initial motivating objective of hedgerow intercropping was to increase crop production in the

alleys by applying the pruned tops of the hedgerow trees to the soil as a green manure to improve soil fertility. More commonly in Haiti, hedgerows fulfill other purposes including harvest of marketable crops from hedgerow plants, soil erosion control, and production of fodder and fuel.

Hedgerow intercropping using the fast-growing, nitrogen-fixing tree *Leucaena leucocephala* was tried on a small scale in Haiti for the first time in the early 1980s. Initial interest in tree-based hedgerow intercropping was stimulated by reports of developments in West Africa, Indonesia, and the Philippines, and general interest in the use of *Leucaena leucocephala* as a fuelwood tree. There is a variety of leucaena native to Haiti known locally as *delen, oriman, ti movye*, or *ti pingi*. This variety is not suited to hedgerow construction because it is extremely invasive, does not produce sufficient biomass, and is very unpopular among farmers. To promote the use of leucaena, USAID introduced seeds of productive varieties to Haiti in 1978, including seeds of *Leucaena* K8, K28, and K67 from trees grown in the Philippines, and later seeds from Flores, Indonesia (Benge 1985).

In 1979, a USAID agronomist proposed leucaena hedgerows for Haiti.[24] The number of hedgerows built by farmers participating in the PADF-PLUS project and its two predecessor projects probably represents the largest number of hedgerows built in Haiti.[25]

Contour hedgerows, such as this of *Leucaena leucocephala*, fulfill many purposes, including harvest of marketable crops from hedgerow plants, soil erosion control, and fodder and fuel production.

[24] M. Benge, personal communication, 1995.
[25] See the timeline on page 20 for project sequence. The Pan American Development Foundation (PADF) was an implementing agency for the USAID-funded Productive Land Use Systems (PLUS) project.

During the seven-year period from 1985 through 1991, 848 km of hedgerows were reported (PADF 1990). The number of hedgerows installed was much greater under the PLUS project with more than 12,000 km installed from 1993 through mid-1999 (PADF 1999).

The composition and management of contour hedgerows is not static. Farmers continually modify them according to their household needs, their ability to invest resources, their experience with hedgerows, and changing marketing opportunities for crops and products derived from hedgerow trees. *Leucaena leucocephala* (pictured on page 28) was originally the predominant hedgerow species, but that changed. During 1995, PADF reported hedgerows made with 22 different tree, perennial food crop, grasses, and other perennial species planted in 54 different combinations. Leucaena was present in less than half of the hedgerows. This reinforces the notion that introducing hedgerow intercropping is just the initial phase of an adaptive technology that farmers will tend to modify as they discover (or not) its as-yet unknown economic possibilities (Sumberg and Atta-Krah 1988, Wiersum 1994).

A CARE project manager recently noted that if participating farmers attained a harvest during the first rainy season after installation, they tended to repair and maintain hedgerows in anticipation of the next season. If not, they tended not to maintain or repair them. There are not enough data to make any solid conclusions about the current level of adoption and management of hedgerow technology in Haiti, but this would make a worthwhile study.

Based on a worldwide review of hedgerow trials covering some of the possible biophysical conditions and hedgerow configurations, Sanchez (1995) lists conditions where alley cropping is most likely to succeed: areas having fertile soils with no major nutrient limits, adequate rainfall during the cropping season, sloping land with erosion hazard, ample labor and scarce land, and secure land tenure.

BANN MANJE

Bann manje (a play on words — either “band of food” or “a lot of food”) are an evolution of hedgerows. They consist of rows of food crops planted across the contour with spacing up and down the slope of more than one meter. Perennial crops such as pineapple or sugar cane serve as the structural components, but annuals such as yam and sweet potato are also planted within the band. Field crops are planted in the interspaces as in hedgerows. During 1999, 20 different combinations of nine species of perennial food crops, trees, and other perennials were used in crop contour bands (PADF 1999). This evolution of the technology is based on farmer needs for short-term cash return.

The structural crops such as pineapple respond directly to a marketing opportunity — a quintessentially Haitian strategy (Murray 1991), and one found in indigenous agroforestry associations in other cultures (Khaleque and Gold 1993). The pineapple based hedgerows are more demanding than tree-based hedgerows. Pineapple-based structures are able to hold soil on the slope; however, the site for such hedgerows needs to be fertile enough and sufficiently well watered to grow the crop, and this limits their

Left: A *bann manje* of pineapple and sugar cane is planted. Right: This *bann manje,* of plantain and sugar cane, is fully matured.

placement. They are also more costly to install because of the materials used and labor requirements. The photos above show a *bann manje* being installed and a mature system.

Linear Structures Made with Rock or Soil

BENCH TERRACES, CONTOUR DITCHES, ROCK WALLS

These three types of structures were commonly used in the earliest soil conservation projects. They are all very labor intensive to install. Bench terraces and contour ditches require a lot of soil movement that exposes the soil to erosion, and terrace construction often results in the most fertile soil being buried under the subsoil. Both contour ditches and terraces accumulate soil after every rainfall, and this needs to be corrected or they become ineffective, or worse, channel rainwater that forms new gullies. Neither structure is common now with one notable exception.

In contrast to the historically widespread non-adoption of soil conservation strategies designed by technicians, the *tram* is a notable example of a successful practice designed by Haitian farmers that responds to a particular market opportunity. This involves the yearly, labor-intensive construction of contour soil bunds (*tram*) to conserve expensive chemical fertilizers used to produce high-value vegetables in a small region (Kenscoff) close to the capital city (Murray 1980). These are re-made every planting season, and are economically viable since the locality is near a paved road with good public transport leading to a very large nearby market.

Rock walls are constructed across the contour after first excavating a level soil base; they require specialized knowledge to build them and a nearby supply of the right sized rocks. Those built by paid labor as part of early *équipement du territoire* projects often

disappeared after a year or two because they were not maintained — the slope was too steep, free-ranging animals kicked the rocks off the slope, or the conveniently placed rocks were used to build foundations for houses. In some areas they are used where high-value crops are grown for nearby markets.

During the PADF/PLUS project, farmers using rock walls in the Marigot area made an interesting observation. Snails hid under rocks during the day, coming out at night to feed on bean plants. Therefore, in addition to ridding the garden of rock obstacles, holding soil on the slope, and slowing the flow of water, rock walls removed the snail shelters from the middle of the garden to the contour rows. The farmers were able to find and kill them more conveniently, and the snails were removed further away from the beans.

Ravine Control Structures

Gully plugs can be made in large ravines or small, but those built in large ravines, usually by paid labor, are intended to correct large problems and are built to a higher standard of construction and often strengthened by gabions (rock and wire mesh retaining walls). Small gully plugs are built by farmers on their own plots with the expectation that they will derive direct benefits from the structures. These can be made with rocks, woven nylon sacks filled with soil, or plant material such as stakes (living or dead) cut from trees. The small gully plugs more commonly have agroforestry plant associations because they are more likely to be near the farmer's residence in a plot having secure access.

The photo below shows a gully plug built with rocks. After construction, eroded soil quickly fills in the uphill side of the structure allowing the farmer to plant high value crops like plantains and taro to take advantage of the flow of rainwater directed to these mini gardens. The drawback is that unless a sufficient number of stable gully plugs are built in a given ravine, and unless the sides of the slopes above the gully are also protected, erosion and water flow can overwhelm them. In Marigot, ravines stabilized with gully plugs having permanent water are producing watercress; those with ephemeral water are used for taro, plantain, and sugar cane. This was also seen in the Ti Lacombe garden discussed below as a case study.

This gully plug, built with rocks, was built by a farmer to capture eroded soil and use the flow of rainwater.

Planting Timber Trees

To farmers, trees are neither a natural resource nor a watershed protection device, but a cash crop and a store of value (Smucker and Timyan, 1995). Trees, like animals, are less vulnerable to climatic variations, and that makes them less risky investments than annual crops. Farmers have always practiced some form of timber tree culture in Haiti; however, prior to USAID agroforestry projects of the 1980s, [26] farmers relied almost entirely on protecting or transplanting volunteer seedlings, and only if the tree was recognized as useful to the farmer.

Top: A farmer works an NGO small container nursery.
Bottom: Farmers plant neem seedlings.

With the advent of large-scale tree distribution projects, there was a gradual shift in attitude. In many rural areas today, hardwood trees are grown as cash crops that are well integrated into the agricultural system. More than 80 million trees were distributed during the 1980s and 1990s, grown by local NGOs in their own nurseries using small container technology and planted by farmers reached by extension agents trained for that purpose (see photos at right). The demand for these tree seedlings at no cost to farmers was never satisfied. Farmers have shown ample willingness to invest heavily in their land and labor resources in order to plant project trees on their own land; however, asking farmers to pay for these seedlings would have drastically reduced demand due to chronic and severe cash shortages among Haitian farmers, especially the 80 percent of peasant farm families Haiti that fall below the poverty line.

The central issue to consider for a prospective watershed management project is whether or not tree planting can have landscape-scale effects such that the watershed becomes more

[26] USAID tree distribution projects since the 1980s included the following: Agroforestry Outreach Project (1981-1989); Agroforestry II (1990-1991); Productive Land Use Systems (1992-2000) (See timeline on page 20).

stable. Opinion regarding large scale tree distribution projects in Haiti appears to be polarized. Some believe they did not live up to expectations; others feel they were a great success and should never have stopped. Field visits made during this assignment suggest that a second look is merited. In two regions, one in the Northeast and one in the Southeast, a major shift in tree culture spawned by project interventions now appears to be widespread and has changed the look of the landscape and the economics of the region. There are other such sites in Haiti, but the team had little time to explore this cultural shift more broadly. Two field visit sites are discussed in the case study section below.

During the PLUS project period, some plots were not usually planted with trees because of tenure issues, so alternative strategies were also tried on a small scale. Two of these are briefly mentioned here. In the Les Cayes region there were absentee landowners interested in planting trees on their land. A contract was written between the landowners and a local community-based organization (CBO) that participated in the PLUS project, and had been trained in administrative procedures. It allowed CBO members to use the land to raise annual crops on condition that they plant tree seedlings and care for them for the life of the contract, which was about five years. After the first contract was successful, several others were written.

The other model was a community forest planted to protect the land above the famous waterfall in Saut d'Eau in the lower Central Plateau. This waterfall is extremely important to the local economy as a religious pilgrimage site for thousands of visitors. The mayor of Saut d'Eau had previously been an extension agent for the PLUS project. He was able to establish a protective community forest. This illustrates the need to make use of a range of creative ideas to protect watersheds, and the importance of site-specific adaptation of program interventions.

In addition to economic and environmental benefits, another advantage of tree seedling distribution programs is the potential to improve tree productivity and reduce risk. Some native trees may be rare and seedlings are hard to find. Also, farmers tend to cut the largest trees having the best form,[27] leaving the least productive trees to provide seed for local planting. In many cases, the seed for propagating exotic trees such as neem, cassia, and others has been collected from very few original mother trees. Therefore, the seed available to nurseries in Haiti may be low in quality with a narrow genetic base. This is risky since susceptibility to pests and diseases are heritable traits in trees. Tree distribution programs supplied with high-quality seeds could mitigate this risk, increase biodiversity, and boost productivity. This would require a long-term parallel program of tree seed improvement carried out by a Haitian institution.

Fruit Trees

Fruit trees and hardwood trees are complementary farm enterprises and should not be thought of as mutually exclusive activities. Small container hardwood trees distributed by projects tend to be planted in larger numbers and at a greater distance from the home;

[27] This practice is called high-grading.

Mangos and akee grow in a cooperative nursery in Gros Morne.

fruit trees are typically grown in plastic sacks (because of the large seed size) or are direct-seeded and planted in fewer numbers closer to the home.

In contrast to hardwood trees, there is some scope for selling fruit tree seedlings at a subsidized price to farmers. The photo above shows a 40,000 plant mango and akee nursery operated by a mango cooperative in Gros Morne. At the time the photograph was taken, the entire nursery production had already been sold to local people at 10 *gourdes* per mango seedling ($0.25). Alternative modes of production include distributing plastic sacks for farmers to grow seedlings in smaller numbers close to their residence, or training farmers to graft bud wood of export-quality fruit on established low-value fruit trees (see the photo on the following page). In this way the whole crown of the tree is replaced and the trained grafter also gains a saleable skill.

The most commonly planted fruit trees include coffee, mango, cacao, citrus, and avocado. These have been linked to marketing projects with varying degrees of success such as creation of the Haitien Bleu brand of gourmet coffee for export. Other locally popular fruit trees such as *Melicoccus bijugatus* (“kenèp”) also have potential for export to the Haitian Diaspora.

Trends in fruit tree culture observed during recent field visits include the following:

This mango, which a farmer has top grafted to improve the export quality of the tree's fruit, is an example of an alternative mode of production.

- Some individuals and projects are applying for organic certification, e.g., the HAP project for mangos and the Mevs project cited earlier for plantains.

- New arrangements between large landowners and farmers allow for planting fruit trees in orchards instead of just a few trees located near the house. For example, in Dubedo a mango exporter planted more than 25 hectares of mangos intended for export. He has a sharecropping arrangement with local farmers: they grow annual crops (maize, sorghum, peanuts) and give one-third of the harvest to the landowner on condition that the farmers take care of the mangos. When the mangos are ready to harvest, the planters gain the benefit of the harvest on condition that they sell them only to the landowner, who will develop a brand name and sell the mangos as organic produce.

- In Acul Samedi, an ex-PADF agronomist has planted six hectares of pineapple in contour rows. In the same field, there is a fruit tree every 10 meters: mango, coconut, or citrus, and in the future he will also plant some cashews. The pineapple is very demanding on the soil, so when the trees mature, the garden will convert to a mixed fruit tree orchard.

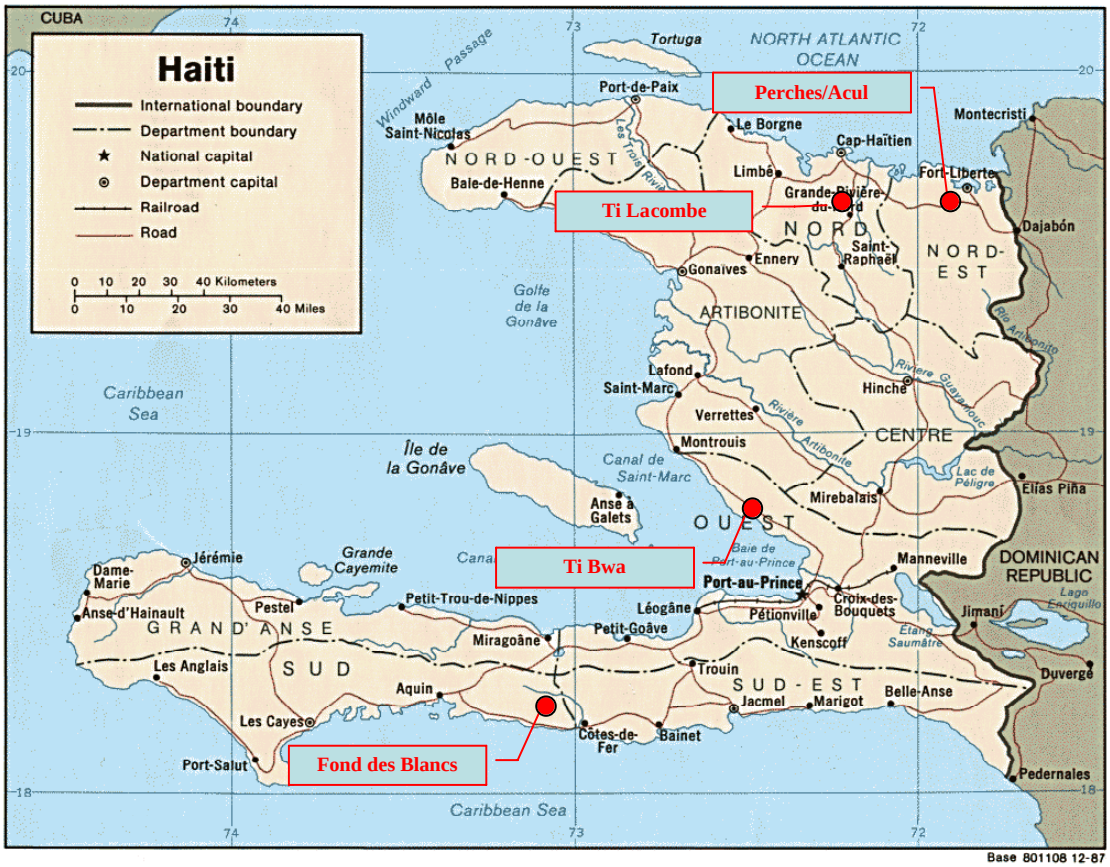
LESSONS LEARNED: NRM PROJECT SUCCESS

Although NRM project interventions have not corrected problems of environmental degradation in watersheds, technical review has shown they can be successful in some regions and under some conditions.[28] The list of lessons learned below is followed by three case studies demonstrating that project interventions can change landscapes, increase farmer income, and positively influence agricultural practices.

- Agroforestry and soil conservation measures require more complex and skilled use of the land than annual cropping; they include more than one plant species, and if there is a tree component, the period between initial planting and economic payoff will be much longer than for annual crops.

- The cost of correcting depleted hillside garden plots using contour structures, such as hedgerows or rock walls, is beyond the economic capacity of most farmers without project support. The cost of management and upkeep of the structures is as important as the initial installation.

Figure 4. NRM Field Sites Visited by the Assessment Team



[28] See Smucker, 2002.

- If threshold costs are supported over an extended period, garden plots can be recovered, productivity increased, and damage to local roads decreased.

- The menu of technical interventions (soil conservation, trees, etc.) initially proposed has evolved in different directions over a period of years due to site feedback and farmer preferences. This evolution is based primarily on economics, plot and household characteristics, and farmer experience.

- Tree culture becomes increasingly important in some plots over time. In part, this is because trees are relatively inexpensive to install and manage compared to other conservation practices, and there is a ready market for their products.

- The large-scale distribution of small-container hardwood trees has had a significant impact on certain regional environments and charcoal economics. This phenomenon should be studied, including a cost-benefit analysis.

- Plot-based projects rarely take animal culture into consideration, but in many places income from animals is the largest percent of agricultural income, and income from trees is second.

CASE STUDIES

Value Added and Landscape Change in Fond-des-Blancs

Fond-des-Blancs is a semi-arid region (about 800 mm annual rainfall) located 20 km south of the national highway half way between Port-au-Prince and Les Cayes. This is the site where PADF made its first delivery of tree seedlings under the AOP project in the spring of 1982. After a few seasons, a local cooperative of small farmers, the Coopérative de Développement de Fond-des-Blancs (CODEF), took over activities and constructed an on-site nursery with the capacity to produce 250,000 seedlings per year. A recent site visit shows evidence of a “radical” change in the landscape since 1982 with trees of project derivation now covering a large percent of the land.[29] CODEF has 3,000 local farmer members, most of whom have tree gardens of 250 to 500 trees. Cooperative members commit to planting 10 new trees for each mature tree that is harvested. There are presently six trucks carrying out one thousand 35-lb. sacks of charcoal daily to Port-au-Prince, and this charcoal is mainly from project-related trees. Charcoal sales are now second in importance to local farmer revenues (after animal-raising).

CODEF has also worked with farmers on potable water, introduction of Nubian goats, swine re-population, fruit tree grafting, and a pilot sawmill project. The reasons for this apparent success include the long-term commitment of CODEF (an NGO cooperative created by a Protestant mission), the multiple areas of intervention that have great economic interest to the farmers, the improved road from Fond-des-Blancs to the national highway that allows efficient transport of pigs, charcoal, and fruit; and the planting of coppicing tree species that permit repeated harvests. CODEF has also organized a pilot wood cooperative with a mobile sawmill to buy wood and transform it into planks, poles

[29] The manager of this local cooperative (CODEF) has lived in Fond-des-Blancs for the past 24 years and has observed this dramatic change in tree cover from the very beginning (1982).

and charcoal. Farmer-members may choose to make their own charcoal without selling to the cooperative. The cooperative also has a woodshop that makes furniture. The scraps left from planks and poles are made into charcoal. All cooperative products are sold in Port-au-Prince; profits are redistributed among the cooperative members.

Landscape and Agricultural Change in Les Perches

The authors of this chapter recently observed significant stands of PADF/PLUS project trees between Terrier Rouge (on the highway to the Dominican Republic east of Cap-Haïtien), and Les Perches and Acul Samedi. Many trees were planted near the road and some in more distant fields. The number of trees visibly increased closer to Les Perches and Acul Samedi. The authors observed *Eucalyptus camaldulensis*, *Senna siamea*, and *Acacia auriculiformis* in sizeable numbers. Some were coppicing after harvest for at least the third time. Seedlings (about 50 cm high) of the prolifically seeding *Acacia* had been allowed to grow in gardens with food crops (maize, peanut, cassava, sugar cane, and pineapple). As the shade from the trees increased, gardens were managed as woodlots for poles and charcoal, and then food crops were subsequently being established again in rotation.

This constitutes a dramatic change in local agricultural practices. One informant indicated that people in this area considered *Acacia* to be a "treasure" in the garden because it makes such good charcoal and poles. Reportedly, before project trees were established in such great numbers, only about two truckloads of charcoal per week came out of this area, but several times that amount goes out at present.

Site Transformation in Ti Lacombe

The locality of Ti Lacombe is near Grande Rivière du Nord east of Cap-Haïtien. A group of 15 farmers cultivate about nine hectares of land owned by an absentee landowner. This area has undergone a remarkable transformation since the PLUS project began using it as a training site over a five-year period during the mid-1990s. It was originally weedy and infertile with few crops and no tree cover. Two ravines running through the property periodically damaged the adjacent road to Grande Rivière du Nord during the rainy season. PADF chose this as a demonstration and training site, so more project subsidies than usual were invested here. Several project-supported training sessions contributed free labor that benefited the farmers working the land here (this was not done on "normal" participant plots).

The former PADF team leader in the area estimated that project investment was about $665 per hectare over a five year period, an amount well beyond the means of most farmers. Because of these investments, the Ti Lacombe gardens were completely transformed. More than 50 gully plugs were installed in two ravines. This effort has completely stabilized the ravines, and they no longer cause damage the road. One ravine now has running water all year long. High value plantains and taro are grown in the soil accumulated uphill from the gully plugs, and they are maintained as a regular part of garden maintenance. Although some of the upper plots still have hedgerows and produce maize, lower plots nearer the road are now almost entirely covered with fruit and timber

trees. Linear soil conservation structures are no longer much in evidence, nor are they needed to stabilize the tree-covered slopes.

The authors interviewed a farmer about revenue from his 5.2 ha plot, which he estimated as $221/ha for the past year. Of this income, 80 percent came from tree products. Charcoal is the most valuable income-generating product and constitutes 24 percent of total income. The sale of fruit tree products is 46 percent of total income, and wood-based products (charcoal, planks, and joists) 34 percent. The farmer also donated 30 eucalyptus poles to the community for electric lines during the past year. This undoubtedly increased his social capital, an important asset in protecting his livelihood.

PROVEN ELEMENTS OF SUCCESS

In many areas, farmers have demonstrated a vested economic interest in shifting away from annual cropping to heightened reliance on perennial polycultures on hillsides. In retrospect, the distribution of free or highly subsidized seedlings has proved to be a successful strategy for transforming local landscapes.

The case studies as well as project models discussed earlier point to several elements that contribute to the success of watershed projects. These include locally focused rather than widely dispersed interventions, long-term commitment on the part of NGOs, and consideration for the multiple concerns of farm families. Successful projects also point to the utility of using social scientists together with technicians, promoting long-term presence of technicians as residents in project areas, creating mechanisms for channeling feedback from participants, using horizontal forms of collaboration between project management and field staff, and conducting independent evaluation of project progress.

TREE PRODUCTS AND TRADE

Trade in crops, such as coffee, cocoa, mango, citrus fruits, banana, and yam, has played an important part in protecting the quality of the Haitian environment; however, there has been a significant decrease in production of these crops due to weak investment, the drop in coffee and cocoa prices on the international market, the ageing of plantations, the production of annual food crops, decreasing farm size, lack of technical assistance, and losses caused by insects and diseases. After the elimination of Creole pigs in 1983 due to African swine fever, large numbers of mango trees with low grade fruit lost their fruit-bearing value as a cheap and abundant pig food. Therefore, many mango trees were cut for fuel and planks.

Table 3. National Production of Environmentally Beneficial Crops in 2003

CROP	PRODUCTION (MT)	CROP	PRODUCTION (MT)
Coffee	25,500	Avocado	40,000
Cocoa	-	Plantain	400,000
Mangos	400,000	Fuelwood	2,500,000
Yams	120,000	Charcoal	300,000
Bananas	270,000	Vétiver (vétiver oil)	200
Sugar cane	1,050,000	Amyris (bois chandelle	40
Pigeon peas	30,000	Lime & Bitter orange	804
Citrus	550,000	Plantain	400,000
Cocoa	-		

Source: FAO

Recent production of environmentally beneficial tree and perennial crops is shown in Table 3, above. Future initiatives should build on project-driven marketing successes based on trees and perennial polycultures. For example, in 2005 the FACN coffee cooperative sold more than 500,000 dollars worth of coffee on the international market.

Haiti's proximity to the Dominican Republic also offers trade benefits to the two countries although the Dominican Republic controls the lion's share of the market due to Haiti's weak production levels. The Dominican Republic sells Haiti more than 72 million dollars worth of agricultural products annually compared to Haitian sales of 13 million dollars to the DR. High and growing demand for Haitian agricultural crops by Dominican purchasers has created enormous opportunities for Haitian producers. Furthermore, the Dominican market is far less demanding than the American market. Haitian crops such as coffee, yam, pumpkin, pigeon peas, mangos, avocado and tamarind are traded on a daily basis with Dominican purchasers (see Table 4, below). There is also strong demand for Haitian livestock such as goats, cattle, and guinea fowl.

Table 4. Annual Export of Livestock and Tree-based and Perennial Crops to the Dominican Republic

Exported crops	Volume (MT)	Value (1000 US$)
Coffee	5,100	5,100
Avocado	3,290	1,744
Pigeon peas	4,420	1,702
Mango	4,650	1,023
Pumpkin	910	268
Tamarind	920	156
Passion fruit	450	140
Vegetables	-	300
Corn	1,640	225
Cattle	49,000	2,199
Poultry	51,500	149
Total	-	13,006

Source: RESAL study (2001)

RECOMMENDATIONS

Strategic Elements

OVERALL LONG-TERM DONOR GOALS

A general characteristic of project-driven development is that activities are closely linked to funding cycles, which is usually about five years. This will not be a long enough period to develop the most effective combination of interventions for protecting watersheds. NGOs with a long-term view of development in a particular region need to count on continued support to maintain the thread of their activities and the trust of their farmer members. Supporting research done by MARNDR in their regional centers will need some time to produce results. Private sector efforts to engage in profit-driven protective activities need time to establish their enterprises before realizing benefits. Both on-farm and jobs-creation infrastructure will be installed progressively and need time to manifest their protective and profit-making functions. Markets go through cycles, and farmer groups learning new market linkages and processes need help to get through the initial phases. Finally, since the development commitment is to geographically fixed watershed regions, leaving after initial failures is not an option. These issues have to be addressed; developing the process to do that will take time and will be the most important result.

USAID should make a 20-year commitment to work in targeted watersheds. This will allow partner organizations and farmers a reasonable chance to evolve and produce returns from their investments in nurseries and watershed improvements. Commitment to these partnerships should be flexible enough to allow for evaluation and evolution.

NEAR-TERM INTERVENTIONS IN WATERSHEDS

Up to now, there has never been successful NRM intervention at the level of whole watersheds in Haiti. Small-scale geographic concentration has succeeded in some cases. A realistic strategy would be to target an intermediate scale of intervention based initially on critical zones within watersheds.

WATERSHED PLANNING

USAID projects should begin with a participatory analysis of selected watersheds, describing the characteristics of plots, households, farmer groups, infrastructure, market networks, and watershed issues (fragile sites, danger of flooding, etc). This analysis should identify critical zones and key assets and result in a division of the watershed into prioritized sections of manageable size. Some activities should concentrate on targeted sections (e.g., large ravine correction, irrigation repair, cistern construction) and others should extend over as large an area as farmer participation allows (e.g., tree crops).

BACKGROUND STUDIES

Some rapid background studies could help validate observations regarding the impact and cost/benefit of tree distribution and soil conservation successes noted earlier including the case studies and also new models of entrepreneurial partnership:

- Identification of old AOP and PLUS project sites where tree cover has attained landscape levels of change.

- A tree inventory and charcoal production and market study in areas where project tree coverage appears to be significant (e.g., Fond-des-Blancs, aux Perches/Acul Samedi, and other old project sites).

- A look at the cost/benefit and cash flow of areas where contiguous soil conservation and tree planting appear to have succeeded, e.g., Ti Lacombe (Grande Rivière), Champagne (Plaisance-Pilate), Maissade.

- A closer look at mutual interest coalitions based on partnership between small peasant farmers and affluent private sector operators.

Technologies

COSTS AND BENEFITS

Agroforestry and soil conservation interventions should be promoted primarily as money-making ventures rather than conservation practices. Technologies should be selected in consultation with farmer groups and NGOs, taking into account the farmer's installation and management costs and the timing of return on investment.

SITE MATCHING

To some extent, it is possible to target technology recommendations by site, physical properties, and rainfall. For instance, drier areas will be more appropriate for energy (charcoal plantations) and essential oil plantations such as jatropha and silvopastoral systems involving goats and forage-trees. In wetter areas, certain hedgerow and *bann manje* systems and vegetable cropping would be better suited. There are species of trees suited to both areas, for instance cashew nut in dry areas and avocado in wetter areas; however, it is imperative to elicit farmer feedback before making decisions about technologies to promote in each region.

FRUIT TREES

Promotion of fruit tree activities should be directly linked to the market. CBO nurseries and on-farm fruit tree nurseries as well as direct seeding could all be used as appropriate. There is a distinct advantage to concentrating on fruit with a well established existing market (e.g., mango Françique), and to identify other niche crops for export (e.g., *Melicoccus bijugatus*). Promotion of fruit trees should include training in top grafting, facilitation of access to improved budwood, establishment of a seed improvement component, e.g., embryo selection in mangos, and establishing fruit tree orchards rather than planting scattered individual trees.

Fruit tree efforts should also include promotion of valued added activities. This should include cooperatives and women's organizations engaged in fruit transformation in watersheds with good production potential, and promotion of market share and value-added employment generation.

HARDWOOD TREES

NGOs should be encouraged to operate small-container nurseries and distribute hardwood trees at no charge, focusing on zones in need of protection such as springs, and

work groups engaged in soil conservation. Outreach efforts should include widespread tree distribution to the extent possible, and should elicit feedback from farmers on choice of tree species. Tree distribution programs should promote the rights of farmers to harvest trees freely from managed plots, work with farmers on woodlot management and nurseries to ensure better seed, and support long-term tree seed improvement programs through regional MARNDR stations and private universities.

CONSERVATION PRACTICES

Conservation efforts should emphasize gully plugs linked to markets for high-value crops, and emphasize practices that supply raw material to value-added activities. Farmer organizations or other local groups should be trained in rapid watershed assessment techniques. Outreach programs should develop local level ability to define management objectives and identify critical mechanisms to achieve conservation goals.

Local participatory planning should identify natural areas of high infiltration or high erosion risk, and promote buffer zones including field borders and wind breaks to recharge groundwater. In areas of high disturbance, conservation measures should include no-till bands, hedgerows, and perennial crop bands. Plots not usually planted with trees may include planting of community forests or afforestation of absentee landholdings. Labor intensive employment may be needed for large ravine corrections, repair of irrigation systems, and improved channeling or diversionary canals near vulnerable urban areas and irrigation networks. River and stream banks may be stabilized with grasses, bamboo, and riparian forest species.

WATER MANAGEMENT

Watershed protection should promote and diffuse technologies that combine improved water productivity with maintenance of soil productivity, e.g., gully plugs, mulching, and shade-adapted and drought-resistant cultivars. Ponds and cisterns may be constructed for multiple purposes including fish-rearing, irrigation, potable water, and household uses. Alternatives to concrete should be explored, particularly for ponds. Investment in cisterns should be linked to vegetable production, marketing, and public health programs. Improved water management includes construction of small scale irrigation systems as feasible, including hillside irrigation, water courses and ponds. Rehabilitation of irrigation systems would allow for increased annual crop production in less vulnerable sites and diminish the need for annual crop production on hills. Pump irrigation may be practical in some arid plains.

ANIMALS

Since animals are commonly the most significant source of farm income, watershed protection strategies should also target small farmer reliance on livestock, including pig multiplication as needed. Don’t fight goats, take advantage of them. It is advantageous to promote collaboration with existing animal-based programs such as Veterimed rather than creating new ones. Promotion of animal husbandry should be directly linked to trees and marketing, including introduction of more productive varieties of cows and goats and improved forage crops.

TRADE

Marketing efforts should fit the total watershed model and strengthen farm systems and value-added employment in target areas. Promotion of markets for environmentally friendly products should include the Dominican Republic, Antilles, North America, and the Haitian and Caribbean diaspora.

Trade promotion should include exploration of a broader range of niche markets for Haitian products that are beneficial to the environment, including development of organic certification and marketing of tree crops. Strong urban demand for charcoal should be used as an economic motor for sustainable production, including niche markets for "green" branded charcoal produced on certified plots and managed as a renewable resource. The fruit market may be expanded by promoting transformation of fruits such as mangos, oranges and grapefruit that cannot be stored fresh.

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APPENDIX A

DISCUSSANT RESPONSE TO INTERVENTIONS IN WATERSHEDS: GAEL PRESSOIR

As mentioned in workshop presentations by Mike Bannister and Marc Portnoff (August 2, 2006), one of the main concerns in promoting perennial plants for Haiti's watersheds is the choice of varieties or genetic stock. Mike Bannister mentioned genetic erosion in tree species caused by their over-exploitation and the total absence of seed selection before planting. Both problems affect the quality and quantity of wood being produced.

Marc Portnoff highlighted toxicity issues and oil storage requirement of the potential species of choice, *Jatropha curcas*, for development of a biofuel agro-industry in Haiti. These concerns would best be addressed by selection and distribution of improved varieties. Sustainable agroforestry could be practiced on Haiti's hillsides and watersheds through management of quality genetic stocks for wood tree species, and selection of high yielding non-toxic varieties producing stable oil under minimum storage requirements. Planting unimproved seeds or plantlets condemns growers to mediocre yields and jeopardizes potential positive outcomes of any given agroforestry project.

All agriculture success stories have been made possible because of local know-how to apply new technologies, e.g., the "green revolution" in India, and biofuels in Brazil. The Brazilian success story is due in part to the creation of sugarcane varieties for cost-effective ethanol production. If agroforestry is to become a Haitian success story, building local capacity will be needed, including a local university, research institute, and seed or plantlet propagation companies), to assure durable and self-sustainable agroforestry systems.

A single funding agency such as USAID cannot fund research and breeding in all plant/shrub/trees of potential interest for agroforestry in Haiti's watersheds; however, funding to breed and disseminate improved technologies (varieties, for example) for one model species (which could be *Jatropha curcas*), would help to build local teams capable of addressing new needs for other tree or other perennial crops. In addition, funding for jatropha variety development would also respond to a stated interest of the Haitian government which has pinpointed biofuels as one of its priorities for agriculture.

Jatropha holds promise for improving the livelihood of poor people in local communities generating rural employment, contributing to Haiti's reforestation, land reclamation, and easing the burden of oil imports. Nevertheless, applied basic research is needed to determine its suitability for specific watersheds in Haiti, to release and distribute improved varieties through an organized selection and breeding program, and to conduct agronomic studies on the productivity of these varieties in various watersheds.

RECOMMENDATION

Fund a local university, eventually in collaboration with a US-based university, to lead a local effort to select locally adapted, improved *Jatropha curcas* varieties and corresponding seed or plantlet dissemination technologies. This university would also

train graduate students in crop improvement techniques and seed and plantlet propagation technologies.

APPENDIX B

CONTACTS FOR FIELD INTERVIEWS

CONTACT	ORGANIZATION	PROJECT SITE
Tanguy Armand	Haitian Environmental Foundation	Montrouis
Junior Paul	HAP, marketing	Various sites
Joanas Gue	“	“
Tim Aston	“	“
Joel Ducasse	Permagri SA, *Jatropha* pilot proj	Cul-de-Sac
Gregory Mevs	Alliance Productive	Cul-de-Sac
Maulik Radia	Terminal Varreux	Biofuels
Paul Duret	Agricorp SA	Foret des Pins
Philippe Mathieu	Minister of Agriculture	
Frederick Nicolas	PADF/PLUS	Marigot
Patrick Vilaire	PRODESELA, *jatropha* project site	Ti Bois (Arcahaie)
Valentin Abe	PRODESELA, *jatropha* project site	Ti Bois (Arcahaie)
Local farmers	PRODESELA, *jatropha* project site	Ti Bois (Arcahaie)
Local farmers	Former PADF project site	Ti Lacombe (Grande Riviere du Nord)
Local farmers	AFII, PLUS, and private sector case study information	Terrier Rouge, aux Perches, Acul Samedi
Rene Eugene	Mango cooperative	Gros-Morne
Lee Nelson	Save the Children & PADF	Port-au-Prince
Wilner Alix	Save the Children	Maissade
Yves-Laurent Regis	CARE	CARE-PLUS
Jean Thomas	CODEF	Fonds des Blancs
Association des Planteurs de Vallue (APV)	IRD	Vallue
Local farmers	PADF, Presten, FACN, MARNDR	Marigot
Chavannes Jn-Baptiste (MPP)	MPP	Papay (Hinche)

IV. WATERSHED VULNERABILITY AND PRIORITIZATION

By Joel Timyan and Ronald Toussaint

PURPOSE

This chapter proposes a strategy for prioritizing Haiti's most vulnerable landscapes according to topography, climate, ecological importance, productive infrastructure, and settlement location and density. It analyzes and ranks all of Haiti's major watersheds and sub-basins in relation to the threat of loss of human life and productive infrastructure due to severe flooding, and assesses current watershed priorities used by the Haitian government and other donors. This chapter also briefly examines other sectors that have a bearing on prospects for watershed stabilization and disaster mitigation including national and local governance, urban planning, sustainable forest and protected area management, and disaster preparedness and risk management.

Degrees of Vulnerability and Risk

The problems of watershed vulnerability are enormous; therefore, it is imperative to establish priorities and make choices. Haiti's watersheds have never been compared and ranked quantitatively in terms of their vulnerability to loss of human life, productive infrastructure, soil potential, or erosion risk. In response to this problem, the assessment team designed a methodology using GIS analysis and hazard mapping to develop an unprecedented new tool for (i) ranking the relative vulnerability of Haiti's watersheds, and (ii) establishing priorities to mitigate risks of natural disaster and promote economic growth. This approach included the following elements:

- Assessment of current approaches used by the government of Haiti to identify and prioritize watersheds
- Acquisition of in-country geospatial data essential to watershed vulnerability analysis
- Ranking of watersheds in terms of their threat to human safety and well being according to three measures of risk and vulnerability: soil erosion risk, population vulnerability, and infrastructure vulnerability

Watershed Management and Vulnerability in Haiti

Watershed management in Haiti involves complex development issues and poses important challenges because of its links to (a) poverty reduction including agricultural productivity, health, energy and water supply, and sustainable growth of communities, and (b) growing evidence of the heightened exposure of Haitian society to natural disaster. The following section reviews Haiti's policy framework for watershed management including principles and criteria used to identify vulnerable watersheds.

OVERVIEW OF HAITIAN WATERSHEDS

Haitian government reports and policy statements use variable definitions of watershed. Sometimes it is defined as a basin or hydrological zone as in the present report, while at other times it is used to refer to Haiti's principal rivers. The scale of Haiti's watersheds also varies greatly. Authorities have used the criterion of size to divide the country into 30 major watersheds (see Table 5 below and Figure 5 on the following page).

Table 5. Major Watersheds and Hydrological Basins of Haiti

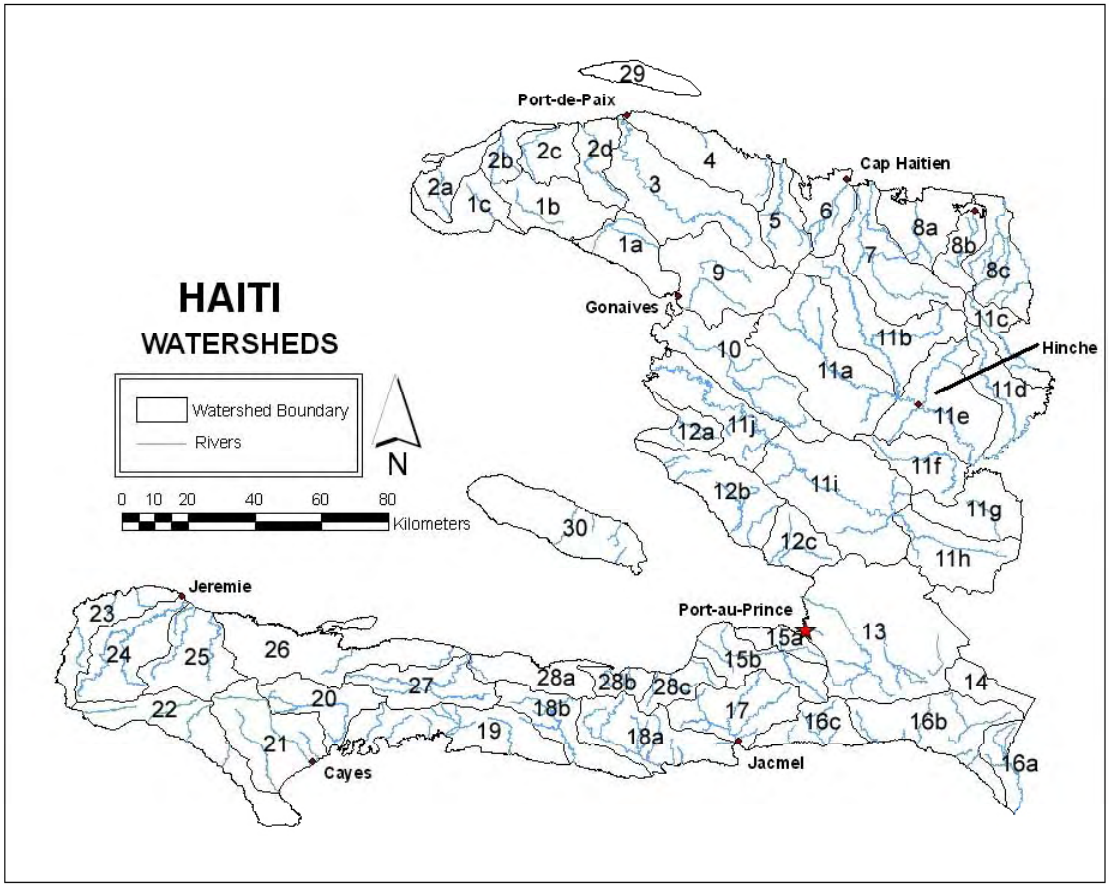
Basin or Zone (# sub-basins)	Drainage Area (Km^2)	Basin or Zone (# sub-basins)	Km^2
1. Bombardopolis/Gonaïves (3)	1130	16. Cayes-Jacmel/Anse à Pitres (3)	1201
2. Môle St Nicolas/Moustique (4)	975	17. Grande Rivière de Jacmel	561
3. Trois Rivières	898	18. Côte de Fer/Baînet (2)	1064
4. Port-de-Paix/Port Margo	547	19. St Louis du Sud/Aquin	714
5. Limbé	313	20. Cavaillon	400
6. Cap Haitie	325	21. Cayes	661
7. Grande Rivière du Nor	680	22. Tiburon/St Jean	657
8. Limonade/Ouanaminthe (3)	1085	23. Jérémie/Les Irois	368
9. La Quinte	700	24. Grande Anse	554
10. Estère	800	25. Roseaux/Voldrogue	524
11. Artibonite (10)	6336	26. Corail/Anse à Veau	849
12. Saint Marc/Cabaret (3)	1118	27. Grande Rivière de Nippes	465
13. Cul-de-Sac	1598	28. Pte. Riv. de Nippes/Grd.Goâve (3)	691
14. Fonds Verrettes	189	29. Ile de la Tortue	179
15. Léogane/Carrefour (2)	598	30. Ile de la Gonâve	691

Source: OAS (1972); PNUD (1998); UTSIG (2001). a This listing follows a geographic order of proximity. Numbers are derived from the OAS study. See Figure 5 below for all 30 watersheds plus 24 sub-basins.

The major watersheds in Table 5 include two major offshore islands, La Gonave and Ile de la Tortue; however, the list also excludes other notable islands including Ile à Vache, Grande Cayemitte, and Navasse. More recently, the geospatial division of the Ministry of Planning has recognized 54 watershed units including 24 sub-basins shown on current maps (see Figure 5).

The geographic limits of Haiti's watersheds do not necessarily follow administrative or political boundaries. Haiti's national environmental action plan (NEAP) identifies municipalities (*communes*) as planning units for watersheds; however, there are watersheds that cover several different *communes*. In terms of jurisdictions for watershed planning, the Constitution of 1987 identifies the *département* as the largest scale planning unit; however, there are also major interdepartmental watersheds including the Trois Rivières (North and North-West *départements*) and the Artibonite (Plateau Central and Artibonite *départements*). Furthermore, Haiti shares four cross-border watersheds with the Dominican Republic (Artibonite, Pédernales, Massacre, and Fond Verrettes). The Artibonite is the most important by far, covering about 6,400 km^2 within Haiti's

Figure 5. Watersheds and Rivers of Haiti



boundaries. This constitutes about two-thirds of the Artibonite's total drainage area and one-fourth of Haiti's entire land area.

Aside from lakes and ponds, Haiti's surface waters are concentrated in a restricted number of important rivers that account for about 60 percent of the flow regime (World Bank, 1991). Haiti's major river beds are defined by the high water mark at flood stages. Due to changes in the environment and the lack of watershed management in Haiti, formerly exceptional floods have become yearly floods. At present it is not unusual for Haiti's rivers to reach the high water line twice each year. See Table 6 on the next page for characteristics of Haiti's major river systems.

Table 6. Major river systems in Haiti

River	Drainage Area (Km^2)	Average Flow (M^3/Sec)	Runoff Coefficient (%)	Department
Artibonite	6,336	99	22.6	Artibonite & Central Plateau
Trois Rivières	898	6.5	18.6	North & Northwest
L'Estère	800	3.1	12.7	Artibonite
Gde Rivière du Nord	680	5.4	20.5	North
Grande Anse	554	12	46.2	Grande Anse
Cavaillon	400	8.0	42.0	South
Momance (Léogane)	437	5.6	-	West
Rivière Grise	290	3.3	24.0	West
Gde Ravine du Sud	205	3.9	32.4	South

Source: GOH Ministries of Agriculture and Environment, MARNDR/MDE (2000)

ENVIRONMENT, VULNERABILITY AND WATERSHED MANAGEMENT

Haiti's population and economy are highly vulnerable to natural disasters. This vulnerability has tended to increase due to climate change, droughts, frequent hurricanes and floods, landslides, earthquakes, and repeated small tremors along fault lines.

Vulnerability

Vulnerability refers to the degree to which a country, a community, or a sector of activity is exposed to damage by external forces such as natural disaster. These risks can be a combination of social and physical processes. Haiti is marked by a mosaic of environmental vulnerabilities due to structural, social and physical factors including weak government and other weak institutions, political instability, extreme poverty, rapid population growth, acute pressure on the natural resource base including coastal and marine resources, wood scarcity, an almost complete disappearance of forest cover, an energy crisis, and pressure on water reserves. The environmental vulnerabilities of Haiti include natural disasters such as hurricanes, floods, earthquakes, and landslides, and also man-made disasters such as deforestation, fire, and pollution.

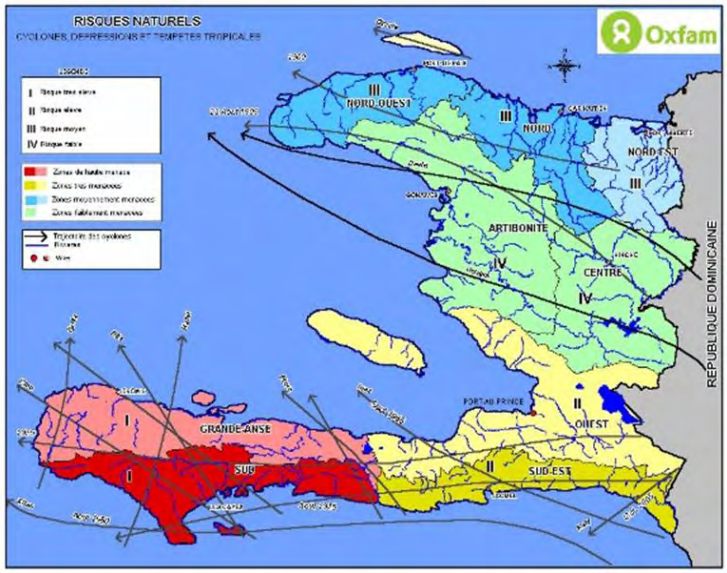
Climate Change

Growing scientific evidence shows new climate trends in the Caribbean. The recorded rise in sea levels and sea surface temperatures are primary causes for increased beach erosion, salinization of fresh water aquifers and estuaries, and increased coral reef bleaching throughout the Caribbean (Burke & Maiden, 2004; Trotz, 2004). There is also a trend that suggests an overall decrease in precipitation combined with increased frequencies of extreme weather events and hurricane intensities. A 20 percent decrease in summer rainfall is predicted by the end of the century (ENS, 2006). Haitian observations tend to confirm these scientific findings: people report dry seasons that last longer, and shorter but more intense rainy seasons.

The North Atlantic has shown a significant increase in hurricane intensities and duration as part of a 30-year trend (Webster *et al*., 2005). Rising sea surface temperatures and the trend in hurricane patterns are undoubtedly linked to global climate change; however, there is insufficient evidence to support a simple, causal relationship.

How climate change will affect watershed vulnerability remains uncertain. It is reasonable to expect that more extreme weather events expose watersheds to greater stress than periods of more moderate climate. The Caribbean's natural systems have evolved mechanisms that enable resilience to cyclical disturbance such as hurricanes; however, the combined effects of climate change and human-related changes in the landscape are forcing watersheds into uncharted territory.

Figure 6. Hurricane Trajectories Across Haiti



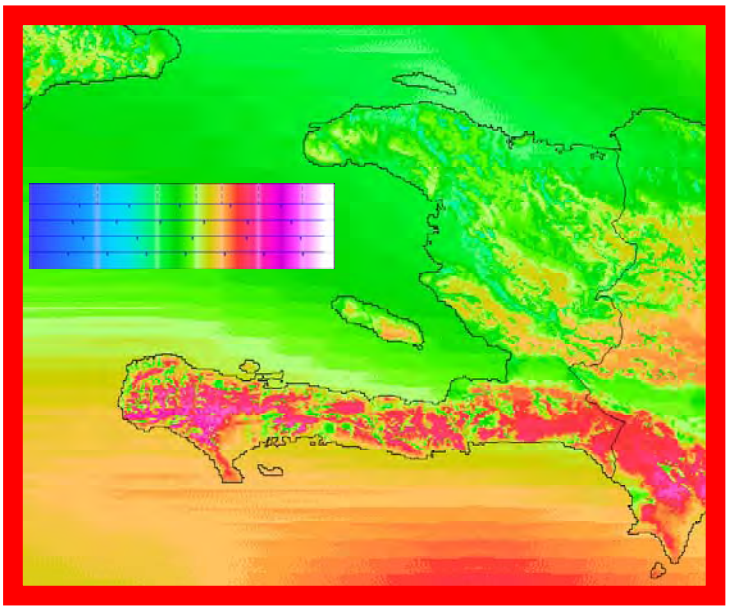
Source: Mathieu *et al*., 2002

HURRICANES

Between 1900 and 2004, Haiti was victimized by 50 major natural disasters including 17 hurricanes, 26 severe floods, and 7 droughts (CCI, 2004). The trajectories of a portion of these hurricanes are shown in Figure 6 (above, right).

Figure 7 (right) summarizes the maximum likelihood of hurricane force winds for 50-year periods of return, i.e., a hurricane force that occurs once in 50 years. The two figures clearly show the heightened vulnerability of the southern peninsula to hurricanes compared to the

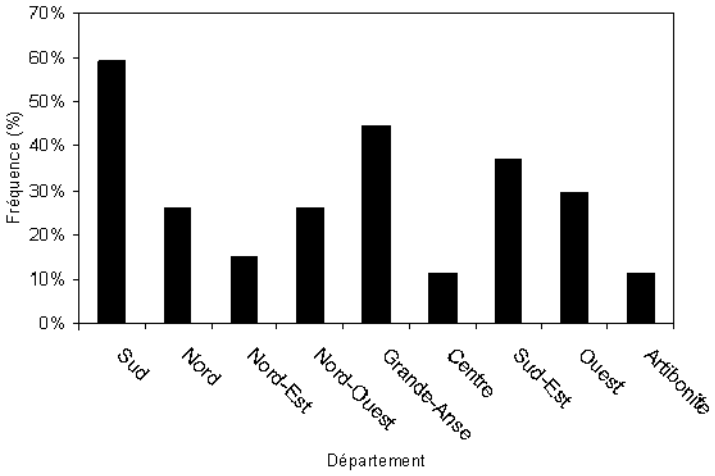
Figure 7. Maximum Likelihoods of 50-Year Return Hurricanes



Source: Wagenseil, 2000

rest of the country. The pattern of wind speeds on the island corresponds to elevation and location. Therefore, the higher mountain ranges of the southern peninsula are more exposed. This is supported by Figure 8 (right) showing a much higher frequency of hurricanes hitting Haiti's southern *départements*: South (59 percent), Grand'Anse (44 percent), South-East (37 percent), and West (30 percent).

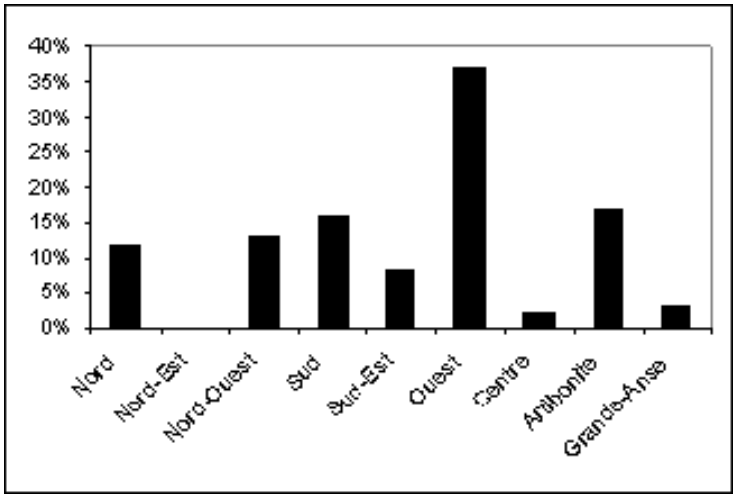
Figure 8. Hurricane Frequencies by Department in Haiti (1954-2001)



FLOODS

Hurricanes or tropical storms threaten the country; however, in the past decade, severe flooding has caused the most damage and accounts for a higher number of deaths than the gale force winds. The *départements* most affected by floods are the West with 36 percent of the cases followed by the Artibonite, the South, the North-West and the North. The other *départements* all together represent only about 10 percent of the cases (Figure 9, right).

Figure 9. Flood Frequencies by Département (1968-1997)



The risk of floods is high in most of Haiti's coastal and lowland areas. Mathieu *et al*. (2002) note that in 53 percent of the cases, floods strike coastal cities or localities where the average population density is relatively high. The scale, extent and high number of victims and deaths caused by the floods of major hurricanes is shown in Table 7.

The severe floods of 2004 in Gonaïves (Artibonite), Fonds Verrettes (West), and Mapou (South-East) forced a new awareness of Haiti's heightened risk of catastrophic floods. These recent precedents also serve as a warning of major threats to densely populated districts of Port-au-Prince. Prospective deaths due to catastrophic flooding in Port-au-Prince would far surpass all other disasters in Haiti's meteorological record.

Improved watershed management could reduce the social, economic and ecological vulnerability of watershed populations and landscapes. Recent response strategies include establishment of early warning systems. Several watersheds are being equipped with such systems, e.g., Fonds Verrettes and Ennery/La Quinte.

TARGETING CRITICAL WATERSHEDS

This section examines various Haitian government criteria for prioritizing critical watersheds and guiding efforts at watershed intervention. Four key ministries are directly concerned with watershed management and their vulnerability: the Ministry of Agriculture, the Ministry of Interior and Territorial Collectivities,[30] the Ministry of the Environment, the Ministry of Planning and External Cooperation; and the Ministry of Public Works, Transportation, Communications is also concerned with the vulnerability of both infrastructures and the population to risks of flooding.[31]

Table 7. Major Hurricanes of Haiti

Date	Name	Impacted Area	Speed (Km/H)	Mortalities	Disaster Victims	Loss (US$1,000)
12/08/1915	NA*	South	76	1,600	NA	NA
1935	NA	South, Southeast, Grand'Anse	NA	2,150	NA	NA
12/10/1954	Hazel	South, Grand'Anse, Port-au-Prince	NA	410	250,000	NA
3 /10/1963	Flora	South, Southeast	240	5,000	NA	180,000
24/08/1964	Cléo	Cayes, Camp-Perrin, Arniquet	150	100	80,000	10,000
29/09/1966	Inez	South, Port-au-Prince, Marigot to Grand-Goâve	120-190	480	67,000	20,000
13/11/1994	Gordon	All of Haiti	NA	1,122	NA	NA
22/09/1998	Georges	All of Haiti	NA	242	385,000	80,000 - 180000
23/05/2004	Tropical Storm	Southeast	NA	3,000	6,000	NA
18/09/2004	Jeanne	Northwest	NA	1,800	300,000	NA

*NA = data not available

[30] The term "territorial collectivities" refers to local levels of government including municipalities (*communes*) and rural jurisdictions (*sections communales*).

[31] The ministry's Laboratoire National de Bâtiment et des Traveaux Publics has submitted a project entitled, « Reduction de la vulnérabilité de la population et des infrastructures aux Risques d'inondation. » (Wilfrid Saint Jean, Bureau of Mines and Energy, personal communication, August 2006).

Ministry of Agriculture, Natural Resources and Rural Development (MARNDR)

Since 2000, MARNDR has gradually pulled back from a program implementation role and focused more on its normative and coordinating role. The ministry issued a policy on watershed management that includes principles for intervening in watersheds (MARNDR, 2000). According to MARNDR, watershed planning and management should be addressed at municipal levels of government (*communes*).

MARNDR has identified priority watersheds but this selection does not appear to reflect a standardized GOH approach based on clearly defined criteria. According to the ministry's director of natural resources, priority watersheds are those with productive infrastructures (irrigation works, roads, bridges) and other socially or culturally significant structures such as public markets, beach hotels, and historic buildings.[32]

Ministry of the Environment (MDE)

The Aristide government created the MDE in 1995 in the wake of the 1992 world summit at Rio. This ministry is responsible for overall coordination of environmental activities in Haiti including implementation of the National Environmental Action Plan (NEAP).

The MDE uses the notion of watershed management as a strategic tool for determining priorities, interventions, and environmental planning to promote macro-economic development. Management of strategic watersheds is one of the ten guiding themes of the National Environmental Action Plan (NEAP). The MDE approach to watershed management integrates ridge-to-reef planning, water, and protection of ecosystems.

According to a ministry spokesman, MDE watershed priorities are not formalized but take into account the following components: (a) earlier efforts at natural resource management, (b) a ridge-to-reef orientation linking upstream and downstream, (c) the vulnerability of local populations and productive assets (threats of loss of human life, infrastructure, and natural capital), and (d) threats to the country's natural heritage, especially forests and mangroves.[33]

Ministry of Planning and External Cooperation (MPCE)

MPCE interests in watershed management are channeled through its area planning unit (Unité d'Aménagement du Territoire et de Développement Local et Régional) and its GIS unit (UTSIG). The ministry's approach includes zoning, preparation of land use maps, maintaining a geospatial database, and preparation of regional and national development plans.

Ministry of Interior and Territorial Collectivities (MICT)

The ministry's civil protection directorate (DPC, Direction de la Protection Civile) has put into place a National Risk and Disaster Plan (PUGRD) to pursue two general goals:

[32] Ogé Pierre Louis, personal communication, May 2006.
[33] Joseph Vernet, personal communication, May 2006.

- Diminish the risk of natural disasters;
- Strengthen capacity to respond to natural disaster at the national, departmental, municipal, and local levels.

In the wake of severe flooding in Gonaïves and Fonds Verettes, the DPC assigned priority to recent storm sites afflicted by severe flooding (La Quinte and Fonds Verrettes) and also to densely populated watersheds including Les Cayes.

The IDB and World Bank are making significant investments in DPC efforts to mitigate watershed vulnerability. The World Bank is assisting DPC to establish local protection committees, and the IDB is helping the DPC to create an early flood warning system focused on a list of watersheds deemed critical. (See "Governance and Disaster Mitigation" below for more detailed discussion of early warning systems.) The UNDP-financed PAGE (Projet d'Appui pour la Gestion de l'Environnement) is laying the groundwork for more sophisticated GOH monitoring and vulnerability assessment, including the *Observatoire National de l'Environnement et de la Vulnérabilité*.

Priority Watersheds

Historically, determination of priority watersheds has been the domain of the forest service (Service des Ressources Forestières) and the Ministry of Agriculture. A list of priority watersheds, difficult to obtain, is presently being finalized by MARNDR to support DPC implementation of the IDB-assisted early warning system. A MARNDR list of 15 watersheds was recently increased to 19 in response to DPC priorities. The revised list includes six additional rivers along with those noted in Table 7 above: La Rouyonne and Cormier (part of the Léogane watershed); Acul du Sud (part of the Cayes watershed); Grande Rivière de Nippes; Grande Rivière de Jacmel; and Ennery (part of the La Quinte/Gonaïves watershed). In most cases, this prioritization does not identify specific portions of watershed basins deemed most critical. Two key selection criteria appear to be driving the current list of GOH priority watersheds: (1) potential loss of human life, and (2) damage to the economic infrastructure due to flood events.

In a recent development, the most active governmental initiative to address watershed prioritization is an inter-ministerial committee, the *Comité Thématique du Système d'Alerte*, operating under the IDB-assisted framework, including representatives of the Ministry of Agriculture, the geospatial unit (UTSIG) of the Ministry of Planning, and the civil protection directorate (DPC) of the Ministry of Interior. This effort includes the selection of priority watersheds based on flood risks. According to field interviews, this committee has discussed factors useful for analyzing watersheds (see Table 8 below); however, at the time of the present assessment, the committee had not formally proposed criteria nor scientifically assessed watershed vulnerability.

In sum, donor support to the DPC for disaster mitigation is based on a list of critical watersheds established by the agricultural ministry and the DPC; however, up to now, no donor or government agency has used a systematic approach to compare and rank the relative vulnerability of Haiti's watersheds.

Table 8. Factors Being Considered as a Basis for Prioritizing Watersheds

CATEGORY	DESCRIPTION
Floods	Frequency, intensity, extent of damage (humans, infrastructure)
Climate	Rainfall patterns, hurricane trajectories, climate cycles
Morphology	Digital elevation models, slopes, geomorphology, geology
Hydrography	River systems, flow rates, hydrogeology
Land Use	Vegetative cover, land use
Population	Habitat density, building categories, growth rates, density, migration rates
Infrastructure & Utilities	Communication channels (roads, ports, utilities), agriculture (irrigation networks, dams), public buildings (schools, government administration, clinics & hospitals)

A WATERSHED VULNERABILITY ANALYSIS

- A rapid assessment tool. Due to the absence of clearly defined priorities, the assessment team designed a GIS-based rapid assessment tool to identify Haiti's most vulnerable watersheds. This tool ranks Haiti's watersheds by using indices devised to measure risk. This tool takes into account factors noted in Table 8 for which GIS data were already available.[34] The following discussion is based on ranking the relative vulnerability of Haiti's 54 major watersheds and subwatersheds.[35]

- Hazard mapping. This approach is based on review of the vulnerability assessments and hazard mapping studies that have been conducted in Haiti since 2000. Given the results of the analysis, USAID managers will be able to substantiate their project proposals more effectively, use the results as a tool in project planning, and identify gaps in the strategic assessment of watersheds by donors and the Haitian government. The new GIS rapid assessment tool should also be useful to the inter-ministerial committee and the IDB-assisted review of priority watersheds presently underway.

- National assessment versus localized risk factors. This broad-scale national level approach to rapid assessment does not adequately capture certain regional risk factors such as the heightened propensity for hurricanes to strike Haiti's southern coast. As shown earlier in Figures 6 and 7, the south face and steep slopes of Haiti's highest ridges (Massif de la Hotte and Massif de la Selle) are especially prone to hurricanes, landslides, floods, and changes in local surface and ground water. Other regional risk factors include the dry coastal zone stretching from Môle St. Nicolas to the northern edge of Lac Azuei. This zone is typical of Haiti's coastal limestone formations marked by sparse vegetative cover, low infiltration rates, and a tendency to flash flooding.

[34] GIS coverages were not available for all pertinent criteria for measuring vulnerability, including a number of the factors noted in Table 8.
[35] For methodology see Appendix C at the end of this chapter, "GIS Analysis of Watershed Vulnerability."

- Environmental factors. Various environmental factors determine the vulnerability of watersheds. Climate and climate change affect all watersheds, yet the interaction of climate with geological and biological features cause certain watersheds to be more vulnerable than others. The index used here to rank and prioritize Haiti's watersheds may be adjusted depending on the factors of primary concern.

- Soil and water resources. A challenge in the rain fed agricultural systems on Haiti's slopes is to increase water productivity (i.e., water use efficiency). Properly managed, this can reduce soil erosion and optimize soil productivity. The coupling of increased water productivity with reduced soil erosion can create a "hydrologically functional landscape" (DER, 1999; USEPA, 2006; World Bank, 2006). Such landscape interventions may compensate for changes in water balance due to land development: an increase in runoff rates coupled with a decrease in evapo-transpiration and infiltration rates. The goal is to minimize runoff and capture excess water runoff for future use. This is especially important for rain fed cropping systems, but it also sets the stage for a more diverse local economic base. Elements of such a landscape are noted below in "Urban Planning" and recommendations for soil and water conservation in Chapter III.

Soil Erosion Risk Index

The risk of soil erosion is a leading parameter for vulnerability analysis of Haiti's watersheds. The soil erosion risk map in Figure 10 (next page) serves as the basis here for deriving an erosion risk index. This classification combines four factors: slope, soil erodibility, climate erosivity, and vegetative cover (MPCE, 2002). The weight of each factor is determined by its relative importance to soil erosion *and* the confidence in assigning weights to the sub-categories of each factor. Thus, slope is given the highest weight (5), followed by soil erodibility and vegetative cover (2), then erosive climate factors (1). Erosion risk is then computed for each map unit, dividing the map into six categories ranging from 0 (zero or very low risk) to 6 (extreme risk).

There are several advantages in using this map to assess watershed vulnerability. Soil erosion is an exorbitant cost to agriculture and other forms of land use in Haiti. The map clearly shows what is at stake given current agricultural practices and policies. Soil erosion is also intricately linked to runoff and water quality since soil erosion is the primary pollutant of surface water systems, diminishing potable water reserves and stressing estuaries and coral reefs.

For this assessment, the erosion risk index combines a number of environmental factors that explain vulnerability. There are several shortfalls to the map: (1) no soil map of Haiti exists on a national scale, thus soil erodibility is based on presumed affinities with the geological parent material; (2) rainfall records are outdated or incomplete for large sections of the national grid; and (3) little or no empirical data are available to support the relationship between erosion rates and vegetation type.

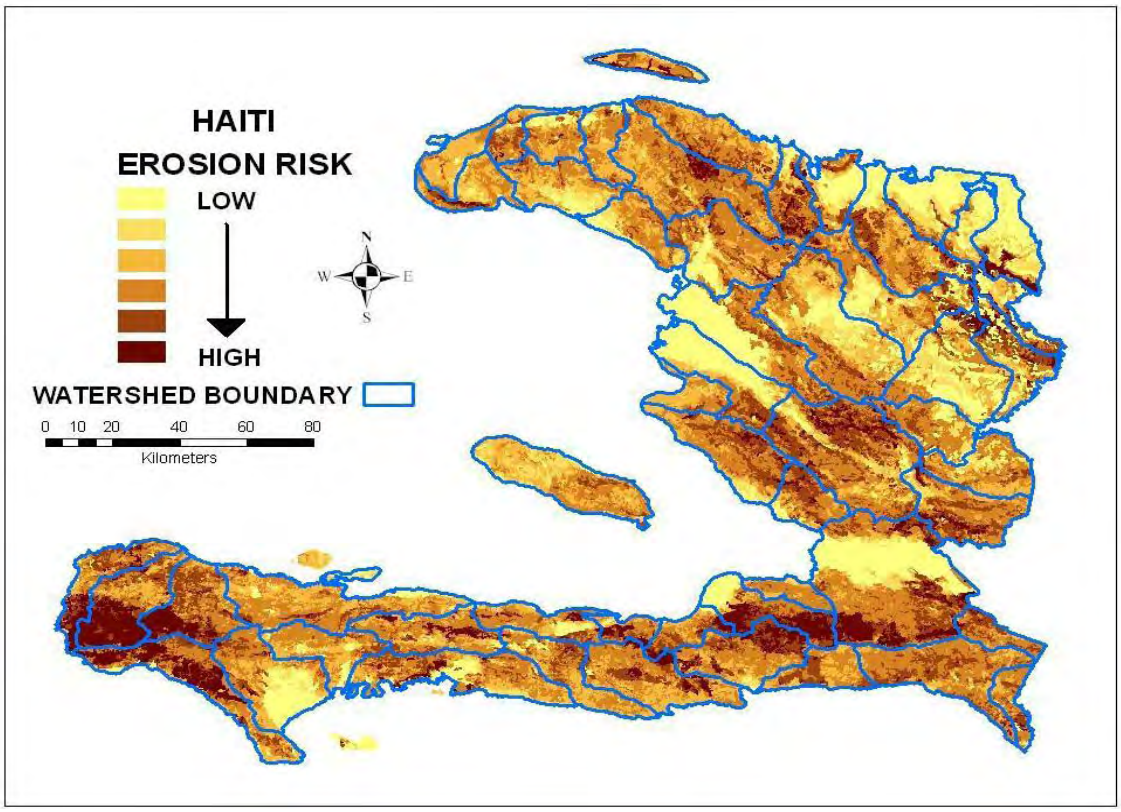
Despite these shortfalls, it can be argued that the erosion risk map is the best single map to index natural resource vulnerability. It shows the differences among watersheds in

terms of the factors that determine their hydrological behavior, water quality and the fragile nature of the montane ecosystems.

See Table 9 on the following page for a ranking of the erosion risk index by watersheds. *The highest ranked watersheds for erosion risk all occur in the southern peninsula*. This is due primarily to the steep terrain, high elevations (the highest peaks in Haiti occur in these watersheds), higher rainfall, and the frequency of extreme storm events. The lowest ranked watersheds occur along the northern coast and are generally characterized by low mountains and large alluvial plains.

For readers familiar with the Grand'Anse, it may seem counter intuitive that despite the area's relatively high level of vegetative cover, this region still scores high for erosion risk. To understand this apparent anomaly, it should be noted that the erosion risk analysis weights slope much higher than ground cover. Furthermore, the risk of soil erosion should not be confused with measures of the present rate of erosion. The significance of this analysis lies in the region's heightened erosion risk compared to other watersheds that are less steep, lower in altitude, less frequented by hurricanes.

Figure 10. Soil Erosion Risk Map of Haiti



Source: Derived in part from interpretation of SPOT XS satellite images (1998)

Table 9. Erosion Risk Index of Watersheds in Haiti (Index scale: 0-100)

RANK	WATERSHED	INDEX	RANK	WATERSHED	INDEX
1	Grande Anse	100	28	Aquin/St. Louis du Sud	57
2	Voldrogue/Roseaux	94	29	La Quinte	55
3	Tiburon/Port-Salut	89	30	Baie de Henne	54
4	Les Irois/Jérémie	86	31	Lociane	54
5	Rivière de Jacmel	84	32	Cavaillon	52
6	Fonds Verrettes	83	33	Thomonde	52
7	Petit Goave	81	34	Cul-de-Sac	52
8	Limbé	78	35	Moustique	52
9	Grand Goave	78	36	Saint Marc	52
10	Fer à Cheval	77	37	Corail/Anse à Veau	51
11	Momance (Léogane)	77	38	Péligre Sud	50
12	Cours Moyen (Artibonite)	76	39	Gatinette	48
13	Belle Anse	74	40	Libon	48
14	Cabaret	72	41	Colombier	46
15	Bainet	71	42	Môle Saint Nicolas	44
16	Trois Rivières	70	43	Bouyaha	42
17	Gde Rivière de Nippes	70	44	La Gonave	41
18	Montrouis	69	45	Canot	41
19	Anse à Pitre	69	46	Anse Rouge	39
20	Jean Rabel	69	47	Les Cayes	35
21	Marigot	69	48	Cap-Haïtien	29
22	La Tortue	64	49	L'Estère	27
23	Port-de-Paix/Port Margot	63	50	Guayamouc Aval	26
24	Rivière Froide	61	51	Cours Inférieur (lower Artibonite)	14
25	Côtes de Fer	60	52	Marion	11
26	Miragoane	59	53	Jassa	10
27	Gde Rivière du Nord	57	54	Trou du Nord	0

The high risk of erosion in the Grand'Anse is not simply a matter of theoretical risk. The most recent available study of woodfuel resources in Haiti states that the Grand'Anse has now replaced the Northwest region of Haiti as the country's principal source of wood charcoal.[36] The present erosion risk analysis thus sounds a warning: If present trends for reduced ground cover in the Grand'Anse are not reversed, the region's high erosion risk renders it highly vulnerable to disaster. This risk is also heightened by the region's high rate of endemic species, the highest in the Caribbean, especially in Pic Macaya National Park, a protected area in the high ridges of southwest Haiti.

Notably, the watersheds that are most vulnerable to erosion also contain the most significant cloud forests remaining in Haiti (Macaya and La Visite National Parks and the

[36] See the ESMAP study (July 2005, 32) of the Ministry of Environment and the Bureau of Mines and Energy.

Forêt des Pins). These highland forests, their critical hydrological function as headwaters of more than a dozen rivers, and their global significance for biodiversity are a strong argument for targeting them as high priority watersheds. These sites are also excellent opportunities to create synergies with GOH and establish co-management approaches discussed later in this chapter.

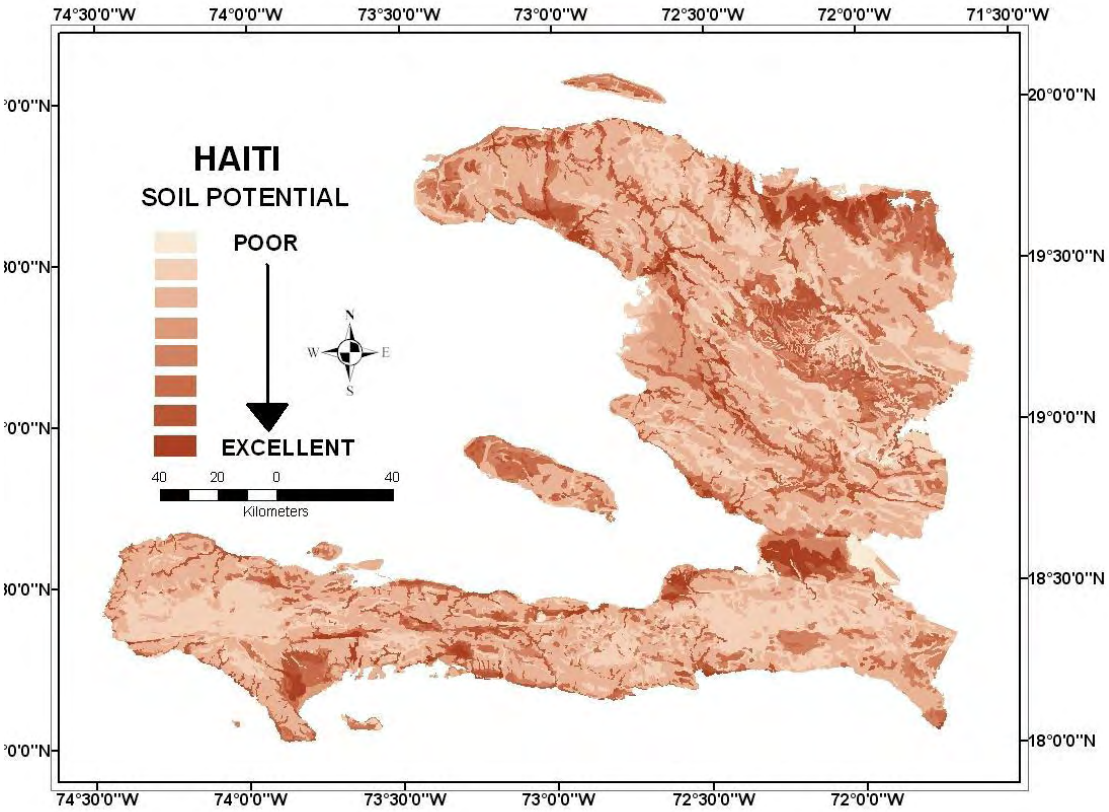
Soil Potential Index

The team's GIS analysis takes into account the productive potential of watersheds as well as their vulnerability. The soil potential map in Figure 11 (below) serves as the basis for this study's soil potential index. This map was created in 1978 to show the areas of Haiti most capable of supporting agriculture (BDPA, 1982). The map weights factors favored for agriculture: slope, soil properties, lithology, and geomorphology. The map divides the land surface of Haiti into eight classes of soils, following the USDA potential soils classification system.

SOIL POTENTIAL INDEX RANKING

The ranking of the watersheds in terms of their soil potential index is basically the inverse of the erosion risk index ranking (see Table 10). The correlation between the two indices is highly significant as shown by the Spearman R statistic: - 0.922. This is expected since slope is the overriding factor and correlated with many other factors included in the agronomic potential of the soil: parent soil material, erodibility, drainage, and salinity.[37]

Figure 11. Soil Potential Map of Haiti



The top three watersheds for soil potential are located in the north of the country (Trou Nord, Jassa, Cap-Haïtien) and the lowest ranked watersheds occur along the high ridges of the southern peninsula (Massif de la Hotte and Massif de la Selle). The highest index values are northern watersheds near the important trade corridor between Haiti and the Dominican Republic, especially Ouanaminthe-Dajabon and Cap-Haïtien, a GOH priority for economic expansion.

Growing urban population densities in the region offer excellent economic opportunities to expand variants of "charcoal gardens," and agroforestry configurations designed for market driven NRM, e.g., fast growing species such as *Acacia auriculiformis* and *Eucalyptus camaldulensis*. [38]

MANGROVES

The delta areas of northern rivers also contain significant stands of mangroves. Mangroves play an essential role as fish habitat and serve a valuable buffering role during storm surges; however, mangroves along the north coast of Haiti are presently under intense pressure especially in the vicinity of Cap-Haïtien (Aubé and Caron, 2001). The main causes for mangrove decline include intensive harvesting of mangroves for charcoal and poles, heavy fishing, and the conversion of coastal areas to residential sites. The entire band of mangroves from Cap-Haïtien to the DR border should be targeted for protection and management.

The Factor of Biodiversity

NATURAL FOREST AND FISHERY RESOURCES

The objective of reducing watershed vulnerability requires an optimal balance of undisturbed natural areas on the most sensitive lands combined with sustainable harvest of locally adapted native species on less sensitive lands.

GIS data were not available to assess biodiversity-based vulnerability for the present study; however, protection of natural areas and biodiversity should be an essential feature of watershed interventions and strategies for flood control. According to 1998 satellite imagery, 9.2 percent of Haiti's land area is considered natural, and categorized as forest (1.3 percent), savanna (7.3 percent) and mangrove estuaries (0.6 percent).[39] Lands with at least 75 percent tree-dominated agroforestry systems cover 18.3 percent of the total surface and occupy moister life zones. The vegetation of the drier areas, dominated by converted grasslands, cacti, shrub and thorny tree species, cover 22 percent of the land. The latter vegetation type, adapted to hurricanes and droughts and further modified by grazing pressures, is common throughout the Caribbean.

[38] See Chapter III on NRM and landscape level change in the semi-arid North-East (Les Perches and Acul Samedi) due to charcoal gardens. Also, see Chapter V on biofuels, including wood charcoal.
[39] See UTSIG (2002), "Statistiques générées à partir de la carte d'Occupation du sol (par image SPOT XS 1998).

Table 10. Soil Potential Index of Watersheds in Haiti (Index scale: 0-100)

RANK	WATERSHED	INDEX	RANK	WATERSHED	INDEX
1	Trou du Nord	100	28	Moustique	32
2	Cap Haïtien	78	29	Baie de Henne	32
3	Jassa	66	30	Gde Rivière du Nord	31
4	Anse Rouge	61	31	L'Estère	29
5	Les Cayes	60	32	Petit Goave	29
6	Marion	58	33	Marigot	27
7	La Gonave	56	34	Cabaret	26
8	Môle Saint Nicolas	55	35	Trois Rivières	26
9	La Tortue	54	36	Les Irois/Jérémie	25
10	Gatinette	52	37	Belle Anse	25
11	Colombier	50	38	Libon	23
12	Canot	49	39	Limbé	22
13	Bouyaha	46	40	Tiburon/Port-Salut	21
14	Anse à Pitre	46	41	Péligre Sud	21
15	Guayamouc Aval	46	42	Grand Goave	21
16	Aquin	44	43	Momance (Léogane)	20
17	Côtes de Fer	44	44	Montrouis	20
18	Cours Inférieur (Artibonite)	42	45	Fer à Cheval	17
19	La Quinte (Gonaïves)	41	46	Thomonde	15
20	Miragoane	40	47	Rivière Froide	15
21	Gde Rivière de Nippes	38	48	Bainet	13
22	Cavaillon	36	49	Port-de-Paix	12
23	Corail/Anse à Veau	35	50	Gde Rivière de Jacmel	10
24	Cours Moyen (Artibonite)	35	51	Lociane	10
25	Jean Rabel	35	52	Grande Anse	4
26	Cul-de-Sac	34	53	Voldrogue/Roseaux	1
27	Saint Marc	32	54	Fonds-Verrettes	0

Interventions to maintain a robust genetic base of cash crops and native species are a critical issue that lacks an easy solution. While there may be market incentives to secure the best available germplasm for cash crops and some domesticated animal breeds, this is not the case for most native species exploited for their economic value. Therefore, a special effort should be made to protect Haiti's few remaining natural areas and incorporate Haiti's rich biodiversity heritage into natural resource management.

The most important natural biological systems left in Haiti in terms of their relative integrity are areas of the country that are the most inaccessible to human habitation: mangroves, coral reefs, montane rainforest, and remnants of the dry forest. These are all highly vulnerable since they are presently exploited for their natural capital with few safeguards to govern sustainable harvests. A risk index would be based on the greater biological value of larger natural areas rather than small fragmented areas.

As noted earlier, mangroves are important for flood control, especially in river deltas. The most important mangroves are those located in the delta areas of Haiti's northern rivers and the Artibonite. Haiti's major stands of mangroves also include the islands of La Gonave, Grande Cayemitte, and Ile à Vache, and the northern coast of the southern peninsula from Mariani to Baradères.

BIODIVERSITY HOTSPOT

Numerous reports identify Haiti as a biodiversity hotspot. Haiti is located at the geographic center of the Greater Antilles, an area with one of the highest concentrations of endemic species on earth (Mittenmeier *et al*., 2000). Within Haiti, the spatial distribution of endemism is complex due to the geological history of the island and the wide range of life zones. Biologists consider southwest Haiti's high ridge (the Massif de la Hotte), including Pic Macaya National Park, one of the two most prominent centers of biodiversity in the Caribbean (Borhidi, 1991). This region is also the wettest spot on the island.

The watersheds of the southwest, including montane forest along Haiti's high southern ridges, would therefore rank the highest in terms of (a) the risk of biodiversity lost and (b) the volume of rainfall as a source of fresh, clean water.

On a biodiversity vulnerability index, the highest ranking natural ecosystems would also include (i) the mangrove deltas (particularly the Artibonite delta, the Baie de Caracol in the North, and Baradères in the Grand'Anse), and (ii) coral reefs throughout Haiti.

Population Vulnerability

Population is perhaps the index of greatest concern to this study since it focuses on the vulnerability of densely populated urban districts along the coast, and requires costly efforts to mitigate disaster and improve current living conditions.

DRIVING FORCE OF VULNERABILITY

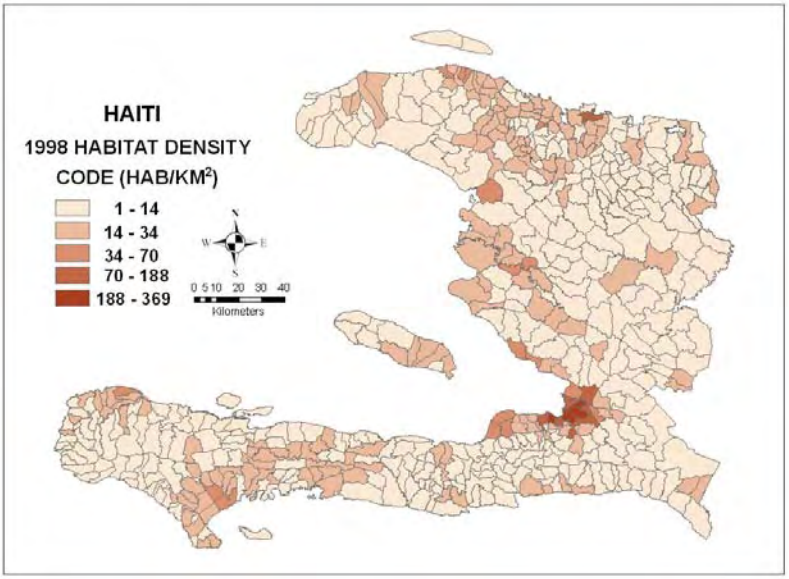
As noted in Chapter II, the rapid growth of Haiti's population coupled with uncontrolled urbanization and acute poverty are the driving forces of Haiti's vulnerability to natural disaster. Therefore, watershed management geared to mitigate environmental vulnerability must integrate demographic parameters and take steps to control population growth.

The rapid increase in population and urbanization do not allow aquifers and wetlands to function as a natural storage, filter and regulator during flood conditions. Hard surfaces caused by anarchic construction methods prevent the infiltration required to recharge the most important aquifers of Haiti's major plains: Cul-de-Sac, Gonaïves, Léogane, Les Cayes, and the northern plains. Demographic pressures further aggravate the trend for increased runoff and flooding during periods of torrential rains.

HABITAT DENSITY

Haiti has an overall population density of 286 inhabitants per square kilometer. Figure 12 shows the most current habitat density map available, based on 1998 satellite imagery aggregated by communal sections. About 40 percent of the population is presently urban, densely inhabiting less than 2 percent of the land area.[40]

Figure 12. Habitat density based on 1998 SPOT images

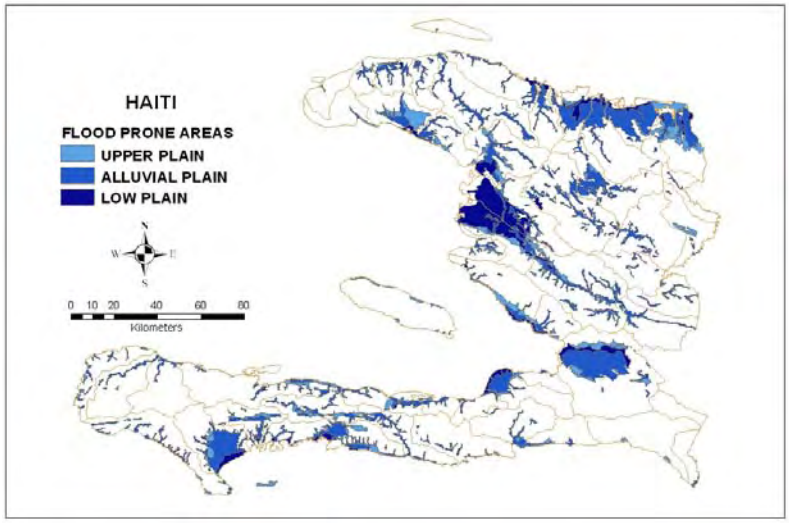


Source: Adapted from Guilland (2005)

POPULATION VULNERABILITY INDEX

The vulnerability of the population is defined here as the intersection of habitat density with flood prone areas (see Figures 12 and 13). The map in Figure 12 features three categories of plains that are likely to flood: low elevations near the coast, alluvial plains, and elevated plains. The intersection of the habitat density map with the flood prone area map serves as the basis for estimating the population exposed to floods, and therefore a population vulnerability index.

Figure 13. Flood Prone Area Map of Haiti



Source: Adapted from Guilland (2005)

The watersheds representing the country's largest urban centers scored highest on the index of population vulnerability (Table 11), i.e., high population densities residing in low coastal plains. At the other

[40] Though the map reflects population density, it is based on the density of habitat structures and therefore caution should be exercised in its interpretation. The map shows categories based on a logarithmic distribution rather than equal intervals.

extreme, the lowest values were characterized by low population densities residing in areas with little or no coastal plain. See Figure 17 of the Appendix to this chapter for an index map of population vulnerability in Haiti's 54 watersheds.

Ironically, watersheds scoring low in vulnerability may be struck by deadly floods as in the severe flooding of Fonds Verettes in May 2004. Fonds Verettes scored low on this index because the GIS-based flood prone map registered no flood plain in this steeply sloped mountain town — and therefore no population living in a flood plain. Hence, the population vulnerability index cannot accurately predict all severe flood events. The index could be refined by overlaying maps of historical flood areas with technically derived flood prone areas. Nevertheless, this index accurately points to the extremely high levels of vulnerability in Haiti's densely populated urban flood plains.[41]

The index value of the Cul-de-Sac plain is more than three times higher than the second ranked Les Cayes, and more than 14 times the average index value of all watersheds. The sheer scale and acute vulnerability of the flood plains of Port-au-Prince makes Haiti's major metropolitan areas a high priority for mitigating the risk of major disaster. Meaningful efforts to mitigate risk on this scale will require a multi-donor strategy and close coordination with NGOs, contractors, and local and national bodies of government.

For secondary cities with less than 30,000 people, a single donor such as USAID could play a significant role. The vulnerability rankings shown in Table 11 (next page) suggest the following priorities: L'Estère, Léogane, Montrouis, Aquin, St. Louis du Sud, Port-de-Paix, Ouanaminthe, and Trou du Nord. Program interventions in these urban areas might well resemble past disaster recovery efforts to rebuild and improve essential infrastructure, incorporate more efficient aspects of urban planning, reinforce the capacity of municipal governments to manage disasters, and rebuild urban areas with closer attention to risk management, including engineering works.

[41] See Figures 20-22 of the Appendix for maps of populous flood prone districts in the Port-au-Prince metropolitan area. See Louis and Laplanche (2006) for other satellite images of densely populated neighborhoods in flood plains of the metropolitan area.

Table 11. Population Vulnerability Index of Watersheds in Haiti (Index scale: 0-100)

RANK	WATERSHED	INDEX	RANK	WATERSHED	INDEX
1	Cul-de-Sac	100	28	Gatinette	3
2	Cours Inférieur (Artibonite)	38	29	Tiburon/Port-Salut	3
3	Les Cayes	30	30	Gde Rivière de Jacmel	2
4	L'Estère	25	31	Guayamouc Aval	2
5	Momance (Léogane)	23	32	Miragoane	2
6	Cap Haïtien	20	33	Saint Marc	2
7	La Quinte (Gonaïves)	18	34	Colombier	2
8	Montrouis	13	35	Marigot	2
9	Aquin/St. Louis du Sud	10	36	Les Irois/Jérémie	2
10	Trois Rivières	9	37	Grande Anse	2
11	Jassa	9	38	Fer à Cheval	1
12	Trou du Nord	9	39	Petit Goave	1
13	Gde Rivière du Nord	9	40	Jean Rabel	1
14	Cours Moyen (Artibonite)	8	41	Bainet	1
15	Port-de-Paix/Port Margot	7	42	Voldrogue/Roseaux	1
16	Bouyaha	6	43	Péligre Sud	1
17	Cabaret	5	44	La Gonave	1
18	Gde Rivière de Nippes	5	45	Moustique	1
19	Cavaillon	5	46	Lociane	0
20	Canot	4	47	Thomonde	0
21	Limbé	4	48	Libon	0
22	Anse Rouge	3	49	Anse à Pitre	0
23	Côtes de Fer	3	50	Belle Anse	0
24	Grand Goave	3	51	Baie de Henne	0
25	Corail/Anse à Veau	3	52	Môle Saint Nicolas	0
26	Marion	3	53	La Tortue	0
27	Rivière Froide (Carrefour)	3	54	Fonds Verrettes	0

NOTE: See Figure 22 of the Appendix for an index map of population vulnerability

Infrastructure Vulnerability Indices

Productive infrastructure is defined in the GIS study for this assessment as the total of roads, markets and irrigation networks. See the map in Figure 14 followed by a ranked list of the combined infrastructure indices for Haiti's watersheds in Table 12. Although roads, markets, and irrigation works are only part of the country's economic infrastructure, these were the only infrastructural GIS data available for the present analysis. For example, national scale layers were not available for mapped public buildings (e.g., schools, administrative, churches, shelters) or electric and water utilities.

The portion of infrastructures falling within the flood prone area of the watershed is the basis of the combined infrastructure vulnerability index. Vulnerability indices are also

shown below for roads (Table 13), markets (Table 14), and irrigation networks (Table 15).

The highest ranked watersheds for combined infrastructural vulnerability fall into a clearly defined group characterized by dense concentrations of population including Les Cayes, Gonaïves, Port-au-Prince (Cul-de-Sac), and the lower Artibonite. In general, the rankings for infrastructural vulnerability in Table 12 closely parallel the population vulnerability index shown in Table 11 above. Therefore, infrastructural improvements would have important economic synergies and would support efforts to mitigate the vulnerability of urban populations.

Figure 14. Major Roads, Markets, and Irrigation Systems of Haiti

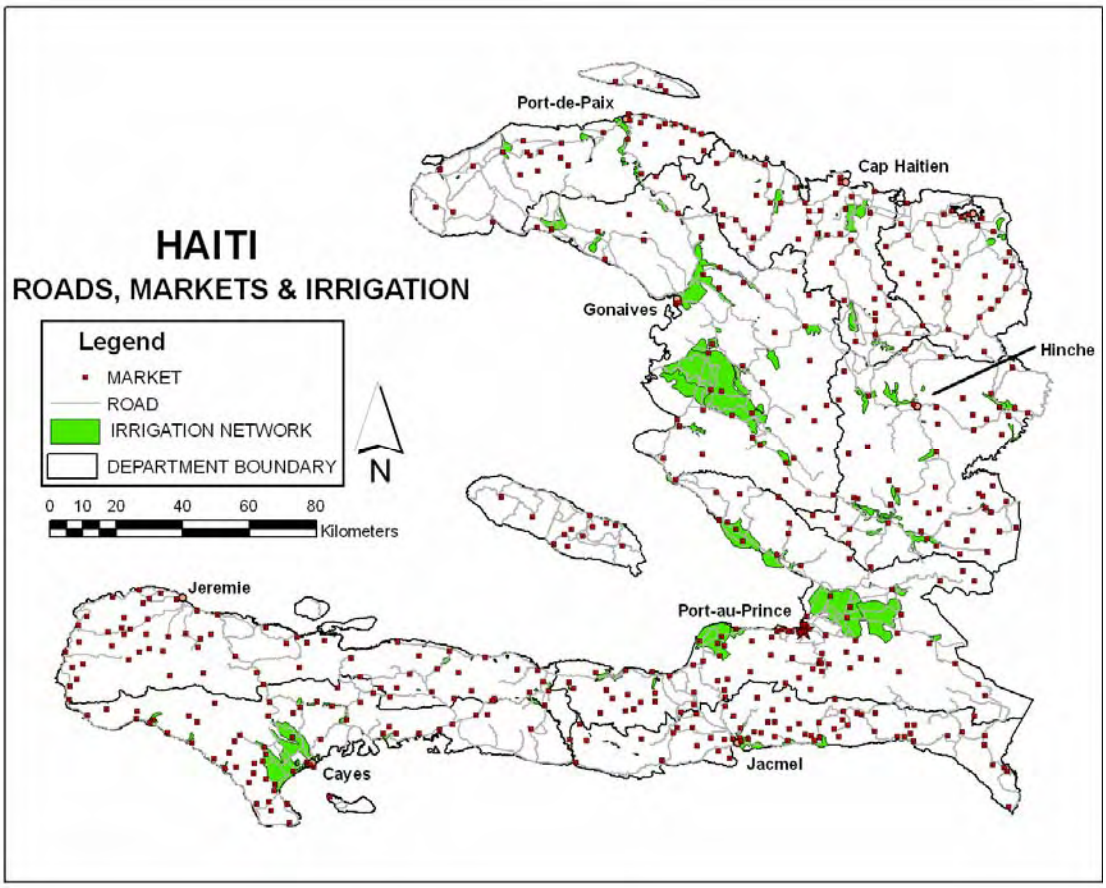


Table 12. Combined Infrastructure Vulnerability Index of Watersheds in Haiti (Roads, Markets, and Irrigation Works) (Index scale: 0-100)

RANK	WATERSHED	INDEX	RANK	WATERSHED	INDEX
1	Les Cayes	100	28	Saint Marc	13
2	La Quinte (Gonaïves)	96	29	Colombier	12
3	Cul-de-Sac	92	30	Cabaret	12
4	Cours Inférieur (Artibonite)	90	31	Voldrogue Roseaux	10
5	L'Estère	78	32	Grand Goave	9
6	Aquin St. Louis du Sud	45	33	Marigot	9
7	Cap Haïtien	41	34	Guayamouc Aval	8
8	Trou du Nord	40	35	Péligre Sud	8
9	Montrouis	38	36	Grande Anse	6
10	Bouyaha	35	37	Jean Rabel	5
11	Gde Rivière du Nord	32	38	Cavaillon	5
12	Momance (Léogane)	31	39	Anse Rouge	5
13	Trois Rivières	31	40	Les Irois/Jérémie	5
14	Cours Moyen (Artibonite)	28	41	Lociane	4
15	Jassa	27	42	La Gonave	4
16	Gde Rivière de Jacmel	27	43	Rivière Froide	3
17	Tiburon/Port-Salut	26	44	Baie de Henne	3
18	Port-de-Paix Port Margot	23	45	Gatinette	2
19	Limbé	22	46	Moustique	2
20	Miragoane	20	47	Thomonde	2
21	Marion	19	48	Anse à Pitre	2
22	Gde Rivière de Nippes	19	49	Belle Anse	1
23	Corail Anse à Veau	18	50	Bainet	1
24	Fer à Cheval	16	51	Môle Saint Nicolas	1
25	Petit Goave	16	52	Libon	0
26	Canot	14	53	La Tortue	0
27	Côtes de Fer	13	54	Fonds Verrettes	0

Road Vulnerability Index. A ranking of road vulnerability by index value is provided in Table 13 below and illustrated in the map shown in Figure 18 of the Appendix. As might be expected, the densest concentration of paved roads is located in the vicinity of urban areas, and many of these are located in large flood plains. The top three watersheds contain major cities: Port-au-Prince, Gonaïves, and Les Cayes. Though the Froide River watershed includes the major city of Carrefour, the narrow flood plain of this coastal zone explains its low index value.[42]

Table 13. Road Vulnerability Index of Watersheds in Haiti (Index Scale: 0-100)

RANK	WATERSHED	INDEX	RANK	WATERSHED	INDEX
1	Cul-de-Sac	100	28	Marion	23
2	La Quinte (Gonaïves)	100	29	Corail/Anse à Veau	16
3	Les Cayes	90	30	Grand Goave	15
4	Aquin/St. Louis du Sud	80	31	Fer à Cheval	15
5	Cours Inférieur (Artibonite)	69	32	Grande Anse	14
6	L'Estère	67	33	Marigot	13
7	Trou du Nord	62	34	Gde Rivière de Jacmel	11
8	Bouyaha	57	35	Guayamouc	11
9	Trois Rivières	55	36	Les Irois/Jérémie	11
10	Montrouis	51	37	Anse Rouge	10
11	Gde Riv. Du Nord	50	38	Cavaillon	9
12	Cap Haïtien	45	39	Jean Rabel	6
13	Miragoane	36	40	Rivière Froide	6
14	Cours Moyen (Artibonite)	31	41	Péligre Sud	4
15	Petit Goave	29	42	Anse à Pitre	4
16	Momance (Léogane)	29	43	Thomonde	3
17	Tiburon - Port-Salut	29	44	Gatinette	2
18	Jassa	27	45	Bainet	2
19	Limbé	27	46	La Gonave	2
20	Côtes de Fer	23	47	Moustique	2
21	Port-de-Paix/Port Margot	23	48	Baie de Henne	2
22	Cabaret	19	49	Belle Anse	1
23	Voldrogue/Roseaux	19	50	Lociane	1
24	Gde Riv. De Nippes	18	51	Môle Saint Nicolas	1
25	Colombier	18	52	Libon	1
26	Saint Marc	17	53	La Tortue	0
27	Canot	17	54	Fonds Verrettes	0

[42] A road vulnerability index map of watersheds in Haiti is shown in Figure 18 of the Appendix to this chapter.

Market Vulnerability Index. The market vulnerability index is based on the weighted value of markets (rural, regional or urban) falling within flood prone areas (see Table 14 below and the map in Figure 19 of the Appendix). The highest indices reflect the importance of urban markets located in coastal flood prone areas. The most vulnerable are those of Cayes, Gonaïves, Jacmel, and Cap-Haïtien. In general, the market vulnerability index is positively correlated with the road vulnerability index. [43]

Table 14. Market Vulnerability Index of Watersheds in Haiti (Index scale: 0-100)

RANK	WATERSHED	INDEX	RANK	WATERSHED	INDEX
1	Les Cayes	100	15	Miragoane	6
2	La Quinte (Gonaïves)	83	16	La Gonave	6
3	Gde Rivière de Jacmel	45	16	Guayamouc	4
4	Cap Haïtien	43	16	Canot	4
5	Cul-de-Sac	34	16	Lociane	4
6	Cours Inférieur (Artibonite)	30	16	Petit Goave	4
7	Port-de-Paix Port Margot	28	16	Trois Rivières	4
8	Trou du Nord	26	16	Côtes de Fer	4
8	Jassa	26	16	Voldrogue/Roseaux	4
8	Tiburon/Port-Salut	26	16	Grand Goave	4
9	Momance (Léogane)	23	16	Baie de Henne	4
9	Gde Rivière de Nippes	23	17	Gatinette	2
9	Corail/Anse à Veau	23	17	Belle Anse	2
9	L'Estère	23	18	Cabaret	0
10	Limbé	21	18	Anse Rouge	0
11	Marion	19	18	Môle Saint Nicolas	0
11	Cours Moyen (Artibonite)	19	18	Thomonde	0
11	Aquin/St. Louis du Sud	19	18	Fonds Verrettes	0
12	Montrouis	17	18	Rivière Froide	0
13	Péligre Sud	13	18	Cavaillon	0
13	Fer à Cheval	13	18	Grande Anse	0
13	Grande Rivière du Nord	13	18	La Tortue	0
13	Bouyaha	13	18	Moustique	0
14	Colombier	9	18	Libon	0
14	Saint Marc	9	18	Anse à Pitre	0
15	Marigot	6	18	Bainet	0

The La Quinte and Jacmel watersheds are extremely challenging due to the unique shape of the watersheds — extensive upland catchments that funnel into a narrow channel to the ocean where the highly vulnerable cities of Gonaïves and Jacmel are located. PADF (2002b) detailed a preliminary study to deviate the Orangers river channel in order to reduce chronic flooding in areas of Jacmel. The most economical option was estimated at $1.8 million.

[43] A market vulnerability index map is provided in Figure 19 of the Appendix to this chapter.

Irrigation Vulnerability Index. The largest irrigation works occur in the alluvial plains of the Artibonite, L'Estère, La Quinte, Cul-de-Sac, Léogane, Arcahaie, and Les Cayes. Smaller networks are widely dispersed throughout the country along major rivers and other water courses. The Figure 14 map shown earlier does not include the many small irrigation works in current use. The highest index values for irrigation vulnerability in Table 15 are the large irrigation works along the lower Artibonite River, including Cours Inférieur and L'Estère.[44]

Table 15. Irrigation Vulnerability Index of Watersheds in Haiti (Index scale: 0-100)

RANK	WATERSHED	INDEX	RANK	WATERSHED	INDEX
1	Cours Inférieur (Artibonite)	100	28	Grand Goave	2
2	L'Estère	81	29	Côtes de Fer	1
3	Cul-de-Sac	71	30	Marion	1
4	Les Cayes	32	31	Rivière Froide	1
5	La Quinte (Gonaïves)	30	32	Bassin du Limbé	1
6	Momance (Léogane)	16	33	Corail/Anse à Veau	1
7	Montrouis	16	34	Miragoane	1
8	Cours Moyen (Artibonite)	13	35	Colombier	1
9	Canot	10	36	Péligre Sud	1
10	Fer à Cheval	9	37	Thomonde	1
11	Trois Rivières	9	38	Port-de-Paix Port Margot	1
12	Cabaret	8	39	Aquin St. Louis du Sud	1
13	Bouyaha	8	40	Môle Saint Nicolas	1
14	Gde Riv. Du Nord	7	41	Baie de Henne	0
15	Jassa	7	42	Bainet	0
16	Lociane	4	43	Gde Rivière de Nippes	0
17	Cap Haïtien	4	44	Fonds Verrettes	0
18	Saint Marc	3	44	Grande Anse	0
19	Guayamouc	3	44	Trou du Nord	0
20	Gde Rivière de Jacmel	3	44	Belle Anse	0
21	Cavaillon	3	44	Gatinette	0
22	Petit Goave	3	44	La Gonave	0
23	Tiburon/Port-Salut	2	44	La Tortue	0
24	Marigot	2	44	Voldrogue/Roseaux	0
25	Anse Rouge	2	44	Libon	0
26	Moustique	2	44	Anse à Pitre	0
27	Jean Rabel	2	44	Les Irois/Jérémie	0

[44] See Figure 20 of the Appendix for an irrigation index map of Haiti's watersheds.

Overlapping Risks and Watershed Priorities

There are several groups of watersheds that consistently score high in two or more indices. The overlap of risk factors tends to heighten their status as priority watersheds since they address multiple mandates, as shown in Table 16.

Table 16. High Soil Potential Linked with High Vulnerability for Population, Roads, Markets, and Irrigation Works, According to Median Values for Watershed Indices

RANK	WATERSHED	INDEX MEDIAN	RANK	WATERSHED	INDEX MEDIAN
1	Cul-de-Sac	71	19	Marigot	6
2	Les Cayes	60	19	Miragoane	6
3	Cap-Haïtien	43	20	Cavaillon	5
4	Cours Inférieur (Artibonite)	42	21	Côtes de Fer	4
5	La Quinte (Gonaïves)	41	21	Grand Goave	4
6	L'Estère	29	21	Guayamouc Aval	4
7	Jassa	26	21	Jean Rabel	4
7	Trou du Nord	26	21	Lociane	4
8	Momance (Léogane)	23	21	Peligre Sud	4
9	Limbé	21	21	Petit Goave	4
9	Tiburon/Port-Salut	21	22	Anse à Pitre	3
10	Aquin/St. Louis du Sud	19	22	Rivière Froide	3
10	Cours Moyen (Artibonite)	19	23	Anse Rouge	2
10	Marion	19	23	Baie de Henne	2
11	Gde. Rivière de Nippes	18	23	Gatinette	2
12	Montrouis	17	23	Grand' Anse	2
13	Corail/Anse à Veau	16	23	La Gonave	2
14	Bouyaha	13	23	Les Irois/Jérémie	2
14	Fer à Cheval	13	23	Moustique	2
14	Gde. Rivière du Nord	13	24	Bainet	1
15	Port-de-Paix/Port Margot	12	24	Belle Anse	1
16	Canot	10	24	Môle St. Nicolas	1
16	Gde. Rivière de Jacmel	10	24	Thomonde	1
17	Colombier	9	24	Voldrogue/Roseaux	1
17	Saint Marc	9	25	Fonds Verrettes	0
17	Trois Rivières	9	25	La Tortue	0
18	Cabaret	8	25	Libon	0

- Group 1: The Cul-de-Sac (Port-Au-Prince) is by far the most vulnerable of all of Haiti's watersheds in terms of the threat of loss of human life and livelihood due to flooding (see Table 11 population vulnerability index). This is due primarily to the large number of people living in densely settled urban slum districts.

  As noted in the Table 11 population vulnerability index, the index value of the Cul-de-Sac plain is more than three times higher than the second ranked Les Cayes, and more than 14 times the average index value of all watersheds. The sheer scale and

acute vulnerability of the flood plains of Port-au-Prince makes Haiti's major metropolitan areas a high priority for mitigating the risk of major disaster.

- Group 2: High population and infrastructural vulnerability combined with high soil potential. Another group is composed of watersheds that consistently rank high in vulnerability indices as well as the soil potential index. The top watersheds in this group correlate those most vulnerable in terms of population-and-infrastructure with those that offer heightened economic opportunity due to the availability of arable land, as indicated by the ranking in Table 16. The corresponding index map associated with these rankings is shown in Figure 15 below. Again, the analysis points to watersheds containing Haiti's largest cities as well the densely populated lower Artibonite and neighboring L'Estère.

- Group 3: High erosion risk combined with protected areas. This group of watersheds was noted earlier in relation to the *erosion risk index* (see Table 9). These watersheds respond directly to priorities for reducing erosion vulnerability *and* for protection of high priority National Parks (Pic Macaya and La Visite) and the Pine Forest Reserve (Forêt des Pins). The location of these southern watersheds in the most hurricane-prone region of Haiti heightens the priority for this grouping.

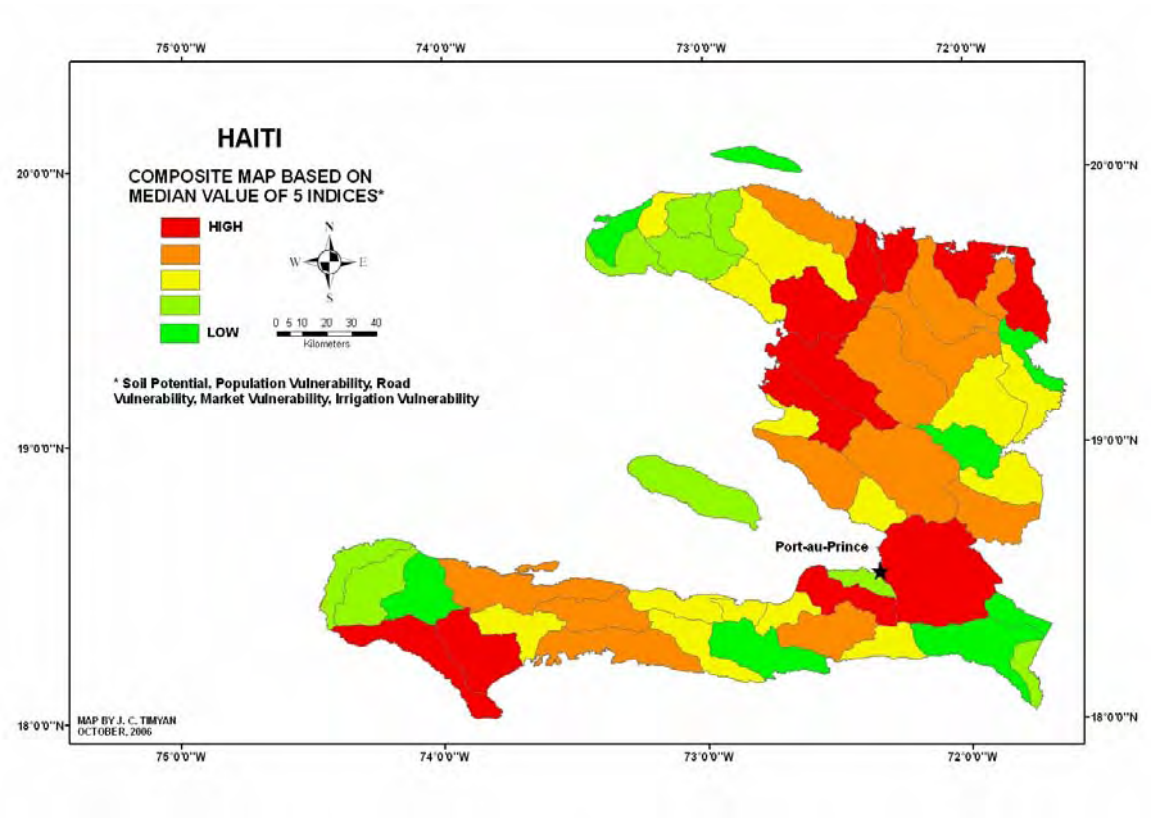
- Group 4: High vulnerability, high potential, and the absence of donors. Within this group, there are several watersheds of interest to the USAID/Haiti Mission that have low potential to duplicate the activities of other donors. Table 17 shows the top 10 watersheds that fall within this group. Most of these are ridge-to-reef watersheds with important regional markets that serve to balance the strong migratory pull of larger urban areas. The economic opportunities associated with these emerging towns have the potential to create a significant impact on local livelihoods. For this grouping, the top five watersheds in order of their index medians are Trou du Nord, Momance (Léogane), Limbé, Tiburon/Port-Salut, and Aquin/St. Louis du Sud.

Table 17. Watersheds of Potential Interest to USAID/Haiti Mission, Based on Index Medians in Table 16

Rank	Watershed	Index Median	Rank	Watershed	Index Median
1 (7)	Trou du Nord	26	4 (10)	Marion	19
2 (8)	Momance	23	5 (11)	Gde. Rivière de Nippes	18
3 (9)	Limbé	21	6 (12)	Montrouis	17
3 (9)	Tiburon/Port-Salut	21	7 (14)	Bouyaha	13
4 (10)	Aquin/St. Louis du Sud	19	7 (14)	Fer à Cheval	13

Note: Ranks in parentheses compared to 54 watersheds

Figure 15. Watershed Index Map Linking High Soil Potential with High Vulnerability for Population, Road, Markets, and Irrigation Works



GOVERNANCE AND DISASTER MITIGATION

Responsible governance is critical to reducing the vulnerability of local populations and the economy to the high risks of flooding. Governance refers here to those responsible for implementing policies and programs affecting vulnerable watersheds, including regional planning and decentralized levels of government. This also includes both governmental as well as non governmental actions, formal and informal arrangements, and local as well as regional and national actions. The following sections address governance issues and specific questions raised in the scope of work for the vulnerability assessment team.

Disaster Preparedness

Early warning systems (EWS) allow individuals and communities to react in time to reduce the risk of loss of human lives, wounds, and damage to belongings and fragile areas. There has been a wide range of disaster preparedness programs in Haiti initiated as early as the mid 1990s (OAS, 1999; PADF, 2002a; Oxfam, 2004a; PAM, 2006). Some programs appear to be fairly advanced in selected areas of the country and include such activities as community emergency response teams (CERTs), rehabilitation of infrastructure, purchase of emergency equipment, network of emergency shelters, community-based evacuation plans, and self-governing disaster preparedness committees. Since most targeted areas were selected in response to a specific disaster, the coverage of disaster preparedness is uneven and has focused for the most part on downstream communities.

Early warning systems are being installed by both the NGO community and the government. Examples include the USAID-funded EWS in the La Quinte watershed and the UNDP-funded EWS in the Fonds Verrettes watershed. The latter is serving as an initial prototype for the civil protection agency (DPC) to establish local disaster preparedness programs in 15 to 19 watersheds deemed critical. Mitigation has focused primarily on improved storm water drainage, the rehabilitation of major roads, construction and maintenance of gully dams in critical catchment areas, improvement of irrigation works, and protective barriers to guard residential areas. Several relief NGOs also promote tree planting and living barriers, though these tend to be given much lower priority compared to the more costly but economically critical improvements of infrastructure.

Investments in Early Warning Systems

Do such investments in EWS and disaster preparedness generate tangible environmental benefits? According to the information reviewed by this team, tangible environmental benefits of EWS are limited due to the way they are presently applied in Haiti. To obtain such benefits, early warning mechanisms must be firmly integrated into an inclusive environmental framework that encompasses whole watersheds. This has never been done. Potential environmental damage could be reduced by reinforcing infrastructure (modernizing buildings and construction codes), planting vegetation to stabilize the soil or prevent mass movements (landslides, falls), and creating shelter areas. Most of these measures require significant long-term investment. Early warning mechanisms should be integrated into a framework of measures to improve environmental management and stem erosion including protection or restoration of ecosystems such as mangroves and riparian habitat, increased perennial ground cover, and increased natural vegetation in water channels and flood plains. Such mechanisms would contribute to more sustainable use of natural resources, reduce waste production, and restore the balance between communities and their environment.

Municipal Land Use Planning

Protect natural buffers. *Early warning mechanisms should reinforce the natural systems which have evolved in response to specific environmental threats and have the potential to absorb them.* Early warning systems in the absence of serious efforts to protect natural buffers are a case of *lave men siye a tè* ("washing one's hands then wiping them in the dirt"). Riparian vegetation stabilizes river banks, slows runoff, and prevents floods. The seashore and mangroves absorb the energy of waves and protect Haiti's coastal areas. Environmental threats have worsened in Haiti because the buffering functions of natural defenses have been destroyed. These natural defenses are a high priority for protection and restoration.

Could municipal land use planning reduce impact of disasters and lead to reforestation or improved environmental conditions? As noted earlier, rapid urbanization is the dominant trend in the current growth and geographical re-distribution of Haitians. High rural out-migration is having a major impact on Port-au-Prince and other major coastal cities including Gonaïves, St. Marc, Cap-Haïtien, Port-de-Paix, Les Cayes, and Jacmel.

This urbanization is almost entirely unplanned, characterized largely by "concrete slums" that cause major problems of water runoff and infiltration. Government response is limited primarily to inefficient “central planning” rather than decentralized planning and provision of local public services.

The poor of urban areas are disproportionately exposed to the negative impacts of urbanization including disastrous flooding. Burgeoning growth directly expands the growth of urban poverty and poor neighborhoods such as Dézermite, Flippeau, Morne Lazare, the southern slope of Juvenat in Petion-Ville, and Carrefour-Feuille, Martissant, 5th Avenue Bolosse, Portail Léogane, Cité de Dieu, La Saline, and Cité Soleil in Port-au-Prince.

Urban ecological footprint. Urban areas leave a large ecological footprint and have an important impact on the local environment. The environmental impact of Haiti’s cities includes the following:

- Loss of arable lands due to urban sprawl (Cul-de-Sac Plain, Gonaïves Plain, Léogane Plain);
- Drainage of wetlands (Bois Neuf wetland near the town of Saint Marc);
- Extraction of stones, sand, gravel and building materials in great quantities resulting in landslides, loss of human life, and increased threats to infrastructure (Boutillier, Carriès near Montrouis).
- Destruction of wooded areas for fuelwood, and increased demand for charcoal in urban areas;
- Pollution of lakes, rivers and coastal water by untreated effluents (Port-au-Prince, St. Marc, Cap-Haïtien);
- Destruction of sensitive ecosystems and modification of the erosion buffering function of the coasts, including mangroves, coral reefs, and beaches (mangroves of Cap-Haïtien/Rivière Salé and Mariani; the reefs of Montrouis).

The focus of urban planning in Haiti has been to improve basic services: sanitation and waste removal, storm water drainage, traffic congestion, and potable water. Innovative approaches include the EU-financed program to manage potable water as a commodity through a single billing arrangement with CAMEP (public water utility). Using this approach, water distribution in a limited number of urban neighborhoods is managed by local water committees, including recovery of recurrent costs through neighborhood level collection of water fees and investment of surpluses to meet other infrastructural needs such as roads and storm water drainage (Snell, 1998).

In many situations, water systems damaged by flooding have created new opportunity to redesign water and drainage systems, clean-up of drainage systems, and remove solid

wastes (Oxfam, 2004b). Current initiatives also include IDB funding for urban programs in departmental capitals and some portions of Port-au-Prince.[45] The primary goals are to alleviate traffic congestion, create public parks, improve potable water access and restore trash collection near urban markets. These are important initiatives; however, *meeting chronic shortfalls in urban services does not necessarily reduce the vulnerability of urban areas to disaster*.

Municipalities generally do not enforce building codes or zoning issues such as setbacks and site permits and there is weak oversight of pollution and waste disposal.[46] USAID should assist municipal governments in formulating policies and practical implementation strategies. The creation of urban zone flood maps for highly vulnerable urban neighborhoods would create an excellent opportunity for an integrated disaster reduction strategy, e.g., Oxfam in Cap-Haïtien (Oxfam, 2004a).

It is urgent to develop urban action plans and to integrate them with watershed plans and programs. Urban planning should be a high priority for managing watersheds and for addressing the heightened vulnerability of human populations and productive infrastructure. This should include reliable local data collection, mapping of flood plains and habitat vulnerability, and risk analysis of specific urban neighborhoods. Disaster mitigation measures should include green buffer zones, preparing urban architecture to handle floods, targeting sites for urban expansion, designing and building protective engineering works (drainage, water courses), and identifying places of refuge in case of disaster.

Local level management. A key to successful urban planning is the creation of decentralized, self-managed governing committees. Financial management and governance at the local level takes time to develop and may require the intermediary role of an NGO to provide local community organization services ("animation"), coordinate specialized technical services (e.g., engineering) , and mediate local sociopolitical dynamics.

Capacity Building among Parks Managers

Can capacity building among parks managers lead to stronger enforcement of protected areas and remaining forest fragments? Haiti's forest heritage is by far the most degraded in the Caribbean region. Most of Haiti's existing forest heritage is located in the country's three main protected areas (Macaya National Park, La Visite National Park, and the Pine Forest Reserve). Technically, six percent of the national territory is under protection; however, Parc Pic Macaya, Parc La Visite, and the Pine Forest Reserve cover less than one percent of the territory, compared to 17 percent in the Dominican Republic, six percent in Cuba, and three percent in Jamaica (IUCN, 1991). Furthermore, Haiti's legally protected areas such as Parc La Visite are under severe stress by resident and transient farmers, grazing pressures that pollute the headwaters of major watercourses,

[45] Services are outsourced to firms under contract to a technical executing unit of the Office of the Prime Minister (Inter-American Development Bank Supports Urban Renewal in Haiti – US Department of State).

[46] See www.disaster-info.net/carib/buildingcodescomparison.htm.

illicit logging and limestone kilns, and anarchic fatwood harvest in old stands of *Pinus occidentalis*.

In Haiti, interventions supporting sustainable forest management date back to 1926, when the Saint Raphaël Forest Reserve was created in the northern part of the country. It was only in the beginning of the 1980's that the first concrete attempts at *in situ* forest and biodiversity conservation were implemented in areas of the Pine Forest Reserve and La Visite and Macaya National Parks. There is also a provision in Haitian law for the creation of a national system of protected areas, but this has not been implemented.

Given current conditions, what can be achieved by enforcing the capacities of park managers to strengthen forests and protected areas? Capacity building of park managers can only be beneficial in terms of forest conservation; however, such training is not the heart of the problem. The more fundamental problem is one of political will and institutional development. At the systemic level, capacity building requires the creation of an enabling environment, a coherent national policy and regulatory framework, institutional mandates, close collaboration with stakeholders including local populations in "protected" areas, and mobilization of science to support decision-making.

Co-Management Activities

How should co-management activities of forests be implemented to reinforce local investment in natural resources? Co-management is understood here to mean a combined effort of government and interested stakeholders to share responsibility and authority for the management of resources (McConney *et al*., 2003). Smucker *et al.* (2005) suggested that co-management options be explored for landscape features that provide essential ecosystem services while generating revenues. Natural resources that lend themselves to co-management options in Haiti include fisheries, pine forests and other woodlands on state land, ravines and watercourses, mangroves, coastal salt evaporation ponds, agricultural activities in riparian flood plains and shifting sands, protected area peripheries, headwaters of springs, and water rights.

Co-management is *theoretically* possible, but would challenge government capacity since there is little precedent for this in Haiti. Nevertheless, co-management is an option that USAID should support as an alternative to the anarchic exploitation of valuable natural resources in a tragedy of the commons.

Constraints. Factors inhibiting the approach should be addressed through stakeholder analysis and participatory planning and implementation. Constraints include program discontinuity due to a "project" orientation and limited funding cycles, a lack of political will, conflicting interests among resource users and also between resource users and government authorities on public lands, problems of corruption and the absence of government authority over public commons, ambiguous property rights, opportunity costs for changes in land use practices, and benefit:cost ratios that provide only limited incentive for change.

Opportunities. Co-management strategies should target sites with high value assets and stakeholders with well defined vested interests. Obvious candidates would be stakeholders in or near the Pine Forest Reserve and La Visite and Pic Macaya protected areas, producer groups in high value coffee, cacao, mango and vegetable growing areas, sites with opportunity for tourism, and fishers, salt harvesters, pole harvesters and other stakeholders (local governments, flood control) with a vested interest in mangrove habitat. Site selection criteria for co-management schemes should include political and economic factors such as park boundaries and transportation nodes. Co-management should be supported by long-term financial investment and technical assistance.

Co-management options should be tested with the GOH and local levels of government, leveraging entrepreneurial interests to capitalize on opportunities presented by various natural resources and forest ecosystems. Zoning and definition of use rights are among the most difficult issues to resolve. Efforts to organize the fishers of Luly to conserve Les Arcadins marine resources are a point of reference for initiating coastal co-management strategies in other areas.[47]

There is some precedent for customary arrangements and sanctions governing access to commons among Haitian fishermen, customary ownership of salt evaporation ponds on public land, and customary buying and selling of small leaseholds on public land classified as "private domain of the state." These practices suggest a basis for local governance of commons via organizational initiatives rooted in the vested economic interests of local users; however, without clearly defined rules of local governance and their active acceptance by local users, unsustainable exploitation of Haiti's mangroves, pine forests, and other resources in the public domain will continue unabated.

The Haitian government should legally promote co-management of forests and forge strong alliances with organized elements of civil society and local populations to achieve sustainable forest management. The involvement of stakeholders in the decision-making process is essential to the viability of forest ecosystems in Haiti.

The government should serve as guarantor and partner to facilitate management of protected areas, including establishment of an adequate regulatory and policy framework. It must also train its personnel to implement these measures. The government should make judicious use of co-management while retaining overall authority for protected areas. Finally, natural forest protection should be directly linked to job creation and poverty alleviation. Therefore, government policy should promote value-added benefits of protected areas as a strategy for their protection, including tourism and the conservation of biodiversity as an economic resource.

RECOMMENDATIONS FOR MITIGATING FLOOD RISK AND SOIL EROSION

The first set of recommendations below is based on the assessment team's GIS-based ranking of watershed vulnerability. The second set describes sector-specific interventions that complement recommendations from Chapters II and III. The final set deals with

[47] J. Wiener, oral communication, 2006.

institutional and public policy requirements for a more effective government role in reducing watershed vulnerability.

The recommendations that follow reflect cross cutting themes. First, given the overwhelming challenges, it is imperative to establish priorities and make choices based on reliable data and careful analysis of risk and opportunity. Secondly, to be effective, interventions must be part of an integrated approach, directly linking natural resource management with other pertinent sectors such as early warning, urban planning, reproductive health, and job creation programs. Thirdly, there is little chance of reducing vulnerability unless program targets encompass whole catchment areas and ridge-to-reef planning. Fourth, to be sustainable, watershed interventions must be rooted in participatory approaches with local levels of government, grassroots organizations, and resource user groups. Finally, there is virtually no chance of diminishing Haiti's vulnerability to severe flooding without mitigation efforts that target densely populated urban neighborhoods in flood plains.

High Priority Watersheds

This section summarizes recommendations drawn from GIS-based ranking of the relative vulnerability of Haiti's 54 major watersheds and sub-watersheds according to soil potential, the risk of soil erosion, flood prone populations, and infrastructure. The index tables facilitate grouping of priority watersheds according to various parameters, depending on the guiding criteria for a donor's watershed intervention strategy.

The first two groups prioritize high risks for loss of human life and infrastructures, especially in urban coastal areas. The third group prioritizes erosion risk and protection of natural areas, and the fourth group privileges the manageable scale of vulnerable but underserved watersheds. The underlying assumption behind all of these groupings is the development of economically based ridge-to-reef strategies that directly link urban with rural interventions, and disaster mitigation linked to the protection of valuable natural resources and access to reproductive health services.

Group 1. The Cul-de-Sac (Port-Au-Prince). A task force is urgently required to create flood maps of high risk zones of the Port-au-Prince metropolitan area. A programmatic response should be firmly rooted in partnerships with neighborhood groups incorporating disaster preparedness with other essential services including potable water and waste management. The sheer scale of programmatic response needed to alleviate flood risk in the Cul-de-Sac will undoubtedly require a multi-donor strategy rather than reliance on a single donor.

Group 2. Secondary cities (Les Cayes, Trou du Nord and Jassa, La Quinte-Gonaïves, and Cap-Haïtien). These are high risk areas that also have high production potential. Therefore, program interventions in secondary cities and their rural uplands should emphasize economic development along with natural resource protection and disaster preparedness. Risk management should be incorporated into the design of local infrastructures. Program interventions should be partnered with municipal governments as well as grassroots organizations including actions that target flood zones, building

codes, waste management, and disaster preparedness. The Inter-American Development Bank and USAID job creation programs are already active in Les Cayes, Gonaïves, and Cap-Haïtien.

Group 3: High mountains and protected areas (Grand'Anse, Rivière Jacmel, and Fonds Verrettes). The highland forests of these watersheds exercise a critical hydrological function as headwaters of more than a dozen rivers and they have global significance for biodiversity. This group links very high erosion risk with Haiti's most significant protected areas, Macaya and La Visite National Parks and the Pine Forest Reserve. Watersheds in this group lend themselves to the development of a national heritage strategy together with the Haitian government and international NGOs, including co-management with local user groups, the promotion of ecotourism, expansion of perennial polycultures on slopes, and protection of economically important native species.

Group 4. Mangeable size, donor absence and vulnerability (Trou du Nord, Momance-Léogane, Limbé, Tiburon/Port-Salut, Aquin/St. Louis du Sud). These watersheds lend themselves to ridge-to-reef management plans encompassing both urban and rural sectors, off-farm employment, enhanced income-generating capacity of local producer groups, risk management design of productive infrastructures, and interventions that reduce economic risk and vulnerability to flooding.

Sector-Based Watershed Interventions

GIS-BASED MANAGEMENT

GIS-based, national flood map. It is urgent to identify the most vulnerable coastal communities and create urban flood maps at a finer scale (1:1000) for high risk neighborhoods, based on current studies by GOH and NGOs.

- This should include production of maps that reflect the spatial distribution of risk and the magnitude and frequency of events likely to occur; locations of emergency shelters and operation centers.
- Task forces should be organized in the most vulnerable urban neighborhoods subject to severe flooding, using flood maps as an essential tool for planning and organization

Rapid assessment tool. Applications of the GIS-based rapid assessment tool designed for the present study include its use as a reference database for USAID efforts in the area of disaster preparedness and risk management, natural resource management, and infrastructural investments.

Monitoring and evaluation. Key economic indicators should be tracked using GIS-based approaches. GIS data should be used as a reference for planning, evaluation and monitoring to reduce watershed vulnerability, and improved productivity and effectiveness of USAID investments, e.g., charting productivity differences in project zones, regional productivity trends, demographic trends, infrastructural constraints, and product flow barriers.

NATURAL AREAS AND VEGETATION RESOURCES

Co-management and local governance by user groups. User groups should be identified, such as sawyers, producer groups and mangrove fishers, and matched with important natural forest and mangrove areas for local co-management plans. Local co-management groups should be trained in rapid assessment of sustainable harvest regimes, preparation of management plans, accountability, and auditing controls. The goal is to establish self-governing user organizations to avoid resource conflicts and over-harvesting. Financial instruments should be developed to support long-term management of strategic natural resources, guarantee the commitment of local members, and provide economic incentives for compliance with rules of sustainable harvest.

DISASTER MITIGATION

Early warning systems integrated with watershed stabilization and local governance. High risk sites should be identified and targeted. Early warning should be linked with best management of natural buffering systems, particularly the *estuaries of mangroves and coastal wetlands*, and *critical watersheds prone to flooding and landslides*. Management planning should include enforcement of appropriate setbacks from waterlines, and strict zoning of floodplains and mangroves to mitigate human vulnerability and the effects of pollution, salinization, and beach erosion. Program efforts should strengthen linkages between job creation programs and the management of critical mangrove and wetland resources.

Environmental health vulnerability. All water sources including wells, springs, and water towers should be targeted for protection and emergency planning, including post-disaster resiliency. There should be local post-mortem disposal systems for dead animals. Local populations should be educated on post-disaster environmental health behaviors such as household water treatment, sanitation, and hand washing.

Infrastructure. Measures should be taken to mitigate the risk of flooding to important trade routes, including through raised road beds, improved drainage, reinforced bridges, and deeper wharfs and jetties to control sedimentation and steer currents.

URBAN PLANNING

Urban planning is a high priority for watershed management and for addressing the heightened vulnerability of urban populations and productive infrastructure. Flood maps should be used as a tool for organizing around drainage, water supply, waste management, building codes, and zoning. This should include promotion of partnerships between local government and grassroots organizations, building on the proven success of grassroots water distribution committees. Urban planning interventions should be coordinated with current job creation programs.

Risk assessment and zoning. For high risk zones, the feasibility and mechanisms for governing land use should be studied. Assistance should be provided to develop norms for environmental risk assessments, and best construction practices for water systems, hospitals, health posts, landfills, wastewater systems, drainage, etc. Zoning should include optimal land use zones for flood prone areas and wetlands important for storm

water discharge. Urban green spaces should be established incorporating storm-resistant tree species in urban neighborhoods. Public parks and markets should be designed to increase tree densities for both aesthetic and buffering purposes**.** Strategies should be promoted for moving people from flood plains and rebuilding in planned areas, including prospective commercial partnerships with investors and builders.

Waste management. Improved urban storm water drainages should be planned and implemented in order to slow runoff velocities and channel runoff to gray water filtering systems (e.g., settling ponds, soak ways). The feasibility of dry solid waste systems should be reviewed, and such systems should be integrated with improved flood design of houses in flood prone areas.

INSTITUTIONAL AND POLICY RECOMMENDATIONS

Strengthening of the forestry sector, biodiversity, and protected areas. The Haitian government requires donor assistance to develop a Forestry Action Plan including a National System of Protected Areas (SNAP), creation of an autonomous agency for protected areas, and protection of natural ecosystems that reduce vulnerability. Donor assistance should help the Haitian government to define roles and responsibilities for co-management strategies with local populations related to national parks, forest reserves, and other protected areas. This plan should also propose a strategy for delimitation, surveillance, zoning, and control of protected areas.

Decentralized local governance to manage vulnerability at the level of local municipalities and rural communities. Donor assistance should include support for local municipalities, communal sectional councils, and grassroots organizations working to diminish watershed vulnerability to erosion and flooding. Assistance to municipal governments should include support for the creation and enactment of policies including improved building codes and the design of storm drainage systems, zoning of high risk flood zones, and partnerships to maintain urban services including disaster preparedness and risk management.

Inter-ministerial agreement on land use planning designed to reduce vulnerability to flooding. Donor support should include assisting the government of Haiti to develop a consistent policy agenda that reflects the concerns of different ministries, including support for the National Observatory of the Environment and Vulnerability (ONEV).

Watershed management planning and policy at the Ministry of Agriculture. Donor assistance should include support for government initiatives to establish national watershed management guidelines, and identify strategic watersheds to be targeted for long-term interventions geared to diminish vulnerability.

Comprehensive energy policy geared to protect the environment. The Haitian government should adopt innovative financial mechanisms through opportunities offered by the UN Framework and the Convention on Climatic Change. Donor assistance should include technical assistance to support Haitian government efforts to develop coherent

environmental policies such as taxes on fossil fuels, promotion of renewable energy industries, regulation on fuel options, and modernization of the regulatory framework.

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APPENDIX C

GIS ANALYSIS OF WATERSHED VULNERABILITY

By Joel C. Timyan[48]

Introduction. The GIS analysis used in this study is a versatile and standardized tool for watershed assessment with several key advantages, including the following:

1. Decision-making tool based on quantitative data;
2. Rapid appraisal based of GIS data;
3. Defensible rationale to develop strategies and orient USAID development activities in three major sectors:
   - — disaster preparedness and risk management,
   - — natural resource management,
   - — infrastructural investment;
4. Effective framework to organize and integrate spatial data for planning, evaluative and monitoring purposes;
5. Reference database for current and future analytical purposes;
6. Opportunity to contribute to the development and use of geospatial tools in Haiti.

The team used existing data to conduct a GIS analysis of the vulnerability of Haiti's 54 major watersheds and subwatersheds through comparing and ranking different indices designed to measure risk.[49] Index Tables 9-16 in Chapter IV summarize the results of this GIS analysis. The indices used for this comparative analysis include soil erosion risk, potential of soil for agriculture, population vulnerability, road infrastructure vulnerability, market infrastructure vulnerability, irrigation infrastructure vulnerability and total infrastructure vulnerability. The following text briefly describes and defines each index used in the analysis. Table 18 below summarizes the GIS procedure used.

Erosion Risk Index. This index is based on the weighted score of the erosion risk categories from the Erosion Risk map (Figure 10 in text). The erosion risk categories are a function of slope, soil properties, vegetation cover and erosive climate factors. The erosion risk score for each watershed is calculated by summing the weighted risk categories, each category being weighted by multiplying its value (0-5) with its fractional area of the watershed. The watersheds are ranked according to their environmental risk index and summarized in a table.

Soil Potential Index. The index is based on the weighted score of the soil potential categories from the Soil Potential map (Figure 11 in text). The categories are a function of slope, soil parent material, salinity, and drainage factors that determine their agronomic potential. Each category is weighted by multiplying the category value by its

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[48] Assessment team member Joel Timyan designed the methodology for a GIS-based analysis of Haiti's watersheds. The technical analysis was carried out by Scot E. Smith, Daniel Hersey, and Hesham Monsef of the School of Forest Resources and Conservation, University of Florida, Gainesville, FL.

[49] Initially, the team tested this tool against 21 watersheds drawn from the basic list of 15 critical watersheds used by DPC and MARNDR plus other selected watersheds of interest to USAID and other donors. As the GIS study evolved, it became feasible to analyze all of Haiti's 54 major watersheds and subwatersheds.

fractional area of the watershed. The indices of the watersheds are ranked and summarized in a table. See Figure 16 below for a soil potential index map.

Table 18. Summary of GIS Procedures to Determine Watershed Vulnerability Indices

GIS Map Layers	Procedure
Watershed (WS)	Determine boundaries and drainage area for 21 watersheds (see below for list). Create WS1, WS2...WSi
1998 Erosion Risk (ER)	Intersect WSi & ER = WSER. Determine drainage area fraction by category of ER index (0-5). Multiply drainage area fraction by ER index category to weight categories. Sum categories to calculate “watershed erosion risk” score. Normalize scores; ranks WSERs.
1998 Habitat Density (HD), Flood Prone Areas (FPA)	Intersect WSi & FPA = WSFPAi . Intersect WSFPAi & HD = FPAHDi. Weight habitat density by multiplying density and flood plain category (1-3). Determine watershed score by summing weighted values. Normalize values on index scale 0-100. Rank watersheds by population vulnerability index.
Roads (R)	Intersect WSFPAi & R = FPARi. Assign road weights as proxy of “road replacement value” (e.g., 10 = national hgwy, 4 = departmental road; 2 = commune road; 1= other roads). Adjust values by multiplying road weights x distance per weight x flood plain category (1-3). Sum weighted values to determine watershed score. Calculate “road vulnerability index” for each watershed by normalizing values on index scale of 0-100. Rank watersheds by road vulnerability index.
Irrigation Perimeter (IP)	Intersect WSFPAi & IP = FPAIPi. Weight IP areas by IP category (1-4) and multiply by actual area to determine weighted values. Sum IP values per watershed to calculate watershed vulnerability score. Normalize scores; rank watersheds by irrigation vulnerability index.
Markets (M)	Intersect WSFPAi & M = FPAMi. Weight markets by market category (urban, regional, semi-rural) and multiply by flood prone area category. Sum market values to determine watershed vulnerability score. Normalize values on index scale of 0-100. Rank watersheds by market vulnerability index.
Soil Quality (Potentialite SOL = PS)	Intersect WSi & PS = WSPS. Determine drainage area fraction by category of PS index (0-8). Multiply drainage area fraction by PS index category to weight categories. Sum categories to calculate “soil potential” score. Calculate “soil potential index” by normalizing scores on index scale of 0-100. Rank watersheds by soil potential index. NB: The attribute table of the “Potentialite Sol” was revised by Joel Timyan to quantify the categories on scale 0-8.
Infrastructure Vulnerability Index	Average road, market and irrigation perimeter indices to calculate infrastructure vulnerability index. Rank watersheds by infrastructure vulnerability index.
10-m DEM, ESRI Hydro Model	Prepare hydro grid from Cul-de-Sac DEM. Compute weighted grid and flow direction. Generate flow accumulation grid from flow direction. Generate link grid using stream and flow accumulation grids. Generate catchment grid using link and flow direction grids. Generate weighted flow accumulation grid using flow direction and weighted grids. Integrate catchment and weighted flow accumulation grids to produce flood risk zone map. Overlay Grise Rive, road network, urban zones and other layers to graphically display vulnerability of population and infrastructure to flood zone category.
Communal Section Pop. Vulnerability	Map Cul-de-Sac population vulnerability at level communal section, based on weighted values of habitat density x flood prone area union. Assign color ramp to show population vulnerability to flooding.

Population Vulnerability Index. The vulnerability of the population is defined here as the portion of the habitat density map (Figure 12 in text) that intersects the three categories of flood prone areas shown in Figure 13 in the text. It is based on the water surface map created from 1982 aerial photos and features three categories of plains susceptible to either a storm surge, a general rise in water levels, or floods: low elevation plains near the coast, elevated plains, and alluvial plains. The intersection of the habitat density map with the flood prone area map allows estimation of the population exposed to floods and the creation of a *population vulnerability index*. Habitat density is weighted according to its density unit multiplied by the flood plain value. The index values are normalized on a scale of 0-100 to determine a relative index. The watersheds are ranked by their index values and summarized in a table. See Figure 17 below for a population vulnerability index map of Haiti's watersheds.

Infrastructure Vulnerability Index. The productive infrastructure is defined here as the total of roads, markets and irrigation networks (see Figure 14 of text). This is based on data available as GIS layers. The portion of the infrastructure falling within the flood prone area of the watershed is the basis of the *infrastructure vulnerability index.* A separate vulnerability index is determined for roads, markets, and irrigation networks based on the weighted score of roads ($\sum$ road distance x road category x flood area category), markets ($\sum$ market number x market category x flood area category), and irrigated land ($\sum$ irrigation category x flood area category). The index maps corresponding to these indices are shown in Figures 18-20 below.

Median Value Index Map. The watersheds were ranked according to the median values of 5 indices representing the soil potential index and the 4 vulnerability indices: population, roads, markets and irrigation systems. The results are provided in Table 16 of the text, and an index map in Figure 14 of the text.

Digital Elevation Model. The digital elevation model of the Cul-de-Sac watershed was selected to create a flood zone map using the ESRI Hydro model. This watershed comprises the highly vulnerable urban population currently residing in the coastal flood plain of the Grise River. A weighted flow accumulation grid is calculated using hydrological functions based on slope and elevation. The union of this grid with the catchment grid generates a flood risk zone map. Layers are added to graphically show the population and infrastructure vulnerable to different levels of flood risk.

River Grise 3D flood zone map. A 3D map showing the most likely high flood risk zones of the Grise River watershed is provided in Figure 21 below. The ESRI Hydro model clearly shows the vulnerability of areas within metropolitan Port-au-Prince due to the high density of an urban population residing in coastal flood plains. These areas include Croix des Missions, Cité Soleil and the Industrial Park. Figure 23 at the end of this Appendix also shows populous districts in the flood plains of Port-au-Prince.

Communal section vulnerability. Figure 22 shows population vulnerability within the Cul-de-Sac watershed as delimited by communal section. Vulnerability is concentrated

among the most densely populated urban areas of the Grise River flood plain. The population residing in the upper catchment of the Grise River is not considered vulnerable due to the absence of flood prone areas; however, localized landslides and flood events may still occur though the data were not available for this assessment.

Figure 16. Soil Potential Index Map for Watersheds in Haiti

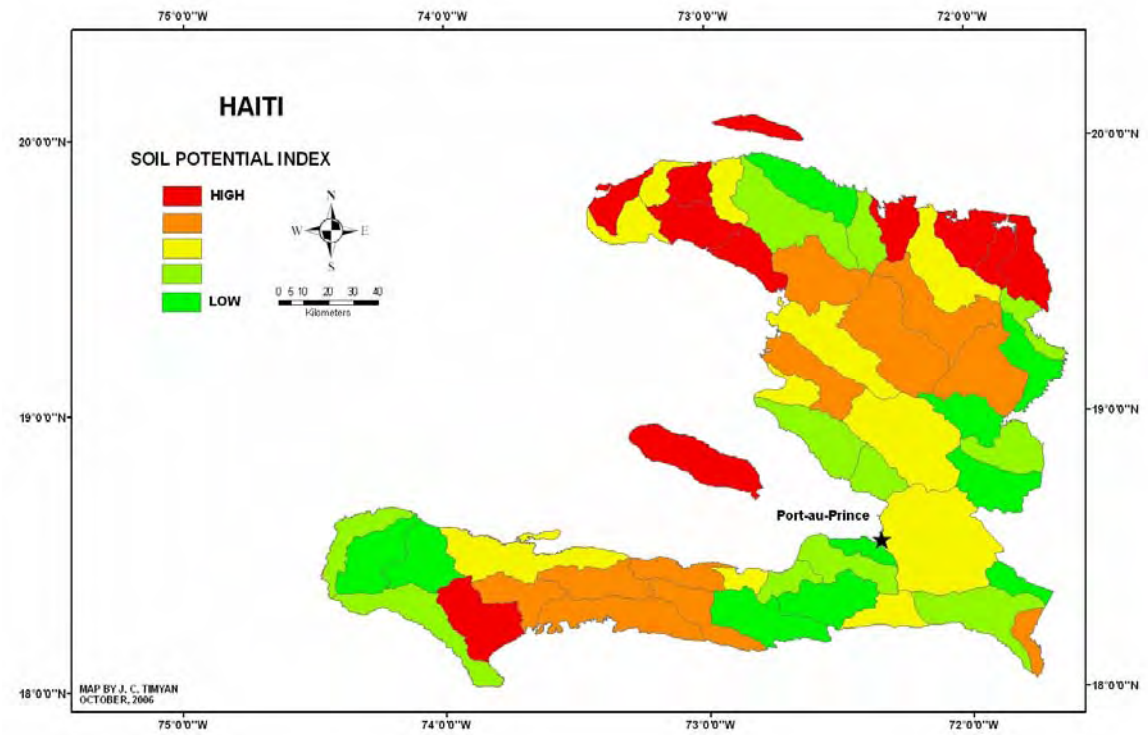


Figure 17. Population Vulnerability Index Map for Watersheds

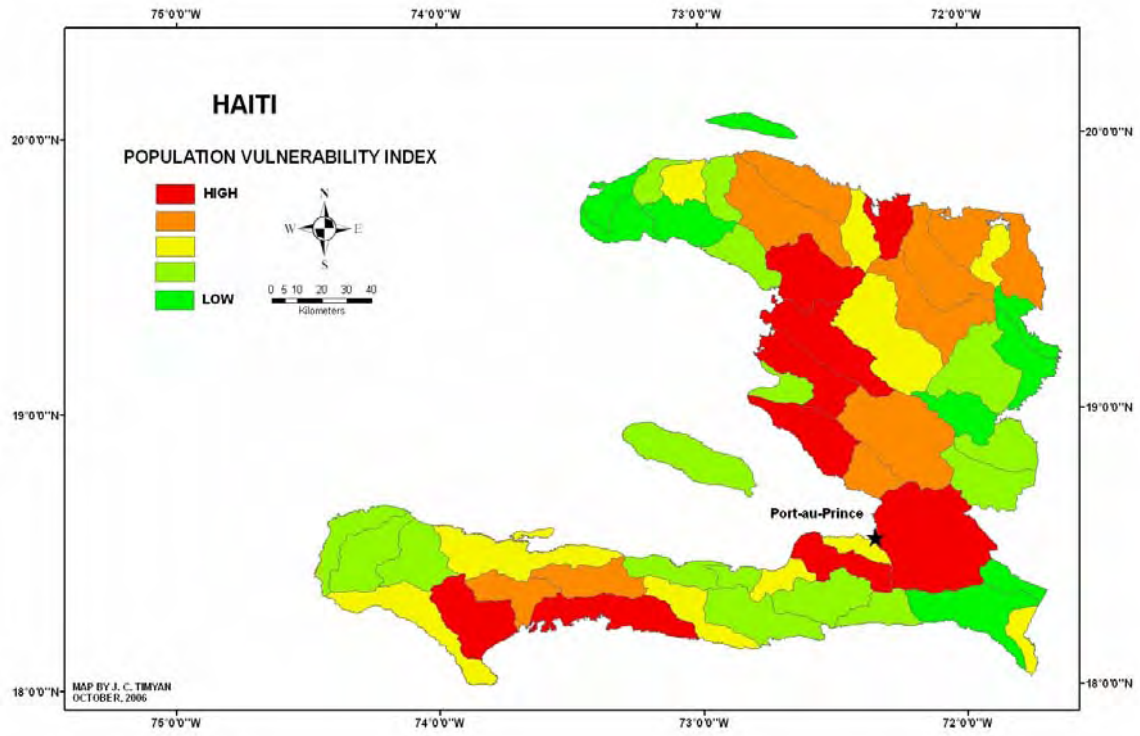


Figure 18. Road Vulnerability Index Map of Watersheds in Haiti

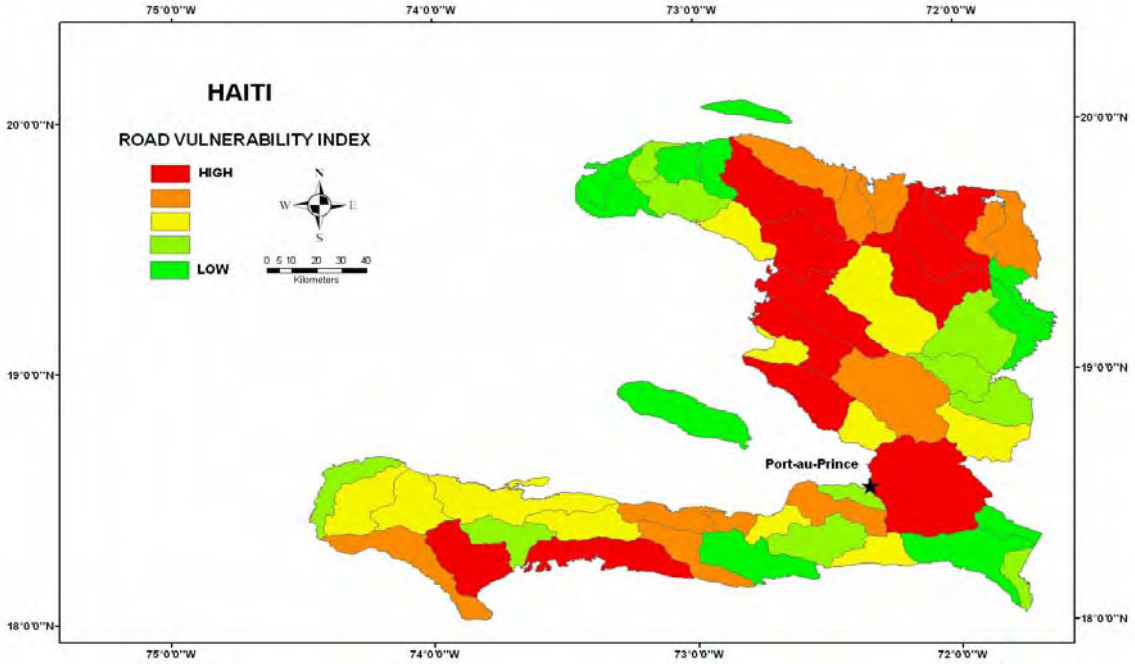


Figure 19. Market Vulnerability Index Map of Watersheds in Haiti

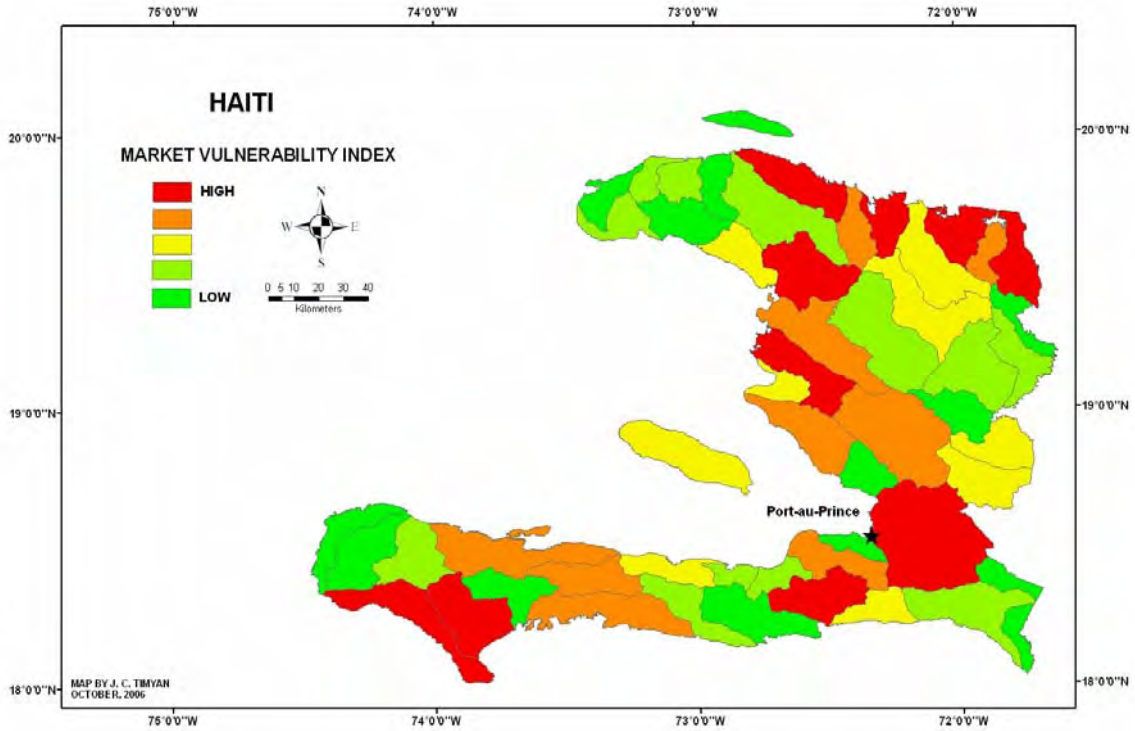


Figure 20. Irrigation Vulnerability Index Map of Watersheds in Haiti

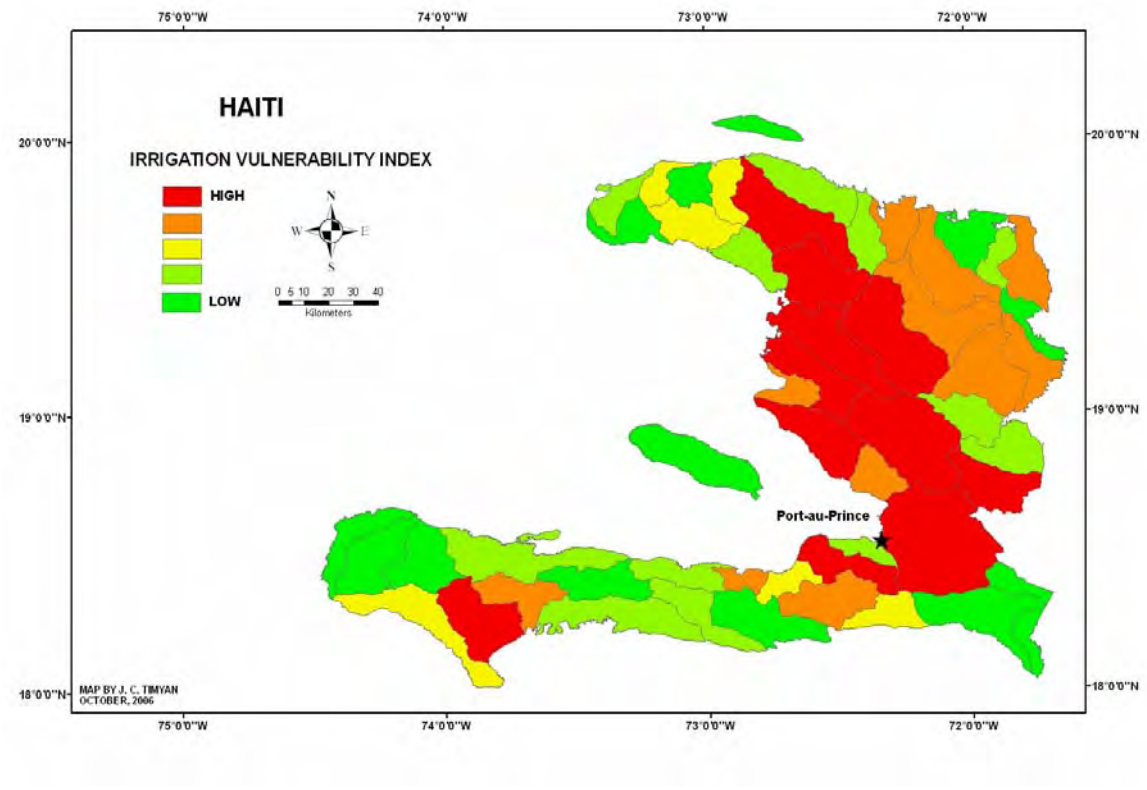


Figure 21. Three dimensional map of flood risk zones in the River Grise catchment area of the Cul-de-Sac watershed, including densely populated areas of Port-au-Prince in the high risk flood zone (noted on map as "urban").

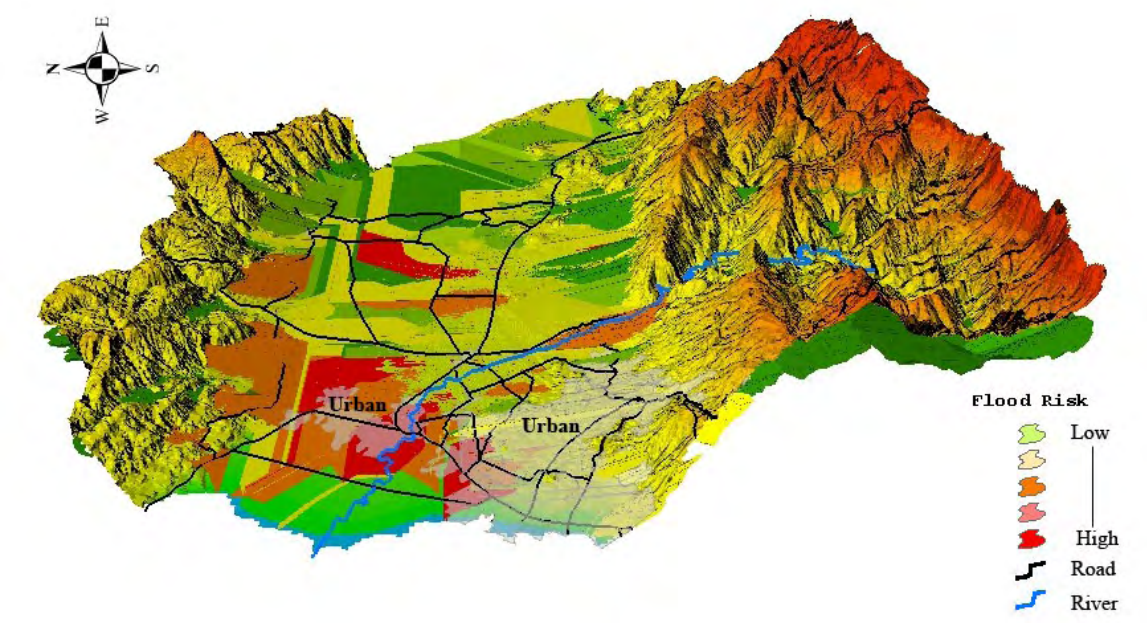


Figure 22. Population Vulnerability Index Map of The Cul-de-Sac Watershed
(showing index values by communal section jurisdictions)

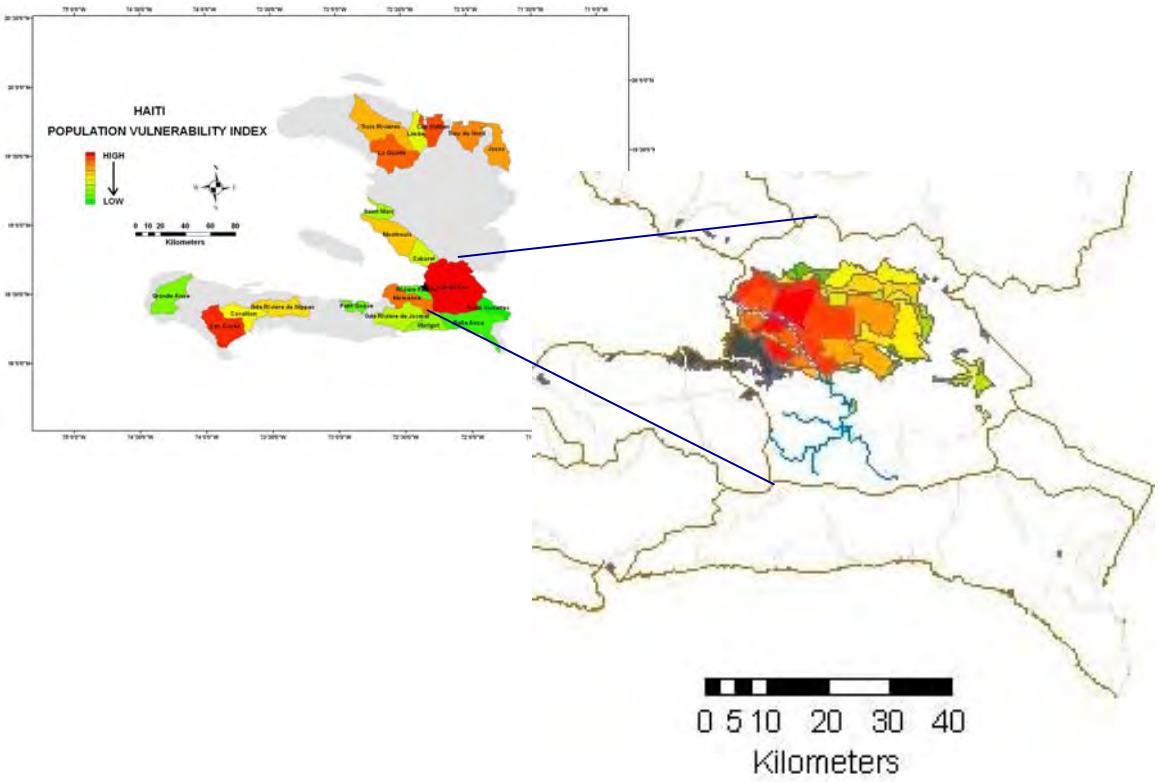
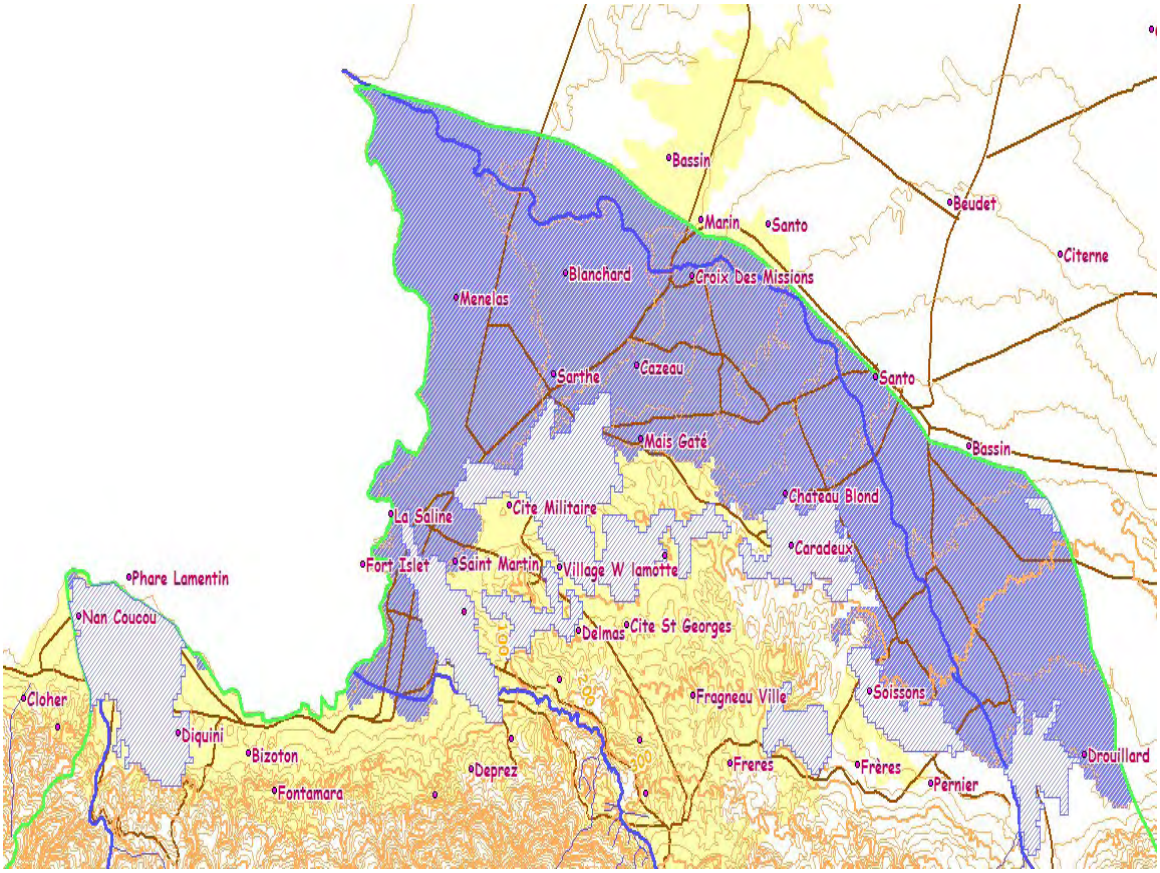


Figure 23. Populous Flood Prone Districts of the Port-au-Prince area (blue)



Source: Louis and LaPlanche (2006).

V. PROSPECTS FOR SOLID AND LIQUID BIOFUELS IN HAITI

By Marc Portnoff [50]

The focus of this chapter is to assess the potential of biofuel crops to promote increased planting of perennials on slopes in place of erosion intensive food crops. As noted in the introduction to this report, the role of both solid and liquid biofuels in Haiti remains controversial. The solid biofuels in question are primarily fuelwood and wood charcoal. Liquid biofuel alternatives include biodiesel, ethanol and pure plant oil.

SOLID BIOFUELS

According to the most recent ESMAP study (2005, 3), Haiti meets 72 percent of its entire energy requirements from local resources, primarily firewood and charcoal (66 percent) along with bagasse (4 percent) and hydro-energy (2 percent). Electricity constitutes on 2.6 percent of the national energy balance. There is growing demand for imported transport fuel; however, there is only one car per 100 hundred persons in Haiti.

The country's primary demand for energy is for household cooking fuel. Rural households rely almost entirely on firewood rather than charcoal for cooking fuel (see Table 1). The wood used for cooking in rural areas is mainly deadwood, small branches from large trees or brush. This does not represent substantial danger to tree cover.

Other users of fuelwood, especially green wood, are bakeries using 156,000-208,000 tons of fuelwood, laundries (23,000-26,000 tons), and distilleries. Charcoal is also produced in rural areas but it is used mainly by urban consumers, and 80 percent of the charcoal is consumed in the Port-au-Prince metropolitan area. Overall demand for charcoal is estimated to be 370,000 to 390,000 tons per year, and it is made primarily from green wood (ESMAP, 17). To the extent that charcoal and fuelwood production are not managed as a renewable resource, the harvest of green wood as a solid fuel constitutes a serious threat to the environment.

Table 19. Consumption of Renewable Primary Energy in Haiti in 2003 (ktep) [a.]

Sources	Urban consumption	Rural consumption	Commerce & Industry	Total consumption	Percent (%)
Fuelwood	17	862	112	991	79
Charcoal	162	-	35	197	16
Bagasse	-	-	66	66	5
Total	179	862	213	1254	100
Percent (%)	14	69	17	100	

Source: BME-ESMAP report, July 2005. [a] Kiloton equivalent to petrol (ktep).

[50] This bulk of this chapter is devoted to liquid biofuels and authored by Marc Portnoff; however, the initial section on solid biofuels (fuelwood, charcoal) was initially drafted by Yves Gossin and extends the discussion of charcoal gardens and case studies in Chapter III, "Interventions in Watersheds."

There is presently no national strategy for sustainable management of charcoal production; however, it is possible to use the persistent growth of the charcoal market as leverage for promoting environmental protection and sustainable development. Annual charcoal sales in Haiti are at least US$ 80,000,000, and the charcoal value chain employs some 150,000 people (IAEA/BME 2004, 4). The product's contribution to the rural economy is quite significant. Charcoal is made in virtually all rural areas of Haiti, and about 20 percent of the selling price remains in the rural economy (ESMAP, 22).

Current charcoal production technologies in Haiti are inefficient. Charcoal yield from rural kilns varies from 15 to 18 percent. In other words, five to six metric tons of wood are required to produce one metric ton of charcoal. Technologies exist that could increase output; however, they would be much more costly than traditional kilns and not nearly as flexible since traditional kilns are constructed on site from soil and vegetation.

There are also inefficiencies in the use of charcoal as cooking fuel. With AID funding, CARE developed more efficient charcoal stoves (*Recho Mirak*) able to save 40 to 50 percent of the energy used for cooking. Some households that used the *Recho Mirak* reported that charcoal consumption dropped from five 35 kg bags of charcoal per month to three bags per month. The improved cooking stoves offered other important advantages including reduction in cooking time, ease of use, and reduced health dangers (see Chapter II on indoor pollution). They were also cleaner than traditional charcoal stoves and could be used inside as well as outside. Factors that reportedly limited wider distribution of the *Recho* Mirak included a poor marketing strategy, dependence on the external market for supply of the raw material to manufacture the stove, and its high price compared to traditional charcoal stoves.[51]

Imported energy sources cost Haiti several times the amount spent on locally produced energy (Table 20). Imported fossil fuels supply no more than a fourth of Haiti's energy but absorb three-fourths of energy costs and 35 to 50 percent of Haiti's hard currency (IAEA 2004, 4). Furthermore, imported propane gas (LPG) remains the most expensive form of cooking fuel in Haiti and charcoal *by the bag* the cheapest.[52] Long term trends in charcoal prices do not reflect exhaustion of wood resources due to the over exploitation of trees in Haiti. There has been a rise in charcoal prices over time; however, it has tended to parallel the growth in prices of other fuels (ESMAP, 4-5).

It is important to promote alternative fuels. Nevertheless, for at least the next 20 years, wood charcoal will almost certainly continue to be the fuel of choice for the vast majority of Haiti's urban population. Clearly, if fuelwood and charcoal could be managed to promote soil conservation, the potential payoff would be highly significant to the Haitian economy as well as its environment. Case studies of tree gardens in Chapter III illustrate the potential for sustainable planting and harvest of trees, and for landscape level changes

[51] The Substitution of Energy for Protection of the Environment project (SEPE) was funded by AID between 2002 and 2004. See CARE, August 2004, *Experiences de CareHaiti dans la conservation et la substitution d'energie*, PowerPoint presentation, Montana Hotel**.** Also, see BME/MDE, 2003, Evaluation des besoins d'Haïti en matière de transfert de technologies énergétiques.
[52] Charcoal retailed by the *marmit* (small local unit of volume), however, is the most costly energy (ESMAP, 11). To the extent that Haiti's poor purchase charcoal in small retail quantities, they end up paying far more for cooking fuel than wealthier households.

in tree cover due primarily to planting and managing trees for charcoal and other wood products.

In future donor investments, the charcoal market should be used as an economic motor including investment in improved efficiency of charcoal production, massive diffusion of improved cook stoves such as the Recho Mirak, and integration of wood energy markets into watershed management.

Table 20. Costs of energy in Haiti in 2003[a].

Sources	National Consumption (MT)	Percent (%)	Price/ton (US$)	Value (US$)	Percent (%)
Fuelwood	401,355	36	100	40,135,500	9
Charcoal	207,000	18	300	62,100,000	14
Gasoline	118,650	10	1,050	124,582,500	27
Kerosene	76,220	7	750	57,165,000	13
Diesel	321,300	29	523.6	168,232,680	37

[a]Source: Bureau of Mines and Energy (BME), 2005.

LIQUID BIOFUELS

The following text provides an overview of clean and alternative energy markets and the Haitian petroleum energy sector. This is followed by analysis of the potential and the barriers to biofuels like ethanol, biodiesel and pure plant oil in Haiti; discussion of energy crop selection and market development; and policy options to promote liquid biofuels. The final section makes recommendations regarding the viability of biofuel and the advisability of promoting this sector in future donor assistance to Haiti.

Clean and Alternative Fuel Markets

In 2005 the price of crude oil increased enough to change the economic paradigm for renewable and clean energy. The US Energy Information Agency (EIA) 2006 forecast for the price of crude oil increased 64 percent over the 2005 forecast because of the tight oil market caused by both political and natural supply disruptions.[53] According to the EIA, this jump in crude oil prices is not an aberration but is expected to remain for the long term because of changes in the global dynamics of supply and demand.

With oil and natural gas prices expected to remain high, the long-awaited crossover point between the costs of clean energy and fossil fuels has arrived. Clean energy, particularly wind power and biofuels, are now often price-competitive with their conventional rivals because of supportive public policy.

The growth of clean energy markets reflects a growing awareness that clean energy technologies are becoming cost-competitive with their fossil fuel counterparts. Global

[53] EIA 2005, New Energy Market Outlook Raises Projected World Oil Price Path and Adds More Coal and Nuclear Power, EIA Reports, December 12, 2005, U.S. Department of Energy, Washington DC 20585

wind and solar markets reached $11.8 billion and $11.2 billion in 2005, up 47 percent and 55 percent, respectively, from a year earlier. The market for biofuels hit $15.7 billion globally in 2005, up more than 15 percent from the previous year. According to Clean Edge research, biofuels (global manufacturing and wholesale pricing of ethanol and biodiesel) will grow from $15.7 billion in 2005 to $52.5 billion by 2015.[54]

The growth for homegrown biofuels is primarily taking place in countries with strong and modern agricultural sectors and whose governments have adopted supportive public policy and tax relief. Around the world, government and the private investment community are putting money into the development of clean energy systems for the future.

Biofuel Background

Ethanol and biodiesel are the dominant liquid biofuels in the global market. Ethanol can be produced from a variety of crops containing appreciable amounts of sugar (e.g., sugar beets, sugar cane) or materials that can be converted into sugar such as starch (corn, barley, wheat) or cellulose (trees, grasses). It can be blended with petroleum gasoline and is most commonly used to increase octane and improve the emissions quality of gasoline. Ethanol blended at a 10 percent level (E10), can be used with current gasoline powered vehicles without the need for adjustments. Engine adjustments are required when ethanol blends at the 85 percent (E85) level are used.

Biodiesel is a renewable diesel fuel substitute derived from plant oil or rendered animal fats. Unlike petroleum diesel, which is composed of hydrocarbons, biodiesel is composed of alkyl esters. Biodiesel is not the same as straight vegetable oil (SVO) or pure plant oil (PPO).[55] Biodiesel can be used straight or as a blend in existing direct injection diesel engines with little or no modifications.

Advantages attributed to bio-ethanol and biodiesel include the following:

- Home grown fuel promoting energy independence
- Promotes rural economic and agricultural development
- Renewable energy source (sustainable)
- Reduces greenhouse gas emissions
- Reduces public health risks associated with air pollution
- Can be used with the existing petroleum infrastructure

Future consideration should also be given to emerging technologies for biofuel production as they come on line. Cellulosic based biofuels are the focus of researchers worldwide.[56] Development of an efficient process would change the paradigm for

[54] Joel Makower, Ron Pernick, Clint Wilder, Clean Energy Trends 2006, March 2006, http://www.cleanedge.com/reports-trends2006.php

[55] Straight vegetable oil (SVO) is a term used primarily in the Americas. It refers to vegetable oils like soybeans. Pure plant oil (PPO) is a similar term used primarily in Europe, Asia, and Africa; however, it is more inclusive, including rape, palm, and *Jatropha* oils.

[56] Enhancing Yeast to Ferment Ethanol from Sugars from Cellulosic Biomass, 8 June 2006

biofuels, providing opportunities for displacing 25 or 30 percent of petroleum based fuels worldwide.[57]

As stated earlier, growth in ethanol and biodiesel markets has been based on supportive public policy. Legislation in the EU, India, Brazil, and the USA has committed to ever increasing levels of liquid biofuels as part of their transportation requirements. Even with the explosive growth in biofuel production, legislative created demand will outpace supplies well into the future.

Each country determines the mix of biofuel use based on the strengths of its agricultural sector. For example, Brazil, the United States and the EU all promote ethanol and biodiesel; however, each favors crops that provide for economies of scale and cost effectiveness. For Brazil it is sugarcane based ethanol; for the EU, rapeseed based biodiesel; and for the United States, corn based ethanol.

Public policy has also been effective in promoting biofuels growth through tax subsidies to producers and agricultural sectors. For example, Brazil is the world's leader in renewable biofuels primarily because successive governments took the brave stand to continue and encourage the use of renewable biofuels. They provided significant funds to subsidize producers, and encouraged their own universities and research centers to take the lead in developing improved seed varieties for local ecosystems. This policy has paid off with the rise in crude oil prices. In 2006 Brazil should become energy independent, allowing their energy dollars to further stimulate local economic growth.

Even with the cost of petroleum at a record high, biodiesel will not be cost competitive until petroleum exceeds $90/bbl. To encourage its use, governments are providing tax incentives. For example, in the United States a tax credit of one cent is provided for every percent of biodiesel blended with petroleum diesel. A 20 percent biodiesel blend provides a $0.20/gal ($0.53/l) tax credit, and straight biodiesel provides a $1/gal ($0.264/l) tax credit. With government tax support, the price advantage moves from petroleum diesel to biodiesel either straight or as a blend.

Biofuels in the Caribbean

Caribbean nations such as Dominican Republic, Jamaica, Puerto Rico, and Martinique have similar opportunities and barriers for biofuels as Haiti. The tropical weather is good for growing crops such as sugar and palm, but these countries lack the capital, infrastructure, and public policy to support the development of a biofuels industries.[58]

In addition to the oil price shock of 2005, the African Caribbean and Pacific (ACP) countries have also had to deal with the loss of EU price supports for sugar.[59] This drastic

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[57] Breaking the Biological Barriers to Cellulosic Ethanol: A Joint Research Agenda, A Research Roadmap Resulting from the Biomass to Biofuels Workshop, December 7-9, 2005, Rockville, Maryland

[58] Will Grow Crops to Produce Biodiesel, Dominican Today, April 12, 2006, http://www.dominicantoday.com/app/article.aspx?id=12381; Deputy: Dominican Republic Must Urgently Pass Alternative Energy Law, Dominican Today, April 24, 2006, http://www.dominicantoday.com/app/article.aspx?id=12381

[59] F.O.Licht's World Ethanol and Biofuels Report, Vol. 3, No. 2/28.09.2004. The majority of ACP countries are former colonies of European countries. During the post-colonial period, sugar exports from former colonies were commonly protected by preferential

change in the sugar market is forcing ACP countries to consider alternative markets or shut down production. In Trinidad, sugar plantations lay fallow, because more money can be made in the petroleum markets. For other ACP countries, this alternative does not exist. In Jamaica, Guyana, and Belize, sugar is a major foreign currency earner and employs thousands of workers. To ensure continued survival of this industry, several initiatives to evaluate the potential of sugar to fuel ethanol production were started in 2004 in these countries, as well as the Dominican Republic.

It will be difficult for the ACP countries to follow the path established by Brazil, but lessons can be learned. Brazil achieved its competitive edge in sugar costs by dropping price supports for food sugar. They also offered technical and financial support for the sugar and ethanol producer industries, encouraging the required economies of scale. Without price supports, sugar costs fell low enough for cost competitive ethanol to be produced. In Brazil, more than 80 percent of the cost of ethanol is related to acquiring the feedstock, i.e., the raw material (such as sugar cane) used to manufacture the biofuel (ethanol).

ACP countries have only been profitable under the preferential price agreements. Their costs of production are from 70 percent to more than 100 percent greater than Brazil. To improve sugar production and reduce costs, the ACP can follow the investment strategy of Brazil in the form of grants, loan guarantees and tax subsidies; however, they need to develop biofuel industries scaled to the strengths and size of their agricultural sector.

While ACP nations may not be competitive with Brazil, the export market is large enough that opportunities exist. The high cost to produce ethanol in the EU has opened up export opportunities for Brazil. If the price is right, this also could be an opportunity for the Caribbean nations.

With regards to energy production, Trinidad is the exception in the ACP because of its vast petroleum natural resources. Trinidad is a net exporter of petroleum and natural gas and is developing refining and chemical processing facilities to add value to its natural resources. One such process is the conversion of natural gas into methanol. Trinidad currently produces more than 6 million mT/year of methanol for export markets.

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trade agreements and price supports between European countries and their former colonies in sugar growing regions. World sugar markets changed drastically with the rise of temperate zone production of alternatives to cane sugar such as beet and corn sugars.

With Trinidad being a major methanol producer in the region, and methanol being an ingredient for biodiesel production, several business opportunities exist. One could either export plant oil to Trinidad or import methanol into a Caribbean nation rich in plant oil. The biodiesel produced could then be used for either local or export markets depending on which provides the best return on investment.

Ethanol in Haiti

Ethanol in Haiti is produced primarily for alcohol (rum) consumption and not as a fuel. It is produced primarily from sugar cane. Current production is insufficient to meet local demand and is thus imported. No Haitian commercial venture was identified that currently produces alcohol for use as an alternative fuel.[60]

Sugar cane crops have been used for erosion control on Haitian slopes (PADF-PLUS project);[61] however, small-scale cane farming is not cost competitive with plantation economies of scale. Another sugar crop well adapted to Haiti is sorghum, commonly grown in drier zones of Haiti where corn is less productive. There are sizeable acreages of sorghum cultivated in the Central Plateau and the Plaine de l'Arbre of the North-West,[62] and the Ministry of Agriculture supports expanded production of sorghum in the droughty North-East.[63] Sorghum is drought tolerant but as an annual crop it contributes to soil erosion and depletion when planted on slopes; however, if Haiti seeks to expand sugar production, sweet sorghums might be considered for flatlands since sweet sorghums accumulate sugar in their stems the way sugarcane does, and sorghums are well adapted to drier zones of Haiti.[64]

The Caribbean Basin Initiative (CBI) may provide an economic advantage for Haiti to establish fuel ethanol production for export to the USA.[65] The USA has an import tax of $0.14/l on imported Brazilian ethanol. This import tax does not apply to Caribbean nations, suggesting a possible business opportunity for reactivating existing Haitian ethanol production facilities (e.g., Terminal Varreux, 25,000 gallons per day capacity).

Haiti Petroleum Energy Sector

According to data from the U.S. Energy Information Agency in 2002, Haiti imports all of its petroleum fuels. Table 21 provides a breakdown of the petroleum products used and the level of consumption in barrels per day (bpd) and gallons per day (gpd). In 2002, Haiti consumed more than 12,000 bpd of petroleum products. Some 35 to 50 percent of Haiti's export-generated foreign currency is spent each year to cover the costs of petroleum imports.[66]

The tax structure for fuels is a significant revenue source for the government because of its control on imports at receiving, blending, and distribution terminals. Table 22

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[60] Haiti Energy Sector Development Plan, 2005 – 2015
[61] Gael Pressoir, Personal communications, June 27, 2006
[62] Gael Pressoir, Personal communications, June 27, 2006
[63] Minister of Agriculture Philippe Mathieu, personal communication, May 2006
[64] Gael Pressoir, Personal communications, June 27, 2006
[65] Jack Goldsmidt, CTI Biofuels, Personnel Communications, June 2006
[66] ESMAP report

tabulates the Haitian diesel price structure in May 2006. These data show that taxes on diesel constitute only 6.4 percent ($0.048/l) of the price paid at the pump. In comparison, 18 percent taxes on diesel in the USA are almost three times as much (e.g. $0.138/l tax on a sale price of $0.766/l),[67] and taxes in Germany are more than ten times at much at 49.7 percent ($0.597/l tax on a sale price of $1.225/l).[68] The relatively low level of fuel taxes and the importance of fuel tax receipts to the Haitian government will influence how fuel tax policy could be used to promote local biofuels markets.

The consumption of diesel fuel is close to 6,000 bpd, and makes up more than 50 percent of Haiti's petroleum consumption. Approximately 50 percent of diesel fuel is used in the transportation sector; the other 50 percent is used for electric power generation. Homes, government installations, small and big business, and industry all use diesel fuel to power backup generators.

The focus of this report does not allow for a discussion of opportunities for clean and renewable energy systems using solar, hydro and wind energy. The Haiti Energy Sector Development Plan, 2005-2015 provides a good summary of the state of clean energy. It is clear that only business models that allow the collection of fees for services rendered, such as the cell phone industry in Haiti, will work in the current Haitian business climate. Creativity in the business model is as important as creativity in the use of advanced technology. For example, if people could get paid for supplying excess energy to the electric power grid from their personal generators, a more reliable power network could develop, furthering economic growth.

Table 21. Haiti 2002 Petroleum Consumption by Product Type

Product Type	Consumption (BPD)	Consumption (GPD)	% of Total
Gasoline	2,410	101,220	20.8
Jet fuel	720	30,240	6.2
Kerosene	1,570	65,940	13.5
Distillate	5,930	249,060	51.1
Residual	310	13,020	2.7
LPG	380	15,960	3.3
Unspecified	290	12,180	2.5
Totals	**11,610**	**487,620**	**100**

Source: http://www.eia.doe.gov/emeu/world/country/cntry_HA.html

[67] http://tonto.eia.doe.gov/oog/info/gdu/gasdiesel.asp
[68] End-User Petroleum Product Prices and Average Crude Oil Import Costs, International Energy Agency, Paris, prices@iea.org, http://www.iea.org/Textbase/stats/surveys/mps.pdf, June 2006.

Table 22. Haiti Diesel Price Structure, May 2006

Price Structure Category	Cost (US$)
Price at terminal	1.9900
Fees	0.2036
Taxes	0.1809
Company margin	0.4008
Transport cost	0.0542
Total	**2.8295**

SOURCE: Ministry of Economy and Finance, published in *Le Novelliste*.

Biofuel Selection

Ethanol is a biofuel for use with gasoline. Biodiesel and pure plant oil based fuels are used as a diesel fuel substitute. In the Haitian context, biofuels like biodiesel and pure plant oil are recommended over ethanol for the following reasons:

- Haiti consumes twice as much diesel as gasoline.
- Diesel is used for both electricity production and transportation
- Ethanol facilities are more expensive, complex and 3 to 10 times larger than those for producing biodiesel. Also, the amount of biomass required to operate ethanol facilities is significantly larger.
- The current price support structure favors sugar production for food rather than feedstock for ethanol production.
- Haitian stakeholders raise concerns about growing food crops for fuel.

BIODIESEL AND PURE PLANT OIL

Biodiesel is not a perfect alternative fuel, but it has gained acceptance world wide as a certified transportation fuel with a large market potential. Pure plant oil (PPO) based fuels are not as popular in the industrialized nations. PPO fuels have primarily been utilized at the village level in Africa and Asia, especially where petroleum transportation costs are high. PPO has been used for generating electricity, powering small mills and irrigation systems, and fueling cooking stoves and lights.

Pure plant oil is pressed from plant seeds, filtered to remove particles, and refined to remove phospholipids, free fatty acids, and other trace contaminants. It is the filtered and refined oil that is used as a feedstock for biodiesel. Biodiesel is produced from a chemical process known as transesterification. While the biodiesel process is a relatively simple industrial process, it still adds another layer of technology and infrastructure requirements. If Haiti had a strong oil-seed crop agricultural sector, these added requirements would not be such a barrier, but without a secure source of plant oil, biodiesel economics are not promising.

Additionally, biodiesel producers will seek to depress the price of plant oil. Biodiesel producers purchase plant oil which may be as much as 85 percent of the final product cost of biodiesel. Furthermore, they expend money to convert the PPO to biodiesel. Without subsidies, biodiesel needs to compete with regular diesel fuel prices. Therefore,

to be cost competitive, they seek to minimize the price they pay for PPO. This in turn reduces the return to local farmers unless they own the biodiesel production facilities. Since the basic purpose here is to propose a model that maximizes return to the farmer, plant oil based fuel is recommended over biodiesel.

ENERGY CROP PLANT SELECTION

There are numerous considerations when selecting a plant whose seed oil will be used for biodiesel production or as a pure plant oil fuel. Most pertain to how well a plant grows, whether it is an annual or perennial, and how it complements the local agricultural ecosystem. Consideration is given to crop yields, oil content and composition, agricultural inputs for crop production and harvesting, and market value for the seed oil and seed cake. Oil and seed cake economics are not obvious to those unfamiliar with agricultural economics. For example, sunflower plants yield more than twice the amount of oil per unit area than do soybean plants, and yet sunflower oil is still more expensive than soybean oil. The primary reason for this is that soybean seed cake is a highly valued animal feed, whereas sunflower seed cake is not.

Seed oil composition is another key factor in plant selection. Seed oils differ in their fatty acid profiles, which vary by the concentration of saturated, mono-saturated, and poly saturated fatty acids. The level of saturation in the seed oil carries over into the methyl esters that make up biodiesel and in turn influence its fuel properties such as oxidative stability, cetane number, and freezing point. Other seed oil properties of importance are density, viscosity, and energy content.[69]

An abundance of information exists on edible vegetable oils like soybean, sunflower, canola (rapeseed), peanut, palm and coconuts. This is true to a lesser extent on non-edible oils like castor, *Jatropha curcas* and *Pongamia pinnata*. A review article lists how 75 plant species were evaluated for use as a feed for making biodiesel.[70] This paper considers plants native to India whose seed oil content is 30wt percent or more, by dry weight, including *Azadirachta indica*, *Simarouba glauca*, *Elaeis guineensis* (African oil palm), *Persea americana* (avocado), *Euphorbia* sp., *Aleurites* sp.

Most of those species either grow in Haiti or represent genera that are present and warrant further investigation such as native species of palm including the critically endangered oil palm, *Attalea crassispatha*, and the common royal palm, *Roystonea borinquena*.[71] Additionally, the native *Simarouba berteroana* and species of the euphorbe family adapted to drought-prone areas of Haiti should be investigated.[72]

For the Haitian context, additional attributes include selecting oil bearing perennials able to grow in depleted soils with limited rainfall and minimal agricultural inputs, which would minimize soil erosion when properly planted on slopes. Table 23 lists the oil yield for the dominant edible oil seeds for biodiesel production, canola (rapeseed) and soybean,

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[69] Biomass Oil Analysis: Research Needs and Recommendations, NREL, June 2004, NREL/TP-510-34796
[70] Azam, M., Waris, A., Prospects and Potential of Fatty Acid Methyl Esters of Some Non-traditional Seed Oils for use as Biodiesel in India, Biomass & Bioenergy 29, 2005
[71] Joel Timyan, Personal communications, June 2006
[72] Joel Timyan, Personal communications, June 2006

along with plants native to Haiti. Most of these plants are food based crops. High yield plants like oil palm, avocado or coconuts do well on favorable sites in Haiti but are not well suited to drought prone areas or degraded soils.[73]

The castor oil plant (*Ricinus communis*) has received much attention in Brazil, the Dominican Republic, and throughout the Caribbean as a feed for making biodiesel. Castor oil is unique in composition among all fats and oils, and has a unique combination of physical properties. These physical properties in turn provide for technical challenges in producing biodiesel and hinder its use in high concentrations. Also, a market for castor oil already exists as a highly valued industrial lubricant, putting additional pricing pressures on its use as a fuel.

JATROPHA CURCAS

Of the native high oil yield species, the *Jatropha curcas* will grow where other plants will not and is well adapted to agro-systems in droughty agricultural zones.[74] The jatropha plant is indigenous in Haiti and produces a toxic, non-edible oil that has traditionally been used for medicinal purposes.

Since the early 1980s, the jatropha has been studied in several agricultural settings ranging from hedgerows, living fence, and small and large plantation settings.[75] The oil is obtained by processing seeds in pressing or expelling operations. The oil has been evaluated and its properties are promising for use as a diesel substitute biofuel.[76] Jatropha pure plant oil can be used in its pure form without transesterification or it can be used as a feed for manufacture of biodiesel. Significant work has been conducted in Africa and Asia evaluating the uses of *Jatropha curcas* to improve the economy of rural villages.[77]

Jatropha curcas is a large shrub/small tree able to thrive in a number of climatic zones with an annual rainfall of 250-1200 mm. It is well adapted in arid and semi-arid conditions and has low fertility and moisture demand. It can also grow on moderately saline, degraded and eroded soils. It has been reported that a jatropha living fence not only protects valuable food or cash crop from foraging animals, but also benefits crop growth by reducing moisture loss from winds and by increasing soil moisture retention.[78]

Jatropha can be grown from seeds or cuttings and the suggested density for plantations is about of 1100-3300 plants/hectare.[79] It should be noted that when grown from seeds, the plants are edible for the first 3 months since the toxic material has yet to be produced.[80] As a plantation crop, jatropha can be harvested within six months of planting, and

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[73] Gael Pressoir, Personal communications, June 27, 2006
[74] Gael Pressoir, Personal communications, June 27, 2006.
[75] Handbook of Jatropha Curcas, First Draft, March 2006, Fact Foundation, www.fact-fuels.org
[76] Vaitilingom, G., Liennard, A., Various Vegetable Oils as Fuel for Diesel and Burners: J. Curcas Particularities, Biofuels and Industrial Products from *Jatropha curcas*, Jatropha 97 Symposium, Managua, Nicaragua, February 1997.
[77] Handbook of Jatropha Curcas, First Draft, March 2006, Fact Foundation, www.fact-fuels.org
[78] Reinhard K. Henning, Using the Indigenous Knowledge of Jatropha: The use of *Jatropha curcas* oil as raw material and fuel, Knowledge and Learning Center, Africa Region, World Bank, No. 47, August 2002, www.worldbank.org/afr/ik/default.htm
[79] Openshaw, Keith, A review of Jatropha curcas: an oil plant of unfulfilled promise, Biomass & Bioenergy 19, (2000)
[80] Handbook of Jatropha Curcas, First Draft, March 2006, Fact Foundation, www.fact-fuels.org

productivity is stable after one year. It reaches its maximum productivity in five years and can live up to 50 years.[81]

Jatropha oil has been used as a diesel fuel substitute to power stationary diesel engines in rural African villages.[82] These engines have in turn been used to provide electric power and operate crop grinding and pressing operations, irrigation systems, and small industrial concerns.

Jatropha pure plant oil has been shown to be a reliable fuel for indirect or pre-chamber diesel engines. Direct injection diesel engines need to be modified in order to run properly using straight PPO or blends.[83] The costs and complexity of modifications is diesel engine specific, but throughout Africa and India villages, diesel engines using PPO have been used with great success.[84]

Jatropha oil has also been used for:

- Fuel for cooking stoves (replacement of charcoal or wood based fuels)
- Fuel for lighting (replacement for kerosene)
- Soap production
- Skin care and cosmetics
- Pesticides
- Medicinal uses (e.g. purging)
- Industrial lubricants

[81] Azam, M., Waris, A., Prospects and Potential of Fatty Acid Methyl Esters of Some Non-traditional Seed Oils for use as Biodiesel in India, Biomass & Bioenergy 29, 2005
[82] Vaitilingom, G., Liennard, A., Various Vegetable Oils as Fuel for Diesel and Burners: J. Curcas Particularities, Biofuels and Industrial Products from *Jatropha curcas*, Jatropha 97 Symposium, Managua, Nicaragua, February 1997. Also see Handbook of Jatropha Curcas, First Draft, March 2006, Fact Foundation, www.fact-fuels.org.
[83] Handbook of Jatropha Curcas, First Draft, March 2006, Fact Foundation, www.fact-fuels.org
[84] Liquid Biofuels for Transportation: India country study on potential and implications for sustainable agriculture and energy, The Energy and Resources Institute, India Habitat Centre, Lodhi Road, New Delhi 110003, German Technical Cooperation, 2005

Table 23. Oil Producing Crop Yields

Plant Type	Oil Yield(Kg Oil/Ha)
Soybean*	375
Rapeseed*	1,000
Corn	145
Cashew Nut	148
Rubber Seed	217
Cotton	273
Coffee	386
Rice	696
Tung Oil Tree	790
Sunflower	800
Cocoa	863
Peanut	890
Castor Bean	1,188
Jatropha	1,590
Avocado	2,217
Coconut	2,260
Oil Palm	5,000

**Non-native plant shown for comparison*

Source: Joshua Tickell, *From the Fryer to the Fuel Tank*, 2000.

For this report, the jatropha plant will serve as the example for developing a biofuels market in Haiti. The same market development process can and should be applied to other native oil bearing plant species sited above.

It should be noted that like all plants used for biofuels, there are proponents and detractors. In Germany, farmers were proponents of rapeseed as the preferred source of oil to make biodiesel. In the U.S.A. the farmers lobbied for soybean-based biodiesel, and corn based ethanol. In Malaysia, farmers support biodiesel made from palm oil.

Who supports jatropha? The jatropha plant does not have a farmer base lobbying on its behalf. Most of its promotion has been from NGOs, seed growers, and for-profit companies like D1 Oils.[85] While this lobbying group is small, it has been effective. Jatropha has become a poster child among some proponents of renewable energy and appropriate technology, especially as an oil-bearing, “drought resistant” tree for small farmers on marginal lands.[86]

There is concern expressed by a vocal minority that the advantages of Jatropha are being hyped and its disadvantages minimized. Some disadvantages raised include the following: (1) the plant is toxic, and if not properly handled — including how it is used as a fertilizer — may injure animals and humans; (2) when used as a living fence it may not keep out goats and pigs; (3) high oil yields are speculative and not supported by science;

[85] D1 Oils PLC, http://live.d1.greencathedral.com/
[86] Benge, M., Assessment of the Potential of Jatropha curcas, (Biodiesel Tree,) for Energy Production and Other uses In Developing Countries, Agency for International Development, USDA Forest Service, International Programs division, Washington, DC, 04/11/06

(4) soil erosion benefits are speculative and not supported by science.[87] For example, the website titled "Jatrophacurcas" lists the potential yields of jatropha oil but not actual yields.[88]

EXPERIENCE WITH JATROPHA IN HAITI

Some of the concerns raised about jatropha are not applicable to the Haitian context. In Haiti, jatropha is an indigenous perennial known as *gwo medsinye*. Rural Haitians generally know and readily identify jatropha for its folk medicinal purposes (e.g., purging). The other common medicinal use of jatropha in Haiti is to treat skin burns, thrush, itches and skin disorders with the milky latex.

It is possible that children and livestock have died eating seeds and leaves; however, the team is unaware of any such reports in rural Haiti. In general, newborn babies given "lok" purgatives (such as jatropha oil) are vulnerable to dehydration which results in higher mortality rates for babies. Jatropha plants are also used in protective magic (protection of gardens from thieves). Farmers throughout rural Haiti commonly use jatropha as a living fence, primarily for livestock control, including pigs and goats. Field observations suggest that living fencing with jatropha is not used alone. It may also include other plant species incorporated into the same fence (e.g., brizyèt/bwa panyol (*Comocladia sp.*), gomye (*Bursera simaruba*), kandelab (*Euphorbea lactea*), and monben (*Spondias mombin*).

Goats are known to dislike the taste of mature jatropha, and farmers interviewed recently in Ti Bois (Arcahaie), an area where jatropha living fence is common, do not report any problems with goats dying from jatropha. In order to keep goats out of gardens protected by living fence, jatropha cuttings for living fence are planted together with other plant species commonly used in living fence. Farmers enhance the efficiency of living fence by attaching wooden collars to small animals left to roam freely.[89]

Two common varieties of jatropha are common throughout the rural landscape of Haiti, especially in drier zones where euphorbes are more common. [90] The smaller species more common on fallow and grazing lands is *J. gossypiifolia L.* Its mature height is one to two meters. The species used for hedgerows and boundary fences is *J. curcas L.* It grows to four meters in height and tends to live longer.[91] There are additional species in Haiti: two natives (*J. hernandiifolia* Vent. and *J. multifida* L.) and one introduced from Cuba (*J. integerrima* Jacq.)[92] Specific data on yields for these species in Haiti were not found.

JATROPHA OIL COSTS

There is no active market in Haiti for jatropha seeds, oil or seed cake. To encourage farmers to plant jatropha, a market for their products needs to exist. Before reviewing

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[87] Benge, M., Assessment of the Potential of Jatropha curcas, (Biodiesel Tree,) for Energy Production and Other uses In Developing Countries, Agency for International Development, USDA Forest Service, International Programs division, Washington, DC, 04/11/06
[88] http://www.jatrophacurcas.com/about.asp
[89] Glenn Smucker, personal communication, July 11, 2006
[90] Glenn Smucker, personal communication, July 11, 2006
[91] Joel Timyan, Personal communications, June 2006
[92] Liogier, A. H. 1986. *La Flora de la Española. IV.* Serie Científica 24, Universidad Central del Este, San Pedro de Macorís, Rep. Dominicana.

potential markets for Jatropha plant products, the following discussion first examines the impact of equipment on oil and seed cake costs. This is followed by a few scenarios for market development. This list is by no means all-inclusive. It is meant to be illustrative and promote discussion so that the best approach for market development can be determined.

To start with, the cost of the seed, the base of the value chain, greatly impacts the sale price of the plant oil. If the seed costs are too high, the oil will be priced out of the fuel market. If the cost is too low, the farmer does not get a fair return for his or her labor.

Team members talked with Valentin Abe and Patrick Vilaire (PRODESELA/Caribbean Harvest) who have initiated a trial jatropha project at Ti Bois (Arcahaie).[93] They speculated on purchasing seed at $0.05/lb to $0.10/lb, and estimated they could sell seed cake back to farmers for around $0.03/lb. The price of seeds and seed cake needs to be better defined as they are the foundation of the plant oil fuel value chain economics.

With a hand press (see Figure 24), five kilograms of seed yield 1 liter of oil. Using a motor driven powered press (Figure 25), four kilograms of seed yield one liter of oil, a 25 percent increase in oil extraction efficiency.[94] This translates to 41.7 lbs of seed for every gallon of raw oil produced manually, and 33.4 lbs of seed for every gallon of raw oil produced with motor driven equipment.

At $0.10/lb ($0.22/kg) for dried seeds, the raw oil would be priced out of the market at $4.17/gal ($1.10/l) for the seed costs alone. At the other extreme, at $0.01/lb ($0.02/kg) for dried seeds, the raw oil seed costs would be $0.66/gal ($0.17/l). This would create a huge demand for the oil, but the seed producers would not be rewarded for their labor.

Using data from Hennings,[95] and assuming that seeds could be collected at a rate of two kg/hr (4.1 lb/hr), a Haitian farmer would need $0.06/lb for dried seeds in order to exceed the official minimum daily rate of 70 gourdes ($1.73). At $0.06/lb, with the more efficient motor powered press, the seed costs translate to $2.00/gal ($0.53/l), still too high for a viable fuel market.

[93] Glenn Smucker and Michael Bannister, Personal communications, June, 2006.
[94] Henning, K., Fuel Production Improves Food Production: The Jatropha Project in Mali, Biofuels and Industrial Products from *Jatropha curcas*, Jatropha 97 Symposium, Managua, Nicaragua, February 1997.
[95] Henning, K., Fuel Production Improves Food Production: The Jatropha Project in Mali, Biofuels and Industrial Products from *Jatropha curcas*, Jatropha 97 Symposium, Managua, Nicaragua, February 1997.

Figure 24. Bielenberg Hand Ram Press, Tanzania

Figure 25. Small Scale Production Press

MULTIFUNCTION, SEED OIL PRESS, WITH HEATING CHAMBER AND VACUUM FILTER, 100 KG/HR, 5.5KW WWW.OILPRESS.COM

This exercise indicates the importance of efficiency in seed collection and oil extraction. It also highlights the need for seed cake market development. The higher the seed cake is valued, the more cost effective will be the jatropha oil. Continuing with our example, if seed cake sold for $0.03/lb ($0.07/kg), then seed costs for the raw oil translates to $1.25/gal ($0.33/l). At this price, a good return to the entire value chain is possible. This example highlights how productivity can reduce price, which in turn increases opportunities for an expanded market, or higher returns to the producers. This example of increased productivity extends to selection of jatropha species with improved seed production and higher seed oil content; however, to assure profits across the value chain, it is crucial that appropriate training and technology to maximize plant products and prevent waste or spoilage be adopted at every step of production (see Figure 26).

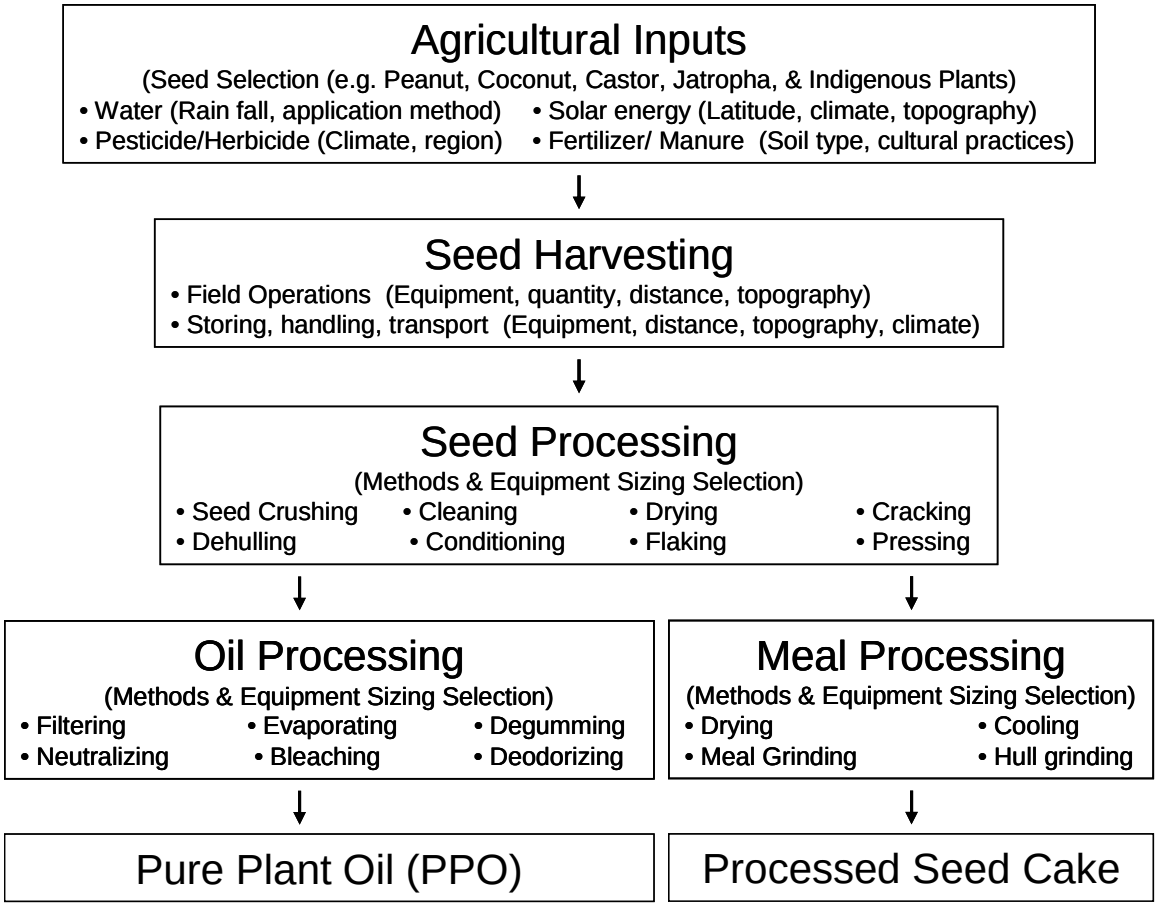
Prospective Markets

Village markets versus external markets. In Africa and Asia, the market for *Jatropha* started slowly at the village level. Hand presses were used and the oil was used for local electric power production, soap making (Appendix D), lighting and cooking. The seed cake was processed to be used as an organic fertilizer. Over time, markets developed for both the oil and seed cake. This approach has merit for Haiti; however, small Haitian farmers need to see a real cash market before they will change their planting patterns. If a cash market for jatropha seeds were established, farmers could determine the benefits of planting jatropha perennials as part of their livelihood. Once established, local markets for jatropha products would follow.

Jatropha oil fuel for utility electric power production. A market for jatropha oil fuel could develop overnight if the local electric power utilities would use jatropha oil fuel, even as a dilute blend, to power their diesel electric power generators. For example, the Electric power utility in Port-au-Prince, Electricité d' Haiti (EDH), burns 832,700 l/month (220,000 gal/month) of fuel oil and 13,200,000 l/month (3,500,000 gal/month) of diesel to generate electricity for 8 hours/day.

If EDH consented to purchase PPO for blending with petroleum diesel, at the one percent level, they would need a supply of 132,500 l/month (35,000 gal/month) of PPO. At the one percent level, EDH will not need to make alterations to their equipment and this should reduce their resistance to using PPO for powering their diesel generators.

Figure 26. Oil Seed Crop Selection, Planting and Growth Flow Chart



EDH currently purchases petroleum diesel in bulk at $0.61/l ($2.30/gal). The size of this market for EDH alone at a one percent blending level would be 132,500 l/month and would have an annual market value of $970,000. To meet this market demand would require the annual production of jatropha oil from more than 7,480 km (4,650 miles) of living fence (see Appendix E for assumptions and calculations).

This is not the highest value market, but it is a large and consistent market, and it does provide sufficient value to process the seeds and transport the PPO to the nearest electric power utility. For this market to develop, a market for the pressed seed cake would also need to be developed.

Jatropha oil fuel for private industry. Smaller markets for jatropha oil potentially exist, based on the interests of environmentally minded Haitians. Agronomist Joel Ducasse suggests that private industry would consider using PPO in modified diesel engines at $0.66/l ($2.50/gal). Agronomist Ducasse's initial survey found several major diesel users willing to use a blend of PPO. Their diesel fuel consumption is 7,570 l/day (2,000

gal/day). A one percent PPO blend would yield a market of more than 55,000 l/yr, which would be the predicted annual production from about 260 km of living fence. The market increases rapidly if users would be willing to modifying their diesel engines to use higher blends of PPO or even pure PPO; however, initially, the supply could not even meet market demands for only a one percent blend.

Jatropha oil for export. One last market for jatropha PPO would be the export market. Unlike castor oil, Jatropha oil has no international markets at present. Kevin Reilly, President of CTI Biofuels located in Pittsburgh, Pennsylvania, USA, has suggested that if the PPO is priced correctly, a large market would develop. He said Turkey, like Haiti, gets a significant share of its tax revenue from fuel and is not interested in providing tax breaks for biodiesel; however, Turkey is considering the importation of palm oil at $0.16/lb -$0.19/lb ($0.35/kg - $0.42/kg) and exporting biodiesel to the EU at 32 cents/lb ($0.70/kg).

CTI Biofuels would be interested in that same model for Haiti in order to create a market for Jatropha oil. The oil would need to be priced competitively with palm oil available on the international market ($0.16/lb -$0.19/lb, delivered dock side Port-au-Prince). Key to creating this market would be the need for limited export taxes on the oil, and long-term contracts that are trustworthy. At $0.19/lb or $1.46/gal ($0.42/kg or $0.39/l), the market size could quickly grow to more than 50 million gal/yr, well outpacing possible production.

Seed cake. The other product from the Jatropha seed is the seed or press cake. No market for jatropha seed cake currently exists in Haiti. Possible markets include the use as an organic fertilizer or a substitute fuel source.

A major breakthrough would be development of a jatropha seed cake that could be used as animal feed. The toxic component of Jatropha is the phorbol esters. Researchers in Asia are working on methods to detoxify the seed cake. Also, jatropha plants free of phorbol esters are available from Mexico and should be evaluated for use in Haiti.[96]

The annual production from 100 km of living fence yields about 100 mT (221,000 lb) of seed cake (see Appendix F). In India, the de-oiled seed cake sells for the same price as the seeds if it is used as chemical fertilizer replacement, or less than half the value of the seed if used as organic fertilizer for local village farmer use. In Mali, the farmers sell the seeds at a reduced rate, but get the seed generated from their seed in return.

In Haiti, it could take time for the seed cake to have a market value. Also it would require new teaching to insure the seed cake is well incorporated in the soil so that pigs and goats would not eat the toxic residue;[97] however, the seed cake, with a nitrogen content (3.2 to 3.8 percent) similar to that from cake of castor bean or chicken manure has the potential to increase the productivity of other cash crops.[98] For this example, if the seed cake has a

[96] Gael Pressoir, Personnel communications, June, 2006
[97] Benge, M., Personal communications, July, 2006
[98] Handbook of Jatropha Curcas, First Draft, March 2006, Fact Foundation, www.fact-fuels.org

value of $0.66/kg ($0.03/lb) the market value of 100 km of living fence would be about $5,100.

The seed cake could also be used as a boiler feed or processed to be used as a charcoal fuel substitute (Appendix F). The seed cake has a relatively high energy value because the motor driven seed pressing operations do not extract all the oil. Again, such markets will need support to be developed.

Training and Access to Improved Cultivars

The oil seed and fuels markets are commodity markets with tight margins. In order to maximize returns to the entire value chain, especially the rural farmers, the best appropriate technology needs to be made available along with training at all levels of planting, production, storage, transportation, and use.

Agricultural science has contributed to the agricultural success stories in the USA, EU, India, and Brazil. The funding at universities and companies, developing local know how and applying that know how on a continuous basis has led over the past 40 years in the doubling of corn (maize) yields as well as palm and sugarcane. The Brazilian success story is in part due to the fact that Brazilian scientists created the sugarcane varieties which have resulted in higher sugarcane stalk yields, sugar content, and improvements in disease resistance.[99]

Farmers should also have access to the best cultivars within a species to maximize the seed oil content. Planting unimproved seeds/plantlets would condemn growers to mediocre yields and revenue streams. If a durable and self-sustainable agroforestry is to become a Haitian success story, the capacity for strong local teams (e.g., local universities, research institutes, and seed or propagation companies) needs to be established.[100]

Liquid Biofuel Policy Options

It is rare for an idea or concept to have broad support across a country's economic, social and political spectrum. Biofuels including ethanol, biodiesel, and plant oil based fuels all represent such an idea in Haiti. There are several private sector groups evaluating how best to start biofuels production. These groups have the technical competence (e.g. agronomists, engineers, entrepreneurs), but lack financial and public policy support. Haiti also lacks a strong agricultural sector upon which all other biofuel economies are based. Tax credits, grants, and loan guarantees should all be evaluated in the Haitian context as to how best to promote the growth of a local biofuel industry.
Some policy options include:

- Requiring biofuel blend for electric power production and for transportation fuels
- Tax exemptions for biofuels
- Tax penalties for petroleum fuels

[99] Gael Pressoir, Personal communications, June 27, 200
[100] Gael Pressoir, Washington DC USAID Stakeholder Workshop, August 2, 2006

- Tax policy to promote diesel over gasoline use

RECOMMENDATIONS

As part of an overall watershed and economic development strategy, promote expansion of bio-energy crops including wood and oil bearing plants in response to viable markets, and incorporate such crops on slopes and in soil conservation structures as feasible.

Solid Biofuels

Promote sustainable planting and harvest of trees for charcoal and other wood products. Take measures to increase the supply of woodfuel including farm-site tree planting and more efficient carbonization. Advocate for a national strategy on sustainable charcoal production. As recommended for health reasons in Chapter II, promote private sector investment in more efficient cookstoves including the use of substitute fuels as well as massive diffusion of the *Recho Mirak* charcoal stove in urban areas.

Liquid Biofuels

Biofuels are a growth industry in world energy markets, especially ethanol and biodiesel. *What is the potential to promote cutting-edge biofuels in Haiti as an economic incentive for hillside farmers to plant tree and shrub crops useful for minimizing soil erosion*?

Up to now the rapid expansion of world demand for such biofuels is directly attributable to public policy support. Petroleum would need to approach $90/bbl before biodiesel fuel would be cost competitive without government support. Petroleum may cross this threshold in the not too distant future. The benefits of encouraging home grown fuel are large.

The USAID/Haiti Mission should work with existing Haitian stakeholders to define an action plan for liquid biofuels. Pure plant oil fuel should be encouraged first – before biodiesel and ethanol production – in order to maximize the economic benefits to the small farmer. The USAID mission can provide a positive example by using plant oil for its local electric power generation and through its use of clean energy (wind and solar). The biofuel action plan should promote markets that directly benefit small farmers and create reliable incentives for biofuel plantations on slopes, including:

- An assessment of the most efficient small-scale seed harvesting and processing technologies,
- A risk assessment of the advantages and disadvantages of *Jatropha* and other perennial oil seed crops,
- An assessment of how best to use plant breeding and genetics to improve *Jatropha* oil seed attributes and yields,
- An initial marketing campaign focused on the sale of pure plant oil to electric power utilities,
- Seed cake market development,

- Local investment in biofuels including loan guarantees to private investors, and grants to non-governmental organizations working with local farmers,
- Support to develop new markets at the village level, after the initial electric power utility market has demonstrated the potential for plant oil fuel,
- Training at all levels of planting, production, storage, transportation, and use in order to maximize return to the entire value chain,
- Investigation of soap as a niche market. Local Haitian soap producers should be approached to determine the potential for using locally available *Jatropha* oil to manufacture soap products.
- Investment in a durable and self-sustainable agroforestry by building the capacity for strong local agroforestry teams,
- Encouragement of the newly elected Haitian government to consider tax policies that promote biofuels, including pure plant oils, biodiesel, and ethanol.

APPENDIX D

SOAP PRODUCTION FROM JATROPHA OIL

Another proven market for Jatropha oils in rural Africa has been soap. Jatropha oil has good properties for making soap and soap production can be accomplished with minimal investment of supplies and equipment.

Presently soap is produced by artisanal methods in Mali and Tanzania.[101] The oil is boiled with a caustic soda solution and poured into molds.[102] Upon cooling, the material hardens into soap and is removed from the molds. Depending on the market, the soap is ready for sale, or wrapped and packaged for higher value markets. The Jatropha based soap has positive effects on the skin and is therefore marketed for medicinal use.

The local production of soap has been found to be one of the most economically attractive uses of Jatropha oil. It is not a high volume market but is higher value than using PPO as fuel. In The Jatropha System report, some economic calculations are given for the production of soap, as well as the production of PPO, in Tanzania. In this example, the inputs were 20 liters of oil, 3 kg of caustic soda, and plastic for wrapping the finished soap. The total input costs to make 252 bars of soap were $55.24. The selling price for the soap was $120, providing a revenue stream of $64.76 for 26 hours of work. Using Henning's example, the value added per hour of labor for soap making is several times that of seed collection and processing.[103]

This is a niche market that requires further investigation. Local Haitian soap producers should be approached to determine what value they see in using locally available Jatropaha oil for their soap products.

[101] (Arusha)
[102] (Henning, 1994)
[103] [The Jatropha system, Henning, 2004]

APPENDIX E

JATROPHA SEED PRODUCTION CALCULATIONS

The production of jatropha oil and seed cake requires a capital investment in equipment to press the seeds and filter the oil. Depending on the market, it would also require equipment to refine the oil via degumming and neutralization. For this report, let's assume that 15 percent of the plant oil yield is required for equipment operations and losses.

The input to the process is the jatropha seeds and the output is raw, filtered oil and seed cake. The following examples assume that Jatropha is planted as a living fence in marginal lands and mountain hillsides and not cultivated on a plantation. Not to be forgotten, marginal yields are obtained from plants grown on marginal lands.[104]

Hennings[105] reports seed production on the order of 1 kg of seeds per meter of living fence per year. Azam[106] reports for yields based on plantations on the order of 2.5 mT of seed for a hectare of land containing 2500 plants. Reports in the literature range from actual yields of 1.0 mT/ha to predictions of 25 mT/ha.

For the calculations below, the following assumptions are made:

- Jatropha are planted one meter apart, or 1000 plants/km
- Seed production per year is 1.0 kg/plant/year (2.2 lb/plant/yr)
- 1 km of jatropha living fence would yield 1.0 mT of seeds

Actual plant yield studies in Haiti are needed to develop a precise business plan. For 100 km (62 miles) of living fence, using the data above, the seed available for processing would be 100 mT or almost 220,000 lbs. Using a motor powered press that yields a one liter for 4 kg of seed (one gallon for 33.38 lbs of seed), then 25,000 l or 23,000 kg (50,700 lbs or 6,600 gallons) of oil would be produced.

Assuming 15 percent of the plant oil yield is required for equipment operations and losses, the amount of sellable oil would be 21,250 l or 19,550 kg (43,100 lbs or 5,600 gallons) of oil would be produced. The value of oil generated from 100 km of living fence, with the assumptions above, would be almost $13,000.

What would be required to process the seeds from 100 km of living fence? In order to process this amount of seed, a small 100 kg/hr diesel powered press and filtering system would be needed to operate 8 hours/day, 250 days. If the production of 200 km of living fence were available, then the 100 kg/hr system could be operated 16 hours a day, or a 100 kg/hr system could be installed.

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[104] Benge, M., Assessment of the Potential of Jatropha curcas, (Biodiesel Tree,) for Energy Production and Other uses In Developing Countries, Agency for International Development, USDA Forest Service, International Programs division, Washington, DC, 04/11/06

[105] Henning, K., Fuel Production Improves Food Production: The Jatropha Project in Mali, Biofuels and Industrial Products from *Jatropha curcas*, Jatropha 97 Symposium, Managua, Nicaragua, February 1997.

[106] Azam, M., Waris, A., Prospects and Potential of Fatty Acid Methyl Esters of Some Non-traditional Seed Oils for use as Biodiesel in India, Biomass & Bioenergy 29, 2005

Once a seed processing center is established, the press can also be used for processing other oil seeds such as castor.

APPENDIX F

JATROPHA SEED CAKE AS A FUEL SUBSTITUTE

Small motor driven press systems do not extract all the oil in the seed, so the seed cake has about 50 percent of the energy value of the oil (20-25 MJ/kg) and it could be used as a fuel substitute, such as boiler feed or charcoal fuel replacement.

Once again the market for seed as a boiler feed would need to be developed with some test market trials to show the energy potential, but with Haiti's experience with bagasse this should be a reasonable possibility. Fuel oil sells $0.39/l or $0.42/kg but has more than twice the energy density of seed cake, thus the seed cake could sell for about $0.20/kg. At this price, the seed cake market value for the annual production of 100 km of living fence (100 mT or 221,000 lb) could be as high as $15,400.

Another possible market for seed cake is as a charcoal fuel replacement. Diligent[107] has suggested that one could use a simple screw type press to make pellets out of the seed cake. These pellets could be used for direct combustion creating a market similar to that of boiler feed. It has also been suggested to convert the seed into charcoal, since the demand for charcoal is so high in Haiti. Charcoal has energy content slightly higher than seed at 30 MJ/kg and sells in Haiti for about $300/mT.[108] Assuming an equivalent yield loss as in the charcoal conversion process,[109] about 25.6 MT of fuel pellet products would be available for sale with a market value of about $7,700.

Each of these markets should provide sufficient return to encourage the planting, harvesting, and processing of jatropha seeds.

[107] Handbook of Jatropha Curcas, First Draft, March 2006, Fact Foundation, www.fact-fuels.org.
[108] BME energy plan, 2004.
[109] BME energy plan, 2004.

VI. TOWARDS A STRATEGY FOR MITIGATING NATURAL DISASTER IN HAITI'S WATERSHEDS

The following summary recommendations pick up on themes and findings discussed in earlier portions of the report.

A watershed strategy. The USAID Haiti Mission cannot directly intervene in all 54 major watersheds of Haiti; however, it should devise a near term strategy for concentrated interventions in high priority watersheds with a view to reducing vulnerability to the loss of human life and livelihood due to flooding and severe storms.

An integrated and multi-sectoral strategy for natural resource management. A USAID strategy for intervening in high priority watersheds should be just one element of a long-term multi-sector strategy for major investments in economic development and the generation of significant off-farm employment, especially in secondary cities, small towns, and flatlands.

The multi-sector strategy should also give high priority to making reproductive health services widely available and also for integrating family planning services directly with interventions in targeted watersheds, especially with families living in fragile highlands.

Disaster preparedness and early warning systems should also be directly integrated with watershed planning, and other efforts to improve natural resource management.

Twenty-year time frame. For such an approach to be effective, the US Government should make a 20-year commitment to poverty alleviation through broad based economic development along with targeted interventions in critical watersheds. An effective strategy will require seamless continuity of funding at major funding levels going well beyond intermittent three to five year project cycles. This will require a major commitment on the part of the US Government as well as an enabling political environment in Haiti.

Inter-donor and inter-agency collaboration. In order to have a discernible impact, there should be a significantly heightened level of inter-donor collaboration at policy levels as well as the targeting of field interventions. This should include active participation in sectoral consultation groups such as the Interim Cooperation Framework, and wide circulation of strategy documents and reports of project activities and successes. Also, Mission programming should make use of other US government resources in addition to AID expertise in urban planning, environmental management, coastal and marine resources, and disaster preparedness.

Prioritizing critical watersheds. Intervention strategies should be guided by prioritizing and targeting watersheds in keeping with science-based vulnerability assessment, government and donor priorities, and available funding levels. Watershed selection criteria should include manageable size and the absence of other significant donor activities devoted to watershed management and disaster mitigation.

Population vulnerability: The most vulnerable sites are densely populated cities in flood-prone coastal areas. These sites are high priority but will require a multi-donor strategy, especially to alleviate vulnerability in Haiti's largest cities, particularly Port-au-Prince. Intervention strategies for watersheds containing Haiti's vulnerable secondary cities should use a ridge to reef approach, including engineering works for irrigation systems, drainage, and diversionary canals in lowland areas.

Watershed management plans. Management planning should use a participatory methodology that encompasses whole watersheds but with particular attention to specialized land use areas or zones, and the targeting of critical sites for different types of interventions. This process should include the direct participation of local farmers and other watershed stakeholders, including communal sectional and municipal levels of government, and inter-communal collaboration in watersheds that cross jurisdictional lines.

This process should include identification of assets as well as high risk sites within watersheds, and development of local site-specific management plans. Targeting of strategic sites should include fragile ravines considered to be commons (not privately owned) as well as micro-catchments, springs, and other fragile sites. Targeting of interventions should also identify sites with superior production potential including flat areas, small artisanal irrigation systems, and pockets of fertility in highland zones.

Watershed interventions should encompass both urban and rural areas as inter-linked elements of an integrated management plan including riparian zones vulnerable to flooding in lowland areas, and urban planning in coastal towns and cities.

As feasible, conservation works should be directly linked to markets. Watershed plans should identify local sites of heightened production potential as the primary starting points for conservation interventions.

Watershed plans should also take into account the special requirements of protected areas and forest eco-systems such as highland pine forest, including protection of the headwaters of major watersheds, and protection and restoration of lowland mangroves, estuaries, and coastal buffers to mitigate storm surges.

Promoting major shifts in land use on slopes. The primary focus should be to scale up interventions from scattered farm plots and promote alternatives to erosion-intensive agriculture on Haiti's slopes, including the following:

- Increasing the proportion of the landscape devoted to perennial crops rather than erosion-intensive annual food crops;
- Expanding employment via transformation of local agricultural and agroforestry products;

- Shifting agricultural pressures away from slopes onto more intensively cultivated lowland plains and other sites less vulnerable to erosion, including irrigated agriculture;
- Broadening opportunity for non-agricultural livelihoods. This might include promotion of tourism in protected areas, certain border regions, and other special interest sites; and
- Promoting market links conducive to spontaneous adoption of improved natural resource management practices triggered by economic incentives.

Water. Water management should be a thematic focus of special interest in watershed planning. This will require targeting high risk sites and points of vulnerability including coastal areas, mangroves, springs, river banks, ravines, and irrigation works.

Energy. Investment in the energy sector should include a renewed emphasis on improved cooking stoves, more efficient technology for charcoal manufacture, expansion of tree planting for the production of charcoal as a renewable resource, and hillside production as feasible for new biofuel markets.

Local governance and co-management arrangements. Program interventions should use revenue generation as an incentive for promoting improved local governance, local land use planning, and sustainable harvest practices. User groups should be organized around specific local resources, e.g., mangroves, fisheries, and production of sea salt from evaporation ponds; local micro-catchment areas as targeted units of program intervention; co-management practices in protected areas and forest reserves.

Program interventions should include practical working partnerships with municipalities and communal sectional councils, and tools of local governance such as local tax collection and the enforcement of grazing restrictions.

Contracts should be negotiated with grassroots organizations or local bodies of government for program-related partnerships. Such contracts should require the local contracting organization to put its own resources at risk, including cash, and the local organization should participate directly in tendering outside technical assistance or service-delivery contracts.

A strategic response to vulnerability. In sum, the Haiti Mission should design a multi-sector strategy in response to the Congressional directive that spurred this broad assessment. Such a comprehensive strategy should have a national impact, respond to Haitian government priorities, and complement the programs of other donors and non-governmental organizations. Above all, a USAID strategy should be firmly rooted in economic incentives geared to diminish Haitian vulnerability in the face of “dangers to human health and safety” stemming from poverty, severe flooding, and a resource base stretched to the breaking point.