Río Fajardo
Watershed Management Plan Project
Final March 2015

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U. S. Forest Service El Yunque
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List of Acronyms

Animal Feeding Operations (AFOs)
Arc GIS Soil and Water Assessment Tool (ArcSWAT)
Centro para la Conservación del Paisaje (CCP),
Capital Investment Projects (CIP)
Clean Water Act (CWA)
Critical Zone Observatory (CZO)
Department of Natural and Environmental Resources (DNER)
Designated Monitoring Areas (DMAs)
Digital Elevation Models (DEM's),
Effective Date of Permit (EDP)
Environmental Protection Agency (EPA)
EPA Enforcement and Compliance History Online (ECHO)
Environmental Quality Board (EQB)
Environmental Quality Incentive Program (EQIP)
Facebook (FB)
Fajardo Northeast Regional Aqueduct Water Treatment Plant (FNRAWTP)
Fajardo Regional Wastewater System (FRWWS)
Geographic information system (GIS)
Global positioning system (GPS)
Hydrologic Response Units (HRU)
Human Ecosystem Model (HEM)
Illicit Discharge Detection and Elimination (IDDE)
Integrated watershed management (IWM)
Interamerican University (IA-U)
Keyhole Mapping Language (.kmz and .kml format)
Laser Imaging Detection and Raging (LiDAR)
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Millions Gallons Daily (MGD)
Multi-sector General Permit (MSGP)
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National Pollutant Discharge Elimination System (NPDES)
Natural Resource Conservation Service (NRCS)
Northeast Regional Aqueduct (NEA)
Northeastern Ecological Corridor Coalition (NEECC)
Participatory photo mapping (PPM)
Puerto Rico Aqueduct and Sewer Authority (PRASA)
Puerto Rico Highways and Transportation Authority (PRHTA)
Puerto Rico Water Quality Standards Regulations (PRWQSR)
Río Fajardo Watershed (RFW)
Río Fajardo Watershed Management Board (RFWMB)
Río Fajardo Watershed Municipal Taskforce (RFMT)
Soil and Water Assessment Tool (SWAT)
Soil Survey Geographical Data Base (SSURGO)

Sludge Treatment System (STS)
Small Municipal Separate Storm Sewer System (MS4)
Supplemental Environmental Project (SEP)
SWAT Calibration and Uncertainty Procedures (SWAT-CUP)
Tons per hectare per year (tons/ha/yr)
Total Maximum Daily Loads (TMDL)
United States Corps of Engineer (USCOE)
United States Department of Agriculture Agricultural Research Service (USDA-ARS)
United States Geological Survey (USGS)
University of Puerto Rico Agricultural Service Extension (UPR-ASE)
US Census Bureau's Census and the American Community Survey (ACS)
Water and Sanitation Services (WSS)
Watershed Conservation School Network (WCSN)

INTRODUCTION

This study documents and explains the analysis process and public consultation approach conducted to identify relevant issues concerning the conservation of the Río Fajardo watershed. These conservation issues were used to establish a management scheme as part of the project Río Fajardo watershed Management Plan (14-CS-11081600-006) developed by the Centro para la Conservación del Paisaje in agreement with the U.S. Forest Service at El Yunque National Forest. It includes the analysis of land uses in the watershed to identify and quantify areas producing above average sediment loads that move downstream with a final discharge at the coastal region of Fajardo. Sediment control and conservation projects directed to reduce sediment loads and to manage or reduce pollutant discharges received in the marine ecosystem of the region are also specified. The coastal range of the region is part of a priority coral reef conservation area in the North East Reserves in Puerto Rico according to the Puerto Rico's Coral Reef Management Priorities report of 2010. This document includes a description of the watershed and explains the analysis applied to identify sediment production ranges, water pollution problems and concerns presented by the residents of the study area. It includes recommendation for the application of practices and potential community watershed integration projects. The report is divided in five sections that include: 1) Río Fajardo watershed description, 2) Physical modeling of the watershed, 3) Human characterization of the watershed, 4) Results, management issues and potential conservation objectives for the Río Fajardo watershed and 5) Management zones and practices recommended. A further clarification needs to be made. This document is not intended to provide a legal framework to regulate the uses and activities within the Río Fajardo Watershed. Rather, the main purpose of this document is to serve as a guide to: 1) integrate and analyze key scientific information related to the watershed's environmental condition, 2) identify the actors and institutions responsible for the implementation, monitoring and enforcement of environmental regulation (legal framework) and 3) present a series of management strategies that can be implemented in order to improve land-use planning at different scales, environmental stewardship and sustainable resource-use activities.

The methodologies are described in their respective sections and further details are included as appendixes. The text guides the reader through a series of recommendations and outcomes resulting from the applied research that are discussed and organized in the last section. Section one has the description of Río Fajardo watershed providing the picture of the area and including historical activities that impact the current behavior of the watershed as well as an overview of the socioeconomic and demographic characteristics of the region. The physical modeling of the watershed was undertaken using ArcSWAT. This is a river, basin, or watershed scale model developed to predict the impact of land management practices on water, sediment and agricultural chemical yields in large, complex watersheds with varying soils, land use and management conditions over large periods of time and is presented in section 2. The public consultation process and analysis is presented in section 3 with the identification of the main community and public concerns associated with the management and conservation of the Río Fajardo watershed. Finally, the last two sections summarize the information to establish the management issues that should be considered in the plan and present recommendations for the potential application of conservation practices to reduce the sediment flows to the coastal areas of the Fajardo shoreline. The last section defined and presents the management zones and categories recommended to address the identified issues. This section provides recommendations for further analysis and monitoring in specific areas of the watershed. The document integrates the nine elements of the United States Environmental Protection Agency (EPA) in watershed planning and implementation process (Appendix A). As part of the final outcomes for this project; a consultation process with federal and state agencies was undertaken to refine the considered practices according to their potential application.

An approach considered through this analysis was the application of a framework that contemplates the components of the study area as a human ecosystem according to Machlis et al. 2007 Human Ecosystem Model (HEM) (see Appendix B). The HEM provide a well-defined organizational framework that helps to identify and consider the blend of different factors that interrelate and flow in a landscape that is under a conservation management review or plan that considers the natural resources of a region. This approach provides the opportunity to identify the critical resources and the human social system of the region to consider strategies in the application of potential conservation practices. Using the HEM a researcher and manager should identify key transfers between individuals (of varying species), of information (from ecological to cultural), and the uses and needs of materials (including natural resources such as water through a watershed system). The model recognizes the human ecosystems as multi-scaled and hierarchically nested system providing the manager and researcher the chance to analyze and recognize the problems from different scales perspective pondering the strategies and practices at the individual, institutional or landscape level.

1. Río Fajardo Watershed Description

The Río Fajardo watershed

The Río Fajardo watershed (RFW) covers about 66 square kilometers near the northeastern tip of Puerto Rico and includes territory of the municipalities of Fajardo and Ceiba; more specifically the wards ("barrios") of Fajardo Urbano (Barrio Pueblo), Quebrada Vuelta, Florencio, Naranjo, Río Arriba, Río Abajo and Chupacallos. The RFW area includes sections of the El Yunque National Forest, both designated and proclaimed lands, as well as part of the Ceiba State Forest near the mouth of the river. A wide array of activities and land uses take place in this watershed, from industrial, urban, agricultural, livestock grazing to conservation. The landscape of the watershed includes steep terrains with elevations of 1,051 meters that descent to a distinct floodplain that stretches to the mouth of the river. Figure 1 presents an image of 2010 with the delimitation of the RFW presenting the steep slopes to the west and north-western fringe of the watershed and the recognizable lower elevations that integrate the flood plain, dominated by patches under agricultural activity and early successional vegetation stages as well a suburban areas that start to dominate the watershed as it continues its course to the coast.

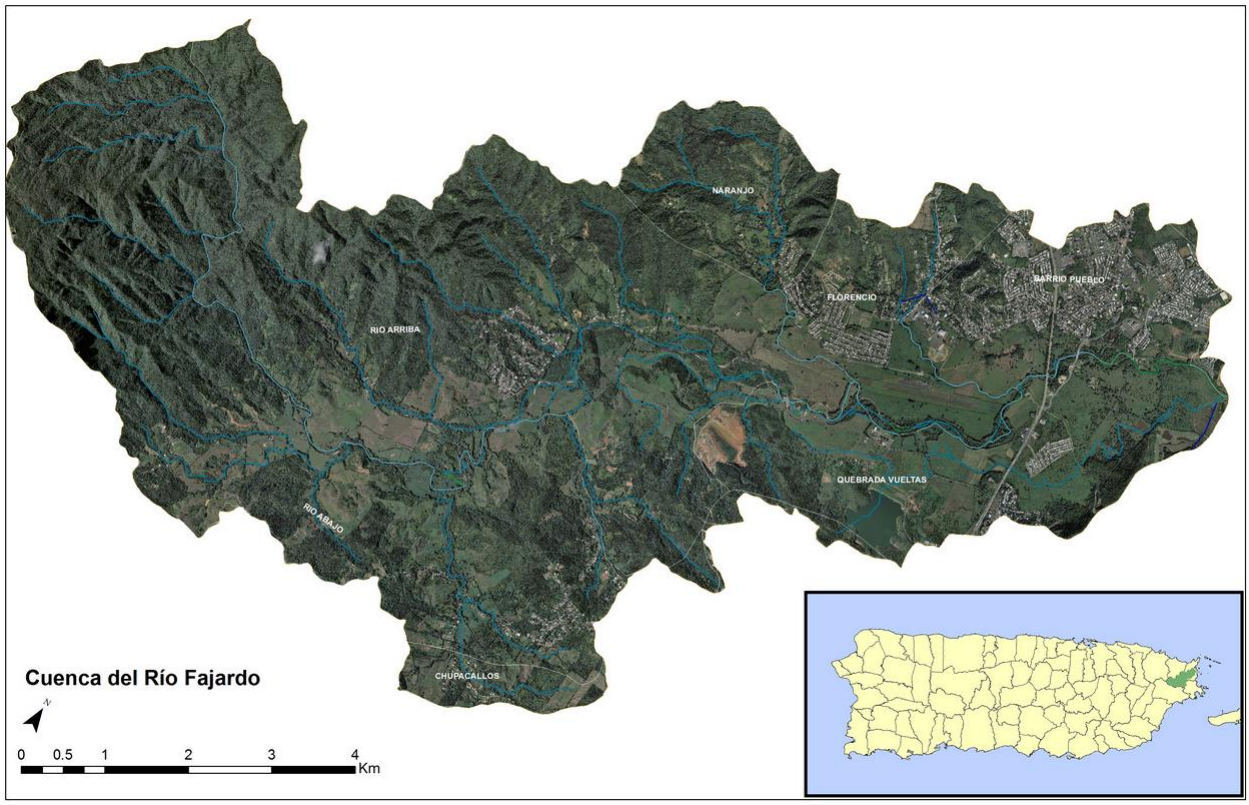


Figure 1 Río Fajardo watershed

The climate in RFW varies according to the changes in the elevations that dominate de area. The mean annual precipitation in Pico del Este (elevation of 1,051 m amsl) is 4,320 mm/yr with an average temperature of 20 C (Murphy and Stallard 2012). At the coast weather station the mean annual temperature is documented at 27 C with an average precipitation of 1,650 mm/yr near the coast.

Soils of the RFW are also influenced by the elevation stratification of the landscape. The soil associations identified in the flood plain are Coloso-Toa-Bajura with two other associations identified as the watershed progress toward the coastal area where the Mabí-Arriba-Cayaguana and the Cataño-Aguadilla associations are present. The soil types dominating the higher elevations of the watershed are the Dwarf and Luquillo while in the flood plain the Toa, Vega Baja and Mucara dominates the area. Figure 2 shows the soil distribution of the watershed as used to develop the applied analyses. The soil information includes the Soil Surveys for Humacao and El Yunque National Forest Soil Survey.

The land uses and vegetation of the RFW were documented in Ortiz-Zayas et al. (2010) and the information is updated as part of the analysis. The forest recovery discussed by Ortiz-Zayas et al. (2010) is supported as we identify 58.4% of the watershed with forest coverage and 7.88% in range-brush representing areas in successional progress towards early secondary forest coverage. Pasture was the other main use identified covering 20.82% of the watershed. This information will be further discussed in the document as part of the management recommendations.

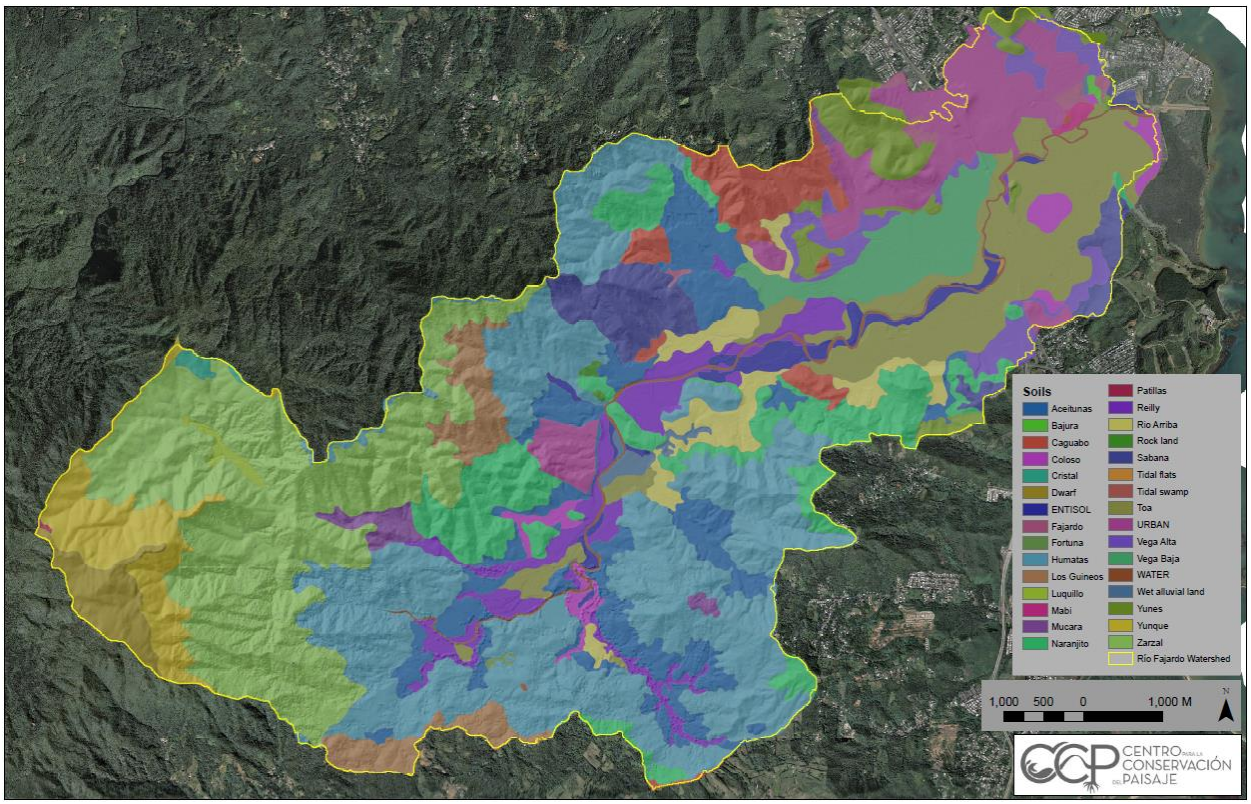


Figure 2. Soils of the Río Fajardo watershed

Historical context

The land and water use history of Fajardo River was very well described in the Ortiz-Zayas et al. 2010 chapter presented in Vaughn (2010). For that chapter several studies were reviewed and the use of

Clark's (1997) historical divisions presented the (Pre-Columbus Era, the Settlement Era, the Agricultural Era and the Modern Era) details of land and water history from years prior to the 1500's to 2000. The main topics relevant to this report are the changes in lands uses and probable modifications applied in the coastal plain combined with the population changes impacting the water quality and watershed functions.

In the first two eras (Pre-Columbus Era and the Settlement Era) described in Ortiz-Zayas et al. (2010) the intensity of the agricultural activities increase periodically producing the change of the lower elevation forests into agricultural lands by the 17th century. Through these periods the Río Fajardo is always recognized as the main sources of water sustaining the increase of population and agricultural activities. The agricultural activities discussed in the literature included sugarcane and cattle raising in the floodplain with coffee, plantain, tobacco, charcoal production and subsistence farming in the steeper slopes. The first watershed conservation initiative can be documented with the proclamation of El Yunque as a Forest reserve by the Spanish Crown in 1876 including the higher elevations of the RFW (Dominguez-Cristobal 2000).

A water intake built in the upper part of Río Fajardo is documented by Ortiz-Zayas et al. (2010) probably constructed before 1950 (Agricultural Era). During the agricultural era (1830-1950) the inputs of contaminations by the raw effluents from the Central Fajardo mixed with the erosion and nutrients effects from the sugar cane activities combined with sanitary problems of the era precipitated the degradation of the water quality in the RFW until the Industrial Era of 1950 to 2000. The constructions of the Fajardo Water Filtration Plant and the Fajardo Wastewater Treatment Plant were two main events documented during the Industrial Area for the RFW. The Wastewater Treatment Plant began functions in 1968 dumping secondary treated waters into the river. The historical chronology explained in Ortiz-Zayas et al. (2010) documents the "arrest" of the Fajardo Wastewater Treatment Plant in 1985 under a Federal Court Order prohibiting new connections to the plant. Even with some improvements done to the wastewater treatment plant in the following years, the Environmental Quality Board considered the plant as a main source of pollution to the river. These industrial and management issues were further complicated by the increase in population and the absence of proper sewage treatment and the disposal of domestic waste from communities at higher elevations zones and in areas not integrated in the centralized sewage treatment infrastructure. In 1977 the closure of Central Fajardo reduced one of the main pollution inputs documented in the history of the RFW but the wastewater treatment plant continued with other polluting activities for years affecting the quality and functions of the RFW producing a plume of pollution toward the coastal region of the eastern part of the Island.

Since the late 1990's the Puerto Rico Aqueduct and Sewer Authority performed significant improvements of the water use and management within the watershed. The Fajardo Regional Wastewater System (FRWWS) was inaugurated in 2006 and provides tertiary treatment to wastewater generated in the municipalities of Fajardo, Ceiba and Luquillo with a total population served of approximately 95,588 residents. The National Pollutant Discharge Elimination System (NPDES) permit for this facility (Permit NPDES # PR0026484 can be downloaded and revised from link http://www.epa.gov/r02earth/water/water_permits/pr0026484_finalpermit_responsetocomments%20.pdf) explains that the plant is designated to provide treatments for a monthly average flow of 4.6 MGD (Millions Gallons Daily) and a daily flow of 9.2. The plant discharges its effluent into Río Fajardo after a treatment process of screening, grit removal, biological treatment, effluent filtration, ultraviolet disinfestation, post aeration, sludge dewatering and sludge lime stabilization. The FRWWS receives

discharges from two industrial users (Pall Corporation and Warner Chillcott Company; see copy of the Renewal Application at http://www.ccpaisaje.org/node/25). There are records of the effluent data for the NPDES # PR0026484 since 2005 and they can be revised in the renewal application. Ortiz-Zayas et al. (2010) mention that the design of the FRWWS presents opportunity for the reuse of treated wastewaters generated at the plant. The document revised as part of the project identified as "Plan de Reuso de Aguas Usadas de Puerto Rico" produced by Ferdinand Quiñones and Rafael Guerrero in 2005 stated that the FRWWS could have two options for water reuse. One of the options is to discharge the effluent to the reservoir after additional treatment and the second is to pump the effluent to the upper segments of the river and then let it flow to the intake of the reservoir providing natural treatment to the effluent and promoting the reuse of the waters. The document also presents the alternative of using the effluent for irrigation of gardens, pasture or golf courses, but this alternative will require additional pumping infrastructure in different areas.

The Fajardo Northeast Regional Aqueduct Water Treatment Plant (FNRAWTP), also inaugurated in 2006, is a water filtration facility that treats raw waters from the Río Fajardo with a permit to extract 12 MGD (Million Gallons per Day). The river intake also incorporated features to minimize maintenance, allow migration of aquatic species, and guarantee release of minimum flows downstream the intake (Torres et al. 2010). The intake was located at a natural scour pool at a bend on the right side of the river. Additional scour protection was provided along the river right bank and at both ends of the river intake. The FNRAWTP provides potable water to the municipalities of Río Grande, Luquillo, Fajardo and Ceiba. The water treatment consists of coagulation, flocculation, sedimentation, filtration and chlorination. A Sludge Treatment System (STS) is used to treat the sedimentation tanks drains and filters backwashes sedimentation tanks. The water from the STS and a portion of the sedimentation tanks drains and filters backwashes are recirculated into the artificial reservoir created as part of the Northeast Regional Aqueduct (NEA). The NPDES application and permit for this facility (Permit NPDES # PR0026379 can be downloaded from link http://www.epa.gov/region02/water/water_permits/fajardo_ne_regional_aqueduct_wtp_final_permit.pdf and copy of the Renewal Application at http://www.ccpaisaje.org/node/25) The FNRAWTP, the most recent NPDES permit is set for July 1 2014 as the Effective Date of Permit (EDP) with an authorization of discharge until June 30, 2019.

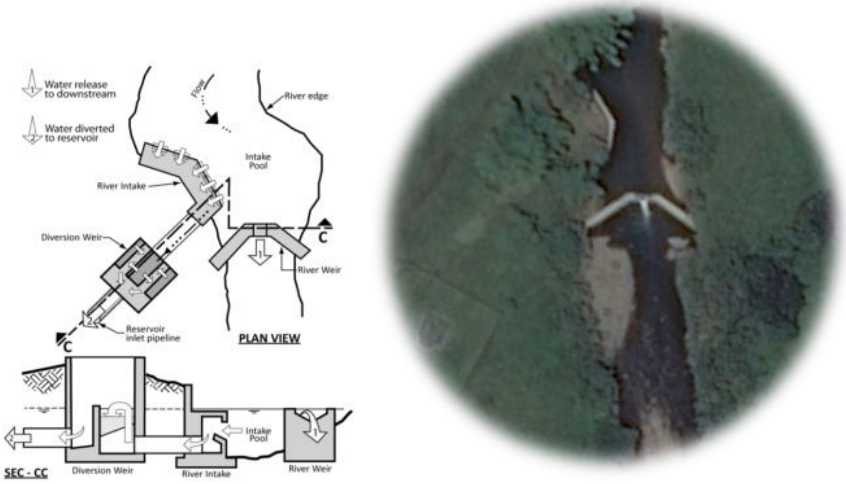
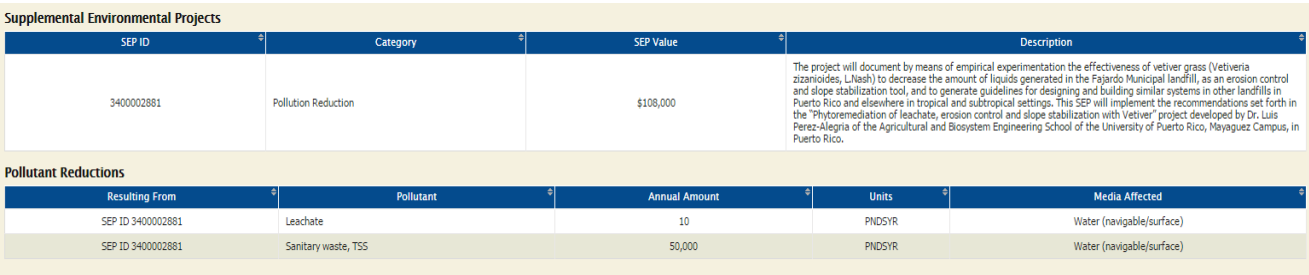


Figure 3. Río Fajardo Intake Operation
(Torres et al. 2010) and Picture from 2013 image.

The intake is outside of the El Yunque National Forest limits and according to Crook (2005), 32% of average annual stream flow and 67% of the median flow will be diverted below the new intake (just outside of the forest). The working protocol for the intake considers a nighttime ban on extraction to protect conditions necessary for the upstream migration of native shrimp. These facilities are considered as a positive infrastructure for the watershed considering the historical inputs of pollutants documented in the history of the RFW. The close proximity between the FRWWS and the NEA will allow for the discharge of the plant effluent to the off stream reservoir (Ortiz-Zayas et al. 2010). It is important to integrate the monitoring strategies and programs of these facilities as part of a management plan for the watershed.

In 1970 the Fajardo Landfill started operations in the watershed area, close to PR-982 as a facility managed by the municipality now under the operation of Landfill Technologies, it accepts waste from the municipalities of Fajardo, Canóvanas, Ceiba, Las Piedras, Trujillo Alto, Loíza, Luquillo, Río Grande, and Naguabo. At least garbage trucks identified from the municipalities of Loíza and Canóvanas were observed in the facilities during field visits, but further details of the uses were not documented in this report because the managers of the facilities were not available. The average filling rate of the landfill is estimated to be 4,095 tons of waste per week (ADS, 2008). The landfill is under consideration for a gas to energy project with a capacity of 2,400 kw/hr and according to the EPA Enforcement and Compliance History Online (ECHO), two civil enforcement cases are documented for the facility. The most recent case is identified as 01-2013-3454 and includes an enforcement action data entered on October 30 of 2013 with a closure on May 2014. The failing of comply with the Clean Water Act (CWA) and its implementing regulations for 2008 Multi-sector General Permit (MSGP) required for storm water discharges associated with industrial activities at the Fajardo Municipal landfill. The company presented the EPA a Supplemental Environmental Project (SEP) for pollution reduction value of $108,000.00. The descriptions of the SEP are included in the next figure. The 2008 Dynamic Itinerary for Infrastructure Projects Public Policy Document of the Administration of Solid Wastes considered the Fajardo Landfill as a facility recommended for expansion. The considered expansion of the site could extend the life of the landfill to 2044.



Supplemental Environmental Projects

SEP ID	Category	SEP Value	Description
3400002881	Pollution Reduction	$108,000	The project will document by means of empirical experimentation the effectiveness of vetiver grass (Vetiveria zizanioides, L.Nash) to decrease the amount of liquids generated in the Fajardo Municipal landfill, as an erosion control and slope stabilization tool, and to generate guidelines for designing and building similar systems in other landfills in Puerto Rico and elsewhere in tropical and subtropical settings. This SEP will implement the recommendations set forth in the "Phytoremediation of leachate, erosion control and slope stabilization with Vetiver" project developed by Dr. Luis Perez-Alegria of the Agricultural and Biosystem Engineering School of the University of Puerto Rico, Mayaguez Campus, in Puerto Rico.

Pollutant Reductions

Resulting From	Pollutant	Annual Amount	Units	Media Affected
SEP ID 3400002881	Leachate	10	PNDSYR	Water (navigable/surface)
SEP ID 3400002881	Sanitary waste, TSS	50,000	PNDSYR	Water (navigable/surface)

Figure 4. Supplemental Environmental Projects for pollution reduction presented by Landfill Technologies

An additional factor that needs to be considered in the evaluation of the land use history and pollution in the RFW are the changes in population and their relations to water resources. According to the 2010 census, the population in this basin is 36,724 with a median age of 38.84 years. According to the same data source, there are 18,054 housing units with an occupancy rate of 76.01%. The land use analysis for the project documents 8.78% of the RFW is under different land uses classes (residential high/low

density, industrial, commercial transportation, etc.) associated with the local population of the watershed. Although this percentage represents a low occupancy for these land uses, as part of the analysis we consider the localities of those uses in relation to the associated sanitary water infrastructure for the residents and in relation to the watershed landscape. This type of information is not collected from satellite images and in most cases is sparsely documented as fragmented pollution events without considering the watershed view. The storm water management and its association with the available infrastructure represent an additional pollution input that needs to be considered for the management of the RFW. The RFW integrates the wards ("barrios") of, Río Arriba, Naranjo, Florencio, Fajardo town, Quebrada Vueltas in Fajardo and Río Abajo and Chupacallos in Ceiba. The Municipal Separate Storm Sewer Systems (MS4s), transports polluted storm water runoff which it is often discharged untreated into local waterbodies. EPA regulates the MS4 through NPDES permits to prevent harmful pollutants from being washed or dumped into waterbodies through the MS4. In Puerto Rico the municipalities must obtain the permit and develop a storm water management program (SWMP) to reduce the contamination of storm water runoff and prohibit illicit discharges.

The MS4 of the municipality of Fajardo serves and estimated area of 9 square miles. The Municipality of Ceiba, presented in its Notice of Intent for the Storm Water Pollution Prevention Plan that the MS4s in general consists of a series of open channel culverts and match basins, typically located within the right of-way of municipal and state roads, interconnected by underground concrete, corrugated steel or PVC pipes which normally discharge into the municipal creeks and streams. The Urban Area of Ceiba shares the main watersheds of the Fajardo and Demajagua Rivers; however the small watersheds of Aguas Claras, El Caño and Ceiba Creeks receive most of the pollutants coming from urban runoff. (Ceiba Notice of Intent 2009)

Demographic characteristics of the study area

The application of the HEM as part of the analysis (see Appendix B) requires the consideration of the social system that rules the study area. This is an essential factor because the conservation practices that can be identified as part of the plan are governed and directed by institutions that are part of the human social system. These institutions base most of their programs in parameters of the social order like territory (private lands vs Land Authority lands), and age (working force) that rule the study area. The institutional and environmental cycles (incentive periods, land use permits, renting time by the Puerto Rico Land Authority, production cycles, wet and dry seasons, etc.) and socioeconomic resources (population, labor, capital available for production, etc.) are also important because they could dictate most of the agricultural activities that are dominant factors in the land use practices of the study area. As part of the HEM the cultural resources also provide information that can help in the implementation of the plan because the model associate those resources with information about the organization (agricultural groups, organize community groups, etc.), beliefs (relation of water quality with forested areas, public acceptance of government agencies, etc.) skepticism in relation to the link of the river and the watershed with the residents and myths (areas that traditionally will flood in rain events, the traditional uses of the river for recreation, etc.)

Demographic, socioeconomic and cultural factors from residents of Fajardo and Ceiba are included and discussed in this section. This information can be used to help design public outreach strategies, identify specific subpopulations to target during the implementation phase, or help determine future trends and needs of the populations (US EPA, 2008). This data allows decision- making to consider socioeconomic

conditions and how they may vary through the study area since the impacts of management decisions also may vary through the watershed (USDA Forest Service, 2014). Different data sources were revised including the US Census Bureau's Census and the American Community Survey (ACS Office, 2012) (a survey performed annually by the Census that evaluates housing, economic, social and other factors), the "ACS estimates are period estimates that describe the average characteristics of population and housing over a period of data collection" (ACS Office, 2012) and the annual estimates of the resident population: April 1, 2010 to July 2014 . 2014 for the most recent population estimates.

The study area comprises seven wards in the municipalities of Fajardo and Ceiba (Table 1). The scale and location of these wards in the watershed are shown in Figure1. Population data is presented in Table 2 as part of the considerations of the potential impacted population within the management plan. Most of the municipality of Fajardo (56%) is inside the watershed and therefore, the Municipality could constitute a key stakeholder for the implementation of the management plan.

Table 1. Wards (Barrios) within the Río Fajardo watershed

Fajardo wards (Barrios)	Ceiba wards (Barrios)
Río Arriba	Río Abajo
Naranjo	Chupacallos
Florencio	
Barrio Pueblo	
Quebrada Vueltas.	

Table 2. Demographic information

According to the Census Data American Fact Finder 2013	Fajardo	Ceiba
Population*	34,049	12,607
Total households**	13,922	5,213

* Annual Estimates of the Resident Population: April 1, 2010 to July 2014 . 2014 Population Estimates Factfinder.
** Households and Families: 2010 census summary
U.S. Census Bureau, American Fact Finder 2013

In relation to the population changes in recent years for the region associated with the Río Fajardo watershed (Municipalities of Ceiba and Fajardo) another interesting data should be considered as part of the analysis. Between the years 2000 to 2010 Ceiba and Fajardo had significant declines in their populations (24.4 percent, 9.0 percent, respectively), largely attributed to the closure of Roosevelt Roads Naval Base in 2004, which led to the relocation of thousands of military members and their families to other bases around the world (USDA Forest Service 2014). In relation to the housing units for the same period in the wards of Ceiba, there was a reduction (-.11%) in Chupacallos and in Río Abajo there was slight increase of 1.5%. In Fajardo, the housing units show an increase in Quebrada Vueltas of 11%, and in Naranjo of 37.5%. Other wards showed a reduction in the number of housing units in Fajardo according to the Population, Housing Units, Area, and Density: 2010**.** The increase of the number of housing units in Fajardo can also represent a potential source of pollutants and sediment load in the watershed. The highest increases in housing units in Fajardo between 2000 and 2010 occurred in the Naranjo ward where there are steep slopes and in the Quebrada Vueltas ward that includes a large area of floodplain close to the coastal region.

In our analysis we use this information to consider resources that can have impacts in the watershed based on these demographic characteristics. One fact in the analysis that is important to consider is that the Census information is tied to political/municipal boundaries, which do not necessarily reflect watershed boundaries. The Census further classifies the population in urban and rural. Urbanized areas often are associated with increased job opportunities (labor as part of the socioeconomic resources) and better health care options (institutions and part of the human social system) as compared to rural areas, but they also often imply increased demands and impacts on natural resources and services (USDA Forest Service, 2014). Fajardo's urban population is of 96.2% and in Ceiba is of 76.6%. For Fajardo around 57% of the municipality is contained within the Río Fajardo watershed. With 96.2% of its population classified as urban, the infrastructure to manage or mitigate this population's impact over the natural resources (Río Fajardo) should be appropriately scaled. Figure 5 presents the Puerto Rico Aqueduct and Sewer Authority (PRASA) service lines available in the region of the watershed. The scarce waste water infrastructure available to the non-urban population within the watershed is evident when compared to the potable water supply infrastructure. Considering the HEM, the analysis to improve the waste water infrastructure needs to consider the institutions and the socioeconomic resources available for this type of project. Another important factor for consideration in watershed management is that the increase in the number of Housing Units in Fajardo occurred in wards without sewer infrastructure. This information is important because the application of conservation practices requires the consideration of scales to distribute the responsibilities and commitment needed from the institutions for the effectiveness of the plan. PRASA has a Capital Investment Program (CIP) which main purpose is to modernize the infrastructure, protect public health, safeguard environmental quality, permit continued economic development and help bring PRASA system into compliance with all regulatory requirements (Fiscal Year 2014 Consulting Engineer's Report for the Puerto Rico Aqueduct and Sewer Authority). The CIP is revised as part of this report to considered actions planned by PRASA in the watershed.

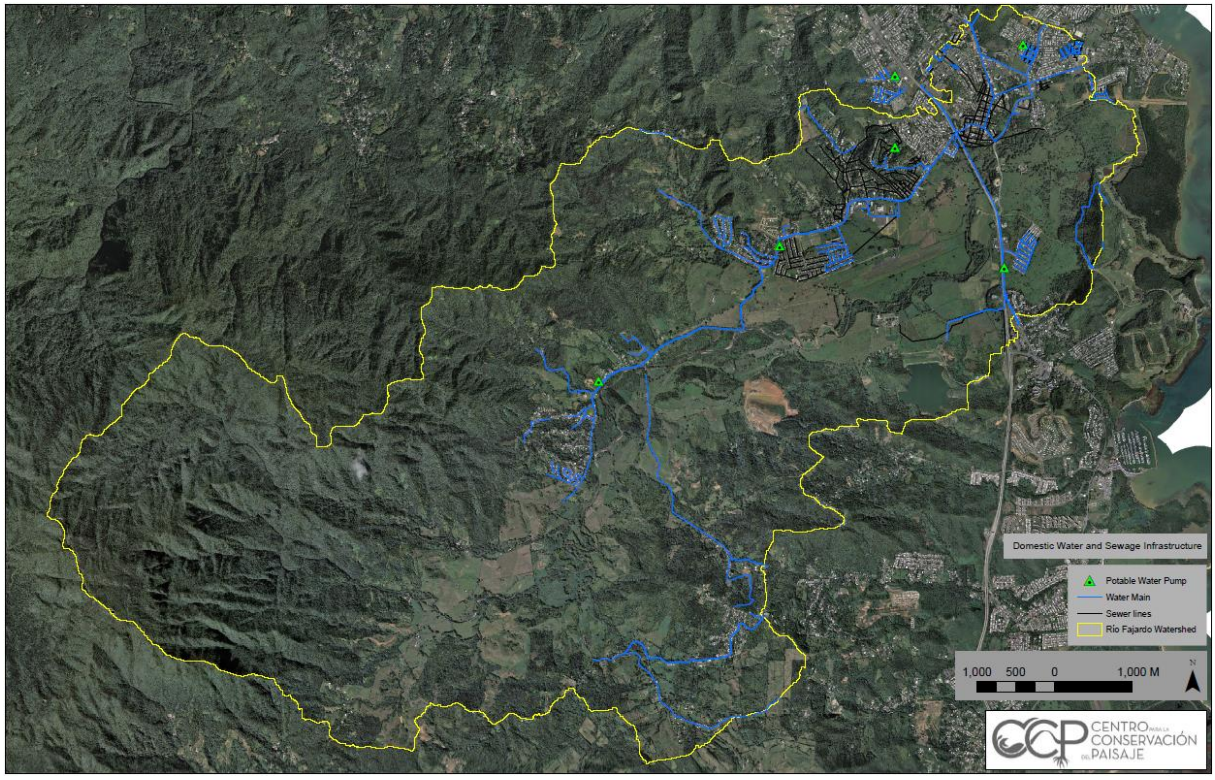


Figure 5. PRASA Infrastructure within the Río Fajardo watershed.

Socioeconomic conditions

Socioeconomic characteristics of a population can determine human well-being and this may possibly influence or impact the environment in which they live. A watershed program development must consider specific socioeconomic situations and the political structure in order to improve the effectiveness of watershed programs. (Peng, Chen, Lin, & Hong, 2013). Information is one of the variables evaluated under the socioeconomic resources considered in our analysis framework. Information flow can significantly alter numerous components of social systems such as educational institutions or hierarchies of knowledge (Machlis et al. 1997).

By reviewing the education levels in the population of the study area the hierarchies of knowledge can be considered in the development of a community interaction program. This information is critical to consider a strategy in which the resident can use and understand the institutional programs and the participation protocol. Knowledge also is important if a community management council is considered as an implementation strategy for the plan. In Puerto Rico, where the institutions are represented by federal and state agencies, a further consideration of the knowledge and understating of jurisdictional areas by the residents should be considered. We cannot expect an active and strong participation of the residents in watershed conservation programs if they don't understand the standards, guidelines and compromises of the programs.

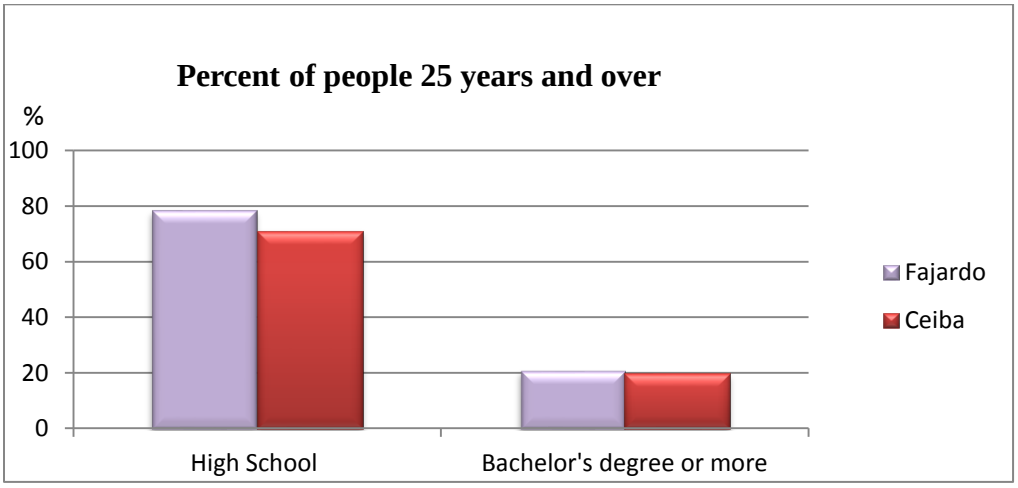


Figure 6. Education level of people 25 years old and over for Fajardo and Ceiba (2011-2013 ACS 3-years estimate)

The 3:1 ratio of people, 25 years of age and over, with high school diploma vs. the people with bachelor degree represents a big gap in the levels of education in both municipalities. This information is important in relation to the potential access to conservation incentive programs because if the resident does not understand the documents or processes the institutions will have lower participation. The need of a facilitator of information or an assistance program to help the residents to complete documents or to facilitate English translation should be an integral part of the management plan implementation.

In the revision of the employment rate for Fajardo and Ceiba we find similarities (see Figure 7) in the percent of employed populations and differences in the unemployment levels. In 2013 the labor force (16 years and over) of the total population was 51.4% from which 40.1% were employed and 11.3% were unemployed. For Ceiba, the 2013 labor force (16 years and over) of the total population was 41.8% from

which 36.2% were employed and 5.6% were unemployed. The principal occupations in Ceiba (29.2%) and Fajardo (26.3%) are sales and office occupations respectively. This information might need further analysis at the ward (barrio) scale to direct potential programs at the community level that might require labor.

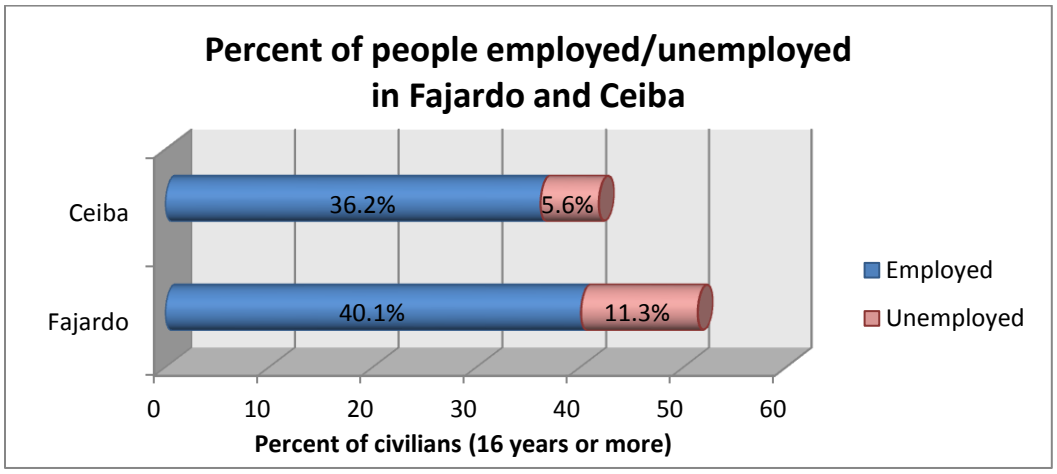


Figure 7. Civilians (16 years old or more) employment status from Ceiba and Fajardo. Source: U.S. Census Bureau, American Fact Finder 2013

Purpose and scope of the RFW evaluation

Through this document we identify management practices that can result in marine/coral reef habitat improvement by reducing or controlling land based sources of pollution. The applied evaluation of the RFW incorporates recent and updated land use analyses to identify land based sources of pollution related to sediments and pollution transference through the watershed and identifies and recommends appropriate management practices. The document also has the intention to consider an Integrated Watershed Management (IWM) approach for the area of interest to provide opportunities of available funds and programs directed towards improving water quality impairments.

The document includes a section that explains the characterization of the RFW from the physical aspects and human dimension components. This section explains the methodology used and the results obtained from the analysis. Through the document, references to the appendix section are made to provide further information of the analysis tools and processes applied. The document makes references to the EPA's nine elements of a watershed management plan to the greatest extent possible and follows recommendations of their Handbook for Developing Watershed Plans to Restore and Protect Our Waters (2008). The document provides recommendations and guidelines for the application of an IWM from the multidisciplinary team that worked the analysis; but it is important to remember that this is an adaptive management approach because of the history and stakeholders needed for this approach.

Implications of integrated watershed management in the RFW

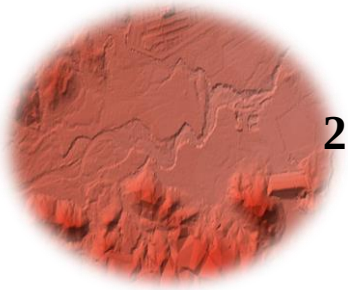
We can discuss examples where practices or management strategies were not successful in achieving the conservation goals in a watershed. Some of these documents include excellent analyses and recommendations, but falls short in the implementation. The scenario of the study area for the human dimension considerations are discussed in the third section of the report and provide the social system analysis to consider the integration of the residents and actors of the watershed in its management. The

analysis achieved for the project focused the potential conservation practices and management recommendations on different components, not exclusively on water. As part of the findings and management recommendations we incorporate and review documents from different sources and from different resources management strategies for watersheds.

Limitations

The project was originally conceived for an extended period of analysis (18 months), however due to time and resources constraints the analysis and data collection time was reduced to 7 months. In this type of analysis, the recognition and understanding of the flow of actions and information between the actors or stakeholders of the watershed is critical to recommend practices and strategies with higher potential of application and success in the plan. The analysis of these flows of information and actions require a more detailed social network analysis that involves a longer consultation process. This type of analysis will help to recognize the human ecosystem components that interact between the social system and the critical resources (see Appendix B) of the watershed to guide the conservation practices and programs through the actors, institutions, cycles and other components of the human ecosystem that rule the Fajardo watershed.

Another limitation was the difficulties to reach some key personnel in state agencies and to get access to some properties in the watershed that were managed by private institutions. These limitations are considered in the analysis and specific recommendations are presented for land use agencies where a monitoring process is recommended. The public consultation processes provided a good feedback and response from the residents, but it was not possible to reach the point of discuss or consider a watershed community council because of the time limitations. The Centro para la Conservación del Paisaje (CCP), as an organization interested in the conservation of the region, will maintain the communication with the community groups and will promote the potential integration of watershed community councils.



2. Physical Modeling of the Watershed

One of the objectives of the analysis was to consider management recommendations according to the behavior of the water flow through the Río Fajardo watershed and direct those recommendations toward the reduction of sediments moved through the river because of the land uses applied in the study area. The physical modeling and analysis applied in the study was done using the Soil and Water Assessment Tool (SWAT). A public domain model, jointly developed by the United States Department of Agriculture Agricultural Research Service (USDA-ARS) and Texas A&M AgriLife Research that is part of the Texas A&M University system. The watershed to river basin scale model simulates the quality and quantity of surface and ground water to predict the impact of land use and land management practices. SWAT analysis is a widely used tool for assessing soil erosion prevention and erosion control in regional management of watersheds. The tool is used by federal agencies, universities and environmental consulting firms for this type of analysis. This section of the report goes over a description of the applied model and data associated for the study. The last segment includes a description of the results considering the land use and data applied to identify the average sediment yield for the entire basin and the main areas that contribute to this yield.

The ArcSWAT Model

The ArcSWAT is an ArcGIS extension and a graphical user input interface for the SWAT model. The model is physically based and computationally efficient, uses readily available inputs and enables users to study long-term impacts. The model is physically based therefore requires the integration and revision of specific data for the study region. Rather than incorporating regression equations to describe the relationship between input and output variables, ArcSWAT requires specific information about weather, soil properties, topography, vegetation and land management practices occurring in the watershed. The physical processes associated with water movement, sediment movement, crop growth, and nutrient cycling among others, are directly modeled by ArcSWAT using this input data.

This tool was chosen for the following reasons:

a) Designed to work with complex watersheds
b) Designed precisely for basins with agricultural activities
c) Most data available publicly
d) Works in conjunction the most used commercial geographical information system, ArcGIS, which is in wide on the Island.
e) The model will identify critical areas causing sediment loads that need to be controlled.

Methodology

Five physical variables were mapped over an equal raster grid covering the complete surface of the watershed. A geographical intersection (overlay) is calculated for all these layers and ArcSWAT models direct the relationships between water movement, sediment movement according to the land use and the

characterization of the variables. This exercise produces what the model identifies as Hydrologic Response Units (HRU); these are portions of a sub-basin that possess unique land use/management/soil attributes as defined in Chapter1: SWAT Input Data Overview of the documentation of the model for the 2012 version. Additional information of the model is presented in Appendix C.

A mobile application/web-map was developed to guide the technical personnel to the top sediment producing HRU's. As part of the methodology the following sections explain the variables worked and the data source to supply the model with the necessary records to provide the considered scenarios for the watershed.

Topography

Topography is an integral part of all hydrologic modeling, since it determines the surface flow of water and slope. For the study area, several sources of topographic data were available. Traditional Digital Elevation Models (DEM's), contour data from the United States Geological Survey (30 meters USGSDEM data) and two Laser Imaging Detection and Raging (LiDAR) datasets were combined in an ArcGIS terrain model to construct an accurate and current digital elevation model which could capture, with adequate fidelity, elements of micro-topography. The core of the LiDAR data is derived from 2004 United States Corps of Engineer (USCOE) mission, with additional data on the edges of the basin from the Luquillo Critical Zone Observatory (CZO) Río Blanco and Río Mameyes LiDAR Survey 2010-2011. Small gaps on the coverage were filled with the available 30 meters resolution USGSDEM data. Only LiDAR points classified as "ground" (i.e. last return) were utilized in the preparation of the DEM. Final resolution is 10 meters for the model. The digital elevation model constructed defines the raster grid upon which all other layers were mapped. Image 4 in appendix D presents the Digital Elevation Model of the study area.

Soils

Soil data was obtained from the Natural Resource Conservation Service´s (NRCS) Soil Data-mart. The soil surveys of El Yunque National Forest and Humacao and Eastern Puerto Rico were used and analyzed. Given that these surveys were not included in ArcSWAT soil database, a new database was created which contained the soil parameters. The original vector cover was created by joining both soil database layers and rasterizing over the DEM. ArcSWAT maximizes the use of the detailed Soil Survey Geographical Data Base (SSURGO) level soil surveys, as parameters are collected on a per-horizon basis. Image 3 of Appendix D presents the soils distribution in the watershed.

Table 3. Soil parameters

Soil name
Soil hydrologic group.
Maximum rooting depth of soil profile (mm).
Fraction of porosity (void space) from which anions are excluded.
Potential or maximum crack volume of the soil profile expressed as a fraction of the total soil volume.
Texture of soil layer.
Depth from soil surface to bottom of layer (mm).
Moist bulk density (Mg/m3 or g/cm3).
Available water capacity of the soil layer (mm H2O/mm soil).
Saturated hydraulic conductivity (mm/hr.).
Organic carbon content (% soil weight).

Clay content (% soil weight).
Silt content (% soil weight).
Sand content (% soil weight).
Rock fragment content (% total weight).
Moist soil albedo.
USLE equation soil erodability (K) factor (units: 0.013 (metric ton m2 hr.)/ (m3-metric ton cm)).
Electrical conductivity (dS/m).
Soil CaCo3 (%).
Soil pH.

Table 4. Soil types in the Río Fajardo watershed and area of occupation

Soil Name	Acres	Hectares
Aceitunas silty clay loam, 5 to 12 percent slopes	206.48	510
Bajura clay, frequently flooded	1.50	3.7
Caguabo clay loam, 12 to 20 percent slopes, eroded	0.28	0.7
Caguabo clay loam, 20 to 60 percent slopes, eroded	75.14	185.6
Cobbly alluvial land	35.99	88.9
Coloso silty clay loam, occasionally flooded	29.43	72.7
Cristal-Zarzal complex, 5 to 40 percent slopes	5.10	12.6
Dwarf-El Duque complex, 5 to 60 percent slopes, windswept	39.68	98
Fajardo clay, 2 to 10 percent slopes	2.55	6.3
Fajardo clay, 2 to 10 percent slopes, eroded	5.87	14.5
Fortuna clay	1.13	2.8
Gravel, Pits, Quarries	0.93	2.3
Humatas-Zarzal complex, 5 to 40 percent slopes	7.25	17.9
Humatas clay, 20 to 40 percent slopes, eroded	274.66	678.4
Humatas clay, 40 to 60 percent slopes, eroded	297.41	734.6
Los Guineos-Yunque-Stony rock land association steep	36.48	90.1
Los Guineos silty clay loam, 20 to 40 percent slopes, eroded	13.08	32.3
Los Guineos silty clay loam, 40 to 60 percent slopes, eroded	19.60	48.4
Luquillo-El Verde complex, 0 to 5 percent slopes, occasionally flooded	7.41	18.3
Mabi clay, 5 to 12 percent slopes, eroded	3.72	9.2
Mucara silty clay loam, 20 to 40 percent slopes, eroded	20.32	50.2
Naranjito silty clay loam, 20 to 40 percent slopes, eroded	83.72	206.8
Naranjito silty clay loam, 40 to 60 percent slopes, eroded	114.29	282.3
Not Complete	143.81	355.2
Palm-Yunque complex, 40 to 90 percent slopes, extremely stony	0.53	1.3
Reilly soils	104.82	258.9
Río Arriba clay, 2 to 5 percent slopes	7.98	19.7
Río Arriba clay, 5 to 12 percent slopes, eroded	61.70	152.4

Rock land	1.94	4.8
Sabana silty clay loam, 20 to 40 percent slopes, eroded	24.62	60.8
Sabana silty clay loam, 40 to 60 percent slopes, eroded	54.90	135.6
Tidal flats	0.28	0.7
Toa silty clay loam	209.80	518.2
Vega Alta silty clay loam, 2 to 5 percent slopes	8.87	21.9
Vega Alta silty clay loam, 5 to 12 percent slopes	51.09	126.2
Vega Baja silty clay loam, 0 to 3 percent slopes	82.43	203.6
Water	19.72	48.7
Wet alluvial land	11.05	27.3
Yunes silty clay loam, 20 to 60 percent slopes, eroded	61.30	151.4
Yunque-Los Guineos-Moteado complex, 5 to 40 percent slopes	7.77	19.2
Yunque cobbly clay,40 to 90 percent slopes, extremely stony	81.30	200.8
Zarzal-Cristal complex, 20 to 60 percent slopes	154.17	380.8
Zarzal very cobbly clay, 40 to 90 percent slopes	289.23	714.4

Land Use

Land use/land cover data was created by interpretation of 2010 air photography, which provides a higher resolution image, necessary for the extent of the Río Fajardo watershed. Final interpretation was revised and verified for major changes against 2014 Landsat 8 satellite panchromatic sharpened images at 10 meter resolution. Land use/land cover classification was ruled by ArcSWAT's land use land cover scheme, which is required in order to operate with the specific algorithms. Figure 8 presents an image of the land use for the study area and another image printed at an 11" x 17" scale is included as Image 6 in appendix D. It is important to identify that 56.5% of the watershed is under forest and some of this area is under the jurisdiction of the Forest Service as part of El Yunque National Forest. The Forest includes a proclamation limit that although is not National Forest designated lands can be considered in potential extensions of the designated limits of El Yunque. Land use activities associated with agricultural activities also cover a significant portion of the watershed, especially in the flood plain and areas close to the riverbeds.

Table 5. Land Use and Land Cover Classes

Land Use/Land Cover	Acres	Hectares	% Coverage
Agriculture	108.2	43.8	0.6
Row Agriculture	32.3	13.1	0.2
Barren	268.3	108.6	1.6
Forest	9,501.5	3,845.1	56.5
Pasture	2,374.3	960.8	14.1
Range	1,531.1	619.6	9.1
Urban: commercial	31.1	12.6	0.2
Urban: industrial	42.0	17.0	0.2
Urban: institutional	66.6	27.0	0.4
Urban	66.3	26.8	0.4

High Density Housing	181.0	73.3	1.1
Low Density Housing	453.7	183.6	2.7
Medium High Density Housing	465.1	188.2	2.8
Medium Low Density Housing	128.0	51.8	0.8
Transportation	308.3	124.8	1.8
Water	199.9	80.9	1.2
Plantains	75.6	30.6	0.4
Hay	848.2	343.3	5.0
Wetlands	32.4	13.1	0.2
Bermuda Grass	94.5	38.2	0.6
Totals	**16,808.6**	**6,802.2**	**100.0**

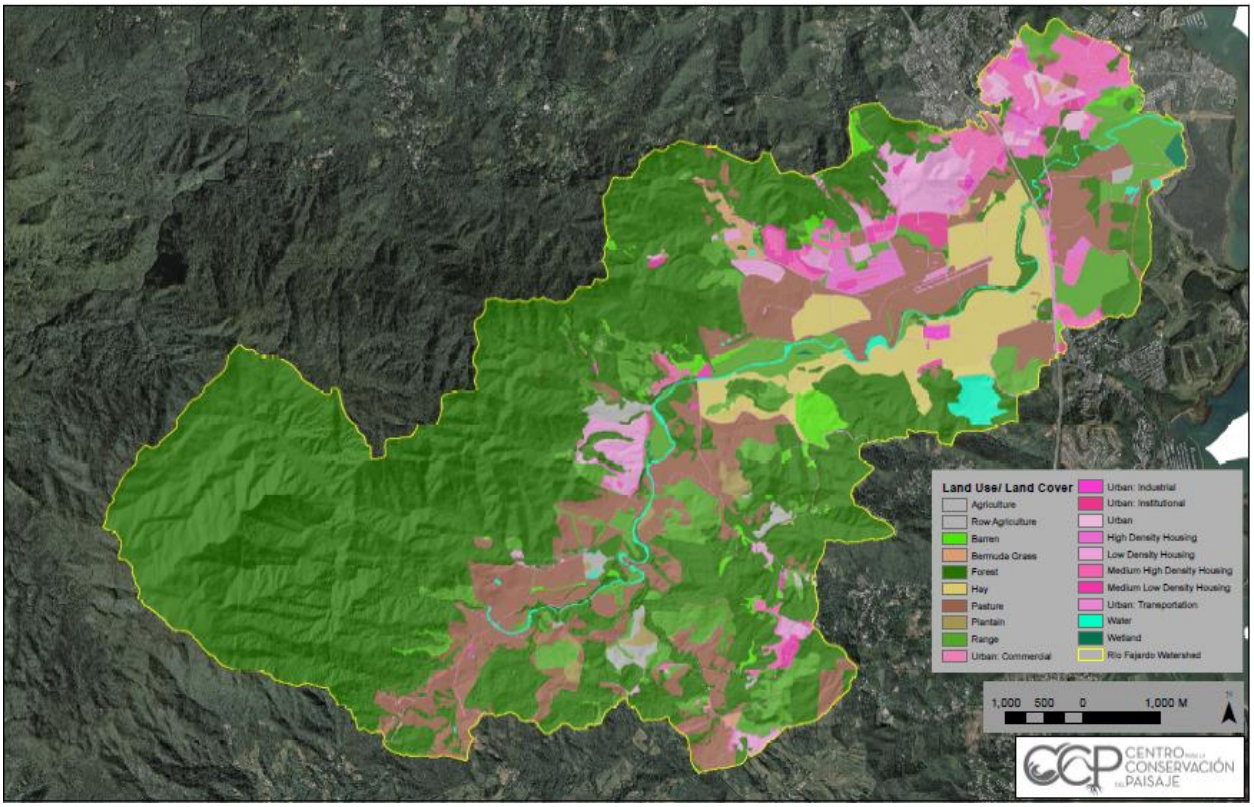


Figure 8. Land uses/ Land cover for the Río Fajardo watershed.

Climate

Daily weather records were obtained from the weather stations in the area. The span of time found to have the greatest number of stations available was comprised by the years 1979 to 2010. Weather stations in Fajardo (18.333°N, 65.65°W, 7m), Pico del Este at El Yunque National Forest (18.2667°N, 65.76°W, 1051m) and Roosevelt Roads (18.25°N, 65.633W, 12m). Daily reading for rainfall, relative humidity, maximum and minimum temperature were obtained from said stations while solar irradiation and wind were simulated from global weather models within SWAT's model. Data gaps were also managed with the same global weather model.

Hydrology

In addition to the drainage network derived from the DEM described above, additional hydrological information was obtained to perform calibration and validation of the model. The "USGS 50071000" streamflow monitoring station located at Latitude 18°17'56.22", Longitude 65°41'37.78" was able to provide water discharge data since 1961 to the present and sediment data (discharge and concentration) from 1982 to 2005. Both date ranges are within the simulation period. The hydrologic network for the Río Fajardo watershed is presented in image 2 of appendix D.

The Puerto Rico Aqueduct and Sewer Authority (PRASA) withdraws 12 million gallons a day for drinking water treatment and the Fajardo Regional Waste Water Treatment Plant has an NPDES permit to discharges 9 million gallons a day of tertiary treated (basically potable) water. Some of the revised literature cited in section one of the report mention the potential feed of this flow in to the Fajardo reservoir, in order to establish a partially closed loop, which potentially, should allow for smaller withdrawals from the river.

Based on the Environmental Protection Agency (EPA) Water Quality Assessment Status for Reporting Year 2012, the overall status of the water body is Impaired. Only fecal coliform bacteria have an assessment for total maximum daily load.

Table 6. Status for designated uses of Río Fajardo (EPA 2012)

Designated Use	Designated Use Group	Status
Aquatic Life	Fish, Shellfish, And Wildlife Protection And Propagation	Impaired
Drinking Water Supply	Public Water Supply	Impaired
Primary Contact Recreation	Recreation	Impaired
Secondary Contact (Recr)	Recreation	Impaired

The Puerto Rico 305(b)/303(d) Integrated Report of September 2014 (EQB, 2014) presented an update of the Puerto Rico Water Quality Standards Regulations (PRWQSR). The document identified Río Fajardo as CLASS SD which includes surface waters intended for use as a raw source of public water supply, propagation and preservation of desirable species, including threatened and endangered species, as well as primary and secondary contact recreation. From this CLASS the designated are the same considered in Table 6 for the 2012 assessment. The 2014 report point out that for the aquatic life, at least one water quality standard was not attained (impaired or non-support assessment units). For the category of drinking water supply, the river attaining the applicable water quality standards in the 2014 report. In the contact designated uses (primary and secondary contact) the river water was designated impaired or threatened and it is expected that they will meet the water quality standards with the implementation of the adequate and corresponding control measures. For Río Fajardo the state developed TMDL has been approved by EPA for primary and secondary contact. The potential sources of pollution identified in the 2014 report were the same reported in the 2012 assessment (see table 8) recognizing low dissolved oxygen and surfactants as causes of impairment but the other causes of impairment presented in Table 8 were not registered in the 2014 report.

Table 7. Causes of Impairment for Reporting Year 2012

Cause of Impairment	Cause of Impairment Group	Designated Use(s)	State TMDL Development Status
Arsenic	Metals (other than Mercury)	Drinking Water Supply	TMDL needed
Cadmium	Metals (other than Mercury)	Aquatic Life	TMDL needed
Copper	Metals (other than Mercury)	Aquatic Life	TMDL needed
Cyanide	Toxic Inorganics	Aquatic Life	TMDL needed
Dissolved Oxygen	Organic Enrichment/Oxygen Depletion	Aquatic Life	TMDL needed
Fecal Coliform	Pathogens	Secondary Contact (Recr), Primary Contact Recreation	TMDL completed
Lead	Metals (other than Mercury)	Aquatic Life	TMDL needed
Mercury	Mercury	Aquatic Life, Drinking Water Supply	TMDL needed
Surfactants	Other Cause	Aquatic Life	TMDL needed
Turbidity	Turbidity	Drinking Water Supply, Aquatic Life	TMDL needed

Table 8. Probable sources contributing to impairment for reporting year 2012

Probable Source	Probable Source Group	Cause(s) of Impairment
Confined Animal Feeding Operations	Agriculture	Arsenic; Copper; Cyanide; Dissolved Oxygen; Fecal Coliform; Mercury; Surfactants; Turbidity
Landfills	Land Application/Waste Sites/Tanks	Arsenic; Copper; Cyanide; Fecal Coliform; Lead; Mercury
Major Municipal Point Sources	Municipal Discharges/Sewage	Arsenic; Cadmium; Copper; Cyanide; Dissolved Oxygen; Fecal Coliform; Lead; Mercury; Surfactants; Turbidity
Onsite Wastewater Systems (Septic Tanks)	Municipal Discharges/Sewage	Cyanide; Dissolved Oxygen; Fecal Coliform; Surfactants; Turbidity
Urban Runoff/Storm Sewers	Urban-Related Runoff/Storm water	Arsenic; Dissolved Oxygen; Fecal Coliform; Surfactants; Turbidity

The Puerto Rico 305(b)/303(d) Integrated Report of September 2014 (EQB, 2014) presents improvements in the water quality for the drinking water supply use. This variation is probably associated with the land use changes and improvements of the water use and management within the watershed by PRASA. The update of the PRWQSR presents that other parameters within the Río Fajardo watershed need to be considered to improve its water quality.

Calibration and Validation

In order to establish the validity of the model, a calibration and validation procedure is undertaken utilizing SWAT Calibration and Uncertainty Procedures (SWAT-CUP) software. The program could be

used to perform calibration, validation, sensitivity analysis (one-at-a-time, and global) and uncertainty analysis. The program links SUFI2, GLUE, ParaSol, MCMC, and PSO to SWAT and is public domain software. Any of the procedures could be used to perform calibration and uncertainty analysis of a SWAT model, but given the specifics of this watershed, and the type of data available for calibration and validation, SUFI-2 was the algorithm utilized for the calibration and validation. SWAT-CUP also has graphical modules to observe simulation results, uncertainty range, sensitivity graphs, watershed visualization using Bing map, and statistical reports. Further details of the SWAT-CUP are provided in Appendix E.

The "mechanics" of a calibration procedure are as follow:

a) The appropriate observed variables are chosen for the model
b) "Run" the ArcSWAT model and make sure to obtain output values for the period of time for which there are observed data, and have enough data for a second period of validation.
c) Specify parameters to be fitted
d) Process the output with the SUFI-2 algorithm in order to undertake global sensitivity analysis of the parameters and obtain the optimal values for the parameters.
e) Update parameter values and re-run the model
f) Compare output with second set of observed variables and determine validation.

Results: Identification of critical areas: How, Why and Where

Our main interest through this exercise and application of the model was to identify landscape sources of sediments within the Río Fajardo watershed. Those landscapes are associated with physical conditions and land use practices. Their behavior according to different weather conditions used in the model produce the results that are presented in Figure 9. The identification of these areas is interpreted according to the land use and actual condition of the sites to recommend conservation practices that can mitigate the production of those sediments loads. Figure 10 present an image with the land use/land cover conditions of the top sediment producing sites.

Statistical analysis of the model output, revealed an average sediment yield for the entire basin of 19.73 tons per hectare per year (tons/ha/yr) with a standard deviation of 86.45. HRU's with abnormally high sediment yields were identified as those producing sediments at a rate larger than 2 standard deviations from the mean and were selected for further management actions. Figures 9 and 10 simplify the identification of main sediment generating areas and the land use/land associated to proceed with the analysis of why this are top sediment production sites. The information evaluated in this analysis requires considering the link between the physical parameters and the human social system of the watershed that is associated with a specific land use/land cover condition. The next section of the report stage the analysis and methods applied for the consideration of the human dimensions parameters considering the human ecosystem framework applied in the study. Further analysis and judgements are discussed in the last section of the report about the results from the ArcSWAT to consider potential sediments reductions with the application of management practices. The development of management zones in the Río Fajardo according to the land use/land cover, special areas (landfill, water reservoir, National Forest proclamation zones, etc.), and community input is considered in the last section of the report.

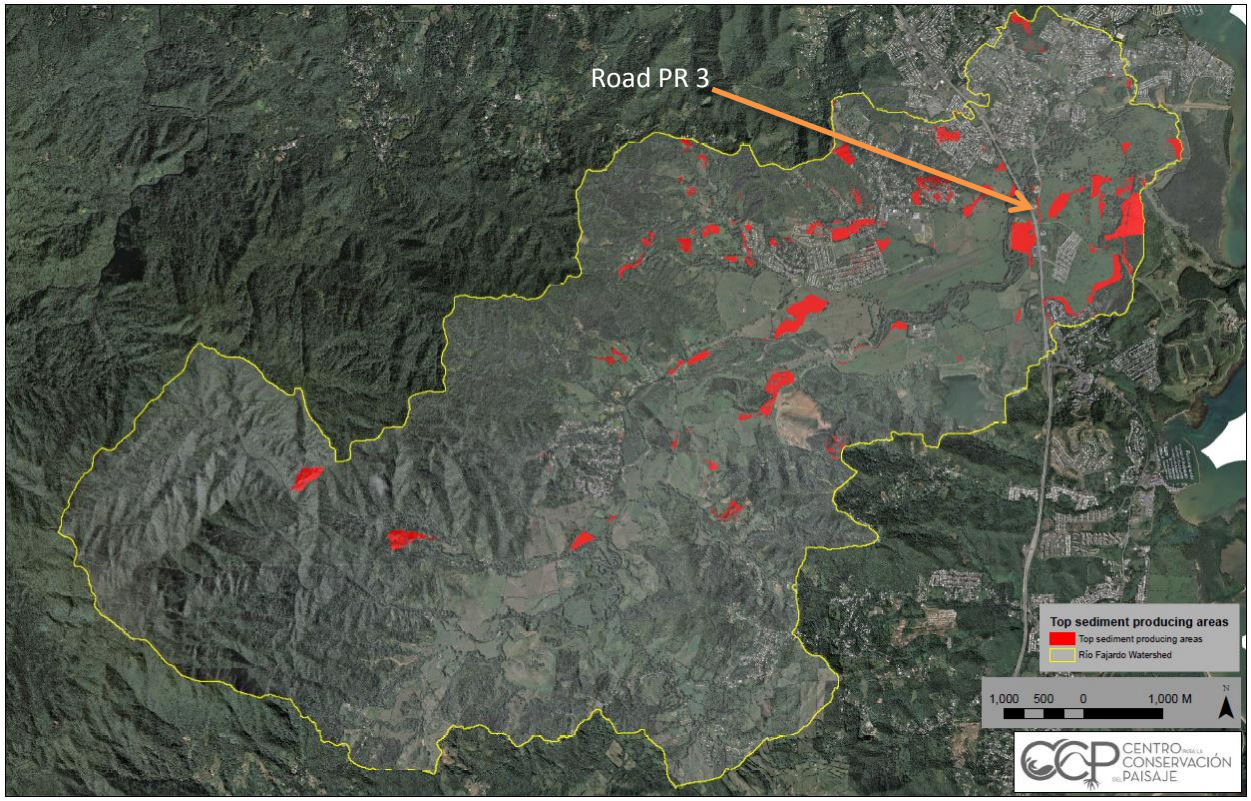


Figure 9. Top sediment generating areas according to the applied model for the Río Fajardo watershed.

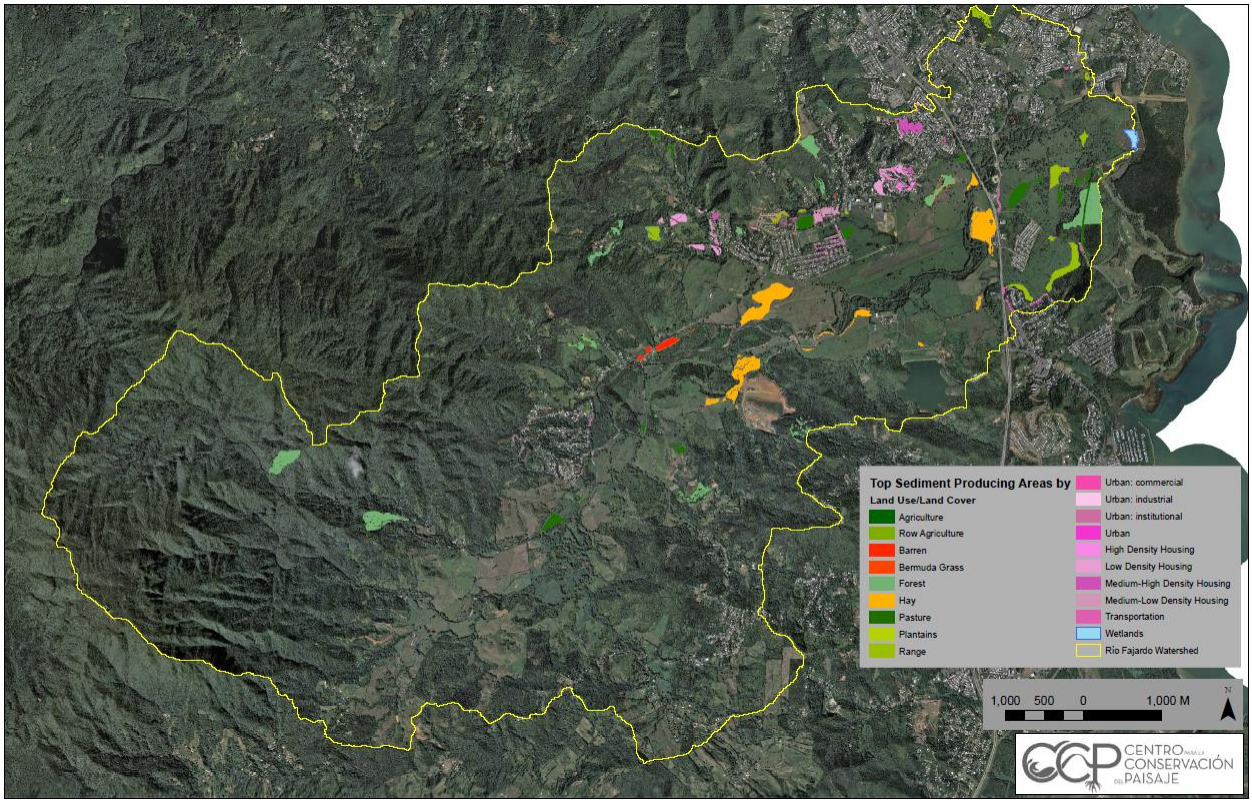


Figure 10. Land use/Land Cover of the top sediment generating areas for the Río Fajardo watershed.

3. Human Characterization of the Watershed

After going over the physical components of the natural resources in the watershed; this section considers the critical socioeconomic and cultural resources as well as the components of the human social system (social institutions, cycles and order) as part of the human ecosystem framework analysis. As Heathcote (2009) describes in the introduction of her book "very often, water management strategies have failed because they neglected to incorporate the full range of values and perspectives present among water users or agencies with an interest in water management". The human dimension is explored in the section as well as the participation strategy with different methods and applications used that can be considered for similar studies. The reflection of the key stakeholders map and the general considerations of the watershed from the landscape perspective, are part of the discussion directing us to identify the main concerns and issues that residents point out for the watershed.

Human dimensions

A holistic and comprehensive approach in watershed management is absolutely necessary to move environmental policy forward (Peng, Chen, Lin, & Hong, 2013). As an integral part of the analysis and to draft an effective watershed management plan, in this case for the Río Fajardo watershed, it is essential to include the participation of stakeholders. They are the people and organizations that have a greater stake in the outcomes of the watershed management plan. This is also a recommendation from the US Environmental Protection Agency, "one of the key characteristics of the watershed planning process is that it is participatory" (US EPA, 2008). The residents of these communities within the watershed or adjacent to it are those who can report on what is or has been happening over time that could change or affect the state of a basin. Kalibo and Medley (2007) recommend recognizing dynamic landscapes and human-resource relationships and elevating the importance of local knowledge in documenting and guiding landscape changes. People living in the basin may know different problems that may disturb the environments, livelihoods or people's health. It is pertinent, therefore, to include the participation of stakeholders for a watershed management plan. However, it is necessary also to acknowledge that such a participatory decision making process should be developed in communities or stakeholders own terms rather than imposing a certain logic or preconceived ideas coming strictly from Science or 'expert'-led knowledge (for a good discussion on this topic see (Heley, 2003)).

Participatory research with residents allows the understanding of resource diversity and its importance to local livelihoods (Kalibo & Medley, 2007). It is also very important for stakeholders to be part of the plan since its beginning because they probably will be the ones who will participate in developing management options and can benefit by the outcomes of the implementation of innovative policies. They can help to identify the funds and support the implementation of actions to improve the situations identified in the management plan. In brief, stakeholders are those who make and implement decisions, are affected by the decisions made, and have the ability to assist or impede implementation of the decisions (US EPA, 2008).

The Centro para la Conservación del Paisaje, Inc. (CCP) designed a public participation strategy to trigger the mobilization and participation of residents living in the Río Fajardo watershed. Through the strategy we performed several community meetings and interviews to include the participation of people, agencies and personnel from the municipalities of Fajardo and Ceiba to exchange valuable information between the communities and the organization. We are moved by the idea that: "[e]ducation, involvement and stewardship raise awareness of watershed issues and the importance of healthy watersheds" (Environmental Services City of Portland , 2006). Below, we present the methodology adopted in this plan in order to trigger a multi-scale exchange with different publics about the co-evolution of Río Fajardo watershed.

Methodology

The study area is described in the first section of this document and the description includes physical and historical aspect of the Río Fajardo watershed. The basin's delimitation shown in Figure 1 includes seven wards of Fajardo and two of Ceiba. The public participation and consulting process integrated interviews and meetings and an outreach process of visits and small gatherings with residents and community leaders recognized or identified by the residents. For each ward, after the initial outreach and familiarization process was done, a community meeting was organized in which a participatory mapping exercise was applied. Additional interviews with representatives of federal and state government agencies were done with similar approaches of collecting the main concerns to produce a picture of the internal structure of the institutions and the links with the socioeconomic resources and social order that sway the human dimension of the watershed. The demographic characteristics of these areas were considered according to the analysis framework and as described in the first section of the report.

Participatory mapping

> *"Participatory research should provide opportunities for local reflection and analyses that promote information sharing, consultation, and self-mobilization". (Kalibo & Medley, 2007 page 146).*

A key challenge in watershed decision-making has to do with how to engage the wider public in discussions, reflections and analysis about socio-environmental conditions impinging upon various ecosystems and in the identification of measures to advance landscape conservation across different scales. During our research, it was found that several methods or tools have been used to carry out the activity of participatory mapping. A study in Kenya used participatory research methods, where residents from local communities mapped and interpreted the distribution of forest resources and examined how it contribute to adaptive collaborative management for biodiversity conservation (Kalibo & Medley, 2007). Other method is participatory photo mapping (PPM) which "has proven an engaging vehicle for community participation" (Dennis Jr., Gaulocher, Carpiano, & Brown, 2009). To produce knowledge they used digital tools like participatory photography, geographic information system (GIS), global positioning system (GPS), and narrative interviews to study neighborhood safety and health. Participatory mapping -using photo mosaics- combined with interviews has been used to investigate land cover change (Mapedza, Wright, & Fawcett, 2003). The researchers concluded that "participatory mapping revealed greater detail about the timing and causes of land cover change than aerial photo analysis alone". Another project utilized Google Earth as a participatory mapping tool that would facilitate sharing understandings of the sustainability and climate change issues (Stocker, Burke, Kennedy, & Wood, 2012). Google Earth is a virtual globe, map and geographical information program that maps the Earth by the superimposition of images acquired from aerial photography, satellite imagery, and GIS 3D globe (Zomrawi Mohammed, Ghazi, & Eldin Mustafa, 2013).

The participatory mapping exercises for the project were accomplished using the Google Earth web tool as the working frame for the discussion. The participants pointed out in the images issues like land uses and environmental issues that they identified as negative impacts for the watershed or people's health. The exercise also included recommendations or actions that participants considered important to improve the watershed conditions in specific areas of their wards. The advantage and value of this process is that it provides a direct line of information of the residents making them part of the process and recognizing the information they know of the area where they lived for years. Most of this information might not be evident in aerial photographs or satellite images because the reference of the event is part of the living experiences of the residents. A detailed explanation of the participatory process applied is included in Appendix F. The main product of the participatory mapping process was the creation of additional digital information layers that were integrated in the analysis with information that was not tangible in the available digital layers for the region. Figure 11 shows one of the participatory mapping exercises and product of the process.

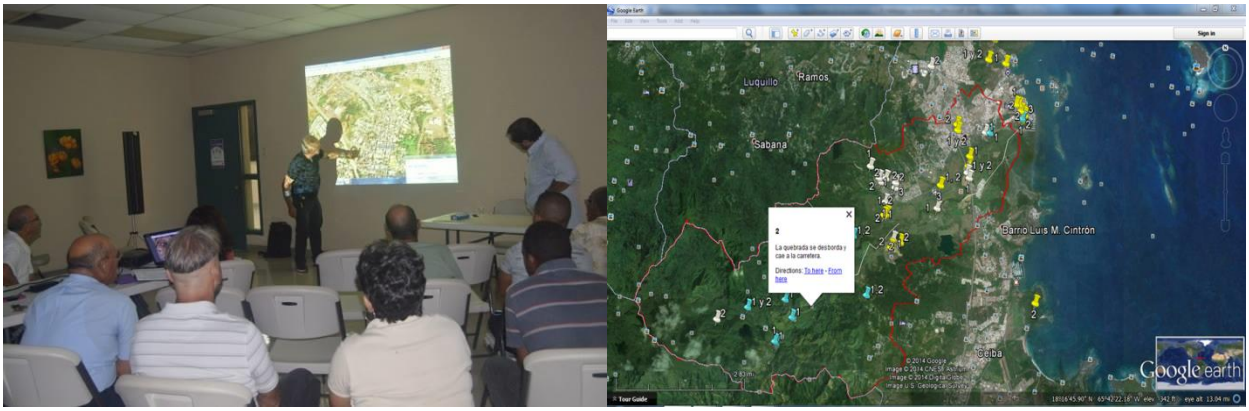


Figure 11. Participatory mapping exercise in Fajardo and layer with items identify by the participants.

One of the advantages of Google Earth is that the established points in the image are site specific and the issues can be positioned in the exact location where the residents identify the problem or need. The software also facilitates to move from a watershed scale to a ward scale as part of the exercise. The locations are saved in digital format and are recorded with coordinates for further field visits or revisions. Another advantage of using Google Earth is that the files can be shared through "Keyhole Mapping Language" (.kmz and .kml format) digital files.

With the produced maps, we were able to capture and analyze the uses, environmental challenges and proposed actions from the residents and also compare that insight with other types of GIS layers produced from the physical analysis explained in section 2 of the report.

Public outreach and community participation methods

Public participation was carried out through community meetings and interviews. The community and local contacts identification process was steer through an initial communication with the head of the planning bureau from the Municipality of Fajardo. Through this office a list of potential contacts of residents of the ward within the watershed was provided to establish contact with community leaders and residents. Other contacts were obtained from Upward Bound Program in the Interamerican University (IA-U) of Fajardo, the Centro para la Conservación del Piasaje records from previous projects in the

region, the Agricultural Extension Service office, and residents provided additional information as part of the meetings and contact process.

Three community meetings were conducted and for all of them, direct outreach contact, promotion flyers (Figure 12), radio announcements and even messages with a vehicle sound system through the streets of the ward. For the third community meeting we contacted a Naranjo's community leader, who helped CCP staff distribute flyers in each house of his community.

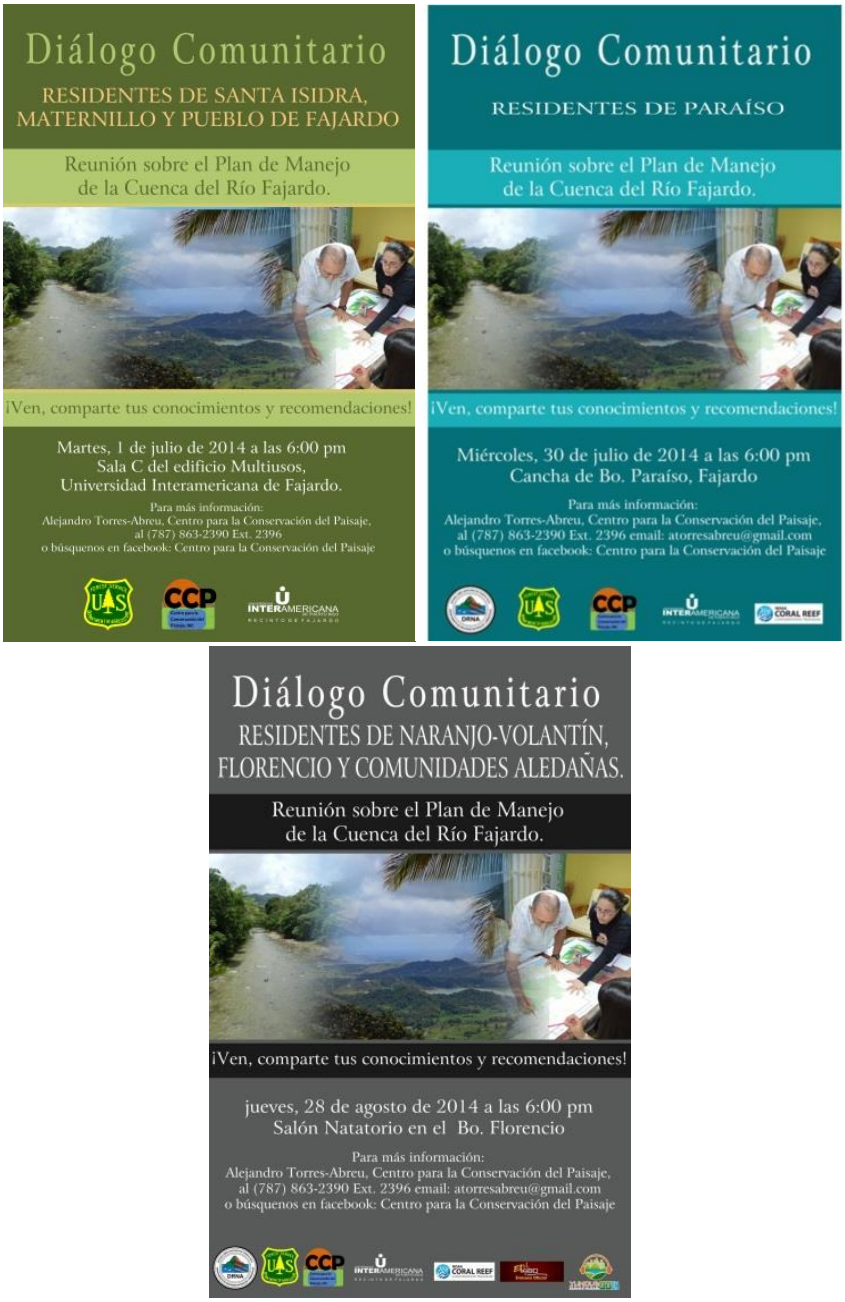


Figure 12. Flyers used for each of the community meetings.

The local radio stations were used to provide coverage for interviews, time to explain the project and promotional airtime to invite the communities to the meetings and to inform people about the project scope and emphasize in the importance of a watershed plan. The project's progress was presented through

radio interviews to develop the trust of the radio audience, increase the interest in the meetings and to raise the flow of information through other resources like the project webpage segment. We participated in WMDD 1480 radio and in Yunque 93 radio, on three occasions for each station, before the community meetings. Almost all radio interviews lasted about an hour to an hour and a half. During the interviews telephone calls were received that brought different concerns of the residents about Fajardo's river. Likewise, we had an interview in Radio Vieques, the first community radio of Vieques, which lasted half an hour and was played on two occasions during that day. In the course of all interviews, we requested people to visit the Facebook (FB) page, to visit the website for more information on the project and invite them to send their concerns and use the Twitter Challenge application (Figure 13) that was an additional community participation tool tested as part of the study. We counted an average of 300 visitors to the web page and Facebook after the radio interviews by monitoring the number of visitors received.

Figure 13. Twitter Challenge promo distributed in the communities and by electronic media.

Twitter challenge consisted in inviting people to identify problems or things that may impact or damage the watershed's health, take a geo-referenced picture with a cellphone and post it on Twitter using the hashtag #RiofajardoCCP. The application was more popular with students than with residents. For other projects we recommend that as part of the community meetings a section where an explanation of the application and how it can be used could increase its use and interest by local residents. The application can provide important information collected by the local communities and improve the data collected for further monitoring strategies, and with proper development, a monitoring tool in it of itself.

Another method to engage participation of community members tested during the development of the project was an online survey in CCP's webpage. The participation in the survey was very limited and less than ten persons completed the survey. We assume that low Internet penetration rates within the target

population might have had affected outcome. But, considering the framework we apply as part of the project that contemplates the different components of the study area as a human ecosystem, we recognize a disconnection of the project topics in public forums or forums for the general community as exposed in the radio interviews. The CCP web page posted news related to the project on August 2014 with pictures associated to a strong raining event in the region with photographs of the Río Fajardo condition and invited people to report areas that should be visited, the post reached 493 people. When CCP presented the project progress on Facebook, showing a video of updated land cover/land use map, it reached 2,458 people. These tendencies to participate or access the posted information through the digital media programs documented the progress achieved in the interest of the project discussion.

The effectiveness of the outreach and promotion process is documented measuring the reached people through our social media tools. According to Facebook analysis, the post for the first meeting at IA-U reached 96 people; for the second meeting in Paraíso 1,978 people were reached and a post in the same day reached 93 people; and for the third community meeting in Florencio, the post was reached by 4,180 people. The methodology shows that, as the project progressed additional sharing of the information could be expected and the integration of key residents provided additional attention to the project. This data show the increase of people interested in the discussion, but not necessarily by residents of the study area. The integration of a watershed council as part of the management plan application can provide a better definition of the local participants, but the outreach process applied can provide guidance for similar projects and community outreach strategies.

Key stakeholders

A key element in the identification of environmental problems and the development and implementation of effective watershed management strategies relates with the various practices, dynamics and relationships from different social groups enacted in the landscape. Several theoretical frameworks have stressed the need to continue strengthening public participation efforts in watershed management and trigger more direct exchanges with stakeholders in order to include their knowledge, experiences and concerns as part of the analysis to develop more inclusive plans (see for example Kalibo & Medley, 2007). In other cases, references are made about the importance of including the community into this analysis, but with a rather monolithic or romantic understanding about what a community is or entails really. Agrawal (1999), reminds us that within that generic label of a *community* there are often different subgroups with different approaches and values towards the environment. He further argues that the "uses", decisions and practices of these groups with the landscape: are the result of 1) an explicit or implicit negotiation process among social actors, 2) shared but changing and strategic community values, 3) alliances, partnerships and responses to different issues as part of the subsistence and resilience repertoire of communities or members within that community (Agrawal, 1999).

Following Agrawal, this section presents an analysis of the principal stakeholder groups within the Río Fajardo watershed. It departs from the idea that the mapping of stakeholders is not only crucial for watershed analysis but most importantly to reflect upon how to incorporate their perspectives and interests into watershed decision-making. This section also integrates the analysis framework presented in the introduction of this report which described the consideration of the different components of the study area as a human ecosystem.

As a local non-governmental organization working with different projects in the region, some of the CCP personnel have been able to chart some groups which are more prominent in terms of influence, practices and presence within the watershed. In Figure 14 we present a detailed 'map' of stakeholders within the Río Fajardo watershed. As part of the analysis at least eight main stakeholder groups or institutions are identified within the study area. Those are: 1) local residents, 2) farmers, 3) fishermen, 4) municipalities, 5) the academia, 6) environmental organizations, 7) outfitters or tourism operators, 8) federal and local agencies[1]. The provided map just delivers the initial identification of actors or stakeholders with an initial organizational structure to facilitate a snapshot of the potential extent in the establishments of the management plan and a watershed governance structure.

The main stakeholders and the considered "map of stakeholders" are pointed out in the following sections of the report to consider a general picture of the participation of each group and to foresee how we recommend their integration into the future watershed governance framework.

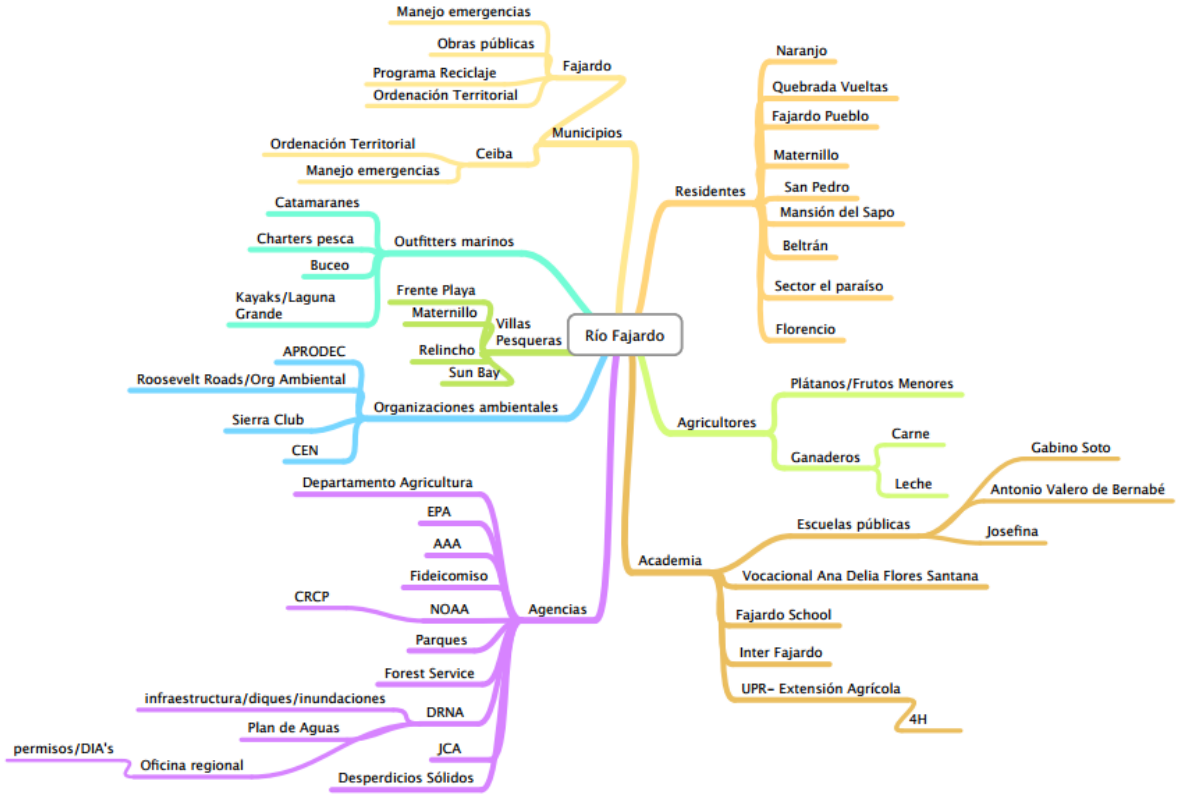


Figure 14. (Names in the figure are in Spanish) Key stakeholders identified in the Fajardo River Watershed.

[1] Of course, we are aware that some of these stakeholder identities overlap and that there are other influential groups as well. But this is the result of our practical insight within the region

Main community concerns

To strengthen our analysis of the community concerns we also adopted a conceptual framework from *Water and Sanitation services; Public Management* by Hukka and Katko (2009, p.153) that argue: "[…] water and sanitation services (WSS) constitute a social right of citizenship, and that there is a need to better integrate the public policy and management aspects of WSS within both analysis and practices". In Puerto Rico, besides the general acknowledgement of the lack of an integrated sewage management system in many rural areas (Plan de Aguas, 2008), there is a need to empirically document the uneven access to basic sanitary services and the possible impacts to the environment and human health. Although this is not necessarily the objective of this plan, it is important to stress the value and the position of communities and local ecological knowledge in identifying and addressing different environmental problems. Along this line, Torres-Abreu (2009) has argued that in order to understand current water challenges in the domestic sector it is not only crucial to focus on the infrastructural and expert-led management policies but also to document and integrate the cultural values and practices enacted beyond the matter into policy making. Considering this statement, we would like to maintain that local ecological knowledge and public participation is central to a more comprehensive and effective watershed management approach.

In this section, a summary of the analysis of several meetings organized in different communities in Fajardo to reflect about the Río Fajardo watershed environmental situation is presented. The main focus is over the environmental challenges that different stakeholders presented as issues of concern in their communities and close neighborhoods. We found that many of the issues presented are framed or understood as issues that could jeopardize the health of the watershed and people living within these communities. Other environmental issues were presented in the meetings especially in relation of illegal landfills. During the third meeting an illegal landfill was identified in a place usually called "Mata Gente" in the Street 984 Km 3.7, where people throw garbage, dead animals, oils and scraps. An interviewee also reported another illegal landfill in Río Arriba near "Charco Frío" produced by recreational activities and residential uses.

Figure 15 present the uses, problems and proposals presented in one of the community meetings done as part of our outreach and participation process. This process is considered an initial step toward the process of building partnerships as required in section 2.6 of the Handbook for Developing Watershed Plans to Restore and Protect Our Waters (2008). From the results of the community meetings some impairment and pollutant sources not evident from the images and the geographical information systems (GIS) were identified. This is an additional product of the participatory mapping exercises and support the steps in the watershed Planning and Implementation Process address by EPA's Handbook (2008) because the characterization and analysis tools of ArcSWAT did not require the community dialogues used to identify causes and source of pollution at the community scale. This approach combined with the identification of causes and sources of water impairment collected by the GIS analysis strengthen the plan and the propose implementation process. All the produced images are included in Appendix D.

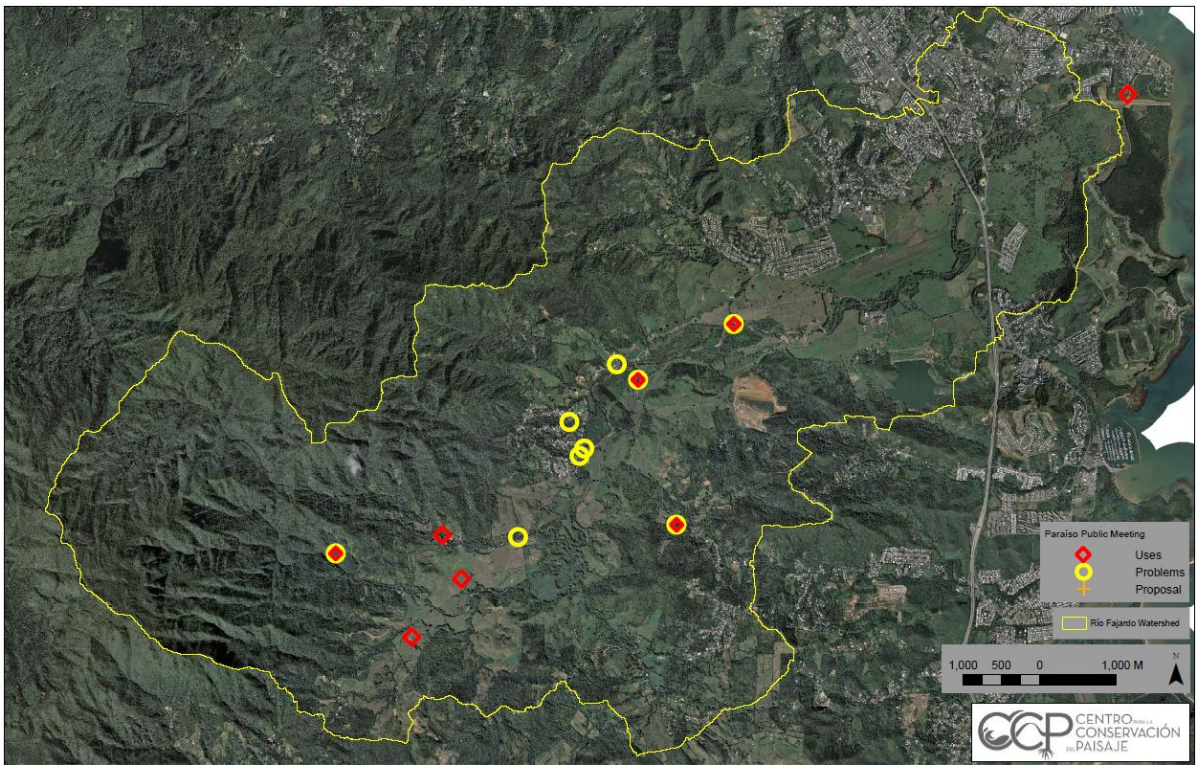


Figure 15. Uses, problems and proposals given by residents of Paraíso.

In Table 9 a summary of all the community concerns presented in the meetings and personal dialogues done during the building partnership steps of the plan are presented. The information is organized according to the environmental incidents that the participants recognized as important, especially in their ward. Most of these concerns and watershed conservation issues are identified with map locations and photographs as part of the participatory map techniques applied. The issues are further analyzed, discussed and considered for the application of conservation practices application in the following section.

Environmental incidents connected with RFW conservation and functions	CM #1 Pueblo, Maternillo and Santa Isidra	CM #2 Paraíso	CM #3 Naranjo and Florencio	Meeting #3 Municipality of Fajardo	Interview USFS	Interview Municipality of Ceiba	Interview leader of Chupacallos	Interview leader of Quebrada Vueltas
Floods and runoffs	X	X	X	X	X	X	X	
Sanitary waters	X		X	X		X		X
Damaged or lack of sewer system	X		X	X				X
Levees (no maintenance)	X				X			
Standing water		X						
Landfill and illegal landfills	X	X	X	X		X	X	X
Deforestation, sedimentation and erosion	X		X	X	X			
Structures that may fall into the river	X	X		X				
Changes in the rivers course	X	X						

*CM- Community meeting

** These incidents and issues where mentioned during the meetings, they are not necessarily present in their community.

Table 9. Main community concerns associated with the conservation of the Río Fajardo watershed.

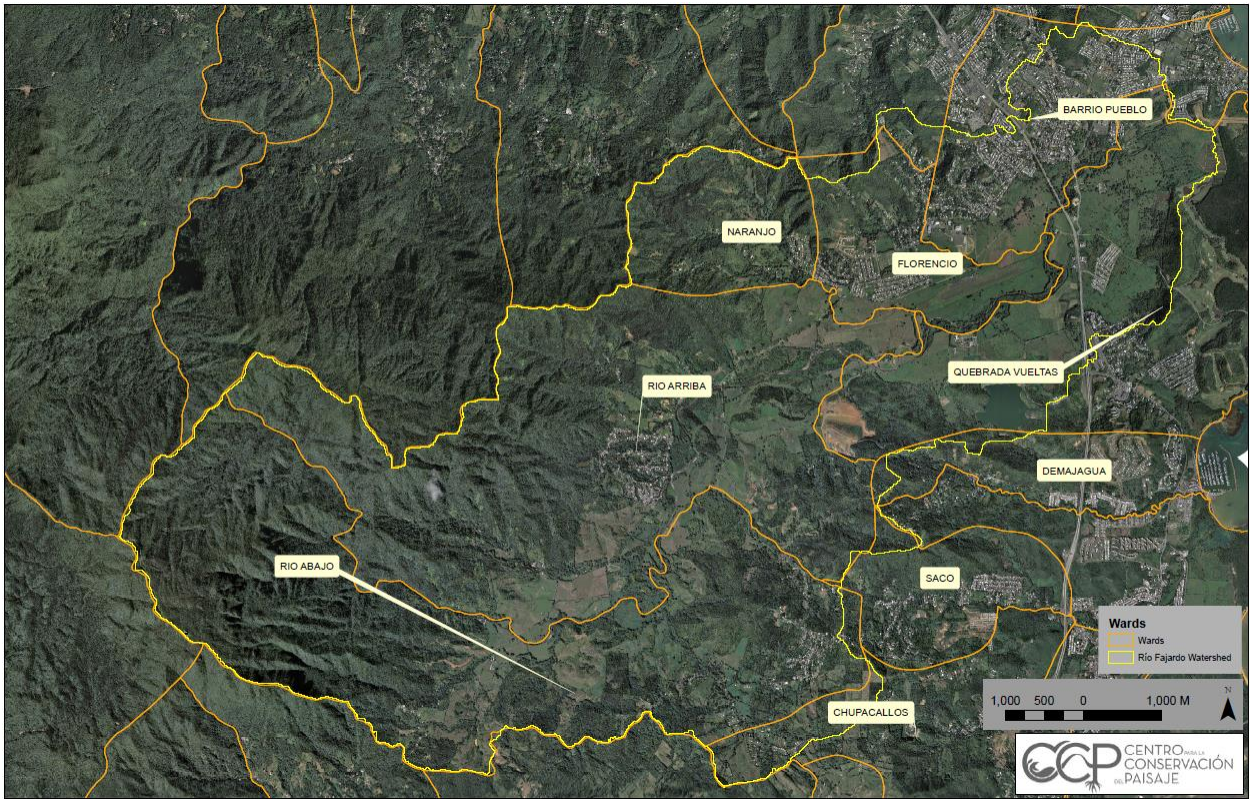


Figure 16. Location of the wards or barrios at the Río Fajardo watershed.

4. Results, management issues and potential conservation goals for the Río Fajardo watershed

This section provides the overall presentation and discussion of the main results of the analysis connecting to conservation goals expected through management recommendations applicable and needed to reduce the sediment load, problems and concerns collected. The section starts with the discussion, identified stakeholders and how we foresee their integration into the future watershed governance framework. The main community concerns and environmental topics are presented and discussed with management recommendations and specific locations to facilitate the consideration of conservation practices and potential practices that the residents and stakeholders can consider as part of the management plan. As the narrative and discussion of the concerns and environmental topics is presented, the issues will be summarized in one sentence and highlighted in a colored text box. The information of the section is also associated with appendixes to facilitate the read out of the report and not saturate the section with technical details and allocation of costs for the recommended practices that are provided in the appendixes.

The last part of this section includes goals and integrates the management recommendations providing proposals of implementation through a watershed governance structure as part of the management plan of the identified concerns and environmental topics in the watershed.

Analysis of stakeholders and local residents

The local communities or residents were the key stakeholders in the study area that provided and confirmed most of the pollution issues identified in the watershed. There are seven wards with communities living within the watershed (see Figure 16 and Table 1) that show transitional characteristics from rural, through suburban to an urban setting. But altogether, residential uses within the watershed constitute roughly less than 10% of the total land uses in the region. Within these communities there are different practices and human activities that have direct relationship with land-use patterns and planning decisions. Communities and wards are considered in our analysis according to the provision of sustenance (potable water, road system, agricultural activities and other critical resources) and the socioeconomic resources that dictates these communities.

To consider a few areas, Maternillo and Mansión del Sapo are communities located along the lower part of the river basin. The local fishermen represent an important stakeholder within the river basin. With more than four *pescaderías* (fish markets) located throughout the lower basin communities, local fishermen constitute an influential stakeholder within the community. There are also important stakeholder groups because historically these communities have experienced flooding events in their homes and this has represented a security issue for the community. This is also the experience in Fajardo Pueblo and other nearby communities such as Santa Isidra. Other more suburban or rural communities within the watershed are Paraíso, Florencio, Santa Isidra and Volantín. The mix of land-uses is important here as agricultural practices mingle with suburban domestic uses and activities.

Special attention is recommended for two areas of the watershed, first the segment east of road PR 3 and the second the flood plain of the Río Fajardo.

The communities and residents east of PR 3 are associated with a denser urban and institutional environment until the coastal areas are reached (Maternillo and Mansion del Sapo). Two main aspects are important in this area. First, is the proximity of the houses to the river bank in the loop of the natural river channel, plus the issue that there are no sanitary sewage connections in these residences. In the informal interviews conducted in this area some of the residents present their approval to the levees because their properties are not flooded and that will provide property rights to their houses. The houses represent a pollution problem at this area because of the use of septic tanks and poor used water collection systems. The second is the evident growth of vegetation through the loop of the natural river channel. The infrastructure of the levees established by the Department of Natural and Environmental Resources (DNER) at the river mouth needs to receive special attention because a better maintenance schedule is needed to keep the expected flows of waters through the natural river channel. The closing of the river banks because of the growth of grasses and vegetation can be associated with a sedimentation process of the natural river channel.

The residents of these areas presented concerns not only because of the closure process occurring in the river but because of the general maintenance of the levee structure. The local communities are interested and willing to participate in a monitoring or conservation projects to protect the natural river channel. Even the Municipality of Fajardo can be considered as part of co-management agreement with the DNER for a program of conservation of the levees and the natural channel of the river. In the river this is even more evident, as some of the fishermen's residences are located along its margins. This condition needs the consideration by

different institutions and should be led by the DNER.

Other areas identified as part of the flood control levee project are not under construction and flooding problems still affect some areas of Fajardo. Figure 17 was provided by the DNER and presets the Río Fajardo Flood Control Project with the considered levees highlighted in yellow.

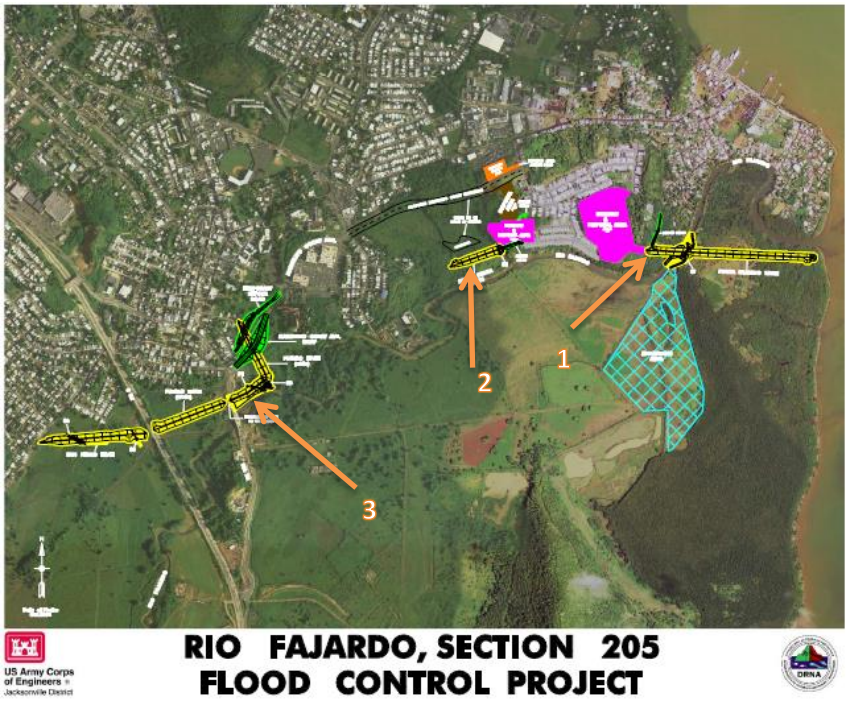
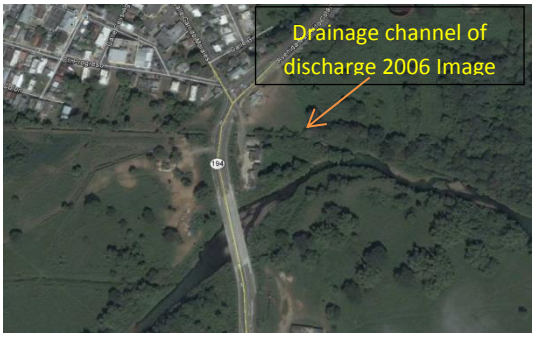


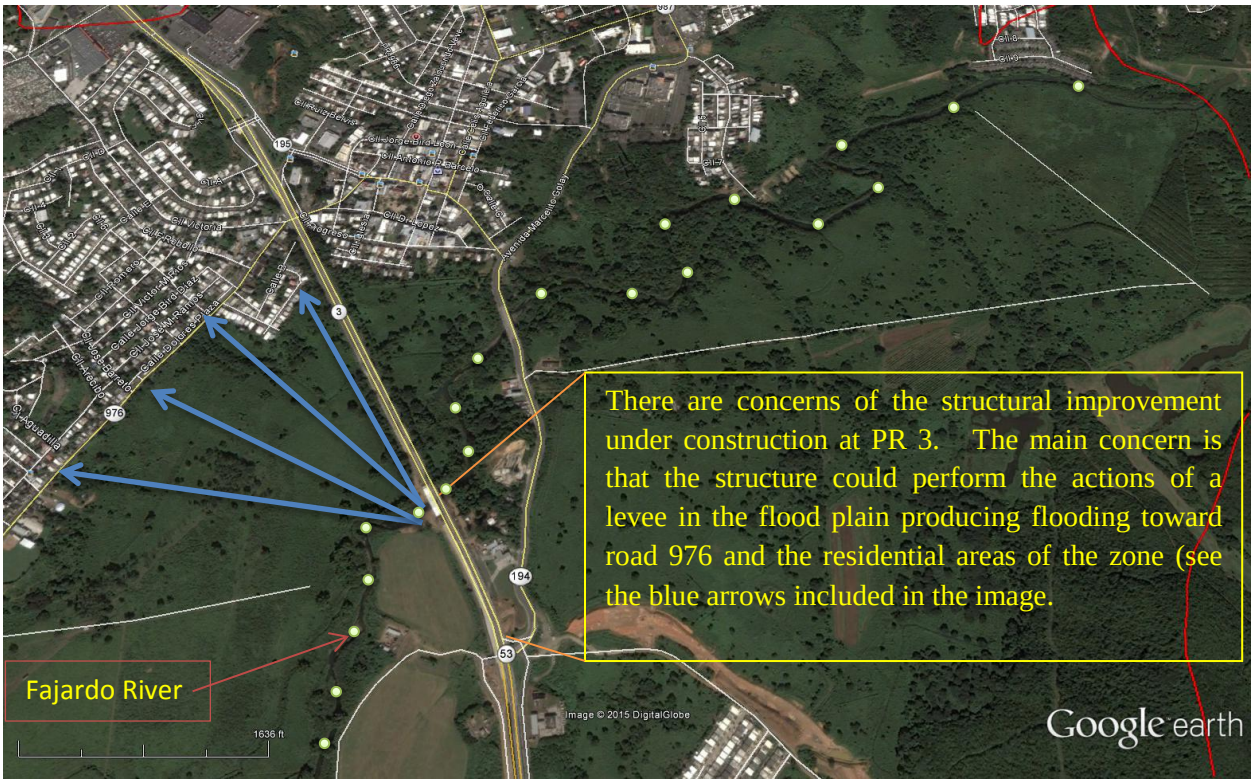
Figure 17. Río Fajardo Flood Control Project

Levees identified as 1 and 2 in Figure 17 were constructed and are functioning as expected. Levee 3 identified in Figure 17 has not been constructed and flooding problems were identified in this zone and has been reported as a problem by the Fajardo Municipality. The next images present another situation that could be related to the flooding events in the area and the old drainage channels must be revised if the flooding control project will not proceed with the construction of the third levee.



Another concern presented in the community meetings and pointed out in interviews with residents is the construction by the Puerto Rico Highways and Transportation Authority (PRHTA) in the connection of PR 3 and PR 53 over the river. Although the construction is considering the structural aspects of the river and its dynamics; most of the residents are worried that the construction will act as a dike in the flood plain creating flooding problems west of PR 3. The next image point out the neighborhoods with

concerns and this area must be considered under a monitoring program to review the response of the structural considerations applied in the construction.



ISSUE 1. Areas of the river mouth and levees for flood control in the eastern segment of the watershed. A review of the maintenance program and the potential participation of the residents should be considered to secure the water flow in the natural river channel. The sewage infrastructure in this area needs to be improved especially if the residents next to the river channel receive property rights. The Río Fajardo Flood Control project must be revised and continued to reduce flooding problems in the area. The improvement in PR 3 over the river must be monitored to review the response of the structural consideration in the construction in heavy rain events.

The land use and cover in the flood plain presents another issue that was discussed by the local communities and that was documented by field visits and is displayed through the ArcSWAT analysis (see Figure 9. Top sediment generating areas according to the applied model for the Río Fajardo watershed). It is recommended, to envision the flood plain as a critical management zone, to reduce the sediment loads and to apply conservation practices to improve water quality.

At the eastern segment of the flood plain (east of Road PR 3), the construction in areas too close to the river channel and in short-term flooded areas, plus the absence or low level of maintenance in the sanitary infrastructure, represents a critical issue in relation

to water quality. The following images document the problem of a collapsing sewage system in the urban areas east of road PR 3 and show the flows toward the storm drainage.

Even the infrastructure of the pump stations of PRASA shows some serious deficiencies that are reported by the residents and that represent a main concern in relation to water quality in the eastern segment of the watershed. Although several coordination phone calls and visits to the Fajardo office of PRASA were done, it was not possible to coordinate a formal meeting with the regional representatives of the institution. The 2010 Fajardo Land Use Plan document identified ten (10) pump stations and all of them must be reviewed as part of an organized monitoring program. The municipal authorities are worried about the waste water infrastructure and maintain communication with PRASA, but the problem continues without a clear work plan defined for its solution.

An interesting case was identified at the Santa Rita urban development because it does not have sanitary connections and a field visit recorded waste water discharges to the flood plain and wetlands of the lower part of the watershed. The 269 houses complex had a permit (C-AG-01-27-0002) for wastewater treatment systems without discharges into a water body granted by the Environmental Quality Board (EQB) granted in 2006 until 2008. This permit required that the treated wastewater needed to be discharged through irrigation onto the terrain. The community and the environment have been experiencing the flow of waste water since the abandonment of the wastewater treatment systems that was probably after the expiration of the permit. As the copy of the newspaper report included (dated October to November 2014) declares, the Santa Rita development issue will be corrected by the institution that financed the project. Although in early in 2015 the financing institution was closed by the Federal Deposit Insurance Corporation the new owner will be continuing with the correction plan for this situation. The wastewater treatment systems of Santa Rita will be closed and sealed because the housing complex will be connected to the PRASA waste water system. Particular follow-up to this issue will be done by the Centro para la Conservación del Paisaje with the Fajardo Municipality. A working group from the watershed management governance structure can be formed to maintain a follow-up plan for this situation and consider any mitigation process required because of the illegal discharges that occurred in the area. Another source of information about water quality in the region is the document "Estrategias para la identificación de fuentes de contaminación y el establecimiento de prácticas de control de erosión y sedimentación en los Municipios del Corredor Ecológico del Noreste, Puerto Rico" (September 2014). A segment of the document is included in Appendix J and sample points considered in the document could be evaluated to start a permanent monitoring process in the river.

8 MI REGIÓN
30 de octubre al 5 de noviembre de 2014

Corregirán derrame de aguas sanitarias

Doral asume responsabilidad

BRENDA A. VÁZQUEZ COLÓN
brenda.vazquez@gfrmedia.com

LUEGO DE siete años de que la comunidad Santa Rita en Fajardo sufriera de constantes derrames de aguas sanitarias provenientes de una planta de tratamiento cerrada, finalmente se está corrigiendo el problema.

La situación comenzó cuando el desarrollador Phillip Diorio Grande construyó un proyecto residencial de 269 casas, pero nunca le cedió al municipio, Autoridad de Energía Eléctrica (AEE) y Autoridad Acueductos Alcantarillados (AAA), las servidumbres para conectar los servicios de agua y electricidad.

18
Los meses que tiene Doral para solucionar el problema

Según el senador por el Distrito de Carolina, Luis Daniel Rivera, se hizo una pequeña planta de tratamiento que serviría temporeramente durante la construcción del proyecto para luego traspasar las servidumbres, pero esto nunca ocurrió.

"Esa pequeña planta acumuló una deuda de casi un cuarto de millón de dólares con la AEE, por lo que cortaron la luz y dejó de funcionar. La planta quedó en desuso y comenzó el problema de aguas sanitarias. La Junta de Calidad Ambiental descubrió que las aguas contaminan los terrenos aledaños y un cuerpo de agua que llega al río Fajardo", explicó Rivera.

El desarrollador evadió su responsabilidad y el Tribunal Superior de Fajardo obligó al garantizador del proyecto, Doral Bank, institución que financió la construcción, a hacerse cargo de la crisis ambiental generada.

"Tuvimos una vista pública en el Senado y logramos el compromiso de acción de Doral Bank ante las denuncias ambientales que han aquejado por largo tiempo a vecinos de la urbanización", indicó el representante.

El banco contrató a una empresa para acarrear las aguas contaminadas, mientras se corrige el problema de forma permanente mediante la conexión a la planta de tratamiento de la AAA.

SUMINISTRADA

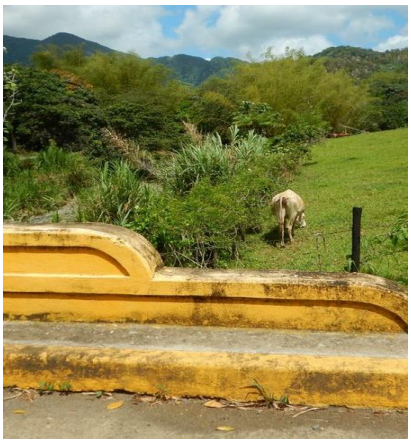
El Tribunal de Fajardo obligó a Doral Bank a corregir los daños ocasionados por los desbordamientos de aguas sanitarias luego que el desarrollador del proyecto evadiera su responsabilidad.

ISSUE 2. There are problems with the condition of the sewage infrastructure in the urban areas within the watershed and in its lower elevations zones. Water pollution is documented by the sanitary waters flowing through the storm drainages and is presented as a major problem by the residents. The areas with more concern are the ones east to road PR 3 and within the river flood plain. (See Figure 9 for reference of road PR 3)

As the flood plain extent from the coastal areas to the upper and highland regions of the watershed it basically overlaps the agricultural areas and the pasture identified in the land use/cover analysis. The stakeholders and institutions associated with the land use/cover for the flood plain areas, which overlap with the agricultural activities; need to be considered in the analysis for a better picture of the conditions and activities identified in our analysis.

According to our investigation, farming and small agricultural activities (20.8% considering agricultural activities identified as pasture management, plantains, hay, and etc. see Table 5. Land Use and Land Cover Classes) represent the second major land-use within the watershed (see Figure 8). The agricultural activities more evident through the landscape of the study area are milk and meat production with some activity associated with plantain, roots vegetables, and other minor crops farms, among others. The USDA 2012 National Agricultural Statistics Service documented for the Municipality of Fajardo that the main items were cattle and calves with a 64.6% of the land in farms in 2012 as cropland-pasture and 15.1% as pasture & rangeland (2012 Census of Agriculture Profile for Fajardo). Considering the spatial distribution and intensity of these activities, we could maintain that farmers are an important stakeholder group within the watershed due to a number of reasons: 1) their practices have a direct impact on the land (with different environmental results); 2) their practices coincide geographically with the watershed's alluvial flood-plain; and 3) agriculture represents a fundamental activity for the local economy and subsistence of livelihoods. In addition, different exchanges throughout the last years with agricultural groups within the region point out the willingness of farmers to adopt and implement soil conservation strategies in their farms. For all the above, any attempt to improve environmental conditions within the river basin has to depart from a more continuous and direct exchange with farmers and concrete measures through which reflecting collectively in the best management practices in the region. Considering the social order that farmers can represent in settings of hierarchy in the landscape we can consider that the farms reported for 2012 in the Fajardo Profile (Appendix G) range between 1 to over 206 *cuerdas* (.97 to 200 acres) (*1 cuerda* = .97 acres and 2.47 acres = 1 hectare) with the highest number of farm grouped in the 20 to 49 *cuerdas* size (19.4 to 47.5 acres). The average size of farms for Fajardo increased from an average of 67 *cuerdas* (65 acres) in 2007 to 75 *cuerdas* (73 acres) by 2012. Although the number of farms in Fajardo between 2007 and 2012 only shows a decrease in 5%; the market value of products sold (crop sales and livestock sales) and the average per farm market value of product sold decreased in 64% and 62% from 2007 to 2012 respectively. This data is significant if we contemplate the application of conservation practices and the economic scenario of these stakeholders to undertake the application of practices without an appropriate economic incentive.

Another consideration in the evaluation of the farmers as key stakeholders in the RFW is that a segment of the flood plain, where agricultural activities are applied, is owned by the Puerto Rico Land Authority (see Figures 6 and 9 in Appendix D) and this can be considered from a positive or negative view depending if the agency preserve a standpoint to use the territory for agricultural activities with the proper conservation practices. The results of the analysis for the flood plain west to Road PR 3 present us that conservation strategies needs to be considered at two scales. One of them is related to the specific cases of farmers that are land managers (they have renting agreements with the Puerto Rico Land Authority) and the other is considering the bigger scale of the land tenure by institutions that establish the hierarchy in the territory. Some of the concerns identified in this zone at the farmer scale include over grazing and the appropriate application of chemicals as part of some practices. There are also good examples of the application of conservation practices by farmers of the area, but considering the river flood plain as a management zone requires a stronger organization of activities with monitoring strategies that can guide the progress and effectiveness of the conservation practices. The discussion of potential conservation practices and the local needs could be developed through the Local Working Group (LWG) mechanism supported and used by NRCS. The NRCS defines the composition of the LWG as groups composed of agricultural producers, nonindustrial private forest land, professionals representing agricultural and natural resources interests, and individuals representing a variety of disciplines in the soil, water, wetland, plant, forestry, and wildlife sciences who are familiar with agricultural and natural resource issues in the local community. This recommendation links the strategies with a route to an integrated watershed management initiative, but needs the participation of local residents and could not be managed as an outside administrative program. The LWG can be created in a community meeting and the group can submit a request to the NRCS District Conservationist to be recognized as a LWG to have a forum and discussion space to move forwards their needs and recommendations with the assistance of the NRCS.



Overgrazing was also identified in the areas of generating higher amounts of sediments (Figure 9. Top sediment generating areas according to the applied model for the Río Fajardo watershed). This activity affects riparian areas because livestock use these spaces for extended periods. It was evident that some farmers were maintaining the protection of the river or stream banks, but other used the space without a clear conservation plan or management strategy of pasture rotation for their animals. The NRCS provide assistance for these areas because riparian areas have received increased emphasis in recent years in many agency policies and programs. The Environmental Quality Incentive Program (EQIP) can be a recommendation to consider at the farmer or landowner scale. EQIP is a conservation program for private lands whose main objectives are to improve soils, water, air and related natural resources. It provides financial and technical assistance to farmers. The LWG can provide assistance to facilitate the process and provide workshops to the residents for the EQIP documentation process. From informal interviews of the residents one of the identified

constrains in the use of this type of incentives is the documentation required and bureaucracy involved in the administrative process.

From the farmer's and landowner's scale our analysis extends to the bigger scale of the riparian areas of the Río Fajardo. The riparian areas are within the flood plain, but because of the historical and social events the river bank is next to a road in some areas of the watershed. The dynamics of the river channel considering the historical land uses over the watershed requires a structured analysis of the riparian zones. This type of assessment is not only needed in the Río Fajardo watershed but probably in many other regions of the island. We recommend establishing an interdisciplinary team led by the Department of Natural and Environmental Resources to work toward a national classification system and evaluation procedure for riparian zones using the Fajardo River as the case study. This recommendation is presented because of its standing in relation to the impacts over a coral reef priority area in Puerto Rico and because of value of the watershed for water management strategies at PRASA. The developed facilities for the reservoir and the water treatment plant established by PRASA represent a major infrastructure development that requires special consideration at the watershed scale by the government. A national classification system and evaluation procedure for riparian zones can facilitate the merge of initiatives and programs of different agencies. An organized and structured analysis of the riparian zones could provide information on the extent and condition of the areas that could then be used to focus agency policies and programs and natural resource planning actions. The need for better and continuous communication between agencies is recognized and we make reference to the stakeholders map (Figure 14) presented because according to our analysis the institutions associated with the watershed management initiatives operate without effective coordination between their programs. The conservation institutions (NRCS, NOAA, EPA, DNER, etc.) present a noticeable communication initiative through committees and working groups, but a further vision of the stakeholders map and the network created by them is needed to reach the watershed management governance structure.

ISSUE 3. The Fajardo River flood plain requires special attention because of the land use/cover activities identified. The farmers and institutions associated with land use need to consider alternatives to improve the application of conservation strategies especially at the riparian zones. The Río Fajardo flood plain is recommended as a special management zone and a national classification system and evaluation procedure for riparian zones is recommended using Río Fajardo as the initial study case.

The governmental institutions are a key component of environmental policy and protection programs that might help in the conservation and management of the Río Fajardo watershed. In the revision, we identified some of the main state agencies associated or responsible for the Fajardo watershed conservation. They can be divided into federal and local. The local ones are: Department of Natural and Environmental Resources, Environmental Quality Board, Solid Waste Authority, National Park Company and Department of Agriculture. The federal ones are: Forest Service, National Oceanic and Atmospheric Administration (NOAA), Fish and Wildlife Service, Environmental Protection Agency and in a lower scale the Army Corps of Engineering. There are other agencies and institutions that use the resources of the watershed, like PRASA or that have ruling authority (Municipalities, PR Planning Board, etc.) at certain levels or scales of the watershed but that their main concern is not watershed conservation.

At the watershed scale, the DNER should have a leading role in the implementation of the plan because of its legal and constitutional responsibilities of guiding local environmental policy, especially with the water resources. As we discussed before, the land tenure related to the floodplain where most of the agricultural activities are happening are under the control of the Puerto Rico Land Authority, an institution that is under the direction of the Department of Agriculture (DA). As a local agency linked to the territory and the potential socioeconomic resources associated to the agricultural activities and norms of the region the DA has a key role in watershed management. The presence and active participation of the DA in any watershed management governance structure is critical and essential. Considering institutions which are connected to the use of resources, but are not the main regulator of the condition of the resources, we have to point out the Puerto Rico Aqueduct and Sewage Authority (PRASA), which runs the entire drinking water and waste water infrastructure in the watershed. The federal agencies more directly linked to the topic of land tenure and control is the Forest Service, being one of the main land-owners within the watershed establishing an important hierarchy in relation to land tenure. In the watershed landscape the zone designated as National Forest includes 17.01% of the watershed area and a further 21.3% of the watershed area is inside the proclamation boundary established for the National Forest. The recognition of the institutions that controls the land tenure is important in the watershed management governance structure to define or consider conditions or strategies that might benefit those institutions as conservation strategies are implemented. This analysis of institutions can also consider the coalition of related agencies to consider joint projects for budgeting considerations. For example, the EQB, EPA,NOAA can help to sets the framework for watershed protection and the pollution standards for the protection of coral reef ecosystems and promote conservation initiative inside the National Forest proclamation zone with the assistance of the State and Private Program of the Forest Service.

To understand the complete network of institutions and stakeholders we recommend applying a social network analysis in the Río Fajardo watershed to categorize the actors and theirs attributes that in some cases are dictated by the norms established by the agencies. This document is intended to help with the identification of specific actions to accomplish the conservation of the Río Fajardo watershed, but a better defined watershed governance structure is needed to accomplish the management proposals. This recommendation is directed to promote the success of the proposed management strategies. The system of formal and informal institutions within the watershed are the ones in which the management actions are implanted and which provide the critical leadership, funds and structure needed to meet the watershed conservation goals. After the analysis applied for the project, we could not identify a defined governance structure to apply to the watershed management plan, although fragmented initiatives and programs guide the main conservation strategies in the region. The recommendation of establishing the DNER as the lead agency in a watershed management governance structure was already presented, but we propose a stronger and continuous presence in the watershed that could be accomplished by the institutions represented by the municipalities. By working together, the DNER and the municipalities can coordinate a watershed technical committee that can provide the forum to maintain a structured work plan with goals and monitoring parameters for the application of the watershed management plan. The municipal authorities could work at the LWG level and facilitate the management activities with local community groups. We insist in the need to perform a social network analysis before the watershed management governance structure is established because this information will provide the actual and current communication and interaction or the absence of communication between the stakeholders. The process to incorporate the watershed governance structure could develop what we identify as the Río Fajardo watershed Management Board (RFWMB). The integrated administrative organization is essential and

central for the achievement of the recommended management practices. The final integration of the RFWMB could be more complex than the development of a list of conservation practices, but it upholds an integrated watershed management system.

ISSUE 4. There is a need to establish a watershed management governance structure to reduce the fragmented and sometimes conflicting conservation actions applied at the watershed level. The DNER should be the lead agency in this initiative and a social network analysis of the stakeholders identified in this report, it is recommended to organize and understand the characteristics and standpoints of key actors and institution for the implementation of watershed conservation actions through the governance structure.

Since the beginning of the analysis for the report, we have approached both municipalities within the watershed (Fajardo and Ceiba) in order to better understand their land-use policies, compliance record with different environmental regulations and exchange valuable information about the river basin. Those exchanges have allowed us to identify some components within these municipalities to advance environmental management and respond to environmental challenges. In Fajardo Municipality, it is important to mention: the Bureau of Land-use Planning, the Recycling program, Emergency Management and Public Infrastructure. The Municipality's connections with EPA's municipal separate storm sewer system (MS4) permit, Landfill technology (the company in charge of the landfill administration and management), the different community boards and other efforts within the region demonstrate its central role in defining and influencing land-use policy within the watershed. In the Municipality of Ceiba there is no formal Storm Water Management Program although there is a letter of intention toward this direction.

The municipalities represent a tactical stakeholder because they will have a big number of contacts in the watershed (people require services and the municipality is first in line as connection for the residents) and they can be a link between actors or institutions that did not communicate between themselves. For example, for residents of Paraiso ward is easier and will be simpler for the follow up of actions to talk with a municipal representative than with an Environmental Quality Board officer. At the municipal level we identify potential opportunities to improve the storm water runoff programs. The municipal programs, especially in Fajardo, are organized and applying actions according to their Storm Water Management Program. The initiative and activities of this plan could be improved with a stronger outreach structure that could be supported with federal funds. The integration of community councils and the facilitation of educational and monitoring tools could be integrated in the program to reduce the work load over the municipal employees and develop a stronger community relation with conservation initiatives.

There are also problems with the discharge of the sanitary waters that was already discussed in this section of the document. For this situation we recommend that the legal offices of the municipalities proceed to establish communication with the agencies responsible for this problem and to consider the assistance or consultation with the EPA to back up the municipalities with this issue. The Twitter option developed as part of the elaboration of this plan could become a communication mechanism that can be considered for residents to document and report about sanitary water discharges in their neighborhoods. As part of the human ecosystem framework used in our analysis we encourage the municipalities to analyze the institutions associated with their tasks and responsibilities within the Storm Water Runoff Plan. This analysis should provide the alternative to develop partnerships to facilitate and improve the activities of the plan. For example, the local schools can be part of a monitoring strategy within the storm water system around the school property. The DNER announced the development of a National Environmental Education Plan on April 2014; the plan can consider Río Fajardo watershed as a study case for an educational and student monitoring initiative. An adoption program or green label initiative could be sponsored by the municipalities to endorse and recognize commercial establishments involve in the maintenance and monitoring of the storm water system next to their facilities or structures. For Fajardo de Municipal Government is already applying its Storm Water Runoff Plan (Gobierno Municipal Autónomo de Fajardo 2013) and they are including educational visits to restaurants and business in the areas that include the plan. The educational component of the plan could be improved with a restaurant and business green label initiative. The Coastal Zone Management Program (CZMP) can help in financing a green label initiative with the development of a sticker or label that can be displayed by the participant commercial establishment. The participation can require a simple monitoring page to count the type of trash or issues recognized by the participants to direct the educational work plan of the CZMP toward the reduction of those problems. A recognition list of participants can be revealed annually by the DNER to encourage the involvement and credit the collaborators. The business and restaurant green label initiative could be a follow up of the emblematic tagging program at the storm water runoff gutters developed by the CZMP.

The analysis recognized that the municipal government can be a more active stakeholder and could be better used by federal and local institutions as tactical stakeholders. The municipal governments can be considered as direct path to develop monitoring strategies, LWG, and facilitate in outreach exercises because of their direct contacts with the residents of the watershed.

ISSUE 5. Although the MS4 Storm Water Management Programs are progressing, we identified the need to provide the municipalities' further assistance to improve the outreach of their plan. The municipalities should also review their programs to integrate additional strategies that encourage and promote the residents participation and assistance.. The municipalities should be considered as tactical stakeholders in the watershed governance structure.

Through the discussion of this section we have provided examples of issues and problems as well as recommendations of conservation practices or initiatives directed toward the management of the Río Fajardo watershed. Through this process we recognize potential management zones to facilitate and

direct the application of some of the recommendations. There are other actors in the watershed that work at a different scale and most of the time are not associated or link with watershed conservation governance structures. The identification and recognition of these actors or stakeholders is important and might require further analysis to define the cohesiveness of subgroups or the ties between the actors for effective watershed management strategies.

The academic sector is another important stakeholder in the region. There is presence of at least two higher learning academic institutions that provide important services in the region at different scales. The University of Puerto Rico Agricultural Extension Service (UPR-AES) has a strong presence within the farmers and knowledge over the agricultural practices applied in the region. The UPR-AES also has educational programs and active contacts with schools through the 4-H programs and with educators in their regional offices that can be part of the educational strategies applied in the watershed. Another institution is the IA-U that is within the study area. The IU-Fajardo serves much of the university student's population of the region, and has different partnerships and collaboration efforts with local environmental organizations and promotes the conservation of environmental resources within the watershed.

Previous research efforts in the area have already identified marine outfitters as an important group within the watershed (see for example Torres-Abreu, 2013). Although their operations are outside the basin topographical boundaries, their economic activity is affected by the quality of the Río Fajardo watershed as it reach the coastal environment and some of them also live in nearby communities. That's why it is important to acknowledge the activities of catamarans, fishing charters, dive charters and kayak rental companies in nearby natural reserves such as Las Cabezas de San Juan. This group is also important because they manage and disseminate information about the region and its natural value; something which is extremely relevant for educational and outreach efforts. These groups are also aware about the connections between in-land activities and coastal resources.

Other important stakeholders in the RFW are the environmental organizations. Within the region, there are some organizations that are very active with different environmental initiatives and others are supporting community development initiatives in the region. As part of this study we recognize the Northeastern Ecological Corridor Coalition (NEECC), Para la Naturaleza, The Sierra Club, El Centro para la Conservación del Paisaje and the environmental organization linked to Roosevelt Roads "Sin Límites" to consider some of them as part of our analysis. These organizations develop and implement their agendas and work plans without direct connections to the watershed conservation initiatives, but can be considered because their actions can represent an important asset to the watershed governance structure. These organizations can assist with: 1) the environmental monitoring activities in the area, 2) the environmental education initiatives with in the region and 3) the promotion of restoration activities such as planting initiatives, among others. Most of their efforts connect different natural reserves conservation initiatives as well as embrace the concept of watershed as a guiding principle. These stakeholders can be important to establish a flow of information and to point out special activities in the region through their cycles of events. For example, the monitoring of sea turtle nesting occurs during certain months is an important outreach opportunity of the RFW conservation initiatives that can be managed through the environmental groups.

All these stakeholders and actors mentioned have specific characteristics and agendas that should be analyzed as part of the social network analysis recommended to facilitate their engagements in a

watershed governance strategy. There is a concluding theme that should be considered as part of the recognized issues that dominate the RFW and is to reconsider the topic of land tenure. At the watershed scale there are three main groups of actors that dominate the ownership of the watershed landscape. The United States Forest Service and the Commonwealth of Puerto Rico represented by the Puerto Rico Land Authority were already mentioned. The third component includes the private owners that are distributed through the watershed. This component can be reached through different strategies that can be analyzed inspecting the links and relations of the actors that compose the group of landowners. This recognition is important to complete our recommendations of potential management zones for the watershed. In Figure 18 we present the land tenure distribution over the watershed to guide the final issue of this section and connect our discussion with the management zones recommended.

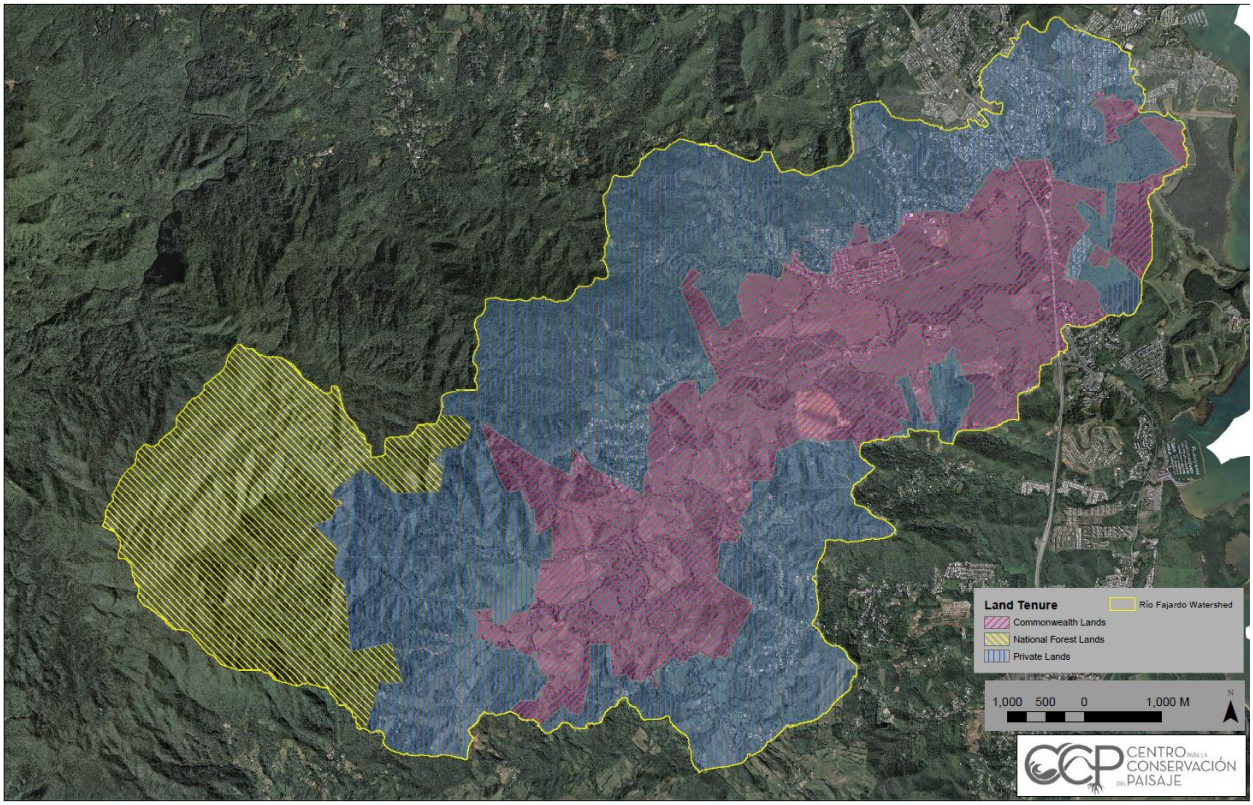


Figure 18. Land tenure distribution in the Río Fajardo watershed.

The Puerto Rico Land Authority was already mentioned as part of issue number 3 as we can observe in the Figure18 they own the areas closer to the river banks. The United States Forest Service owns most of the higher elevation areas of the watershed and the private landowners surround much of the Puerto Rico Land Authority properties. In terms of potential ownership and special interest we can study another layer of information if we consider how much of the watershed is under the proclamation boundary of the United States Forest Service.

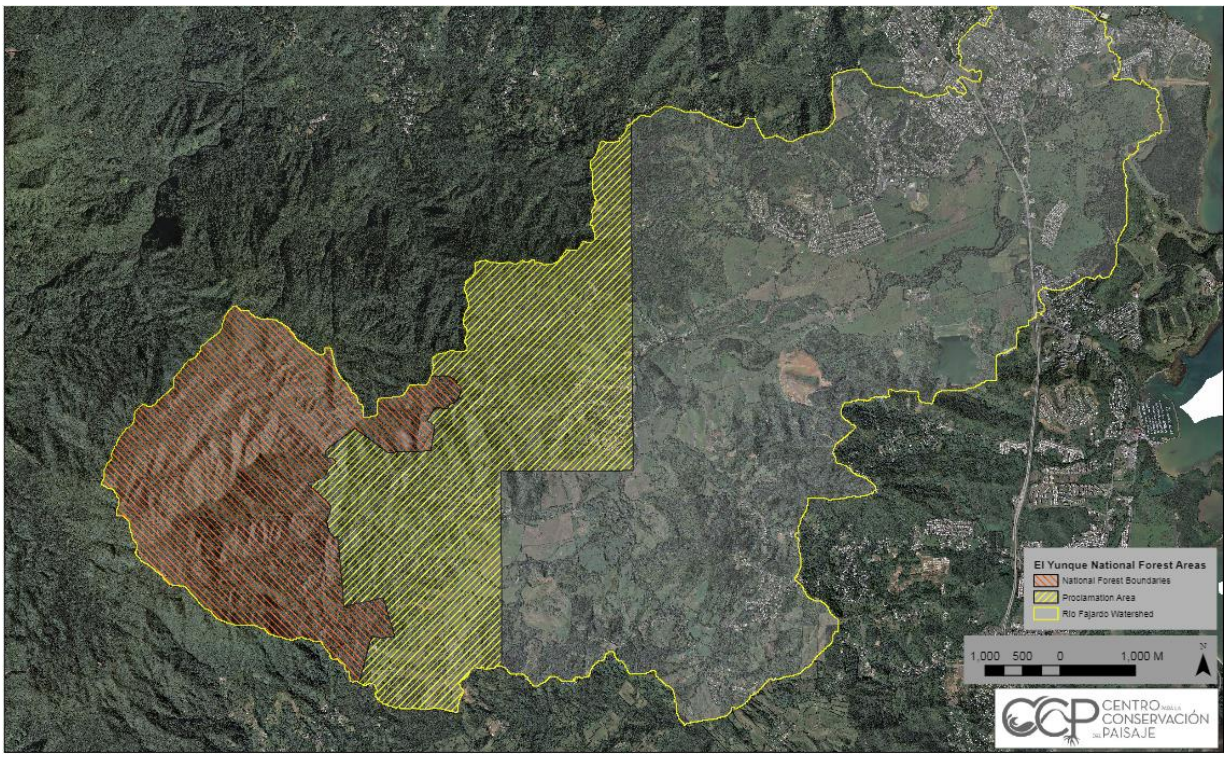


Figure 19. El Yunque National Forest property and proclamation boundaries.

Following this analysis to direct our attention toward potential management zones and conservation strategies we need to consider another layer of information in relation to special management conditions. We can define special management conditions as settings within the watershed that dictate opportunities or disturb the natural conditions that need be accounted as part of the management strategies. For example, we can consider the locations of USGS streamflow gages as opportunities for monitoring strategies but the presence of a landfill can be considered as a disturbance in the watershed landscape.

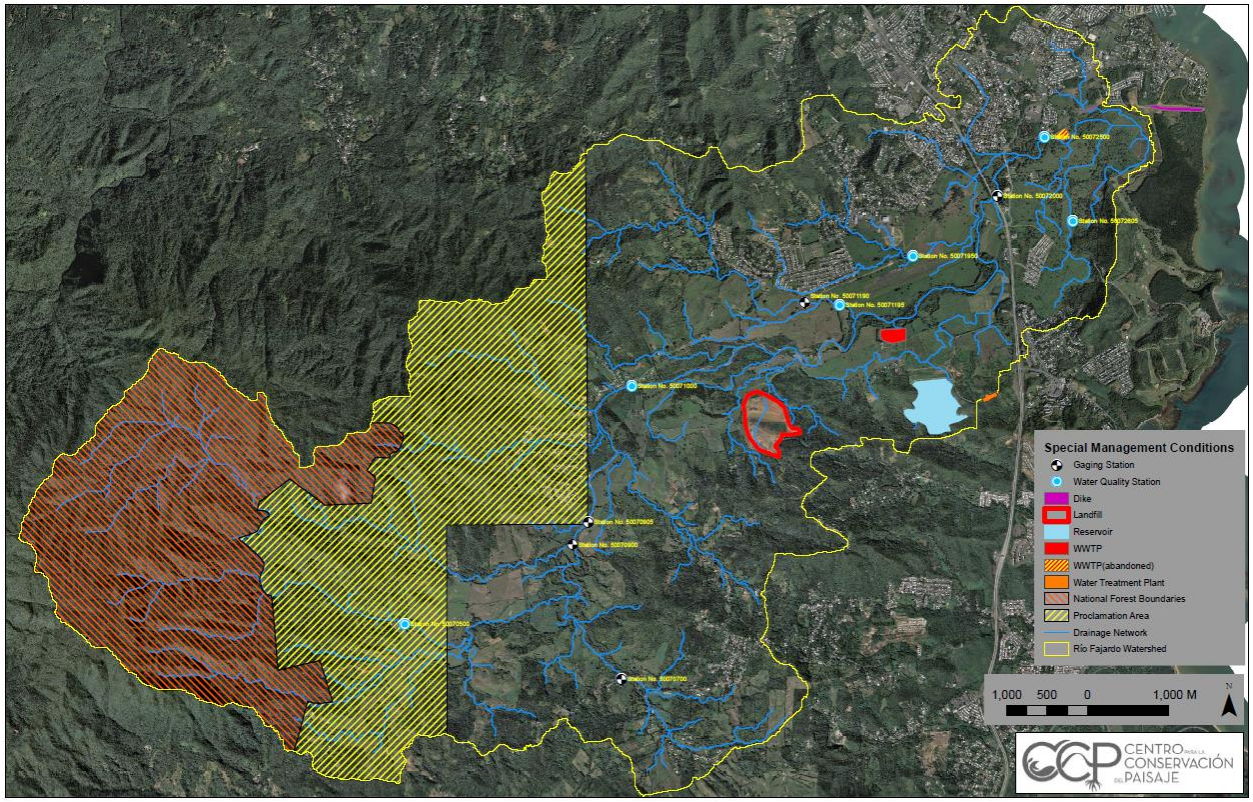


Figure 20. Special management condition areas in the Río Fajardo watershed.

This information plus the merging of the land use/cover identified in Figure 8 takes us to define and recommend seven management categories or zones to enable a watershed management program at the Río Fajardo watershed directed to reduce pollutant sources, reduce the sediment loads, include an educational component, define measurable milestones and a monitoring component to evaluate the effectiveness of the management plan implementation. The definition and establishment of these management zones only has the intention to define operational and functional limits according to our analysis to propose management actions and strategies. These management zones do not have the intention to regulate or propose changes in the zoning established by municipalities. We encourage the consideration of the management zones and the recommended conservation initiatives as an additional means to review and consider adjustments in planning process at the watershed scale. In the following section we present the proposed management zones as part of our analysis.

ISSUE 6. The Río Fajardo watershed needs to be defined according to management zones to facilitate the application of a management plan directed to reflect conservation practices that improve the water quality and reduce the sediment loads produced. The management plan needs a watershed governance structure different from the traditionally fragmented institutional and actors participation framework to achieve an integrated watershed management approach. The management zones can be considered to define standards and guidelines that can further be supported with the appropriate land use regulations or ordinances.

5. Management zones and conservation practices recommended

In this section we present the management zones recommended for the Río Fajardo watershed and proceed with recommendations and practices applicable to achieve the conservation benefits contemplated. The final discussion of this section directs the attention toward the implementation of the recommended practices and the watershed governance structure for the plan.

The management zones

As part of the analysis to develop the management zones we integrate land use/cover categories according to their relation in the type of activity. The different urban categories were reclassified in a single category. For further management strategies the urban areas can be subdivided according to their locations west or east of road PR 3 and according to the municipality urban and rural classification to facilitate the application of programs at those scales. The boundaries of the floodplains were defined to consider the application of additional weight in the evaluation and selection of conservation practices in this zone acknowledging the physical condition of the zone instead of the land use applied. For example, if we verify the land use/cover identified in Figure 8 (Land uses/ Land cover for the Río Fajardo watershed), we can recognize land cover identified as hay west to the road PR 3 that is next to the river channel; but because of its proximity to the river and the physical conditions of the zone most of these areas are included in the floodplain management zone. The same integration was done with wetland covers identified within the flood plain limits. The barren areas (including the landfill), the hay areas outside the flood plain, some range land cover areas (naturally recovering areas) that were not under a defined land use, but its vegetation density was not enough to be considered as forest, were categorized under an "other" classification. The pasture coverage was maintained as management zone because like the floodplain, these areas are associated with the farmers and agricultural activities identified in the watershed. The agriculture land use/cover was verified with the collaboration of the local agents of the Agricultural Extension Service and they help to define specific practices at that scale. Even one of the agricultural parcels was identified within the floodplain and it is pointed out in the management zone map (Figure 21).

The analyses applied consider the influence of the human and natural systems embedded in the RFW. It is important to consider local realities of changing livelihoods and land use patterns plus components of the social system that might trigger changes over critical resources such as water. The management zones represent a synthesis of a complex system that embraces wards, sub watersheds, land uses, changes in topography, different population densities, businesses and industries and many other patches within the topographical delimitation of the Río Fajardo watershed area. These patches that integrate the RFW will be more relevant or evident depending on the considered scale of reference and each of them will have influence for the efficient management of the RFW. As discussed in the previous section these management zones only have the purpose to define operational and functional limits according to our analysis to propose management actions and strategies. The management zones do not have the intention to regulate or propose changes in the zoning established by the municipalities.

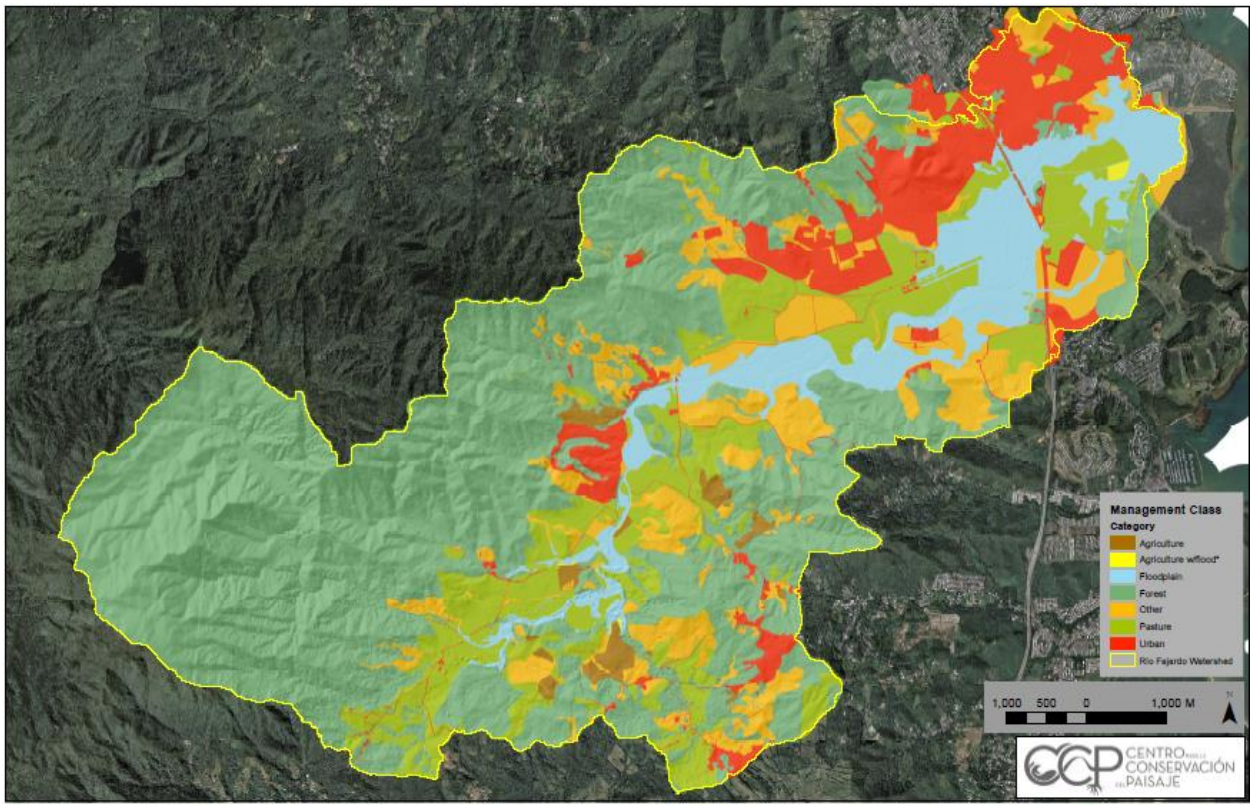


Figure 21. – Management zones and categories for the Río Fajardo watershed.

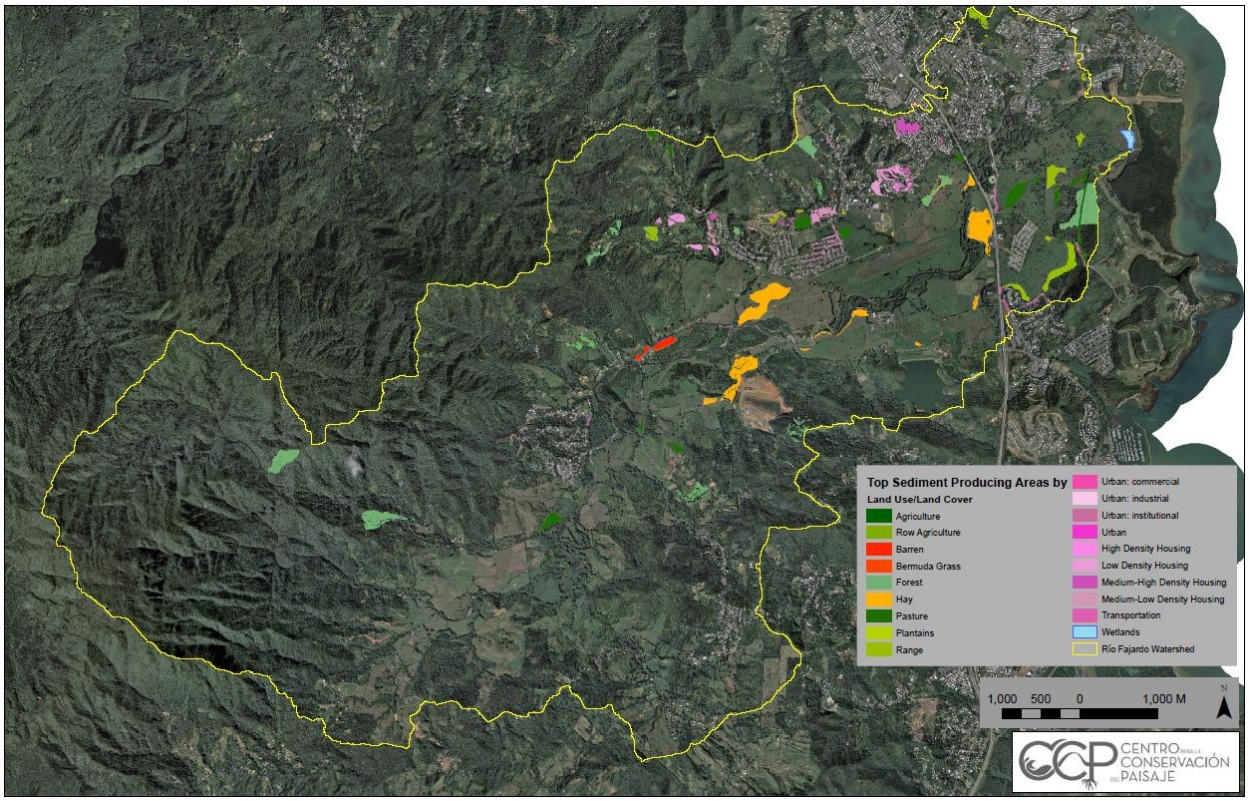
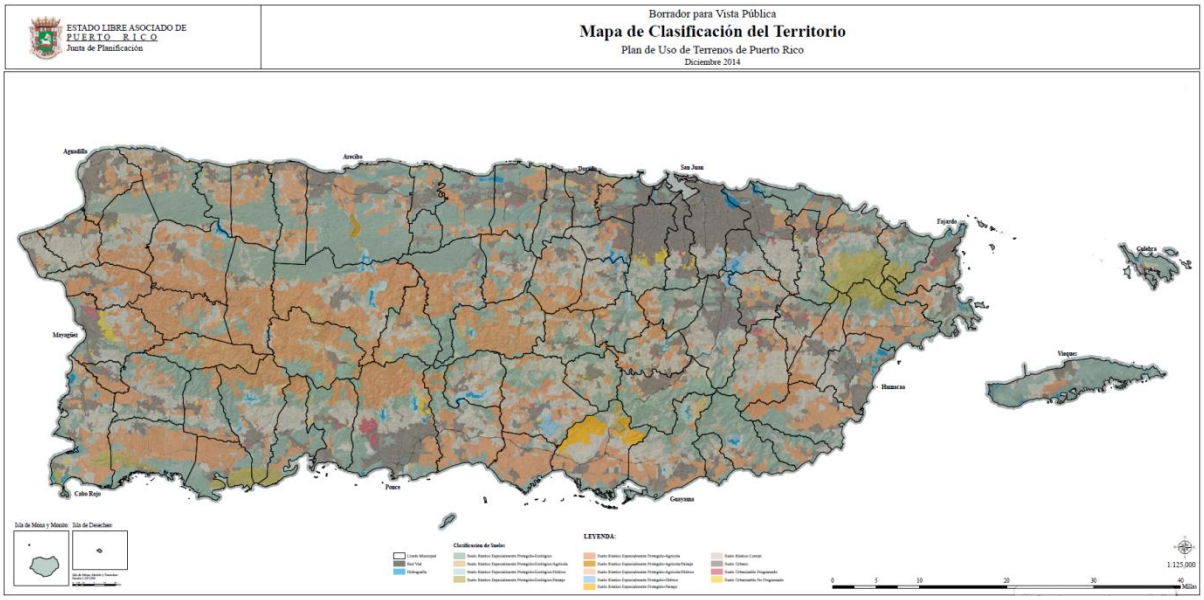


Figure 22. Land use/cover activities of the main sediment generating areas in the Río Fajardo watershed. (Also Figure 10)

The 2010 Fajardo Land Use Plan document could be used to define the expected and considered demands in housing, industrial development and urban expansion. The Land Use Plan for Puerto Rico is not a final document at the moment of finishing this document but it should provide additional opportunities to consider or analyze regulatory parameters in the future. Copy of the most recent Land Classification Map for the island is included in appendix D.

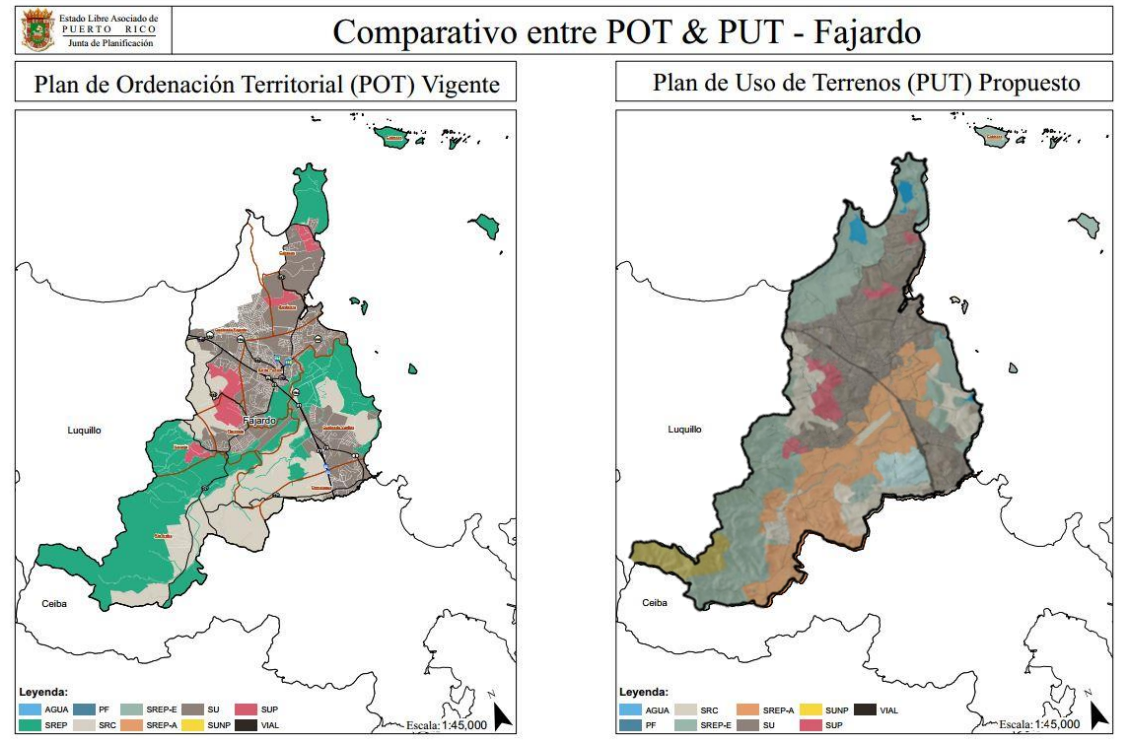


Proposed Land Classification Presented by the Puerto Rico Planning Board December 2014.

If we compare the Fajardo Municipal Land Use Plan and the proposed classification by the Puerto Rico Planning Board we can identify congruencies and differences that can be discussed in another document or even in a seminar. We encourage the consideration of the management zones and the recommended conservation initiatives as an additional means to review and consider adjustments in planning process at the watershed scale. The proposed Land Classification Presented by the Puerto Rico Planning Board for the Land use plan includes the following categories:

- Specially Protected Rustic Soil-Ecological
- Specially Protected Rustic Soil-Ecological / Agriculture
- Protected Rustic Soil-Ecological / Hydric
- Specially Protected Rustic Soil-Ecological / Landscape
- Specially Protected Rustic Soil-Agriculture
- Specially Protected Rustic Soil- Agriculture / Landscape
- Specially Protected Rustic Soil-Agriculture / Hydric
- Specially Protected Rustic Soil-Hydric
- Specially Protected Rustic Soil-Landscape
- Common Rustic Soil
- Urban Soil
- Programed Urban Soil
- None Programed Urban Soil

The proposed classification by the Puerto Rico Planning Board recognizes the recommended designation of the higher elevations in the Naranjo, Río Arriba and Río Abajo wards as special protected classes and the integration of the specially protected rustic soil-hydric for the zone of the water reservoir. These areas are also the areas identified with moderate landslide susceptibility in the Strategic Impact Statement of the Territorial Plan of Fajardo.



The included images compare the municipal land use plan of Fajardo and the proposed classification by the Puerto Rico Planning Board for this municipality. We encourage the studying of the management zones and the recommended conservation initiatives as an additional means to review and consider adjustments in planning process at the watershed scale. In the following section we present the proposed management zones as part of our analysis

In the next page we can compare the management zones recommended with the land use/cover activities of the main sediment generating areas to provoke the attention and exploration on specific conservation practices suggested for the watershed.

Management categories or zones for the watershed

Forest: Areas identified as part of the ArcSWAT analysis as sediment source points and classified as forest were revised to identify conditions that could represent the sign presented by the model output. These areas (2 sites) are within the proclamation boundary of El Yunque National Forest but on private property. These areas are under natural forest coverage recovery and no special practices are recommended. The identification of the areas could be associated with landslides of the areas and after review aerial photographs of 2004 a lower density of tree coverage was visible in these areas.

Management recommendations: The areas associated with forest coverage should be conserved or increased especially in areas with slopes over 40% (See Figure 5 in Appendix D). The use of the proclamation limits of El Yunque National Forest as a guide to provide additional incentives to the private landowners of these areas should be considered by the agencies that could facilitate this strategy. The DNER should evaluate the Auxiliary Forest Program (see Appendix H) to consider the legal or legislative process to increase the incentive reflected under this program for any landowner with a forested property within the watershed limit and inside the proclamation limits of El Yunque National Forest. The program provides property tax exception if the land owners maintain the conditions of their property under a conservation plan that could include harvesting of selected forest products and activities defined and accepted as part of the management plan. The designation as an Auxiliary Forest also provide the opportunity to consider the commercial management of forest products that are also tax free as part of the benefits of the program. It is recommended to amend the program to establish Río Fajardo watershed as a critical forest area under the program and consider additional incentives to the landowners that participate in this program, especially those that are inside the El Yunque proclamation boundaries or include lands with slopes 40% or higher. The recommended parameters for the application of the program in the watershed in relation to the property location and the slope bounds are directed to increase the forest coverage in the higher elevation zones of the watershed and protect the source drainages areas of the Río Fajardo. Additional attention needs to be directed to the waste water management in the houses in the steep areas of Naranjo, Río Abajo and Río Arriba wards. A review and monitoring process for the septic tanks in these wards should be implemented in the first two years of the plan. The United States Department of Agriculture Rural Development Program has a Water and Waste Disposal Loans and Grant program that provides funding for clean and reliable drinking water systems, sanitary sewage disposal, sanitary solid waste disposal, and storm water drainage to households and businesses in eligible rural areas.

A work plan to review the Auxiliary Forest program could be develop in less than six months to present any legal or legislative process that should be considered or needed to direct the program to the watershed parameters. The review should include the potential increase of the existing incentives considering the financial mechanisms that the DNER can define. Through the review time, a further analysis with the municipality and the state office of property registration could be applied to identify potential participants of the program. This initiative and program could represent the increase and a conservation strategy to keep forest coverage especially within the proclamation limits of El Yunque National Forest. Additional programs from the Forest Service, like the State and Private initiatives as well as the Conservation Education program could be engaged in this strategy. This recommendation also supports the initiatives of El Yunque National Forest as part of their Forest Plan revision to integrate a broader landscape management perspective for the National Forest.

The type and nature of the incentives could represent a higher participation of land owners. Considering a moderate scenario that at least the program is encouraged and exposed under its current level to the landowners the increase of at least 3% of forest coverage in the watershed could be expected in the next five years. This could be higher if the recommended strategy is considered and more attractive incentives are considered for the landowners within the watershed.

Urban

Most of the urban areas identified as sediment source points are at the north eastern segment of the watershed. The urban zones should include an assessment of the MS4 Storm Water Management Program to provide additional tools to the municipal planning offices to expedite the application of the Storm Water Management Plan mainly in Fajardo. The completion of the Storm water Management Plan of Ceiba should be enforced by the responsible government agencies. The discharges of storm water from central urban areas through the Fajardo MS4 must comply with the established parameters and with the implementation of the requirements of the General Permit. The watershed governance structure is especially critical for the implementation of strategies in this category. The municipalities were already identified as tactical stakeholders in the watershed governance structure and the conservation actions applied at their level need the support of the government institutions from the federal and state level. The urban management zone is not a major contributor of the sediment load in the river but is strongly associated with causes of impairment and pollutant sources. Issues 2 and 5 presented in section 4 of this report are related to the PRASA infrastructure problems and the potential use of the municipalities at the urban scale.

Management recommendations**:** The initial management recommendation for these zones is the attention of the sewage water discharges that are flowing from the failure infrastructure of PRASA through the storm water drainages to the water bodies and streams associated with the watershed drainage. The implementation of minimum control measures of Illicit Discharge Detection and Elimination (IDDE) should be a priority. As tactical stakeholder the municipal government of both municipalities (Ceiba and Fajardo) should integrate a Río Fajardo watershed Municipal Taskforce (RFMT). The main intention of this team approach is to, first consider and analyze the recommendations presented in this document and second present projects considering a municipal consortium at a watershed level to facilitate the funding considerations and to provide a feasible monitoring plan directed toward the Río Fajardo watershed. Both municipalities should use the six minimum control measures that operators of regulated small MS4 storm water systems most incorporate into storm water management programs. These are:

- Public Education and Outreach
- Public Participation/Involvement
- Illicit Discharge Detection and Elimination
- Construction Site Runoff Control
- Post-Construction Runoff Control
- Pollution Prevention/Good Housekeeping

(source: Small MS4 Storm Water Program Requirements.
http://water.epa.gov/polwaste/npdes/stormwater/Small-MS4-Stormwater-Program-Requirements.cfm)

The RFMT should establish contact with the DNER, which was already identified as the agency to lead the management plan at the state government scale, to define a work plan and additional participants as part of the watershed governance structure. One of the first issues that should be considered in these meetings is the deficiencies and pollution discharges from the PRASA infrastructure. The management zones could be used to establish priority areas as part of work plan with measurable milestones and a monitoring component to evaluate the effectiveness of the implementation efforts. From our analysis we recommend the areas east to road PR 3 within the river flood plain and these could be established as a test case to refine the strategy. During the public meetings and the interviews the participants claimed that several sanitary pumps from the PRASA lack proper maintenance. The ones mentioned at the meetings

and interviews are located in Santa Rita, in Barriada Obrera, near Quebrada Fajardo and in the sports complex. Key informants expressed major concerns due to direct contamination to water bodies and human health. Residents from Pueblo, Maternillo and Santa Isidra neighborhoods reported problems with sewage near the postal service office, in front of the public car terminal and Amparo Street. According to an interviewee in Northeast of Vista del Convento there is a "sewage lagoon". The municipal representatives could use a similar methodology as the one used in this report for community meetings to consider citizen science water quality monitoring program.

It is recognized that funding could be a major constrain for PRASA to develop the infrastructure improvement program. Our report documents serious deficiencies in the sanitary water pump stations and the presence of collapsing sewage systems in some of the urban areas in Fajardo. The watershed governance structure should consider the financial constraints, but a reasonable work plan should be maintained so that agencies such as PRASA direct their budgets priorities to settle the identified deficiencies. The identified deficiencies could be evaluated by the municipal consortium under the federal regulations that apply for the pollution problem considering the Clear Water Act and the assistance of the EPA. The watershed governance structure should provide a mechanism to inform the community of the actions and obligations of the participants with a yearly scoring process. The management zones under the urban category can be subdivided and brought to a lower administrative scale to consider the wards or "barrios" to define conservation projects at that scale. The problems and concerns identified in the community outreach process are presented in Table 9 in section 3 of this report.

Although throughout the field visits no major issues were observed in the septic tanks visited and most of the interviewed residents exposed that they were receiving service from the municipal government, we recommend an assessment of the septic tanks of the communities within the watershed. At community meeting #3 interviewees informed that some residents discharge their septic tanks into their land and it ends up in some community streets during rain events. They reported seeing pieces of toilet paper running down the streets after significant rain events on the zone. One of our informants reported that he has always seen water running down the street in Naranjo. A "barrio" / municipality alliance (see Figure 12 in Appendix D) could be developed to receive the assistance from the UPR-Agricultural Extension Service (AES) in a monitoring program of the septic tanks that should be updated every three years as part of the work plan of the watershed governance structure. The AES provide information and have qualified personnel to assist in this initiative. The program can be used to collect additional information like the GPS locations of the septic tanks to potential water quality analysis that could be financed through the Urban Waters Small Grants program of the EPA. The program could fund, trainings, surveys studies and other projects directed to restore urban waters by improving water quality with activities that can also support community revitalization. This program should include an educational component that is proposed for the schools of the "barrios" to build up a Watershed Conservation School Network (WCSN) in the Río Fajardo watershed. The program should include the collaboration of state agencies (DNER, PRASA, Department of Education, and others) as well as federal agencies that have conservation and education programs like the Forest Service, EPA and NRCS. It is recommended to use the UPR-AES approach of the 4-H groups in the schools to start the WCSN in the Río Fajardo watershed.

Pasture / Agriculture / Agriculture within flood plain / floodplain / other

These management zones and categories are discussed together basically because the management recommendations can have similar application through the zones. The land cover between these zones

was classified mostly as pasture, hay, range and agriculture. In terms of management perspective most of the pasture, agriculture and other zones are next to or associated with flood plain management zone and could be seen as a buffers or extensions of the river valley. The agricultural activities were discussed with the UPR-AES technician of the area to facilitate the identification of specific conservation projects and identify the practices that will help to reduce the pollutant loads and estimate the load reductions expected as a result of the management measures to be implemented. The "other" category includes the barren areas as well as the range and hay coverage that were next, but not inside the floodplain. Field inspections recognized activities such as power lines easements in the region that also provide top sediment production readings because the interpretation of soil exposure they produce in areas associated with agricultural activity or within the floodplain.

Management recommendations**:** In these management zones we direct our attention toward pasture and agricultural activities associated with sediment production points identified by the ArcSWAT analysis. The identified areas show an overgrazing pattern that was discussed and verified with UPR-AES staff. They even recognize that the sites presented in the analysis refer to locations of farmers that they had visited as part of their work in the region. The additional issues recognized are the activities taking place around the agricultural areas that are not managed by the farmers and in the management categories are considered under the "other" category.

The barren area identified in the analysis associated with the location of the landfill is next to a farm that is used for pasture and it's connected to the floodplain zone. This zone is one of the top sediment production areas and the analysis identifies the point source in the agricultural areas. After consulting with stakeholders, we recognize that the sediment load could be produced in the landfill area, but reflected in the agricultural areas next to the landfill. Figure 23 point out specific cases and sites considered for management practices application within these management zones.

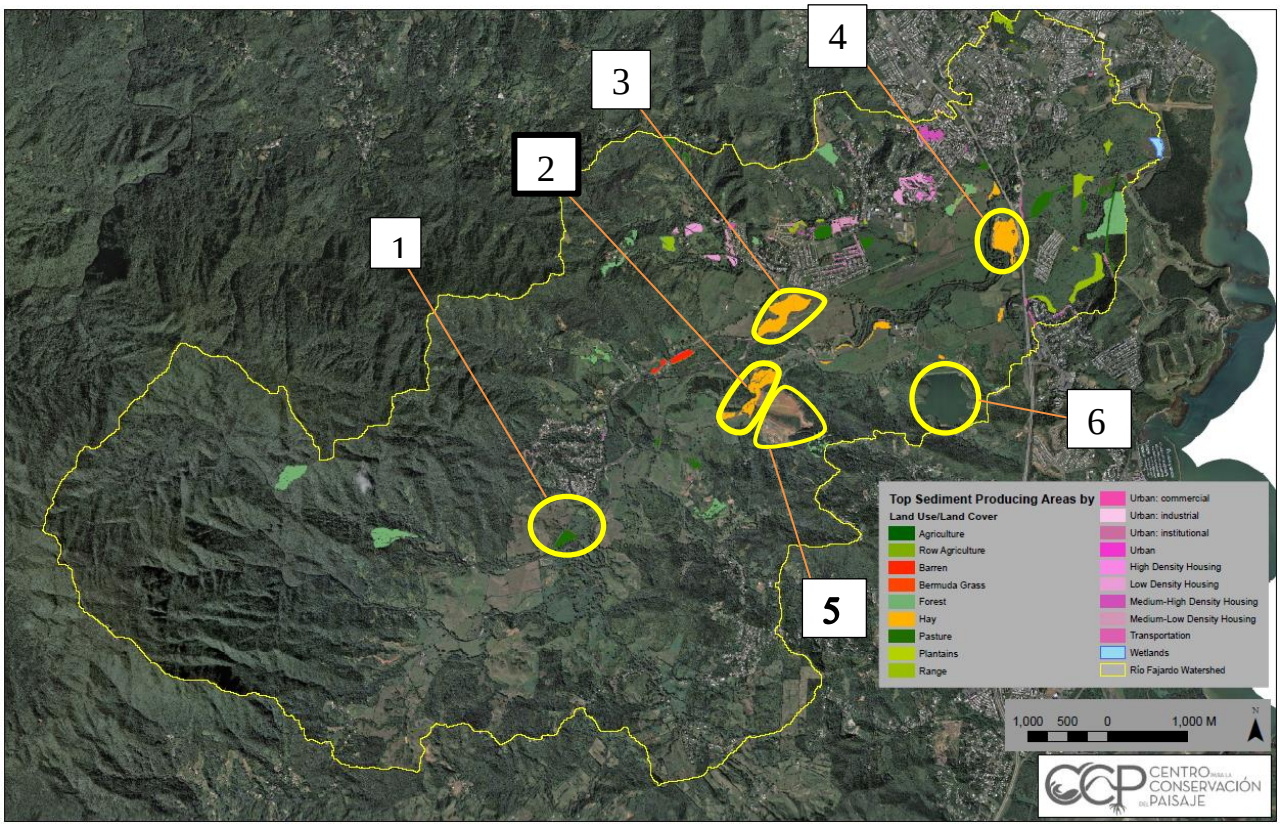


Figure 23. Sites considered for management practices application within the Pasture / Agriculture / Agriculture within flood plain / floodplain / "other" management zones.

Site 1 and 3 are within the pasture/other management zone and next to the flood plain zone. Both of these areas are recognized as farms where overgrazing is taking place. The areas were identified through the ArcSWAT analysis, field visits and were also independently verified with the AES staff. For areas documented with these negative practices, the main recommendation is the development of a grazing management plan with the description of the best management practices recommended for the activity.

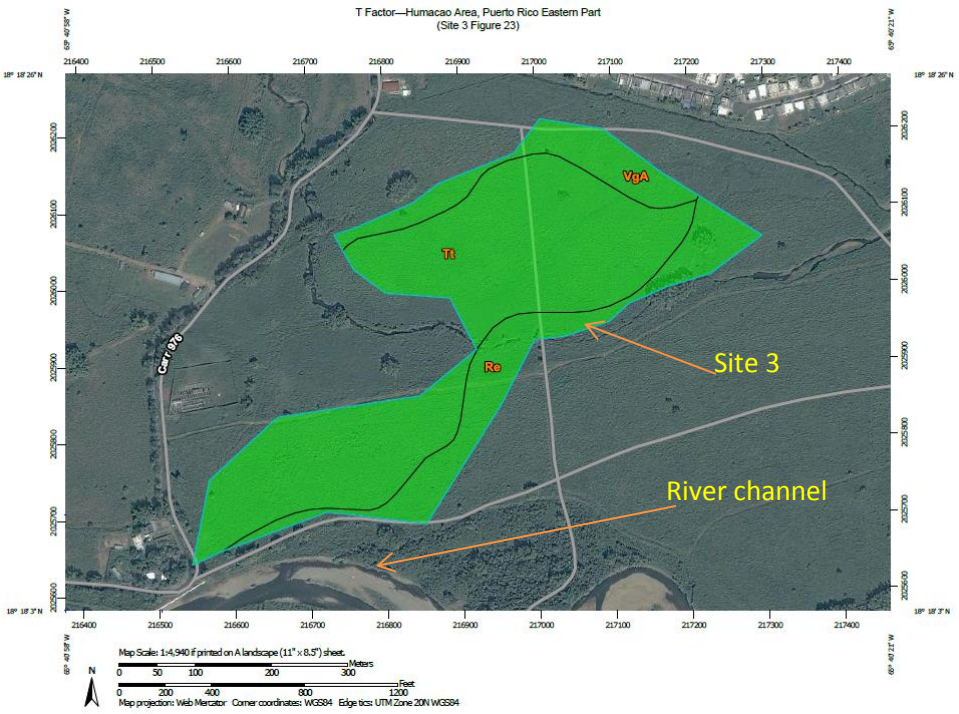
Further analysis done to consider the soils properties of the sites presented additional reasons to support an active farm management program. The NRCS use the T factor as an estimate of the maximum average annual rate of soil erosion by wind and /or water that can occur without affecting crop productivity over a sustained period. The T Factor is the maximum amount of annual sheet and rill erosion that permits the fertility and productive capacity of the soil to be maintained indefinitely.

The silvopasture practices and the establishment of a grazing system through a conservation plan can provide alternatives for farmers in the region. Two main funding options could be considered to assist the land owners to redirect their practices toward these practices on their lands. The first is the possibility of participation in the Natural Resources Conservation Services (NRCS) programs associated with the Environmental Quality Incentive Program (EQIP). This program provides financial assistance payments to the eligible farmers based on a portion of the typical costs associated with conservation planning and practice implementation. A requirement for these funds is a conservation plan that NRCS field staff prepare with the farmer. The expected action is the establishment of a planned grazing system in these areas for the reduction of exposed ground, as well as sediment loads. The management plan could also

include other best management practices needed by the farmers and considered for financial assistance by the NRCS. An assessment of all the Animal Feeding Operations (AFOs) in the watershed should be done, starting in the Puerto Rico Land Authority areas. EPA defines AFOs as agricultural operations where animals are kept and raised in confined situations. AFOs congregate animals, feed, manure and urine, dead animals, and production operations on a small land area. Feed is brought to the animals rather than the animals grazing or otherwise seeking feed in pastures, fields, or on rangeland. Although the management practices can be directed to the farmer/farm scale and this process can be applied in the identified sites (see Figure 23), we encourage the consideration of a watershed scale program according to the land tenure distribution in the Río Fajardo watershed (Figure 18).

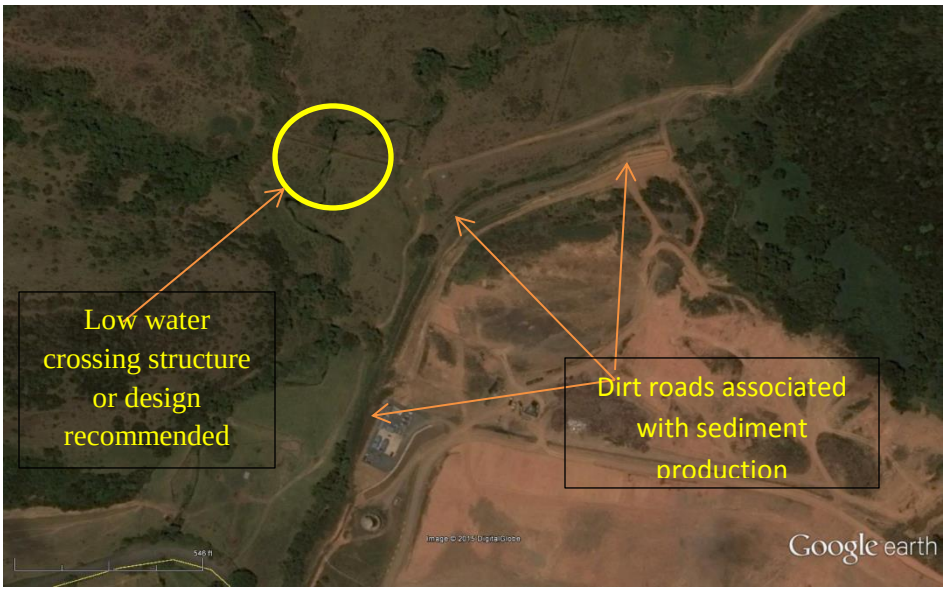
Another alternative is to promote a watershed project through the Puerto Rico Land Authority to assist the landowners to establish the best management practices in their rented properties. The Authority could evaluate and consult EQB, NRCS, DNER and EPA for alternatives and potential funding opportunities to do an assessment of their property directed toward the definition of the BMPs applicable in their property according to the current agricultural practices done under their land lease contracts. The assessment could identify conservation standards and guidelines that could be included in the contracts granted to the farmers. One of these standards could be the accomplishment of a conservation plan with NRCS in the first year of the contract. The noncompliance of the standards could be considered to review of the lease and the established fee. The program can consider a potential credit to the farmers leasing fee as they apply accordingly the management practices defined in the conservation plans.

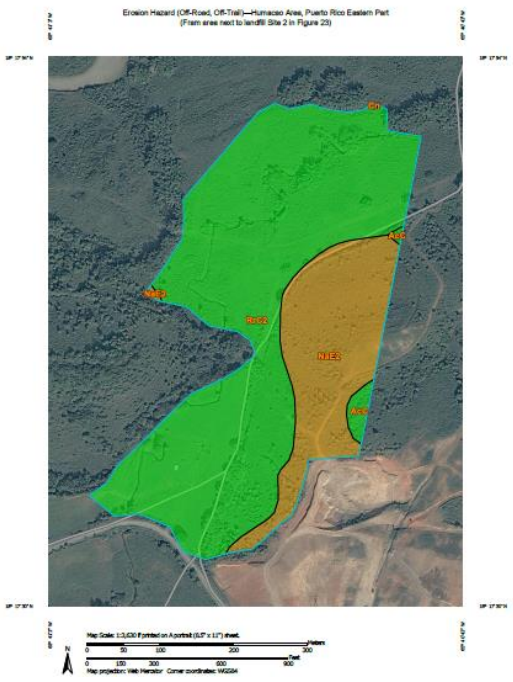
Other land uses were identified in the field visit of **Site 3** (Figure 23) related to a power line easement that contributes to the presence of barren areas. These types of activities should be documented and worked throughout the watershed governance structure to establish responsibilities of the institutions that have infrastructure within the watershed. The review of the soil properties associated with the current use is compatible but other land uses in the zone could affect the behavior of the zone because of the drainage pattern toward the river channel. A comprehensive assessment of land uses identified in this document with a social network analysis of the stakeholders and actors associated with the uses should be done to consider land use regulations according to the



prevalence of municipal ordinances or other land use regulations. The need of additional regulations could be defined from the assessment and the consideration of special land use conditions that can established by the land owners or administrators could be considered through the social network analysis. The management zones could be used to define standards and guidelines in which the institutions, with infrastructure in specific management zones, should manage their facilities under certain norms recognized by the watershed governance structure.

At **site 2** according to Figure 23, the activities associated with the landfill management (**site 5**) are recognized as the cause of sediments loads identify from this zone. The dirt road system in the farm that is managed under a concession of the Puerto Rico Land Authority has been affected by the runoff that is produced from the landfill. Through the area a drainage watercourse was identified and low water crossing structure or design could be considered for the site. The main recommendation is to first develop the management plan with the assistance of the NRCS staff to verify the possibilities to establish a stream crossing conservation practice. This stream crossing conservation practice's main purposes is to improve water quality by reducing sediment, nutrient, organic, and inorganic loading of the stream and reduce stream bank and streambed erosion. This can be an important conservation practice in this area, but it has been identified as a difficult practice to apply because regulations of some institutions make the accomplishment of the required permits for the practice a thorny process. These types of situations identify the need of a working forum through a watershed governance structure that can help in these potential conflicting views or administrative processes between institutions. The dirt road can be also considered under a best management practice scheme if constructed as part of a conservation system and the low water crossing structure could be considered under the EQIP incentive program (Conservation Practice Code 578 for Stream Crossing). The NRCS defines a rating based on slopes and soil erosion factor to define the hazard of soil loss from off-road and off-trail areas after disturbances activities that expose the





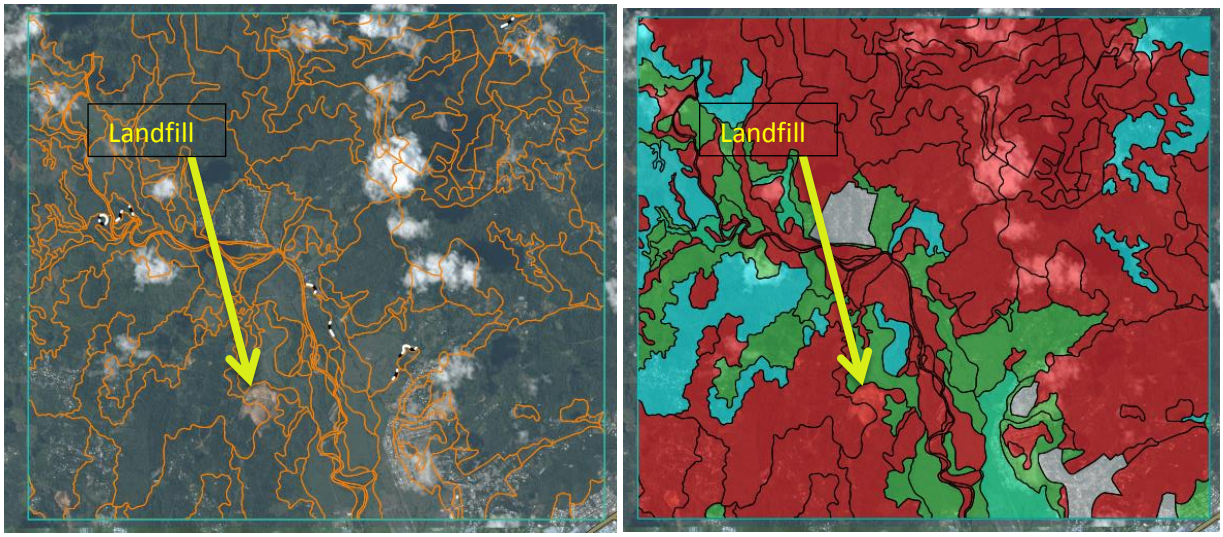
soil surface. The analysis for site 2 is included in appendix K and it shows areas of sever rate of erosion hazard within the identified area.

In relation to **site 5** and the zones associated with the landfill facilities some additional concerns were presented in the community meetings and documented in field visits. The margins of the roads that provide access to the landfill are used as illegal dumpsites. Residents who participated in community meetings expressed concerns regarding the landfill location and its proximity to the river. Some of them also expressed concerns about what they called "fugitive dusts and lixiviates" as they could contaminate to the river. Some others argued that Fajardo's landfill is over its capacity and that runoffs negatively affect the nearby river. Indeed, it is well known by residents (and because the media coverage it received) that some time ago some livestock from a cattle farm close to the landfill were found dead. Although several exchanges were carried out with the landfill management, it was not possible to obtain a reasonable explanation to these concerns or to obtain access to the facilites.

The watershed governance structure needs to evaluate and monitor the activities at the landfill and even include them as part of the workgroup and in the yearly scoring process recommended. Agencies like the EPA and the Environmental Quality Board, which have reports and complaints of the incidents in the facilities, could work with the municipal representatives to maintain a monitoring process of the activities in the facility. The entrance of the Landfill Technology facilities can establish a public access dumpster facility to provide the residents with an appropriate structure with concrete floor and side walls. This facility can help to reduce the illegal dumping activities mentioned on community meetings, especially on PR-982. Road barriers can be used to eliminate access to the illegal dumping areas of the road. As part of the conservation strategies, in some areas the road barriers must include a reforestation and restauration initiative behind the protected area.

An adoption process of PR-982 by the company that manages the landfill could be established with the assistance of the municipal government and with the participation of the Puerto Rico Highways and Transportation Authority (PRHTA). A reforestation project could be coordinated through the boundaries of the landfill to separate the visual impact and promote a vegetation buffer that can help to reduce impacts or runoff from the industrial facilities. Through PR-982 some reforestation areas and zones for road barriers could be established to prevent illegal dumping in the area. PR-982 can be recognize by the municipal

government as a special recovery area for the protection of the RFW and a Municipal Ordinance could be established to increase the fees for illegal dumping in PR-982 areas. The PRHTA and the DNER can be part of this initiative participating as state agencies to provide assistance with the road barriers and a reforestation plan providing suitable trees and other vegetation for the project. A soil analysis can be done of different areas of the watershed to identify the prime and not prime farmlands according to the farm classification system of the NRCS. In the following figures the red areas are not prime farmland areas and although they have agricultural potential these types of soils could incorporate reforestation initiative in riparian areas as a requirement of a conservation plan.



Custom Soil Resources Report for areas next to the Landfill –
Segments of the Report are included in Appendix K

A working calendar through the watershed governance structure could be created with the landfill administrators to conduct at least 2 educational activities throughout the year that include: educational information of the waste management techniques applied by the company, recycling information, reforestation and/or enhancement of the reforested areas. The educational campaign and activities can take place on alternate locations to include some activities in the zones associated with the Río Fajardo and its tributaries. A working committee toward the reduction of illegal dumping areas and the development of alternate, communal facilities, as well as the development of monitoring process to guide management activities can be guided by the municipality and Landfill Technologies.

PR-982 also presents sediment discharges after raining events that require the application of practices compatible with road adoption program. Framers next to this road have to consider the application of sediment control practices to reduce the sediment discharges form their farms. The practices can be applied in the farms and next to the road and can be considered as a standard for farms next to PR-982 to include sediment control practices in their farms as part of a management

plan. In Appendix I a series of structural and none structural practices are shown that can be considered for PR-982.

In **site 4,** shown in Figure 23, lawn production farm is recognized as a sediment generating area because of this type of activity results in frequent soil exposure. The site is within the flood plain management area and the land use of this management zone requires special attention. The definition of standards and guidelines in the management zones could provide regulations to the type of activities allowed in the zones. This strategy requires a recognized watershed governance structure that could establish regulations within the management zones through the different agencies, institutions and members. The actual practices conducted, and the types of activities allowed within the concessions of the Puerto Rico Land Authority are affecting the conservation initiatives of the Río Fajardo watershed. The Puerto Rico Land Authority could change this situation by issuing a set of standard and guidelines defining the allowed and desired activities recommended through the defined management and applied by the agency as part of the watershed governance structure. The agency can also require to all the farmers in their property a management plan assisted by the NRCS during the first year of their concession. Considering a conservation/credit incentive program, the Puerto Rico Land Authority could revise the management plan annually to provide credit to the renters that apply the management practices as part of their yearly work plan. The Puerto Rico Land Authority could negotiate the conservation credits provided to the farmers as part of a watershed protection strategy that could be evaluated to receive federal funding support based on the significant per cent of the watershed extension owned by the agency (See Figure18).

Further analysis in **site 4** at the soil considering the rate soils for their use in establishing and maintaining turf for lawns and golf fairways and ornamental trees and shrubs as a guideline for the actual use of the site shows the incompatibility of the use with the soil characteristics. Most of the soils of the site are Toa silty clay loam and have somewhat limited rating for this type of use because of flooding conditions. If the current activity includes soil exposure, as some historical photos shown, the mismatch of uses and location is more evident. The soils conditions and parameters could be revised by the institutions providing guidance and recommendations to the Puerto Rico Land Authority to reduce the incongruences of uses according to the soil physical conditions of the watershed.

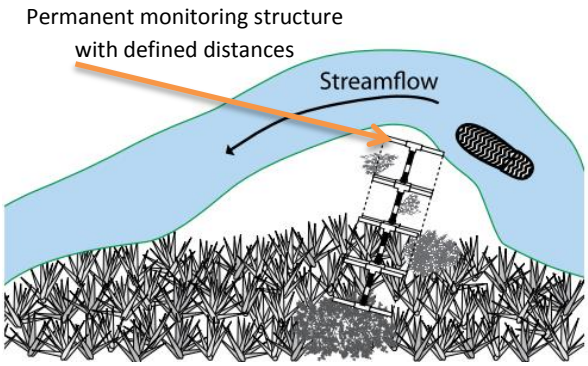
The flood plain management zone requires a program to establish management practices on the appropriate application of agrichemicals, including herbicides by the farmers. The recommended practice is to promote and educate farmers to properly and safely apply herbicides inside the fence and reduce the application in the areas next to the roads. This initiative might need a team to coordinate visits to the farmers and explain the plan and need of change in their practices. The visit should include the encouragement of participate in other conservation programs and agendas. This practice can be improved with a long-term strategy in which the farms start to contemplate living fences as an initiative that can be considered under the incentive programs of the Natural Resources Conservation Service.

Some of the recommended species of trees for living fences area *Prendedor* (Gliricida sepium), *Bucare* (Erythrina berteroana), *Jagüey* (Ficus sp.), *Jobo* (Spondius mombin), *Roble* (Tabebuia sp.), and Teak (Tectona Grandis).

The flood plain areas should improve or maintain effective agricultural conservation practices, but the land use of this management zone will also require a definition of standard guidelines to reduce constructions within this zone. The existing structures should be inventoried and categorized according to the land use activities and infrastructure conditions. The presence of septic tank has to be inventoried and the condition of the structure has to be assessed as well. The residents of this zone should participate in riparian forest buffer practices. Programs within DNER could help to reforest the river bank and create community forest assisted by the Urban and Community Forestry Program, to provide reforestation guidelines for the residents and communities of the zone. Further collaborations could be considered with the residents of these zones by developing a citizen's

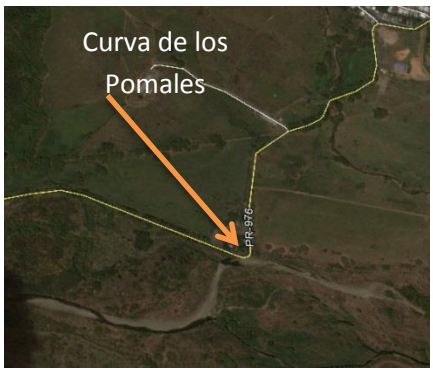
science program directed toward a monitoring agenda conducted with the residents and the communities close to the river bank. The information of this initiative could be shared by the Watershed Conservation School Network recommended before. Guidelines and monitoring strategies could be revised from different sources and modified according to Río Fajardo dynamic forces to develop a Multiple Indicator Monitoring (MIM) program of stream channels and streamside vegetation. The technical document Riparian area management: Multiple indicator monitoring (MIM) of stream channels and streamside vegetation. Technical Reference 1737-23 (2011) could be a guiding document for a national riparian area management plan. The identification of Designated Monitoring Areas (DMAs) could be established as part of technical committee of the watershed governance structure at two levels. A short term monitoring protocol to observe the agricultural areas and a long term monitoring protocol to observe river stream dynamics, changes in vegetation and other parameters.

Permanent monitoring structures could be established in strategic areas of the river as part of a MIM in the river channel. This monitoring process could help to identify changes in vegetation cover that is critical for stabilizing physical stream processes and functions that influence the channel geometry. The following graphic adapted from the Technical Reference 1737-23 (2011) presents a permanent monitoring structure that could be part of a community monitoring initiative with the technical assistance of the institutions.



The recommended national classification system and evaluation process for riparian zones commented in the previous section (See Issue 4 in section 4) could establish the stratification of the hydrologic network of the watershed to define the complexes (grazing areas, road proximity, houses and septic tanks distances, etc.) and the monitoring objectives as part of MIMs.

In terms of the infrastructure in the flood plain and in the areas close to the river banks, an assessment of the road network within the watershed could be included in the complexes of the watershed management to define their MIMs and monitor DMAs that should be considered for re-routing roads to areas outside the immediate floodplain. One concern repeated in various meetings has to do with landslides produced by vegetation cover removal and the structures at risk of falling into the river. A retaining wall in what the residents call "La curva de los Pomales" at road 976 is in a critical state and residents are worried that in the next episode of rain it may fall into the river. This is an example of the proximity of some infrastructure to special zones for the conservation and integrity of the watershed.



Site 6, identified in Figure 23, identifies the PRASA's reservoir within the watershed. This site is discussed because other than the conservation or safety considerations that the agency is applying in the areas close to the reservoir, the management plan recommend identifying this site as a special area. The management of the reservoir is responsibility of PRASA, but its management should not be divorced from the source of their main resource. The watershed governance structure needs the continuous and

active participation of PRASA. The watershed conservation strategies and practices considered in the plan must be analyzed under a payment for environmental service system as part of PRASA participation in the watershed governance structure. The monitoring strategies have to consider not only the environmental and ecological parameters, but also the marketing of the resource and production costs associated with the selling of the resources. Better and continuous water quality and flows can produce savings in plant operations, savings that could be re-directed towards management of the watershed and the administration of the required watershed governance structure. Further commitments are required by PRASA for the ecological improvement of Río Fajardo. For example, the intake should maintain a protocol to cease water extraction during key times at night hours when migratory shrimps are most active. This type of action can be discussed, monitored and documented as part of the watershed governance structure.

Table 10 summarize some of the discussed management recommendations and present a preliminary implementation schedule and a summary of key management strategies for the Río Fajardo watershed. The table includes recommendations for monitoring alternatives according to the management zones and priority actions that can help with a reasonably expeditious conservation program for the watershed.

Conclusion

The presented analysis of the Río Fajardo watershed was done to provide guidelines and recommendations for an integrated watershed management approach leaded by resource managers and other stakeholders to achieve the following goals.

- Reduce the load of sediments produced by the RFW and document this through the SWAT model analysis applied in the project.
- Reduce pollution due to sewage runoff.
- Reduce pollution due to activities in the RFW (construction activities, illegal dumping areas, use of chemicals in the agricultural activities, improve management and educational activities in areas without PRASA sanitary water infrastructure)

Many findings were identified through the analysis process for this document. Some of the findings can be categorized as more critical than others depending on the scale and different actors, but some specific results that we consider important to point out are:

- There is an average sediment yield for the entire basin of 19.73 tons per hectare per year (tons/ha/yr) with a standard deviation of 86.45. This sediment yield represents a serious problem that is affecting the coastal resources associated with the watershed. Sediment generation was associated with land uses without the best management practices applications.
- There is a need to establish a watershed management governance structure to apply, stir and supervise the plan application. Recommendations and strategies are presented in the document.
- Environmental problems are associated agricultural activities, waste water management infrastructure through the urban, septic tanks maintenance and use in rural areas and from other activities in the watershed.
- Although the water use infrastructure of PRASA was improved (WTP and WWTP) the performances and management of these structures need to be monitored to achieve a healthy river ecosystem connecting the higher elevations of the watershed to the coastal areas of Fajardo. As

part of this process a systemic analysis and improvement of wastewater infrastructure; in particular, the PRASA's sewage waters pump stations and associated infrastructure requires special attention.

Depending on the implementation of the recommended practices and programs recommended, a 30% reduction of the sediment load could be achieved as identified by the SWAT analysis. This represents a reduction of about 6 tons per hectare per year. As the plan progresses and a better watershed governance structure is established, we can expect additional sediment discharge reductions and water quality improvements. The estimated cost of implementation is $15,550.00 for a five year program considering a conservative scenario (see Table 10). Although different programs were mentioned in the document as potential funding sources for the application of the management practice we also recommend the review of the Catalog of Federal Funding Sources for Watershed Protection Web site that is a searchable database of financial assistance sources (grants, loans, cost-sharing) available to fund a variety of watershed protection projects (https://ofmpub.epa.gov/apex/watershedfunding/f?p=fedfund:1). Other programs like the Rural Development Water and Waste Disposal Loans and Grants (http://www.rd.usda.gov/programs-services/water-waste-disposal-loan-grant-program). Information of these and other financial assistance programs plus other relevant documents related to the project will be available in the Centro para la Conservación del Paisaje (CCP) web page (www.ccpaisaje.org). The CCP will be doing a series of community meetings to present the results and recommendations of this document to the communities that provide the information and participate in the data collection process.

The watershed management plan presented considers and recommends new analytical processes of the human ecosystem within the study area. It is expected that the readers and users of the document recognize the potential benefits of the application of the selected framework to facilitate the management considerations that need to be worked through a human ecosystem perspective to move the management approaches from an institutional standpoint to a more integrated and collaborative management system. The recommended watershed management governance structure is critical for the implementation of an integrated watershed management strategy. This document does not have the intention to discourage small and single watershed conservation initiatives and the discussion present examples from different scales to connect any particular conservation practice to a potential watershed management strategy. This report must be seen as a dynamic and adaptive document because the recommended practices could evolve at different scale of time, space and dimension. The conservation practices could start with a single farmer but agreements between institutions through a watershed management governance structure could impact almost a third of the watershed. The assignment of funds and supports could accelerate the rate of actions and the legal actions applied as necessary to comply with established regulations could also change the dynamics of conservation practices and action in the watershed.

As part of the final review and editing of the document; a consultation process with federal and state agencies was conducted to discuss the considered practices according to their potential application. The assistance and cooperation of all the consulted agencies is recognized and shows an institutional commitment to move forward the conservation of the Río Fajardo watershed.

Table 10. Key management strategies for the Río Fajardo watershed and preliminary implementation schedule and estimated budget

Plan Engagements	Objectives	Actions recommended	Monitoring and metrics recommended	Recommended lead or associated institutions	Implementation Year and Estimated Planning Level Cost (Thousands of $)				
					1	2	3	4	5
I. DEVELOPMENT OF THE GOVERNANCE STRUCTURE	1. Develop a watershed management governance structure	1. Formalize a watershed governance structure- Create the Río Fajardo Watershed Management Board (RFWMB)	# of meetings / formal registration of the group / work plan and meeting schedule	DNER and Municipalities	30	30	30	30	30
		2. Develop community watershed conservation councils	# of meetings / # of organized groups / community work plans	RFWMB and Municipalities	20	20	20	20	20
	2. Identify additional stakeholders and activities that involve vegetation clearing or management in the watershed	1. Do an assessment according to the land uses identified in the watershed management plan to extend and associate land impacts with specific stakeholders.	% of accomplishment and presentation of the assessment.	RFWMB	50	20			
	3. Define standards and guidelines to the management zones	1. Integrate a management committee in the RFWMB	# of meetings	RFWMB	N/A				
		2. Work with the management zones identified to define the standards and guidelines. Review conflicts and congruence's of land use regulations in the watershed.	# of meetings / work plan and definition of products	Management Committee of the RFWMB	60	30			
		3. Consider and apply the Multiple Indicator Monitoring (MIM) program	work plan and development of the MIMs Program	Management Committee of the RFWMB	10	75	75	75	75
		4. Identification of Designated Monitoring Areas (DMAs)	work plan and development of the DMAs Program for a monitoring program every two years	Management Committee of the RFWMB		100		100	

II. URBAN MANAGEMNET ZONE	1. Apply and complete the MS4 Storm Water Management Programs	1. Integrate a Río Fajardo Watershed Municipal Taskforce (RFMT).	# of meetings / development of a municipal watershed management consortium / work plan and meeting schedule	Municipalities	10				
		2. Complete the Ceiba MS4 Storm Water Management Program	% of progress according to the Program requirements	Ceiba Municipality	20	10			
		3. Revise and apply the six minimum measures that operators of regulated small MS4 must incorporate in their programs	Follow the recommended metrics of the Municipal Plans	Municipalities	20	20	20	20	20
		4. The implementation of minimum control measures of Illicit Discharge Detection and Elimination (IDDE)	Follow the recommended metrics of the Municipal Plans	Municipalities	40	20	20	20	20
	2. Correct deficiencies and pollution discharges from the PRASA infrastructure	1. Communication with PRASA to establish a contact person for the RFWMB	Response and formal designation from PRASA	DNER	0				
		2. Present an assessment of the PRASA infrastructure and the Capital Investment Program (CIP) considered for the Río Fajardo watershed area. Include an infrastructure improvement plan with budget allocation recommendations for its completion.	# of meetings with PRASA / Infrastructure improvement work plan from the CIP	PRASA, DNER, Municipalities	500	500			
		3. Develop and implement the needed infrastructure improvement according to the CIP for the region.	% of accomplishment according to the work plan / completion of projects	PRASA	1000	3000	2000	2000	2000

III. AGRICULTU**RE**	1. Apply potential conservation practices at landscape scale	1. Review the possibilities of integrate a conservation management plan requirement with the PR Land Authority in all their property.	# of meetings / develop a work plan / # of Conservation Plans	RFWMB PR land Authority NRCS AES	25				
		2. Work with farmers to apply the conservation practices recommended in the plans.	# of plans approved / # of practices applied and acres under the practice	RFWMB, PR land Authority, NRCS and AES	100	50	50	50	50
		3. Monitor the changes in the landscape with the application of the objective	Development of a monitoring plan	RFWMB, PR Land Authority, NRCS, AES and Other Institutions (Universities)	50	25	25	25	25
		4. Promote and educate farmers to properly and safely apply herbicides inside the fence and reduce the application in the areas next to the roads.	# of farmers participating in workshops / changes in fence management	NRCS, AES	50	20	10		
	2. Apply management practices and BMPs at the framers and watershed scales.	1. Consider the development of Local Working Groups (LWG)	# of meetings / Development of LWG at wards or at watershed scale	NRCS	20	10	10	10	10
		2. Do an assessment of all Animal Feeding Operations (AFOs) in the watershed and present management recommendations and practices as needed.	% of accomplishment and presentation of the assessment.	AES and NRCS	15	20	20	20	20
		3. Do an assessment of the farms next to riparian zones to consider management recommendations and practices needed. Coordinate according to I. 3. 3 of the table	% of accomplishment and presentation of the assessment.	AES and NRCS	15	15	15		
		4. Apply a silvopasture practices and a grazing system programs in the farms.	% grass coverage in farms / % grass coverage in riparian areas / presence of erosion (gullies)	AES and NRCS	50	50	20	20	20

IV REFORESTATION	1. Define Río Fajardo watershed as a critical forest areas under the Auxiliary Forest program of DNER and consider additional incentives to the landowners that participate in this program, especially those that are inside the El Yunque proclamation boundaries or include lands with slopes 40% or higher.	1. Review the program and establish an inventory of the approved Auxiliary Forest in the area and the potential Auxiliary Forest	Work plan / report of approved Auxiliary Forest / Inventory of the potential properties that could participate in the program	DNER	15	50			
		2. Recommend amendments to the program to consider additional benefits to the participants in the region	Review of the program and presentation of amendments	DNER	5	5			
		3. Start the integration of the new landowners in the program	# of new participants in the program / # of acres under the conservation initiative	DNER			50	25	10
	2. Maintain a reforestation program in the watershed.	1. Reforestation project and litter control strategy at PR-982 with road barrier	work plan / # of areas to be reforested / # of planted trees / % of survival of planted trees	DNER, PRHTA and MUNICIPALITIES	15	25	5	5	5
		2. Coordinate with NRCS to selected and reproduce species for a living fence project in the farms	work plan / # of meetings / production of a species list / a program for reproduction and growth of the selected species	DNER / NRCS / CONSIDER FWS FOR The Partners for Wildlife Program	20	40	40	40	30
		3. Participate in the Multiple Indicator Monitoring (MIM) program (I.3.3 of the table) to develop and apply the monitoring component of trees and forest of the watershed	work plan / # of meetings / monitoring program	DNER	30	60	60	60	60

V FLOODPLAIN	1. Apply management practices in the management zone	1. Evaluate and adapt a national classification system and evaluation procedure for riparian zones	work plan / evaluation and review of classification systems applied in other regions / develop a classification system for Puerto Rico with Fajardo as a study case	RFWMB a technical subcommittee can be integrated	60	60	30		
		2. Start an operational monitoring process with the USGS to measure sediments in the rivers – potential agreement with PRASA	work plan / data base production of available data / monitoring protocol / coordinate with working group of I.3.1	RFWMB a technical subcommittee can be integrated	20	20	20	20	20
VI OTHER	1. Reduce impacts from infrastructure through the watershed	1. Assessment of the road network within the floodplain management zone- establish a monitoring strategy of conditions, landslides, rerouting options applied and conservation programs (reforestation, road barriers, etc.)	work plan / # of roads assessed / 3 of proposed improvement projects	RFWMB a technical subcommittee can be integrated	100	100	75	50	50
		2. Conduct an assessment of the septic tanks of the communities within the watershed	work plan / reports by zones and # of required projects	RFWMB a technical subcommittee can be integrated	60	60	40	40	40
		3. Conduct an Assessment of the infrastructure in the river banks: mapping and categorization according to land use and infrastructure conditions and a monitoring program	work plan / reports by zones and # of required projects	RFWMB a technical subcommittee can be integrated	75	75	50	50	25
		4. Sediment control practices / PR-982	work plan / # of applied practices	PRHTA / NRCS / PR Land Authority, AES and Farmers	100	50	50		
	2. Promote educational initiatives for watershed conservation	1. Build up a Watershed Conservation School Network (**WCSN**) in the Río Fajardo watershed	work plan / # of meetings / activities of the network	RFWMB a technical subcommittee can be integrated	60	60	30	30	30
		2. Develop a community educational and assistance program	work plan / # of meetings / practices applied at community level	RFWMB a technical subcommittee can be integrated	50	50	50	50	50
			ANNUAL TOTAL		2,695	4,670	2,815	2,760	2,610
			5 YEAR TOTAL		$ 15,550.00				

References

Autoridad de Desperdicios Sólidos. (2008). *Dynamic itinerary for infrastructure projects public policy document*. (Report prepared by MO Engineers of Puerto Rico, P.S.C. in collaboration with Technical personnel from the Autoridad de Desperdicios Sólidos). San Juan, Autoridad de Desperdicios Sólidos

Agrawal, A. (1999). Enchantment and disenchantment: The role of community in natural resources conservation. *World Development* vol. 27, No. 4, pp. 629-649.

American Community Survey Office. (2012, October 2). *American Community Survey Multiyear Accuracy of the Data (2009-2011 ACS 3-year and 2007-2011 ACS 5-year)*. Retrieved October 29, 2014, fromhttp://www.census.gov/acs/www/Downloads/data_documentation/Accuracy/MultiyearACSAccuracyofData2011.pdf

Cartagena-Colón, M. (2011). Cuenca hidrológica del Río Fajardo de Puerto Rico: Un análisis geo espacial con carcaterísticas sociodemográficas y vivienda, 2000. CIDE digital, 2(1), 25-52. Retrived from http://soph.md.rcm.upr.edu/demo/index.php/cide-digital/publicaciones.

Choctawhatchee, Pea and Yellow Rivers Watershed Management Authority. (2000). *A guide for maintenance and service of unpaved roads.* Retrieved from http://water.epa.gov/polwaste/nps/unpavedroads.cfm

Clark, J. J. (1997). *Effects of land use change on northeastern Puerto Rican rivers* (Doctoral dissertation). Johns Hopkins University, Baltimore, Maryland.

Commonwealth of Puerto Rico Department of Natural and Environmental Resources. (2008). *Plan Integral de Recursos de Agua de Puerto Rico*. San Juan: DRNA

Commonwealth of Puerto Rico and NOAA Coral Reef Conservation Program. (2010). *Puerto Rico's Coral Reef Management Priorities.* Silver Spring, MD: NOAA.

Crook, K. E. (2005). *Quantifying the Effects of water withdrawals on streams draining the Caribbean National Forest, Puerto Rico.* (Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree Master of Science) University of Georgia, Athens, Georgia.

Dennis Jr., S. F., Gaulocher, S., Carpiano, R. M., & Brown, D. (2009). Participatory photo mapping (PPM):Exploring an integrated method forhealth and place research with young people. *Health and Place*, *15*, 466-473.

Dominguez-Cristobal, C. (2000). Panorama histórico forestal de Puerto Rico. Primera edición Universidad de Puerto Rico.

Environmental Protection Agency. (2008). *Handbook for Developing Watershed Plans to Restore and Protect Our Waters*. (EPA reference number 841-B-08-002). Retrieved from http://www.epa.gov/owow/nps/watershed_handbook.

Environmental Quality Board. (2014). Puerto Rico 305(b)/303(d) Integrated Report. Plans and Special Project Division Evaluation and Starategic Planning Area.

Environmental Services City of Portland . (2006). *2005 Portland watershed management plan.* Portland: River Renaissance.

Gobierno Municipal Autónomo de Fajardo (2010). Declaración de Impacto Ambiental Estrategica. Plan Territorial de Fajardo.

Gobierno Municipal Autónomo de Fajardo (2010). Plan Territorial De Fajardo.

Gobierno Municipal Autónomo de Fajardo (2013). Plan de Manjeo de Aguas de Escorrentías Informe Annual de Implantación 2012-2013.

Gray, B. (1989). *Collaborating: Finding common ground for multiparty problems*. San Francisco CA: Jossey-Bass

Gray, B. (2004). Strong Opposition: Frame-based Resistance to Collaboration. Journal of Community & *Applied Social Psychology*. 14:166-176

Heathcote, I.W. (2009). *Integrated Watershed Management-Principles and Practice (*2nd ed.). Hoboken, New Jersey: John Wiley & Sons, Inc.

Heley, S. (2003). Public participation as the performance of nature. In B. Szerszynski, W. Heim, & C. Waterton, *Nature performed environment, culture and performance* (pp. 94- 108). Oxford: Blackwell Publishing.

Hukka, J. J., & Katko, T. S. (2009). Complemnetary paradigms of water and sanitation services: Lessons from the finnish experience. In J. E. Castro, & L. Heller, *Water and Sanitation Services* (pp. 153-172). UK: Earthscan.

Hufschmidt, Maynard M. (1986). A conceptual Framework for Analysis of watershed Management Activities. In Strategies, approaches and systems in integrated watershed management FAO Conservation Guide 14 Rome. Retrieved from http://www.fao.org/docrep/006/ad085e/AD085e00.htm

Kalibo, H. W., & Medley, K. E. (2007). Participatory resource mapping for adaptive collaborative management at Mt. Kasigau, Kenya. *Landscape and Urban Planning, 82*, 145-158.

Machlis, G.E., Force J. E., & Burch JR. W. R. (1997): The human ecosystem Part I: The human ecosystem as an organizing concept in ecosystem management, Society & Natural Resources, 10:4, 347-367. Retrieved from http://dx.doi.org/10.1080/08941929709381034

Mapedza, E., Wright, J., & Fawcett, R. (2003). An investigation of land cover change in Mafungautsi Forest, Zimbabwe, using GIS and participatory mapping. *Applied Geography, 23,* 1-21.

Murphy, S.F., & Stallard, R.F. (Eds.). (2012) *Hydrology and climate of four watersheds in eastern Puerto Rico. Chapter C of Water quality and landscape processes of four watersheds in eastern Puerto Rico.* (Professional Paper 1789-C U.S. Department of Interior. US Geological Survey). Retrieved from http://pubs.usgs.gov/pp/1789/pdfs/ChapterC.pdf

Murphy, S.F., & Stallard, R.F. (Eds.). (2012) *Water quality and landscape processes of four watersheds in eastern Puerto Rico.* (U.S. Geological Survey Professional Paper 1789, 292 p.) Retrieved from http://warnercnr.colostate.edu/biocomplexity-home

National Research Council (U.S.) Committee on Twenty-First Century Systems Agriculture. (2010). *Toward sustainable agricultural systems in the 21st century.* Washington, DC: National Academies Press.

Neitsch, S.I., Arnold, J.G., Kiniry, J.R., & J.R. Williams. (2011) *Soil and Water Assessment Tool Theoretical Documentation.* Version 2009. 2011. Grassland, Soil and Water Research Laboratory, Agricultural Research Service Blackland Research Center, Texas AgriLife Research. http://swat.tamu.edu/media/99192/swat2009-theory.pdf

Ortiz-Zayas, J.R., Terrasa-Soler, J.J., & Urbina, L. (2010). Historic Water Resources Development in The Río Fajardo Watershed, Puerto Rico and Potential Hydrologic Implications of recent Changes in River Management. In: Watersheds: Management, Restoration and Environmental. Editor: Jeremy C. Vaughn, pp. 245-268 Nova Science Publishers

Peng, B., Chen, N., Lin, H., & Hong, H. (2013). Empirical appraisal of Jiulong River Watershed management program. *Ocean and Coastal Management, 81*, 77- 89.

Protectores de Cuenca Inc. (2104) "Estrategias para la identificación de fuentes de contaminación y el establecimiento de prácticas de control de erosión y sedimentación en los Municipios del Corredor Ecológico del Noreste, Puerto Rico" a document prepared for the Department of Natural and Environmental Resources

Puerto Rico Aqueduct and Sewer Authority. (2014). Fiscal Year 2014 Consulting Engineer's Report

Quiñones, F and Guerrero R., (2005). Plan de Reuso de Aguas Usadas de Puerto Rico. Retrieved from http://www.recursosaguapuertorico.com/InformeReuso_Plan_Aguas_22nov_04.pdf

Schramm, G. (1980). Integrated River Basin Planning in a Holistic Universo. *Natural Resources Journal* 20: 787-805

Soil Survey of Humacao Area of Eastern Puerto Rico. Retrieved from http://www.nrcs.usda.gov/Internet/FSE_MANUSCRIPTS/puerto_rico/PR689/0/Humacao.pdf

Stocker, L., Burke, G., Kennedy, D., & Wood, D. (2012). Sustainability and climate adaptation: Using Google Earth to engage stakeholders. *Ecological Economics, 80,* 15-24.

Swyngedouw, E. (2009). Troubled Water: The political economy of essential public services. In J. E. Castro, & L. Heller, *Water and Sanitation Services* (pp. 38-55). UK: Earthscan.

Thomson, A. J. (2008). Google Earth as a tool for participatory 3-D modelling and elicitation of Traditional Ecological Knowledge (TEK). *"Mountain GIS e-Conference: Promoting Geographic Information and Earth Observation Applications for the Sustainable Development of the Hindu Kush- Himalayan Region"*. Canadian Forest Service.

Torres-Abreu, A. 2009. ¿Satisfacer of manejar la demanda? Perspectivas dominantes en torno al consumo de agua en Puerto Rico. Revista de Ciencias Sociales, Número 20, pp. 176-205. Número especial sobre Ambiente y Sociedad. Universidad de Puerto Rico.Torres-Abreu, A. (2013). Plan para la participación ciudadana y la Educación Ambiental, Reserva Natural Arrecifes de la Cordillera 2013-2015 (32 pags.)

Torres, P.A. , Morris, G., Rosa, R., (2010). New Strategies for the Desogn of Raw Water River Intakes for Potable Water in Puerto Rico. AWRA 2010 Summer Speciaty Conference. San Juan P.R.

U.S. Department of Agriculture. (2012). *Census of Agriculture - Municipio Profile for Fajardo Puerto Rico.* Washington, DC: U.S. Government Printing Office.

USDA Forest Service. (2014). *Forest Plan Assessment El Yunque National Forest.* Southern Region, Puerto Rico: El Yunque National Forest.

US EPA. (2008). *Handbook for developing watershed plans to restore and protect our waters.* Washington: Office of Water Nonpoint Source Control Branch.

US EPA (2012) Water Quality Assessment Status for Reporting.

U.S. Department of the Interior. 2011. Riparian area management: Multiple indicator monitoring (MIM) of stream channels and streamside vegetation. Technical Reference 1737-23. BLM/OC/ST-10/003+1737+REV. Bureau of Land Management, National Operations Center, Denver, CO. 155 pp.

Vaughn, J. C. (Ed.) (2010). Watersheds: Management, Restoration and Environmental. Nova Science Publishers, Inc. New York.

Videira, N., Antunes, P., & Santos, R. (2009). Scoping river basin management issues with participatory modelling: The Baixo Guadiana experience. *Ecological Economics, 68*, 965-978.

Zomrawi Mohammed, N., Ghazi, A., & Eldin Mustafa, H. (2013). Positional accuracy testing of Google Earth. *International Journal of Multidisciplinary Sciences and Engineering, 4*, 6-9.

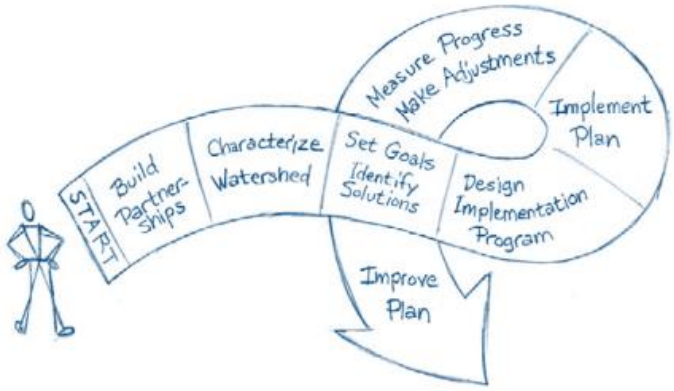
APPENDIXES

Appendix A

Nine Minimum Elements to Be Included in a Watershed Plan for Impaired Waters

According to the Handbook for Developing Plans to Restore and Protect Our Waters
United States Environmental Protection Agency 2008

The Handbook for Developing Watershed Plans to Restore and Protect Our Waters (2008) and the Section 319 Nonpoint Source Guidelines are the documents used for the development and implementation of watershed plans to meet water quality standards and protect water resources. The document provides a very detailed and organized set of steps towards management plans. The steps in the watershed planning and implementation process (see Section 2.3 Handbook for Developing Watershed Plans to Restore and Protect Our Waters 2008) point out in the following figure the importance of engaging a strong watershed partnership.



Sections "3.2 Identify Driving Forces", established the importance of having driving energies motivating the development and implementation of the watershed plan. The section identifies these forces as the foundation for developing the plan goals and objectives.

In section 4.1 the document points out the importance of the scope of the watershed planning effort. The Handbook (2008) uses the word scope to describe the boundaries of a program or project, which can be defined in terms of space (the area included in the watershed plan) or other parameters. In the framework used in the plan the social scope set a central role to recommend a watershed governance structure.

The EPA has identified nine key elements that are critical for achieving improvements in water quality and these are explained in the section 2.6 of the Handbook. Although these elements point out very important components of a watershed plan we want point out that our feeling is that they did not establish the importance of the watershed governance structure. The following table present the nine elements and references to sections of the document that relate to the identify issues by each element.

	Elements to Be Included in a Watershed Plan for Impaired Waters	Reference to sections of the document that relate to the elements
1	*Identification of causes of impairment and pollutant sources or groups of similar sources that need to be controlled to achieve needed load reductions, and any other goal identified in the Watershed Plan.*	Sections 2 and 3 of the document (pages 11 and 20)
2	*An estimate of the load reductions expected form management measures.*	Forest management recommendations (page 44) and document conclusions
3	*A description of the nonpoint source management measures that will need to be implemented to achieve load reductions in ITEM 2, and a description of the critical areas in which those measures will be needed to implement this plan.*	The application of the Auxiliary Forest Program (page 51) Reforestation Practices in road PR 982 (page 56)
4	*Estimate of the amounts of technical and financial assistance needed including the associated costs, and/or the sources and authorities that will be relied upon to implement this plan.*	Table 10. Preliminary implementation schedule and estimated budget. (page 66)
5	*An information and education component used to enhance public understanding of the plan and encourage their early and continued participation in selecting, designing, and implementing the nonpoint source management measures that will be implemented.*	Río Fajardo Watershed Management Board (page 37). Integrate a Río Fajardo Watershed Municipal Taskforce (page 45). Watershed Conservation School Network (page 53)
6	*Schedule for implementing the nonpoint source management measures identified in this plan that is reasonably expeditious.*	Table 10. Preliminary implementation schedule and estimated budget. (page 66)
7	*A description of interim measurable milestones for determining whether nonpoint source management measures or other control actions are being implemented.*	Table 10. Preliminary implementation schedule and estimated budget. (page 66)
8	*A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made toward attaining water quality standards.*	Table 10. Preliminary implementation schedule and estimated budget. (page 66)
9	*A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established.*	Table 10. Preliminary implementation schedule and estimated budget. (page 66)

As part of the document we will like to recommend additional guiding questions to use the nine elements recommended by the Handbook. The following two figures present these recommendations and a flowchart adapted to the Río Fajardo plan where we point out the importance of the watershed governance structure as central mechanism of the plan.

Questions to guide the development of the elements for the watershed plan

1. Identification of causes of impairment and pollutant sources

Guiding Question: Why and what other factors trigger the causes? Follow the reasons behind the impairment and pollutions source-what stakeholders are related?

2. Estimate of the load reductions expected form management measures

3. Management measures that will need to be implemented

4. Estimate of the amounts of technical and financial assistance needed

Guiding Questions: What mechanism and structure will apply the management practices? As part of analysis consider who will be responsible for the implementation and the links between the stakeholders (institutions, residents, farmers, etc.)

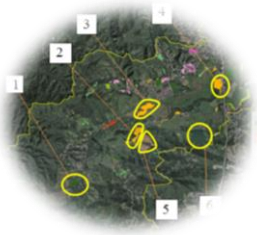
5. *Information and education component used to enhance public understanding of the plan*

Guiding Questions: Information and education is usually considered as a shallower component and need further compromises form the agencies or the structure that will apply the management practice. Are there any formal structures of education established in the study areas? Works around the school systems and related institutions developing networks

6. Schedule for implementing the nonpoint source management measures identified in this plan that is reasonably expeditious

7. Measurable milestones for determining whether nonpoint source management measures or other control actions are being implemented.

Guiding Questions: The implementation time will be dependent of the governance structure to implement the plan. Are there any formal watershed governance structure? How can we start the watershed governance structure?

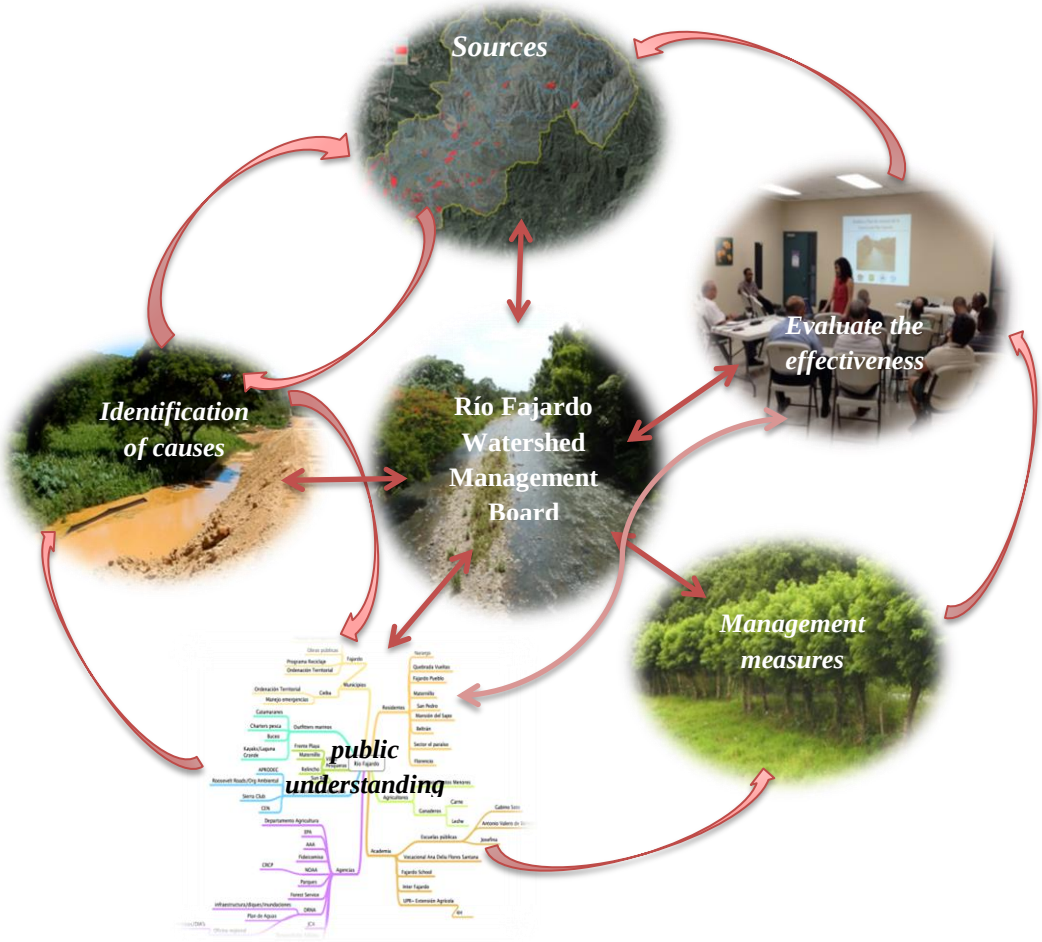


8. A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made toward attaining water quality standards

9. A monitoring component to evaluate the effectiveness

Guiding Questions: without a watershed governance structure the monitoring process will probably be fragmented by institutions and it will be difficult to integrate a reasonable monitoring process.

Flowchart of activities in the Río Fajardo watershed associated with the Elements to Be Included in a Watershed Plan for Impaired Waters



Through the sediment source analysis the identification causes will be evident but causes identified through the field revision and presented in community meetings will also identify additional sources of pollution or problems in the watershed. The public and community (stakeholders) will be related to the identified causes or can help to identify the sources. The public can be important to measure and evaluate the effectiveness of the management practices recommended. The evaluation of the effectiveness will take the analysis back to the sources to review and adapt the practices. The links and flows identified need a central governance structure to move and achieve the expected results.

Appendix B

Why we use the Human Ecosystem Model

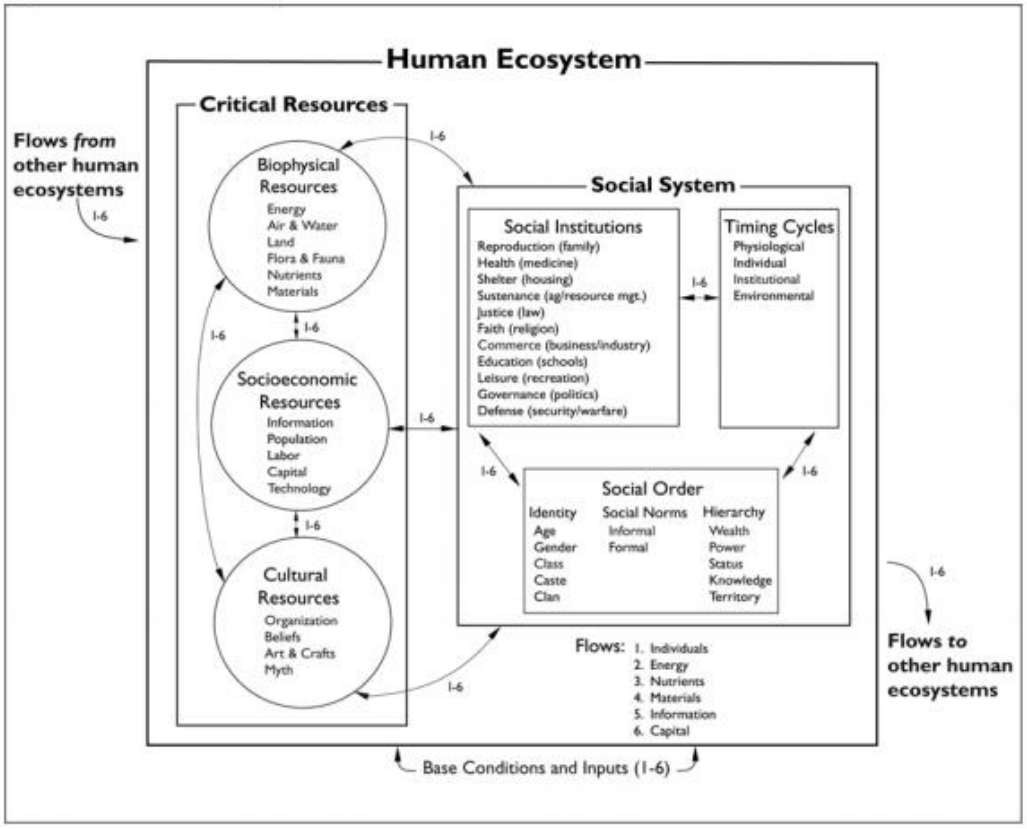
The Human Ecosystem Model (HEM) was first presented in a series of papers (see Machlis, et al. 1997; Force et al. 1997; Machlis et al. 1999) and is being prepared in book form (Machlis et al., forthcoming). It has had significant application, from United States parks and a long-term urban ecological research site (Baltimore), to Asian mega-cities planning (Kuala Lumpur) and the monitoring of sustainable development in the Sonoran desert.

The human ecosystem is defined as a coherent system of biophysical and social factors capable of adaptation and sustainability over time. The HEM provide a well-defined organizational framework that helps to identify and consider the blend of different factors that interrelate and move in a landscape that is under a conservation management review or plan that consider the natural resources of a region. Boundaries can be spatially identified through ecological transition zones, administrative and political boundaries, or more fine-scaled analysis of sharp perturbations in system flows.

The included figure in this appendix illustrates the components and dynamics of the model. The HEM identifies a set of critical resources that provide the system with necessary supplies. These include biophysical, socioeconomic, and cultural resources. The flow and use of these critical resources are regulated and measured by the social system in the considered region; the set of general social structures (including institutions, patterns and processes) guide much of human behavior and interaction with the administrative actors (institutions) that regulates or promote the activities that disturb or conserve the critical resources of the region.

The social system is composed of the social institutions, defined as collective approaches and activities that occur and deal with the challenges, wants and needs of the considered region. The second subsystem is a series of social cycles; these are temporal patterns for allocating human activity that are related to management of the studied area. The third subsystem is the social order that provide the guide to consider a set of cultural patterns for organizing interaction among people and groups, and people and nature. The social order can help to define strategies at different scales providing the identification of the identity (age, gender, etc.), norms (informal-what people use to do, formal –what people should do or is enforced to do), and the hierarchy (land tenure, power, status, etc.) Taken together, these three subsystems organize the social system. Combined with the flow of resources, these create the human ecosystem and provide a holistic view of the review or plan that considers the natural resources of a region.

Using the HEM a researcher and manager should identify key flows transfer between individuals (of varying species), of information (from ecological to cultural), and the uses and need of materials (including natural resources such as water through a watershed system). These flows identified through the application of the model fluctuate and adjust according to different scales, duration, frequency, and distribution. Another important attribute of the HEM is the attentions of the human ecosystems as multi-scaled and hierarchically nested systems. Machlis et al. (1999) acknowledge the utility of the model for predicting and evaluating cascading and nonlinear first-, second-, and third-order effects, and its capabilities of synthesizing a large range of theory, method, and evidence.


Human Ecosystem
Critical Resources
Flows *from* other human ecosystems
I-6
Biophysical Resources
Energy
Air & Water
Land
Flora & Fauna
Nutrients
Materials
Socioeconomic Resources
Information
Population
Labor
Capital
Technology
Cultural Resources
Organization
Beliefs
Art & Crafts
Myth
Social System
Social Institutions
Reproduction (family)
Health (medicine)
Shelter (housing)
Sustenance (ag/resource mgt.)
Justice (law)
Faith (religion)
Commerce (business/industry)
Education (schools)
Leisure (recreation)
Governance (politics)
Defense (security/warfare)
Timing Cycles
Physiological
Individual
Institutional
Environmental
Social Order
Identity
Age
Gender
Class
Caste
Clan
Social Norms
Informal
Formal
Hierarchy
Wealth
Power
Status
Knowledge
Territory
Flows:
1. Individuals
2. Energy
3. Nutrients
4. Materials
5. Information
6. Capital
Flows *to* other human ecosystems
Base Conditions and Inputs (1-6)

APPENDIX C - SWAT

SWAT Model Details (adapted from S.I. Neitsch, et al., 2011)

The Soil and Water Assessment Tool (SWAT) model was developed by US Department of Agriculture – Agriculture Research Service (USDA-ARS). It is a conceptual model that functions on a continuous time step. Model components include weather, hydrology, erosion/sedimentation, plant growth, nutrients, pesticides, agricultural management, channel routing, and pond/reservoir routing. Agricultural components in the model include fertilizer, crops, tillage options, and grazing and have the capability to include point source loads. The SWAT model predicts the influence of land management practices on constituent yields from a watershed. SWAT is a public domain model which is actively supported by the USDA Agricultural Research Service at the Grassland, Soil, and Water Research Laboratory in Temple, Texas, USA.

SWAT is a theoretical model that operates on a daily time step. In order to adequately simulate hydrologic processes in a basin, the basin is divided into sub-basins through which streams are routed. The subunits of the sub-basins are referred to as hydrologic response units (HRU's) which are the unique combination of soil and land use characteristics and are considered to be hydrologically homogeneous. The model calculations are performed on a HRU basis and flow and water quality variables are routed from HRU to sub-basin and subsequently to the watershed outlet. The SWAT model simulates hydrology as a two-component system, comprised of land hydrology and channel hydrology. The land portion of the hydrologic cycle is based on a water mass balance. Soil water balance is the primary considerations by the model in each HRU, which is represented as:

$$SW_t = SW_0 + \sum_{i=1}^{t} (R_{day} - Q_{surf} - E_a - w_{seep} - Q_{gw})$$

where SW is the soil water content, i is time in days for the simulation period t, and R,Q, ET, P and QR respectively are the daily precipitation, runoff, evapotranspiration, percolation, and return flow. Water enters the SWAT model's watershed system boundary predominantly in the form of precipitation. Precipitation inputs for hydrologic calculations can either be measured data or simulated with the weather generator available in the SWAT model. Precipitation is partitioned into different water pathways depending on system characteristics. The water balance of each HRU in the watershed contains four storage volumes: snow, the soil profile (0-2 m), the shallow aquifer (2-20 m) and the deep aquifer (>20 m). The soil profile can contain several layers. The soil-water processes include infiltration, percolation, evaporation, plant uptake, and lateral flow. Surface runoff is estimated using the SCS curve number or the Green-Ampt infiltration equation. Percolation is modeled with a layered storage routing technique combined with a crack flow model. Potential evaporation can be calculated using Hargreaves, Priestly-Taylor or Penman-Monteith method.

Loadings of flow, sediment, nutrients, pesticides, and bacteria from the upland areas to the main channel are routed through the stream network of the watershed using a process similar to HY). The stream processes modeled by SWAT include channel sediment routing and nutrient and pesticide routing and transformation. The pond/reservoir routing allows for sediment settling and simplified nutrient and pesticide transformation routines. The command structure for routing runoff and chemicals through a watershed is similar to the structure for routing flows through streams and reservoirs.

The SWAT watershed model also contains algorithms for simulating erosion from the watershed. Erosion is estimated using the Modified Universal Soil Loss Equation (MUSLE). MUSLE estimates sediment yield from the surface runoff volume, the peak runoff rate, the area of the HRU, the Universal Soil Loss Equation (USLE) soil erodability factor, the USLE cover and management factor, the USLE support practice factor, the USLE topographic factor, and a coarse fragment factor.

After the sediment yield is evaluated using the MUSLE equation, the SWAT model further corrects this value considering snow cover effect and sediment lag in surface runoff. The SWAT model also calculates the contribution of sediment to channel flow from lateral and groundwater sources. Eroded sediment that enters channel flow is simulated in the SWAT model to move downstream by deposition and degradation.

Soil N is also simulated in the SWAT model. Soil N is partitioned into five N pools with two being inorganic (ammonium-N (NH_4-N) and nitrate-N (NO_3-N)) and three being organic (active, stable, and fresh).The SWAT model simulates movement between N pools, such as mineralization, decomposition/immobilization, nitrification, denitrification, and ammonia volatilization. Other soil N processes such as N fixation by legumes and NO_3-N movement in water are also included in the model. All soil N processes are simulated in the SWAT model using relationships described in the model's theoretical documentation.

Once N enters channel flow, the SWAT model partitions N into four pools: organic N, NH_4-N, nitrite-N (NO_2-N), and NO_3-N. The SWAT model simulates changes in N that results in movement of N between pools. The algorithms used to describe N transformations in channel flow were adapted from the QUAL2E model by SWAT model developers. Large-area simulations are possible due to the advances in computer software and hardware, including speed and storage, GIS/spatial analysis and debugging tool software. SWAT model development primarily emphasizes (1) climate and management impacts; (2) water quality loadings and fate; (3) flexibility in basin discretization; and (4) continuous time simulation.

Another nutrient simulated in the soil profile of the SWAT model is P. Soil P is divided into six P pools. Three of the pools are characterized as mineral P and three are characterized as organic P. Transformations of soil P between these six pools are regulated by algorithms that represent mineralization, decomposition, and immobilization. Other soil P processes included in the SWAT model are inorganic P sorption and leaching. The algorithms describing soil P dynamics are available in the SWAT model theoretical documentation.

P that enters stream channels is evaluated in the SWAT model similar to N. Two pools of P are simulated for channel processes: organic P and inorganic/soluble P. The algorithms used in channel P calculations by the SWAT model were adapted from the QUAL2E model and are available in the SWAT model theoretical documentation.

While the SWAT model provides algorithms for calculating different watershed constituent dynamics, the ability of the SWAT model to depict processes in a particular watershed is partially dependent on the quality of input data. The input data that describe the physical structure of a watershed are generally incorporated into the model using the AVSWAT interface. AVSWAT is an ArcView interface version of the SWAT model. Mandatory GIS input files for AVSWAT include the Digital Elevation Map (DEM), land use, and soil layers. Other data that are not in GIS format are optional. Such additional data might include spatial referenced fertilizer data, animal production data, land management data, and point source data.

Inputs entered into the SWAT model are organized to have spatial characteristics. The SWAT model provides three spatial levels: the watershed, the sub-basins, and the hydrologic response units (HRUs). Each level is characterized by a parameter set and input data. The largest spatial level, the watershed, refers to the entire area being represented by the model. The sub-basins refer to subdivisions of the watershed that are connected hydrologically. Sub-basins are then subdivided into HRUs. HRUs are areas within a sub-basin that have the same soil and land use combination. Both sub-basins and HRUs are user defined, providing model users with some control over the resolution considered in the SWAT model

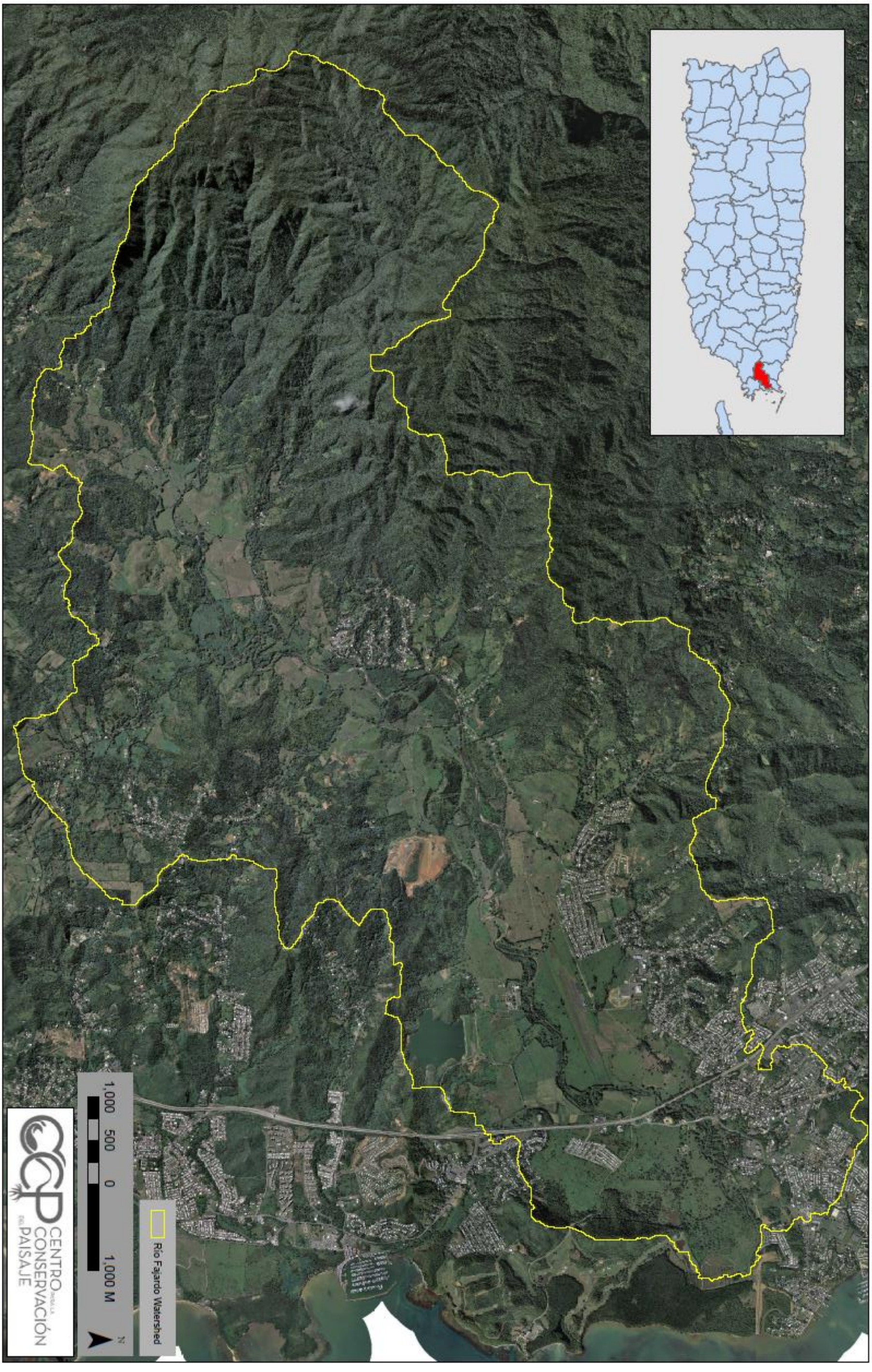
Although the SWAT model simulates on a daily time step, the model has options for the output that allow the user to define the output time step (daily, monthly, or annual). Output variables include flow volume, nutrient yields, sediment yield, and plant biomass yields. These variables are provided on the sub-basin or HRU spatial level depending on the output time step selected. The output files generated by the SWAT model are created in text and database file formats.

Model Limitations

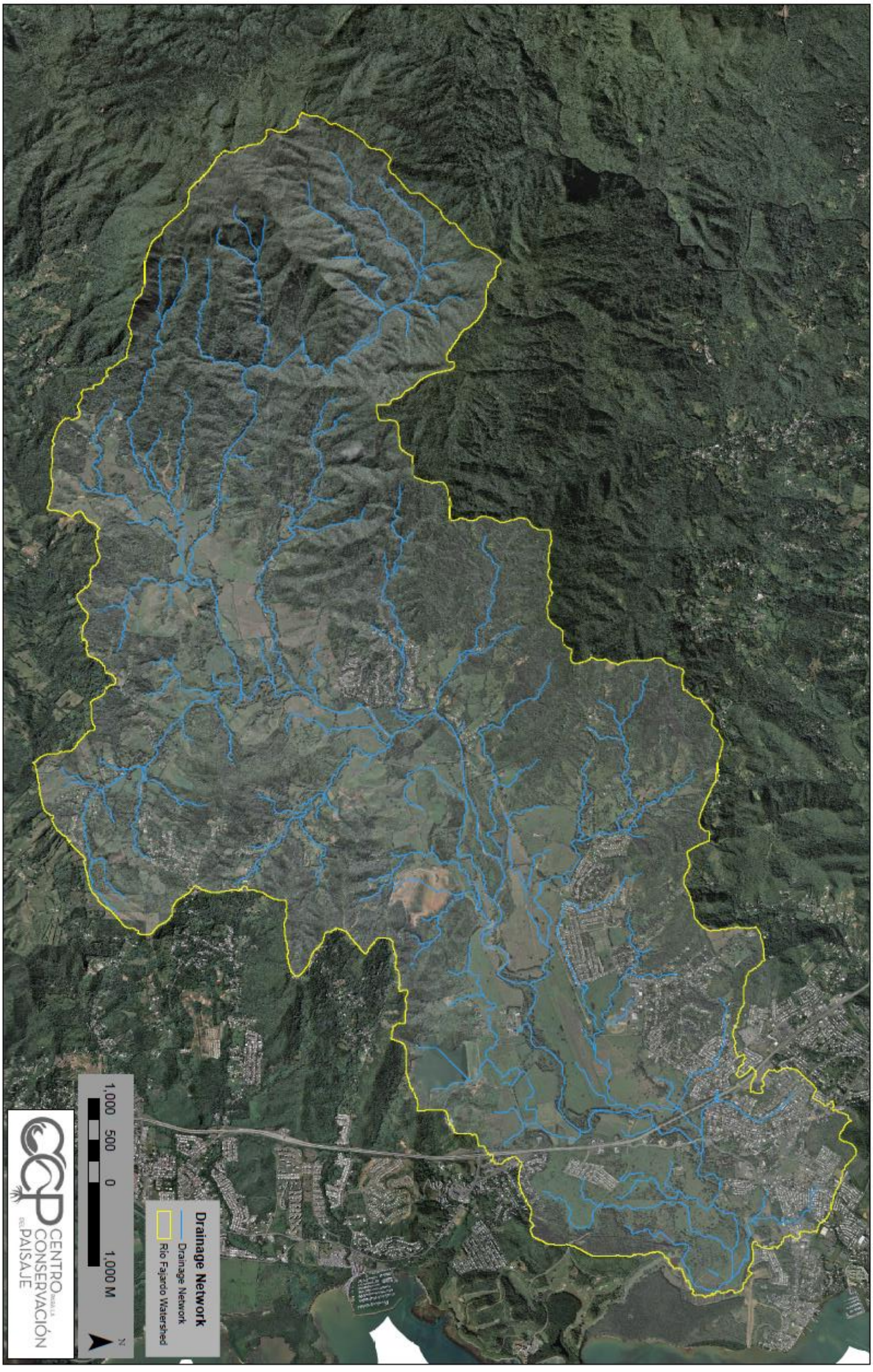
A major limitation to large area hydrologic modeling is the spatial detail required to correctly simulate environmental processes. For example, it is difficult to capture the spatial variability associated with precipitation within a watershed. Another limitation is the accuracy of hydrologic response units simulating field variations including conservation practices. SWAT is being altered to account for landscape spatial positioning so that conservation practices such as riparian buffers and vegetative filter strips can be adequately simulated.

Data files can be difficult to manipulate and can contain several missing records. The model simulations can only be as accurate as the input data. SWAT does not simulate detailed event-based flood and sediment routing.

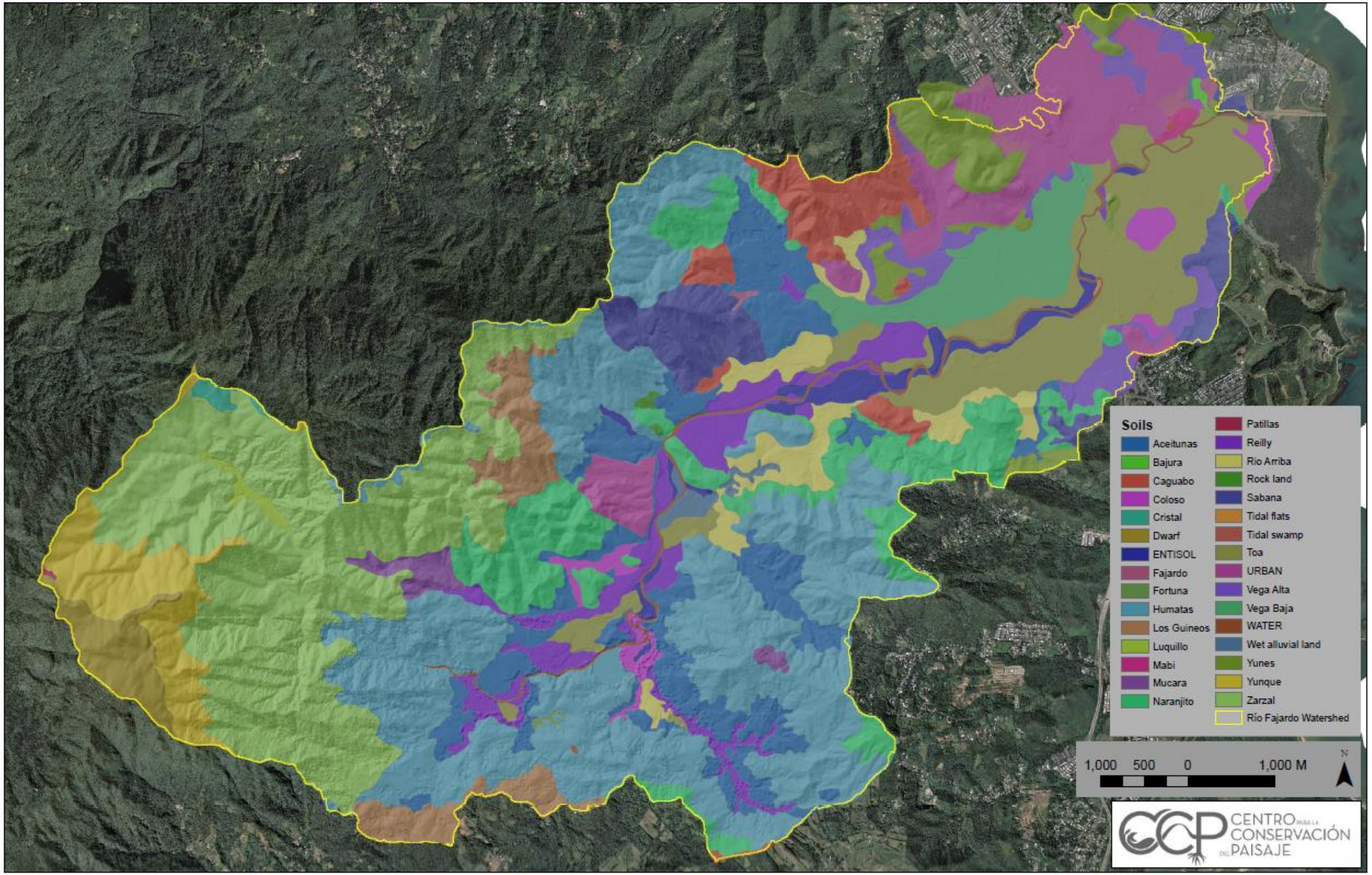
Appendix D Images for Río Fajardo watershed



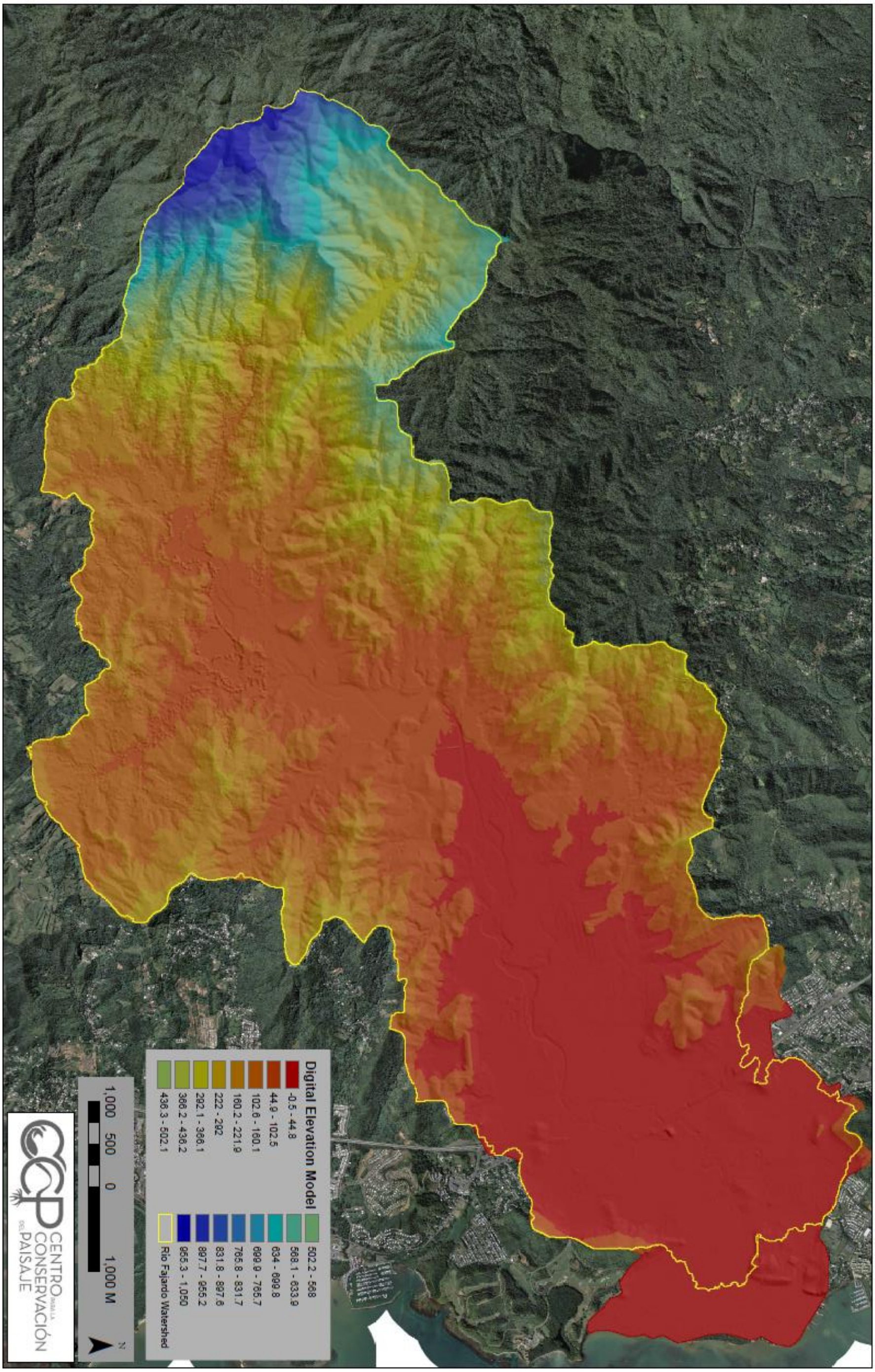
1. Limits of the Río Fajardo watershed.



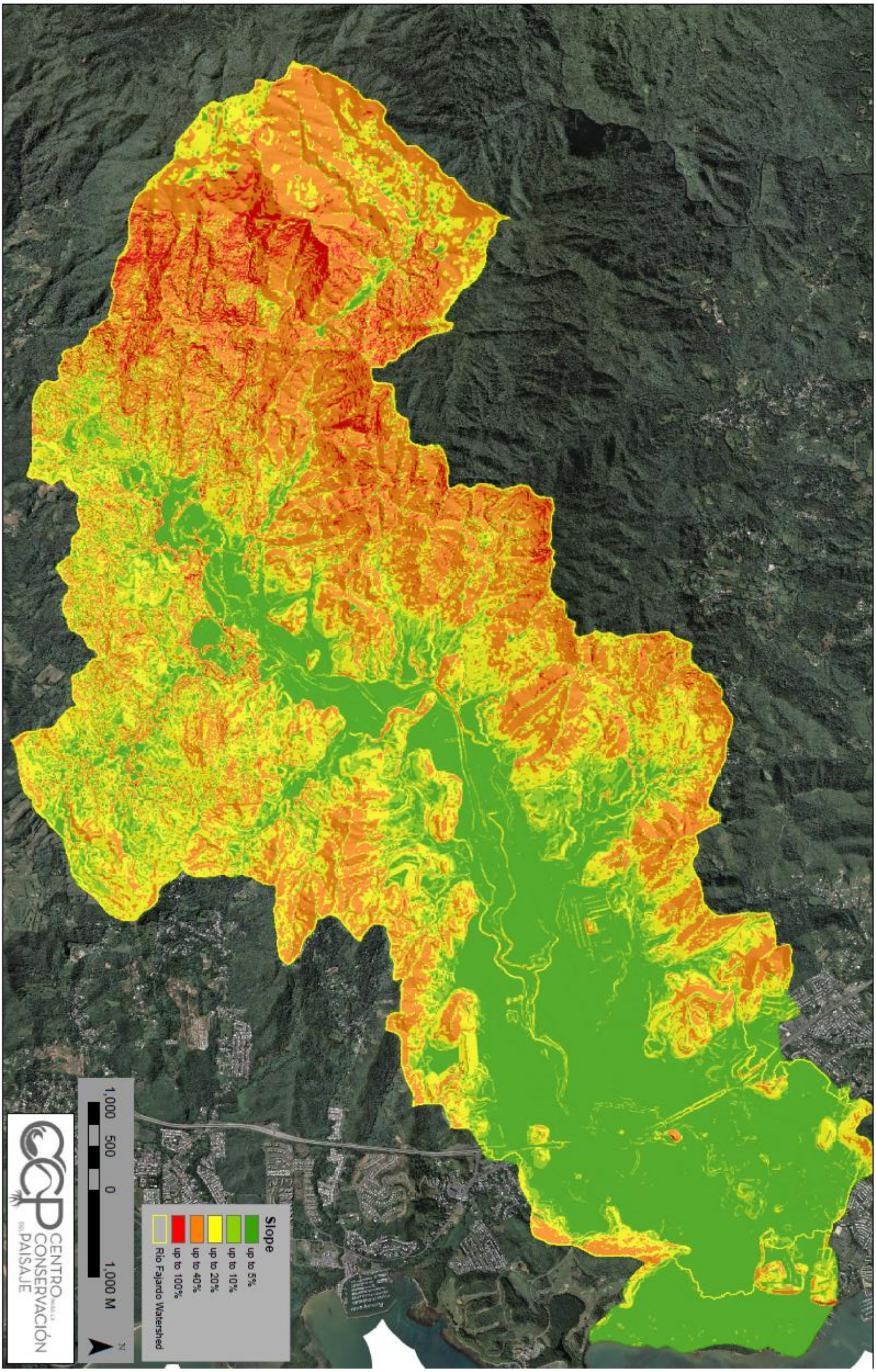
2. Watershed drainage network of Río Fajardo watershed.



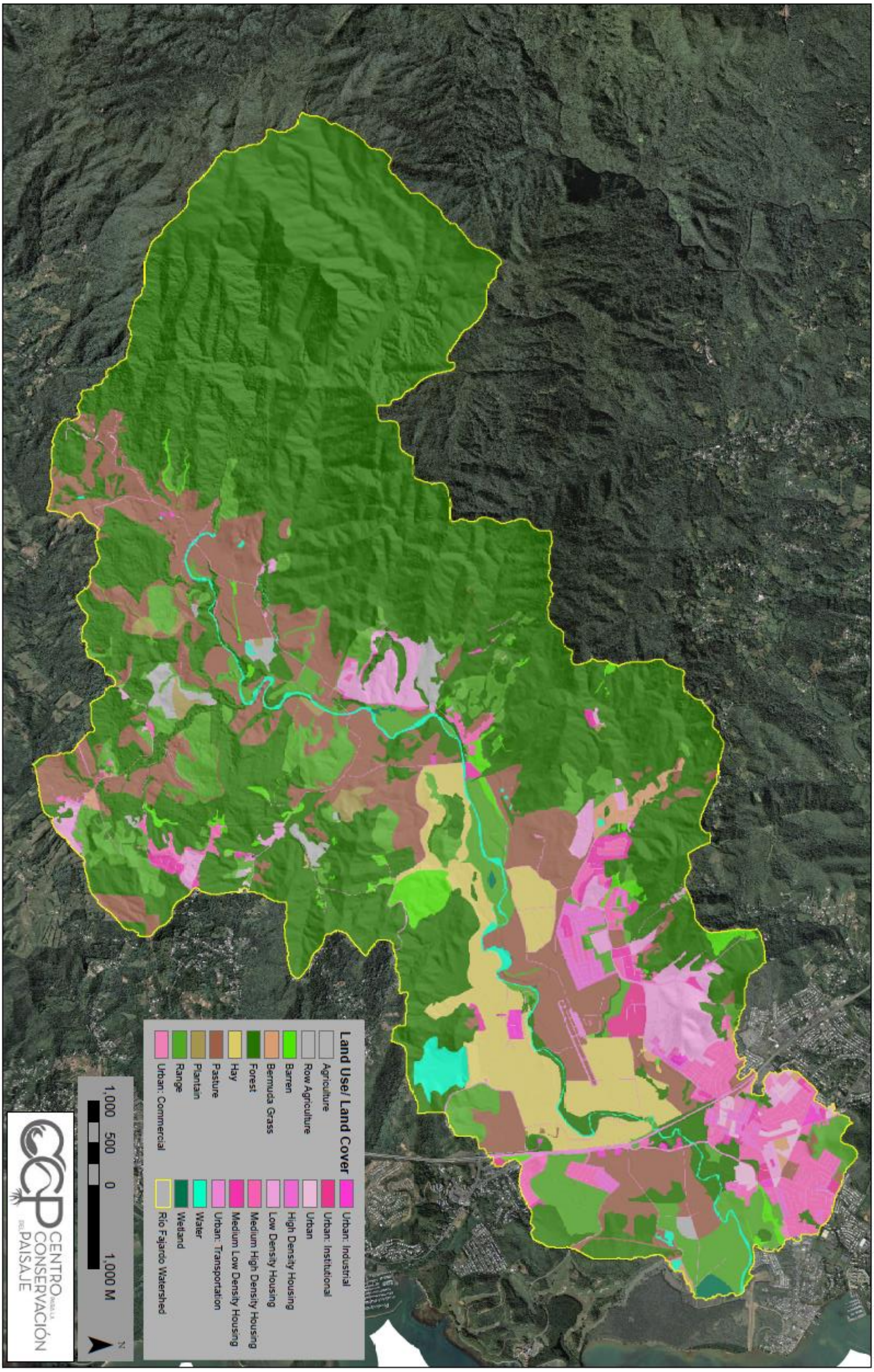
3. Soil distribution in the Río Fajardo watershed.



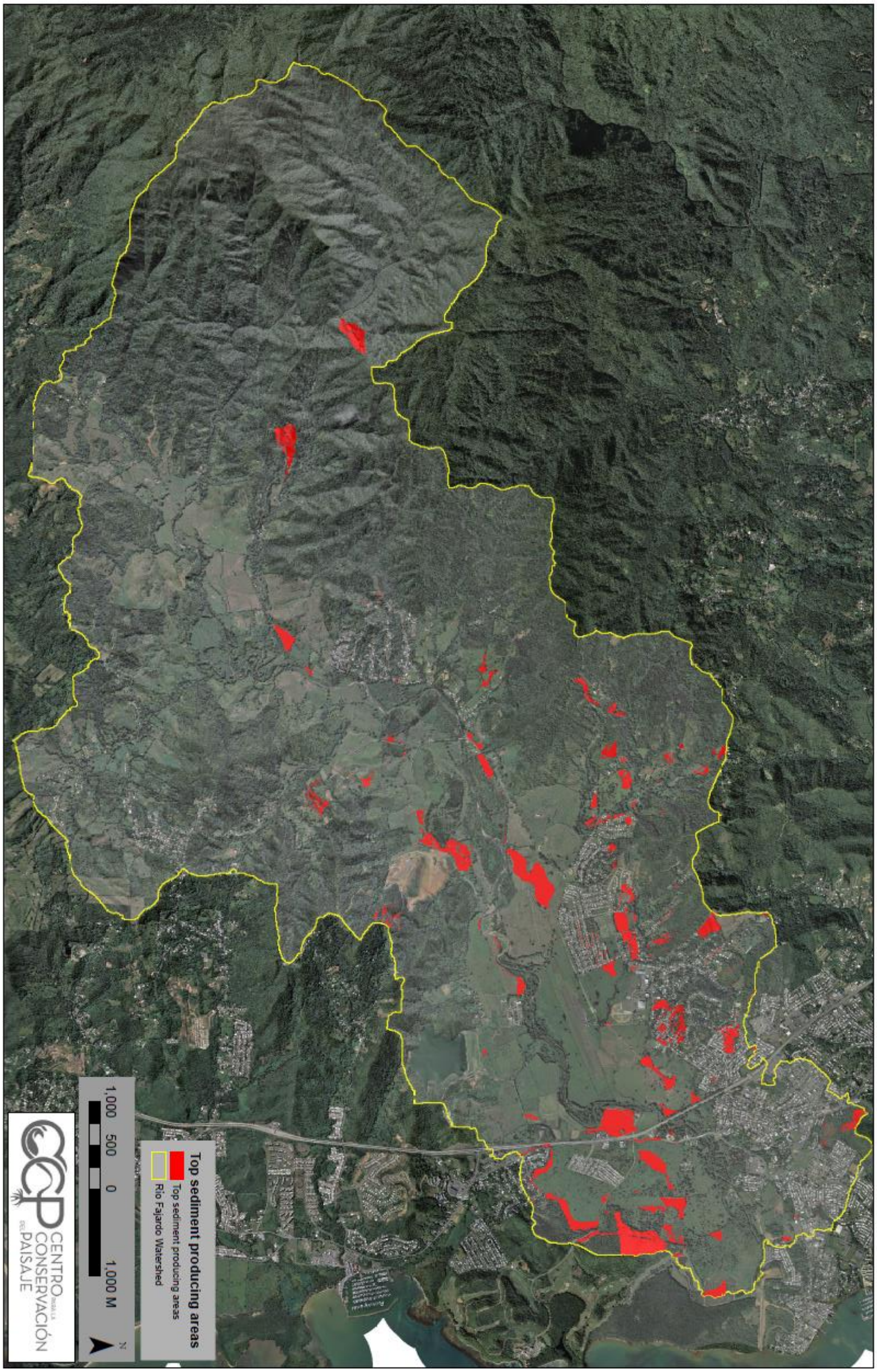
4. Digital elevation model for the Río Fajardo watershed.



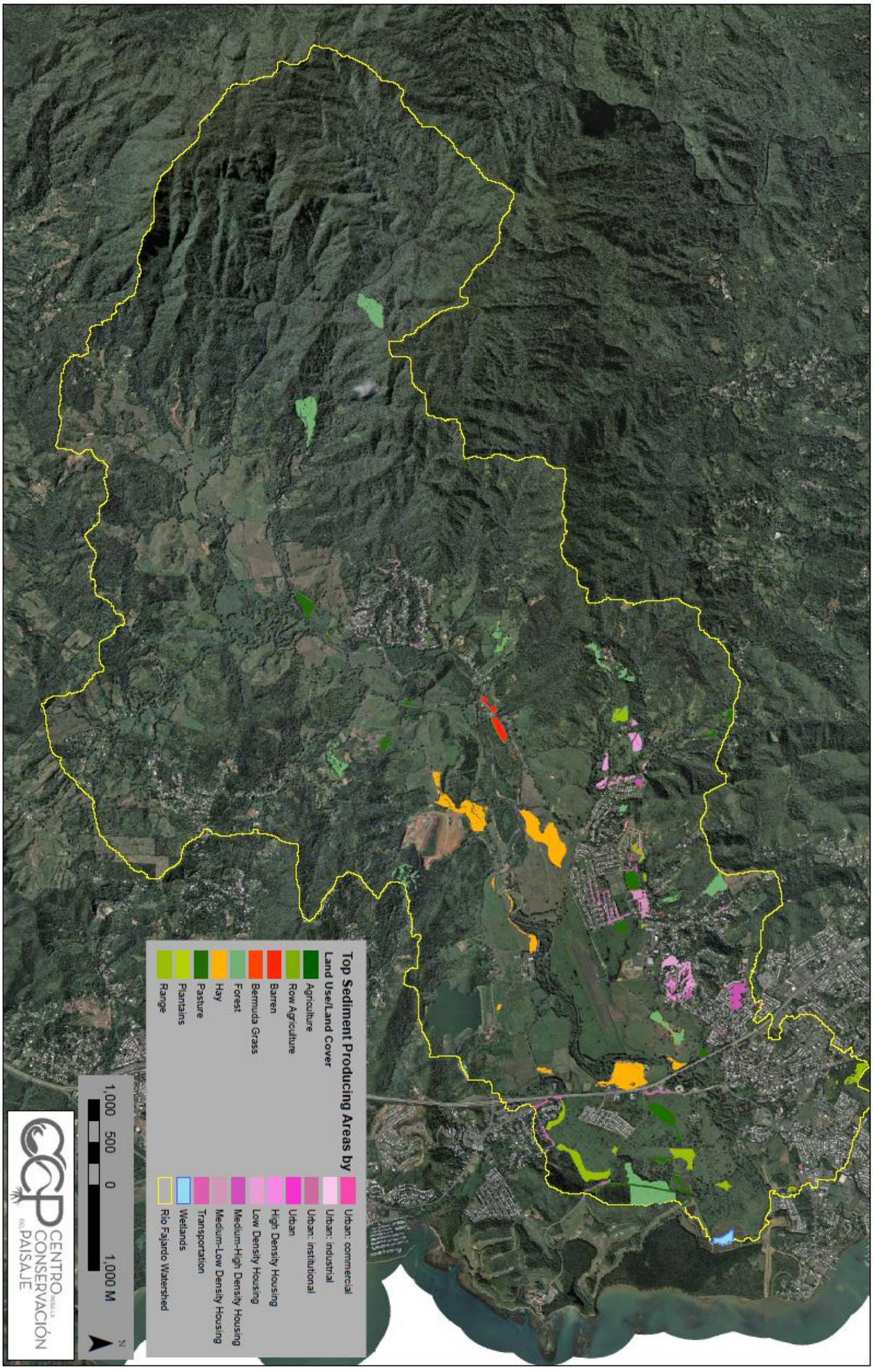
5. Slopes of the Rio Fajardo watershed.



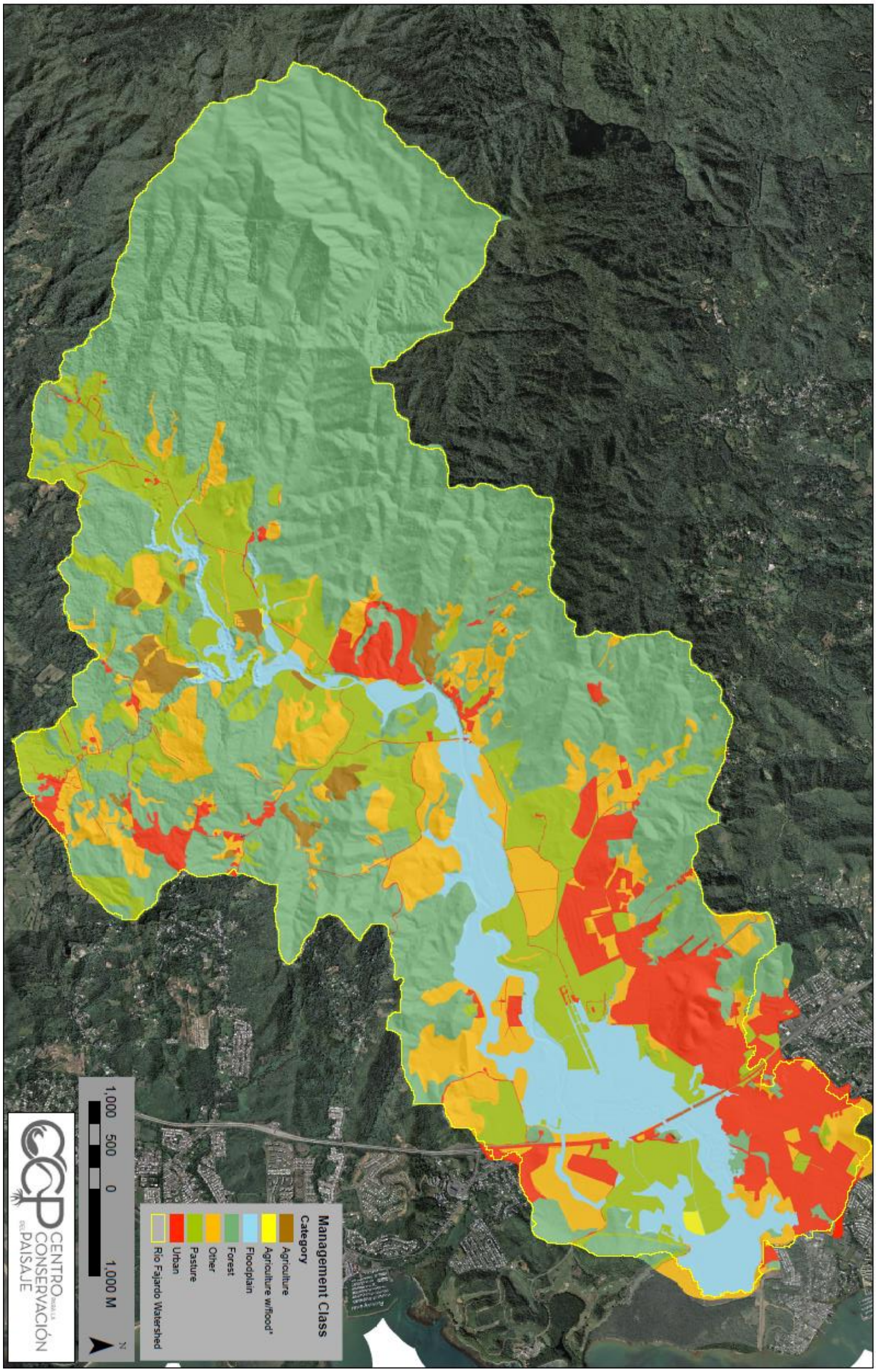
6. Land use / Land cover of the Rio Fajardo watershed.



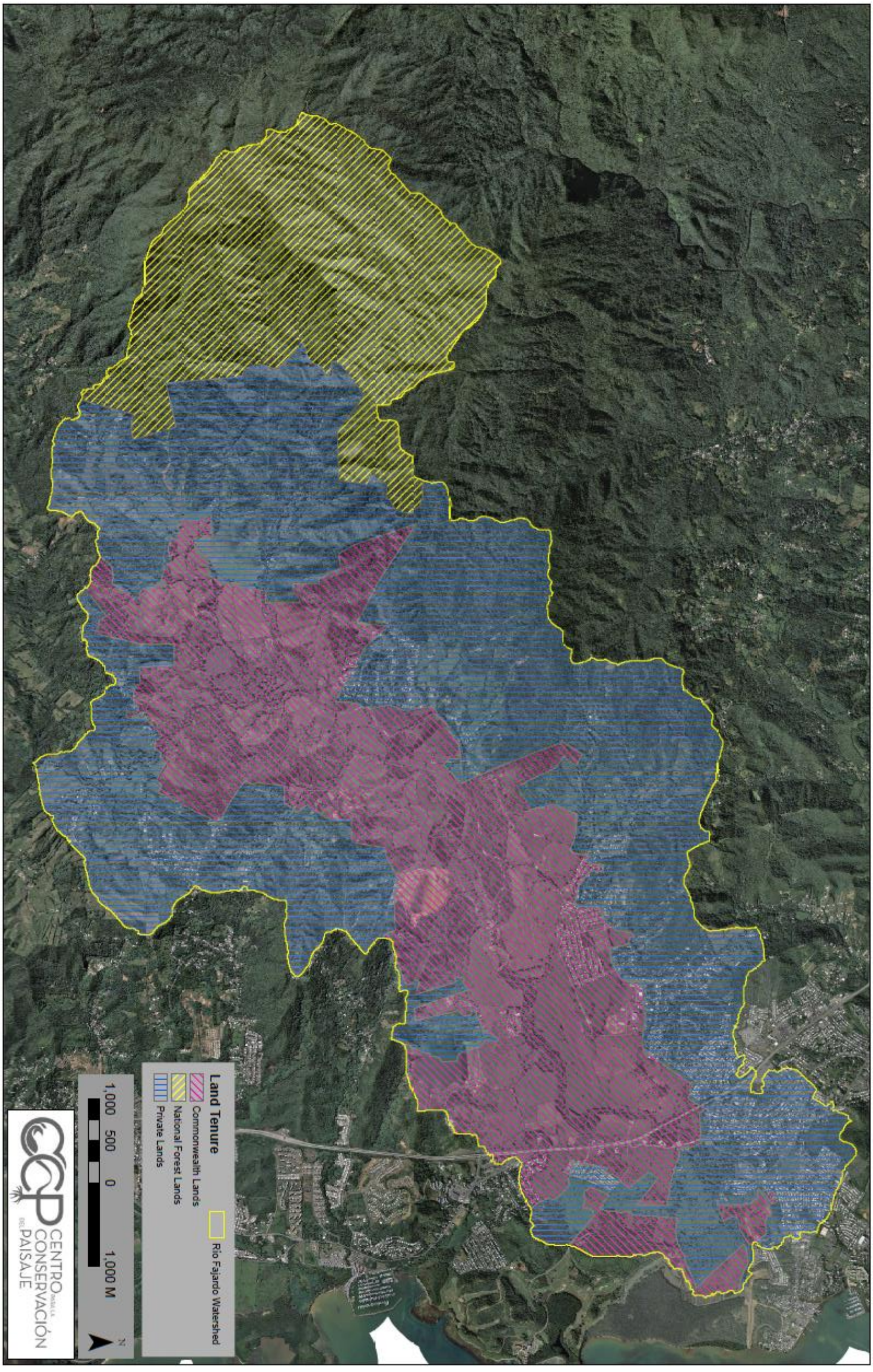
7. Top sediment producing areas of the Rio Fajardo watershed according to ArcSWAT analysis.



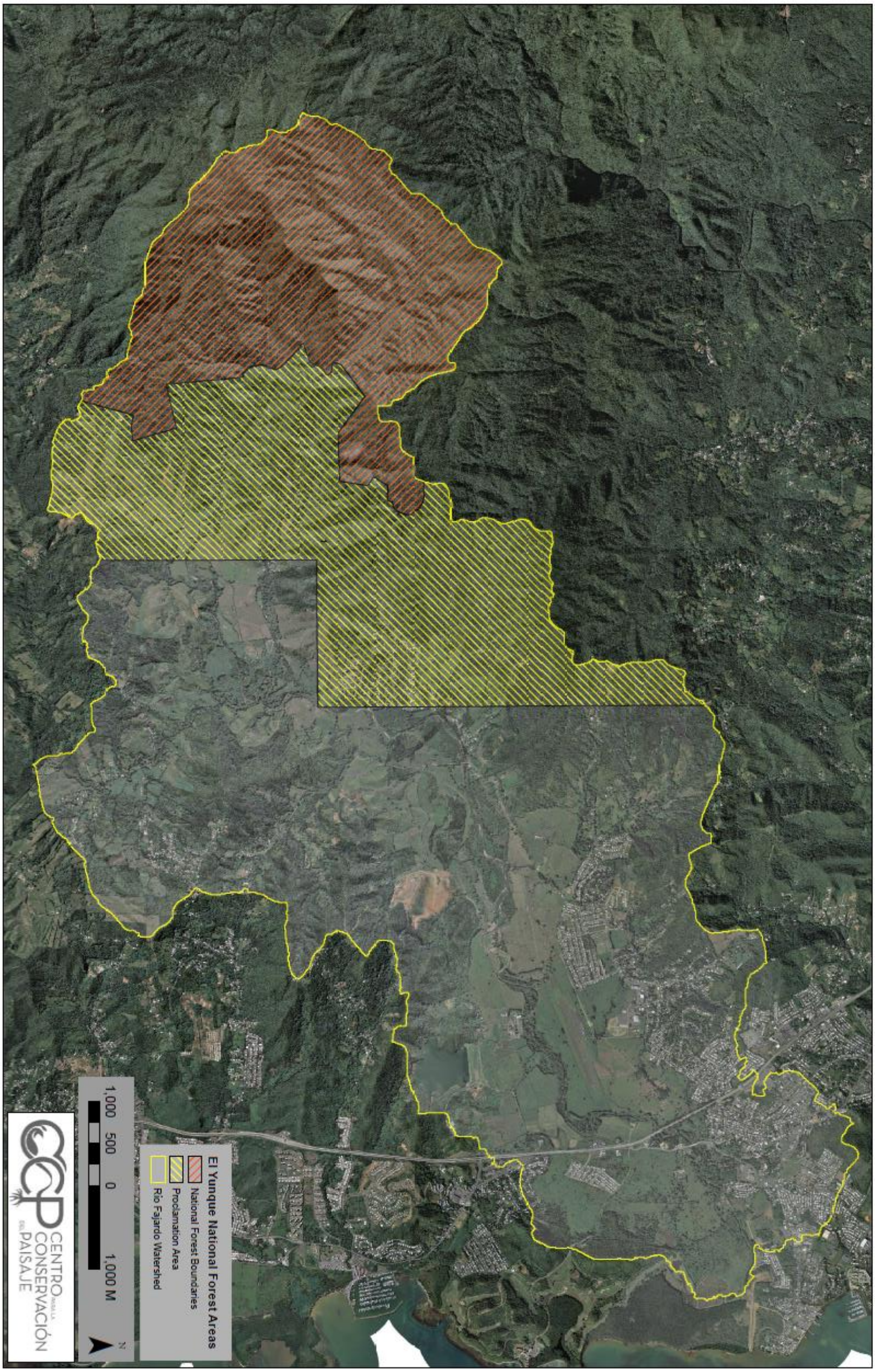
8. Top sediment producing area by Land use / Land cover of the Rio Fajardo watershed.



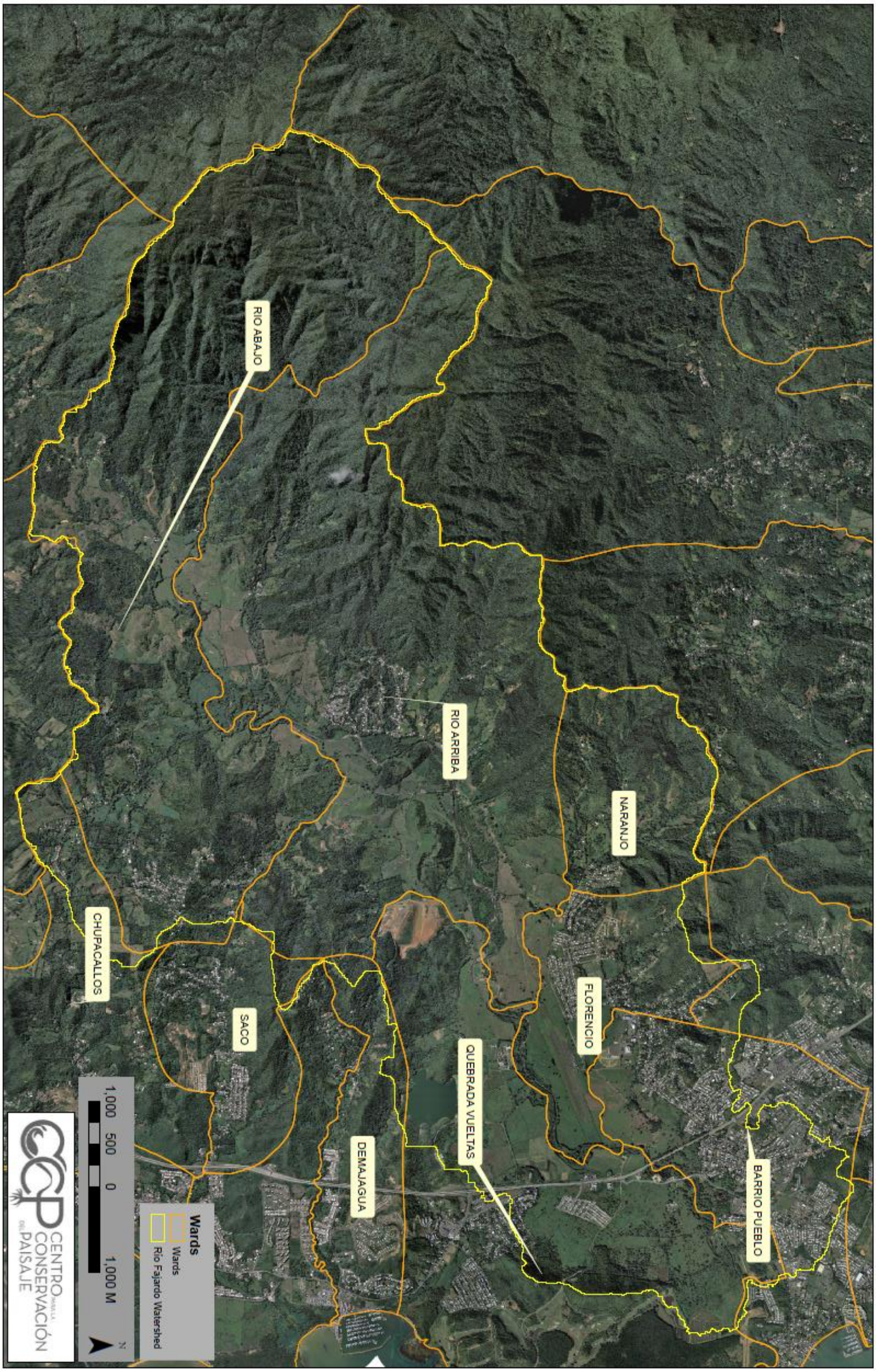
9. Management Classes considered for the Río Fajardo watershed analysis.



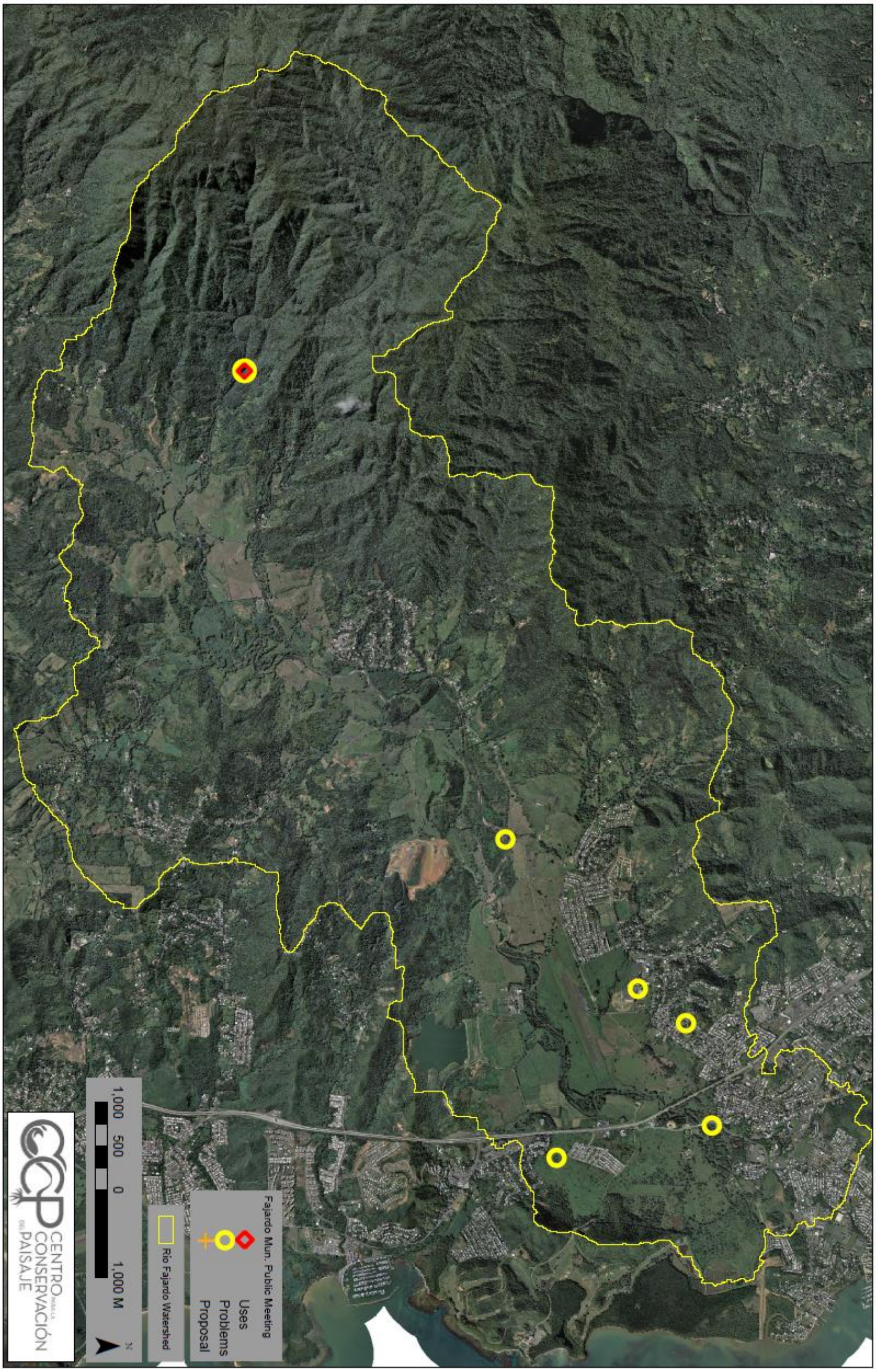
10.Land tenure in the Río Fajardo watershed.



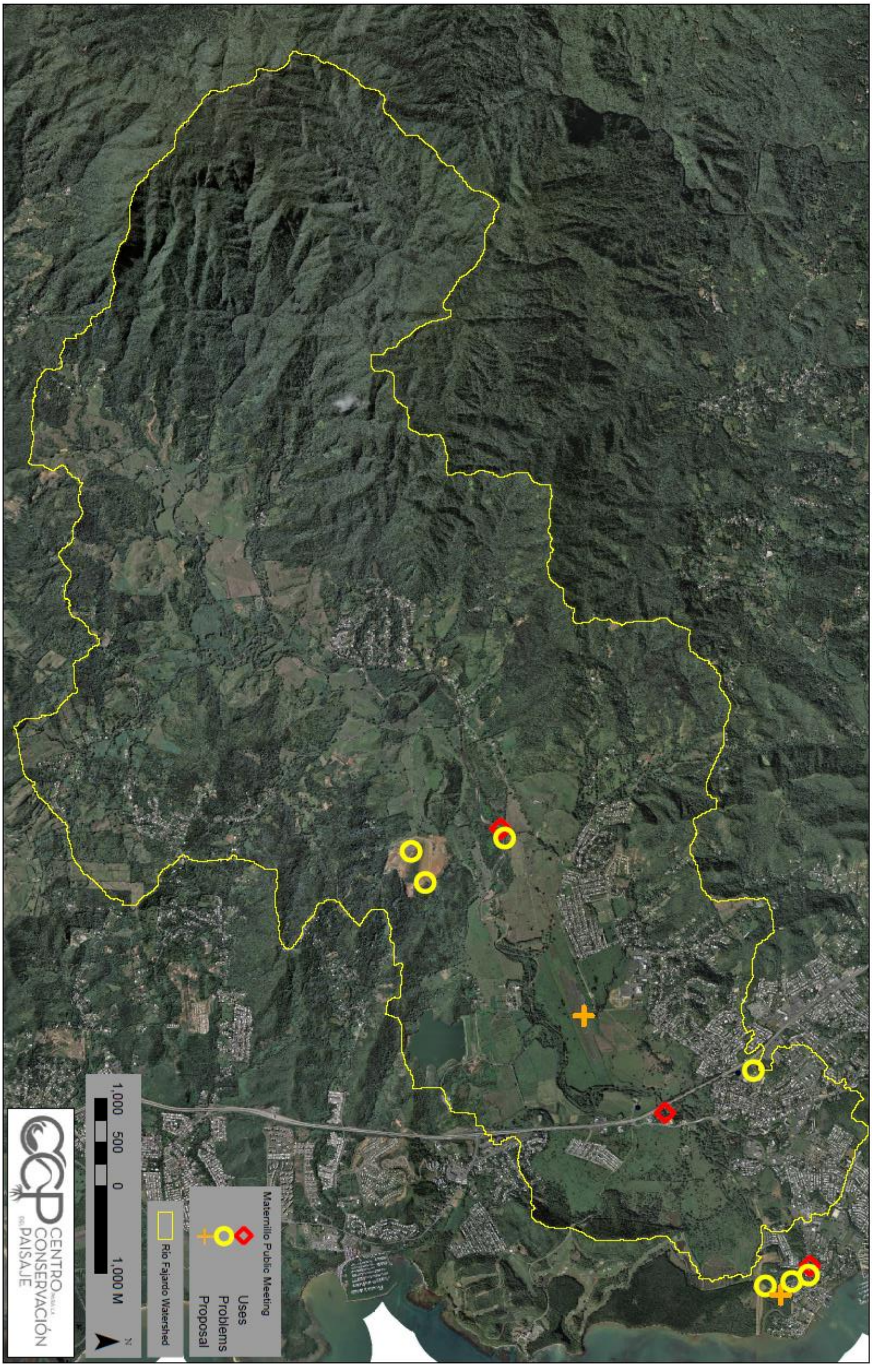
11.El Yunque National Forest Areas within the Río Fajardo watershed.



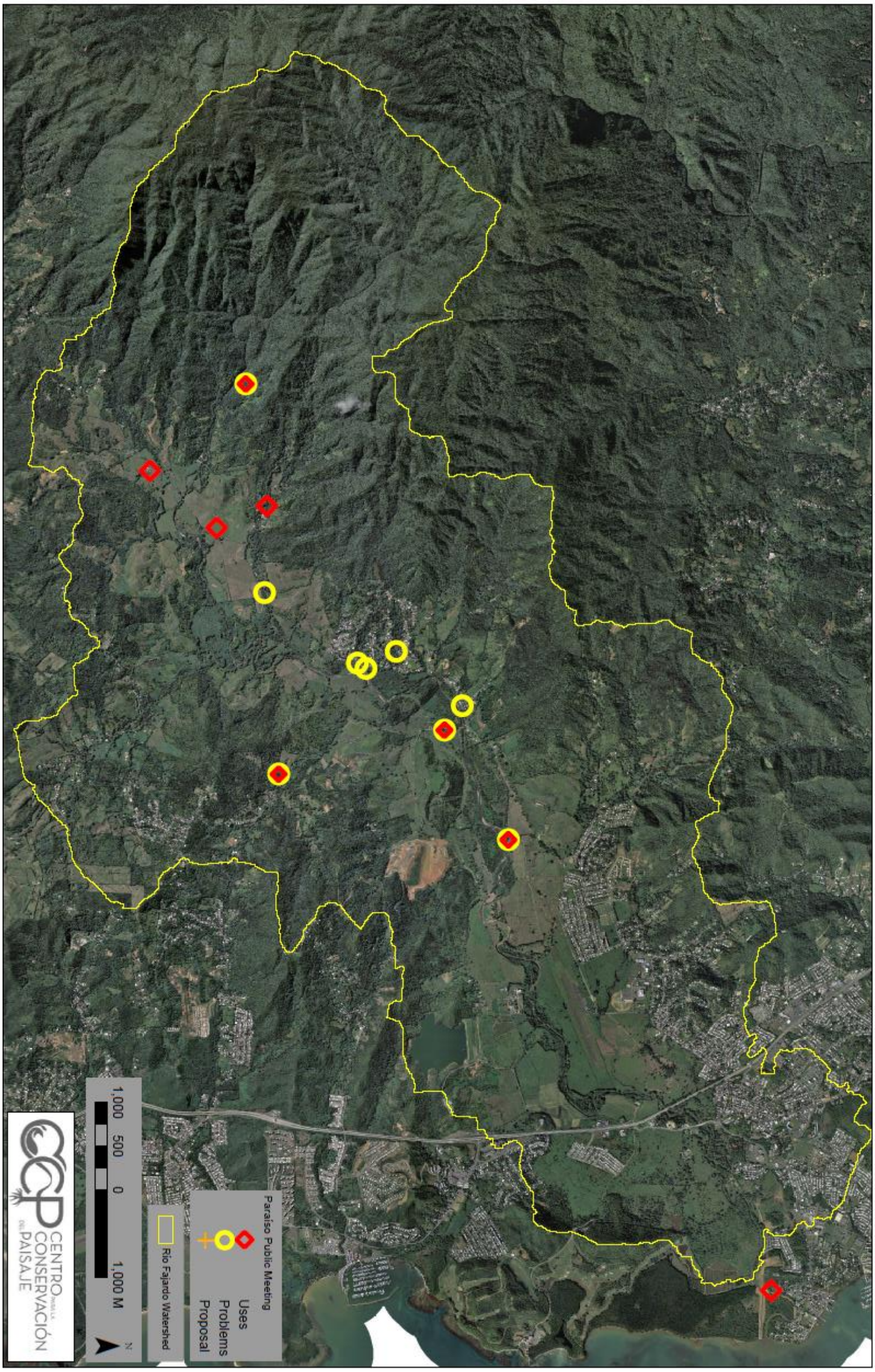
12.Wards within the Río Fajardo watershed.



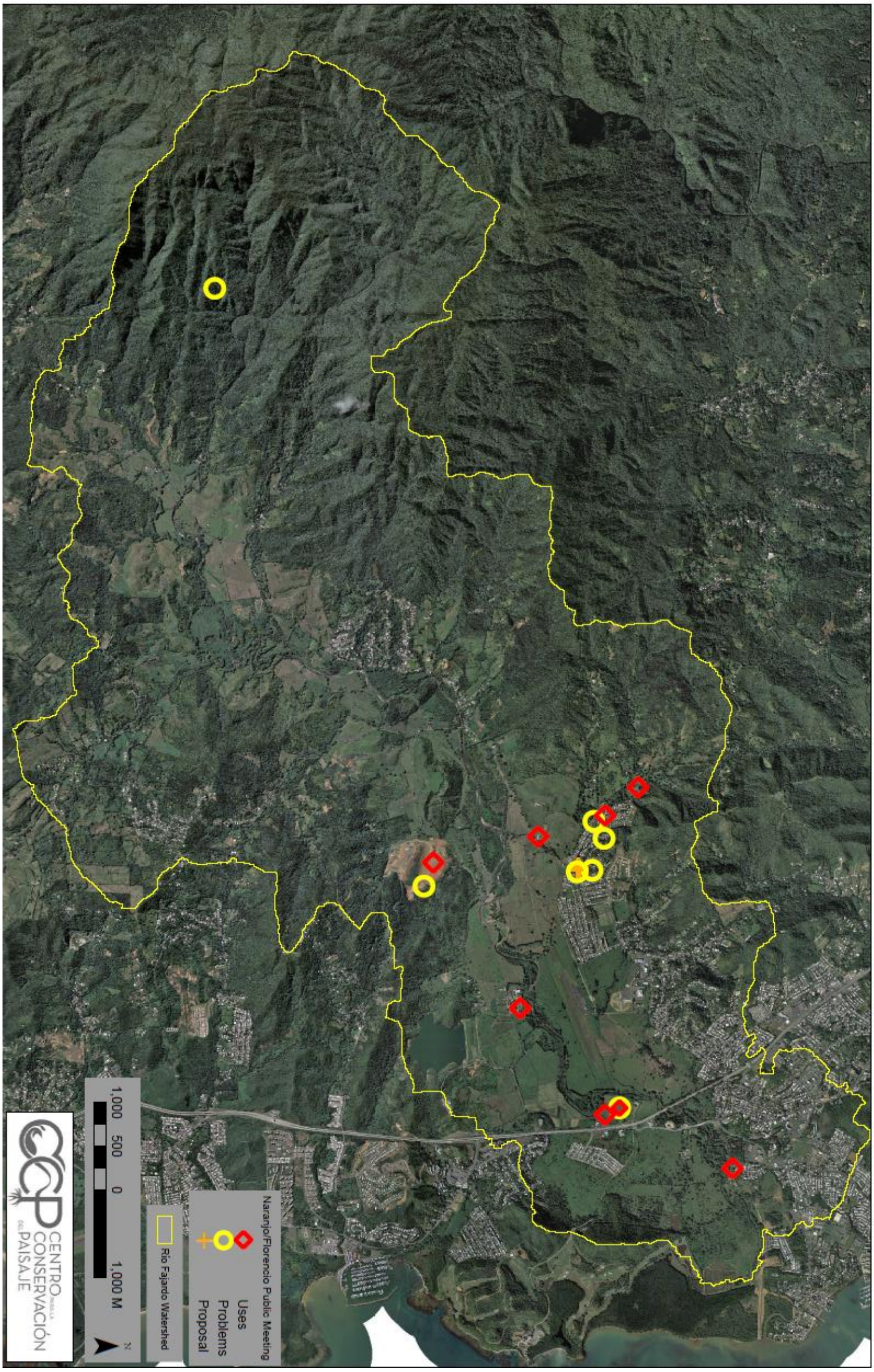
13. Areas identified as part of the participatory map exercise for Fajardo Municiplaity Meeting.



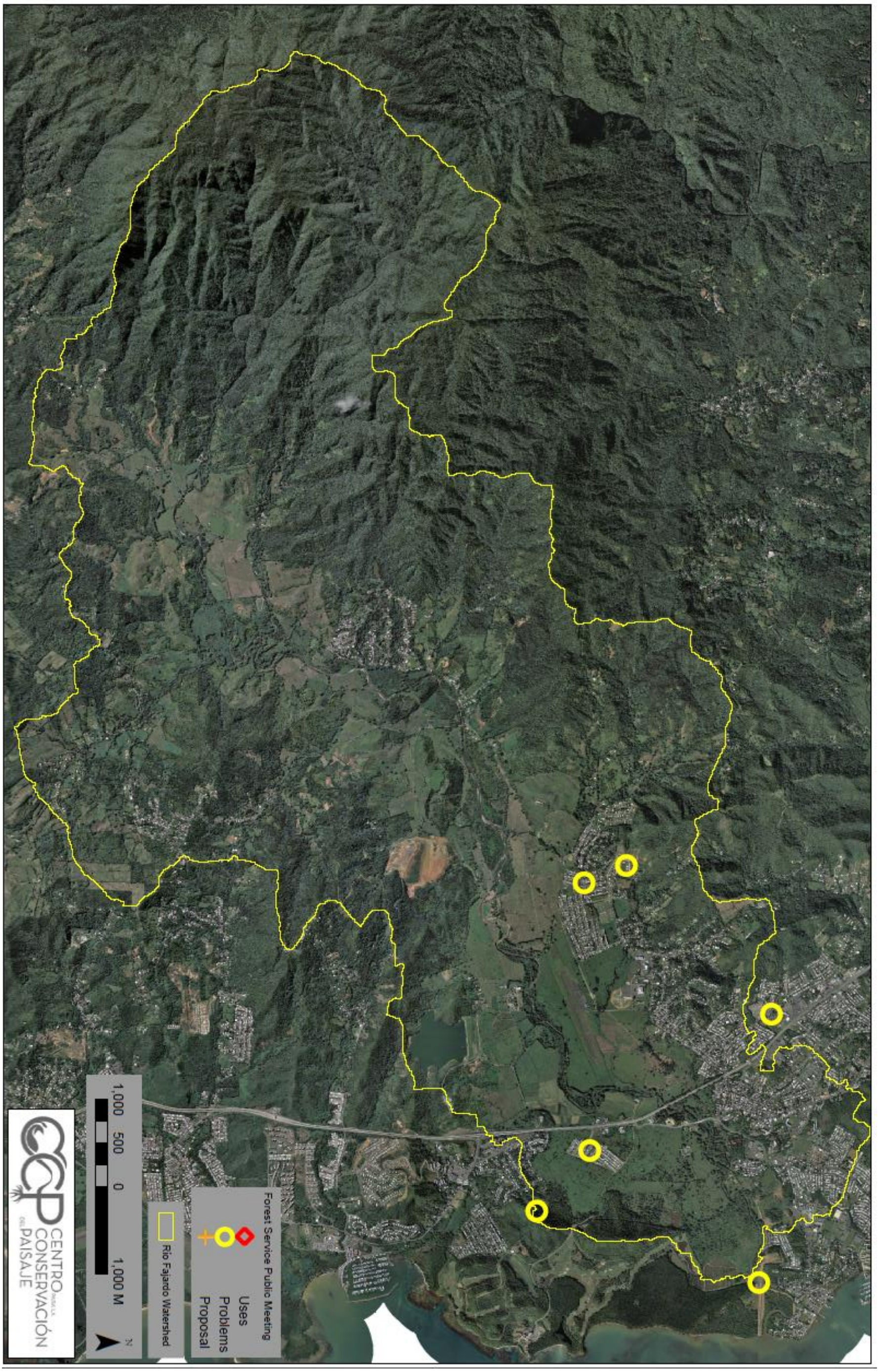
14. Areas identified as part of the participatory map exercise for Maternillo Meeting.



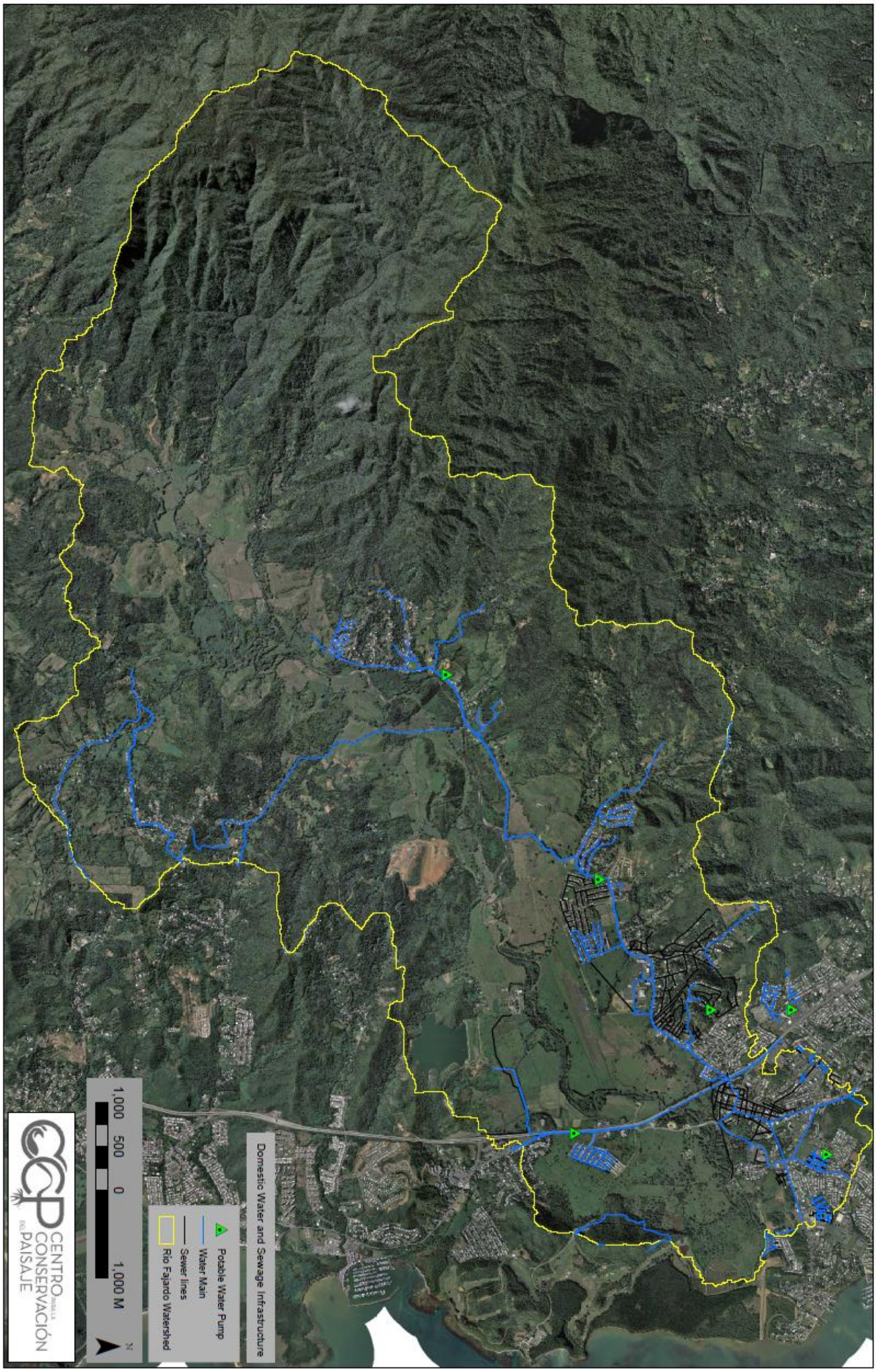
15. Areas identified as part of the participatory map exercise for Paraiso Meeting.



16. Areas identified as part of the participatory map exercise for Naranjo/Florencio Meeting.



17. Areas identified as part of the participatory map exercise with Forest Service representative.



18. Domestic water and Sewage Infrastruture for the Río fajardo watershed (provided by DNER).

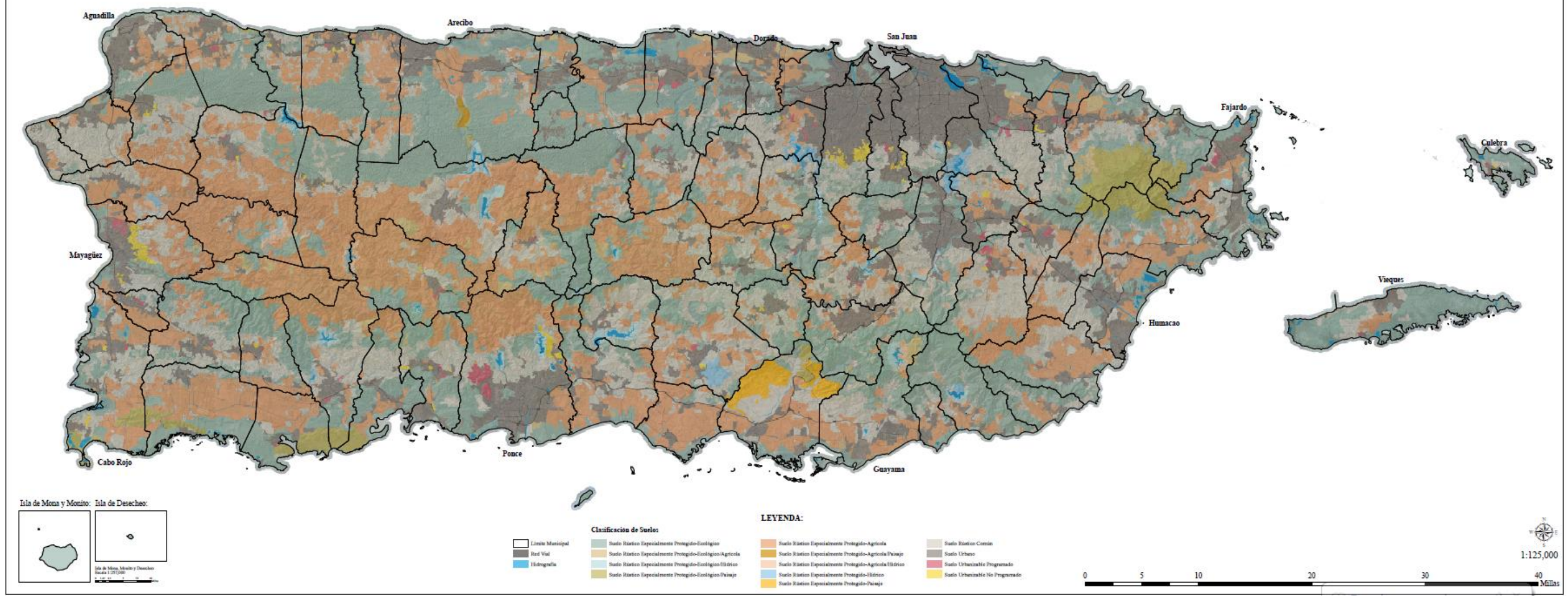
ESTADO LIBRE ASOCIADO DE
PUERTO RICO
Junta de Planificación

Borrador para Vista Pública

Mapa de Clasificación del Territorio

Plan de Uso de Terrenos de Puerto Rico

Diciembre 2014



19. Proposed Land Classification Presented by the Puerto Rico Planning Board December 2014

Appendix E SWAT-CUP information

http://www.eawag.ch/forschung/siam/software/swat/index

Forschung » Siam » Software » SWAT

eawag
aquatic research

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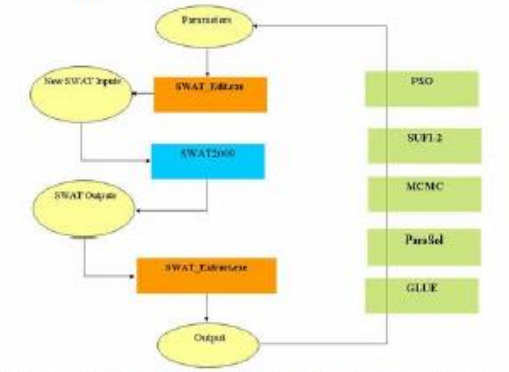
Systemanalyse und Modellierung
SWAT

SWAT-CUP is a computer program for calibration of SWAT models. SWAT-CUP is a public domain program, and as such may be used and copied freely. The program links GLUE, ParaSol, SUFI2, MCMC, and PSO procedures to SWAT. It enables sensitivity analysis, calibration, validation, and uncertainty analysis of a SWAT model. The overall program structure is as shown in the Figure below.



In the new version, SWATCUP_4.3.1, a more powerful SWAT_Edit program is provided where ALL SWAT parameters are handled, including different soil layers and management rotation-operations, precipitation data, etc. The users are also allowed 20 "free" parameters placed at the end of *.gw files to use for their own programs, which may be linked to SWAT. This version also includes parallel processing (which is licensed but 20 simulation are allowed to be made for testing the program), visualization of the outlet locations using the Bing Map, creation of multi_objective objective function, extraction and calculation of 95PPU for all variables in output.rch, output.hru, and output.sub files without measurements, and one-at-a-time sensitivity analysis).

Upcoming functionalities of SWAT-CUP would include visualization of calibrated variables superimposed on Bing Map, as well as ArcSWAT's river map, and subbasins.

Publications

- Abbaspour et al. 2007 (Application of SUFI2 to Thur Watershed in Switzerland) [pdf, 465 KB]
- Abbaspour et al. 2004 (Application of SUFI2 to two landfills in Switzerland) [pdf, 1.9 MB]
- Schuol et al. 2008 (Application of SWAT in Western Africa) [pdf, 4.6 MB]
- Yang et al. 2008 (Comparison of five optimization programs) [pdf, 1.6 MB]
- Schuol et al. 2008 (Application of SWAT to Continent of Africa) [pdf, 2.1 MB]
- Faramarzi et al. 2009 (Application of SWAT in Iran) [pdf, 1.2 MB]

Contact

Karim C. Abbaspour (abbaspour@eawag.ch)

Downloads

- Program software and manual can be downloaded from

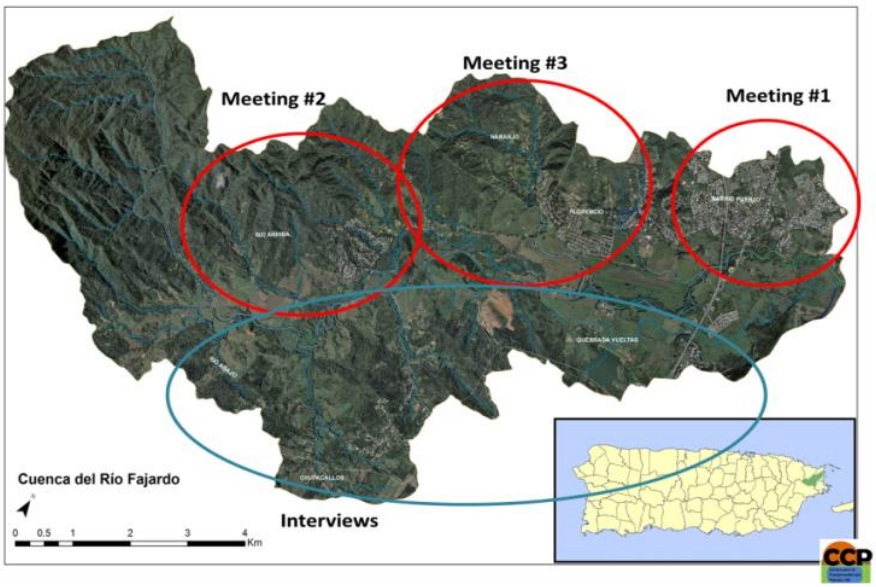
http://www.neprashtechnology.ca/

Appendix F: PARTICIPATORY MAPPING

Below a detail account of the steps made in order to do the public outreach and social mobilization needed to develop the plan. First, we identified and map local contacts, local stakeholders or partners, and agencies associated with the project to gather input for the watershed planning process. This is one of the first steps in the watershed planning and implementation process (US EPA, 2008). Then, we went to interview the director of the Bureau of Land Management and Planning of the Autonomous Municipality of Fajardo. The Director of Public Works, the Recycling Program Coordinator among others was present during this meeting. From there we gathered information related to environmental problems within the basin, their opinion on the basin's actual status, how the waste is being managed, and they provided us with some important documents for the characterization of land uses and storm sewer system. We first used participatory mapping with them. Also, we had a meeting with a personnel from the US Forest Service with knowledge and expertise on the Fajardo River Watershed with the intention to use the same tool (acquire information using participatory mapping). He told us about some of the environmental problems in the basin.

On the other hand, due to time and resources constraints we previously had decided that it was going to be performed at least 3 community meetings to discuss land use changes through time, environmental problems that may impact or affect the basin's and people's health. Participatory mapping was carried out using Google Earth. This is a good way to promote interaction among stakeholders and CCP. "By using overlays and Google Earth, mapping can become more dynamic and interactive". (Stocker, Burke, Kennedy, & Wood, 2012)

The basin was divided in four parts according to the concentration of population in certain regions. Then we selected 3 areas where the community meetings were going to take place; and decided to carry out personal interviews to community leaders in the basin's south.



Before the meetings, we went to the community to recognize the study area. During the meetings and interviews we provided a brief description of our organization (CCP). In this introductory phase of the meeting we presented some of our projects, defined what a watershed is and the area Fajardo's river

watershed comprises. Finally, it was explained the ultimate purpose of this project and the tool we were using to gather important information from them.

The first meeting was in the IA-U in Fajardo for the residents from downtown Fajardo, Santa Isidra and Maternillo neighborhood, which 12 people of the community attended. The second dialogue was held in the indoor basketball court of Paraíso for the people of this ward and surrounding areas. The attendance was about 11 people. The third dialogue was held in the Municipal Natatorium of Florencio ward, for residents of Naranjo- Volantín, Florencio and surrounding communities. Twelve people of these communities attended to this meeting.

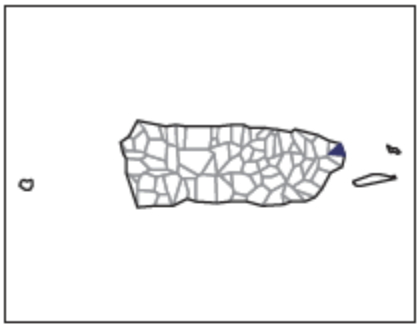
Another way to acquire information is by personal interviews. We did this activity with people living in the south of the watershed. The latter includes Quebrada Vueltas in Fajardo, and Río Abajo and Chupacallos in Ceiba. The characteristics of the interviewees are community leader or people that have lived in the area long enough to have seen the different environmental problems, changes in land use, and their opinion on what has to be done to improve the watershed's health. The dynamic in the interviews was same than the one used in the meetings: participatory mapping using Google Earth.

Appendix G - 2012 Census of Agriculture-Municipio Profile for Fajardo Puerto Rico

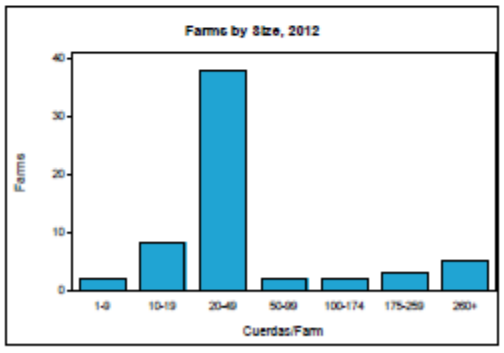
2012 CENSUS OF AGRICULTURE

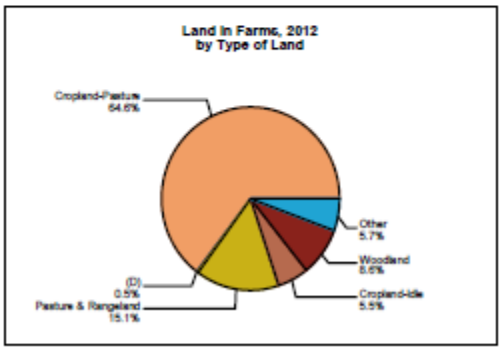
MUNICIPIO PROFILE

Fajardo Municipio
Puerto Rico



	2012	2007	% change
Number of Farms	60	63	- 5
Land in Farms	4,496 cuerdas	4,204 cuerdas	+ 7
Average Size of Farm	75 cuerdas	67 cuerdas	+ 12
Market Value of Products Sold	$656,314	$1,822,937	- 64
Crop Sales $213,078 (32 percent) Livestock Sales $443,236 (68 percent)			
Average Per Farm	$10,939	$28,936	- 62
Government Payments	$22,558	$66,948	- 66





USDA US Department of Agriculture
National Agricultural Statistics Service
www.agcensus.usda.gov

2012 CENSUS OF AGRICULTURE

MUNICIPIO PROFILE

Fajardo Municipio – Puerto Rico

Ranked items among the 76 municipios, 2012

Item	Quantity	Island Rank	Universe [1]
MARKET VALUE OF AGRICULTURAL PRODUCTS SOLD ($1,000)			
Total value of agricultural products sold	656,314	72	76
Value of Value of crops sold	213,078	72	75
Value of livestock, poultry, and their products	443,236	56	75
VALUE OF SALES BY COMMODITY GROUP ($1,000)			
Nursery and greenhouse crops	-	-	-
Plantains	(D)	53	71
Coffee	-	-	-
Vegetables or melons	(D)	37	69
Fruit	-	-	-
Bananas	(D)	56	60
Root crops or tubers	-	69	63
Grains	-	-	-
Grasses	(D)	56	58
Poultry and eggs	(D)	42	63
Cattle and calves	430,986	24	75
Milk and other dairy products from cows sold	-	-	-
Hogs and pigs	-	-	-
Aquaculture	(D)	6	19
Other livestock and other livestock products	-	-	-
TOP LIVESTOCK INVENTORY ITEMS (number)			
Cattle and Calves	3,119	22	75
Poultry	428	50	74
Sheep	112	21	63
Horses	99	24	76
Rabbits	68	34	57
TOP CROP ITEMS (cuerdas)			
Plantains	35	56	71
Vegetables	21	39	69
Grasses	(D)	56	60
Oranges	4	58	70
Bananas	(D)	58	61

Other Municipio Highlights, 2012

Economic Characteristics	Quantity
Farms by value of sales:	
Less than $1,000	15
$1,000 to $2,499	8
$2,500 to $4,999	15
$5,000 to $7,499	4
$7,500 to $9,999	2
$10,000 to $19,999	9
$20,000 to $39,999	4
$40,000 to $59,999	-
$60,000 or more	3
Farm production expenses ($):	
Wages and salaries	458,448
Contract labor	5,900

Operator Characteristics	Quantity
Principal operators by primary occupation:	
Agricultural	29
Nonagricultural	31
Principal operators by sex:	
Male	60
Female	1
All operators by highest level of school attended:	
None	-
Elementary	8
Secondary	8
High school diploma	31
Some college	7
Bachelor's degree	6
Master's or PhD	-

See "Census of Agriculture, Volume 1, Geographic Area Series" for complete footnotes, explanations, definitions, and methodology.
- Represents zero. (D) Withheld to avoid disclosing data for individual operations.
[1] Universe is number of municipios in Puerto Rico with item..

Appendix H - Information about the "Bosques Auxiliares" Program from the DNER.

Introducción

Nuestra isla tiene 2,261,362 cuerdas de terreno,aproximadamente
698,500 son tierras cubiertas de bosques. Solamente 100,000(15%) cuerdas las protege el gobierno. El restante 85% están en manos privadas.

La conservación de los bosques de Puerto Rico; así como el aire, el agua y la vida que refugian, está en las manos y buena voluntad de los hombres y mujeres hijos naturales o adoptivos de la tierra puertorriqueña. Dependerá en gran medida de la participación de los dueños de terrenos privados, propietarios del 85% del total de tierras en Puerto Rico cubiertas de bosques.

El Artículo 10 de la Ley 133 de 1975 establece que los bosques Auxiliares son aquellos que se desarrollan en terrenos privados y son certificados por el Secretario del DRNA a petición del propietario. Los terrenos en bosques auxiliares estarán exentos de contribuciones sobre la propiedad y los ingresos provenientes de la venta de productos forestales de los bosques clasificados como bosques auxiliares estarán exentos del pago de contribución sobre ingresos.

Beneficios de los Bosques Auxiliares

Además de proteger el suelo, el agua y la vida animal y vegetal; los bosques auxiliares son un lugar para el disfrute de la familia, los buenos amigos y en algunos casos de visitantes que acuden a recrearse y compartir con su familia o con la naturaleza.
El Bosque Auxiliar; refugio de vida silvestre, es alimento del alma. Alimento del espíritu pues allí el ser tom consciencia de que uno es parte de la naturaleza. El individuo oirá en el bsque lo que tiene que decir el guaraguao, entonará la canción del jilguero, recibirá el mensaje del coquí. Allí le hablará el ausubo, el capá; prieto y blanco, la cobana, el legendario roble, el majestuoso flamboyán, y el medicinal guayacán. También el perfume de la reina de las flores; flor como la mujer de nuestra tierra, madre, hija, hermana, amiga, compañera, maestra.

En el bosque; el pájaro bobo tiene su romance, se alimenta y cría su prole. El Ser Humano; en su estado natural, habita en el bosque. El Ser Humano es el bosque y el bosque es el Ser Humano; porque junto al planeta, se hizo uno en el Universo.

Administración

Una vez completada la solicitud, y examinada la finca por un técnico, el dueño firmará un convenio en el que se compromete por escrito a atender, cuidar, y conservarel bosque auxiliar de acuerdo con las instrucciones del Secretario. El tiempo mínimo para mantener un Bosque Auxiliar como tal no podrá ser menor de un año.

Requisitos de participación

Puedes participar si tienes cinco o mas cuerdas dedicadas a bosques. Además hay que llenar la solicitud y someterla al Secretario del DRNA. Tambien la finca será certificada por un técnico. Por último; el dueño del terreno donde está el bosque firmará un convenio escrito junto al Secretario.

Procedimiento de solicitud.

La solicitud para la certificación de un bosque auxiliar se somete al Secretrio de Recursos Naturales y Ambientales en la forma prescrita por el. Esta solicitud deberá contener una descripción del terreno. Debes indicar también las colindancias, donde está localizada la finca, areas, y cualquier otra información si la Secretaría la pide.

PROGRAMA DE BOSQUES AUXILIARES

FOLLETO INFORMATIVO

Porque no somos amos y señoras de la naturaleza; estamos llamados a ser sus protectoras y guardianes.
autor no identificado

El país en donde vivo me da el derecho inalienable de tener mi propia tierra, legado para futuras generaciones, legado que ancestros dejaron.

•

Mi Tierra no es única en el Universo. Pertenece al planeta Tierra.

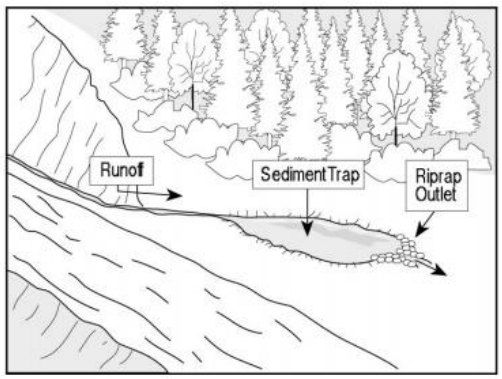
•

Lo que sucede en mi finca se refleja en el aire, el suelo y el agua. Mi Tierra es parte del planeta y el planeta es mi Tierra.

Javier Enrique Mercado

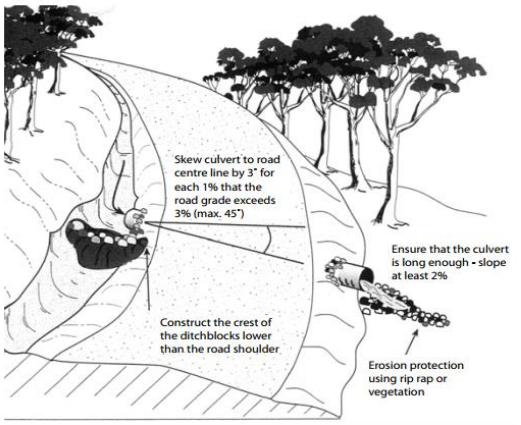
Appendix I – Sediment control alternatives

There are different practices that could be used for sediment control in the watershed. The sediment traps and geotextiles provide effective means for controlling sediment during construction. The main problem identified in the Río Fajardo watershed through PR-982 is associated with sediment moved from the farms next to the road. Sediment traps and basins can be either simple, small pits or large, complex structures designed to impound large quantities of sediment. Sediment traps used on forestry roads can be used for the issues identified in PR-982 and these traps are generally small, excavated pits that capture coarse sediments from ditch lines before they can enter the road or a stream. All sediment traps and barriers must be cleaned frequently while they are in place if they are to be effective. The next figure presents a sediment trap to control runoff.



Catch drains can also be used for the identified issues in PR-082 and this practice requires a depression above a cut or fills batter to prevent batter erosion and direct runoff to the road. The size and lining of catch drains will depend on the size, slope and rainfall characteristics of the catchment above and the distance that water must flow along the catch drain before it is discharged. The next image present the practice implemented in a dirt road and this practice could start in the farm dirt road system and in the steeper slopes next to PR-982.

In some areas cross drains could be used to move the water flow form a high side of a road by piping the water under the road to the lower side for controlling the runof. This practices could be coordinated with the assitance of the municipal authorities or considered as part of the farms management plans. Additional information could be revised in the Chapter 6 Sediment and Erosion Control Tools of the document A Guideline for Maintenance and Service of Unpaved Roads (2000).



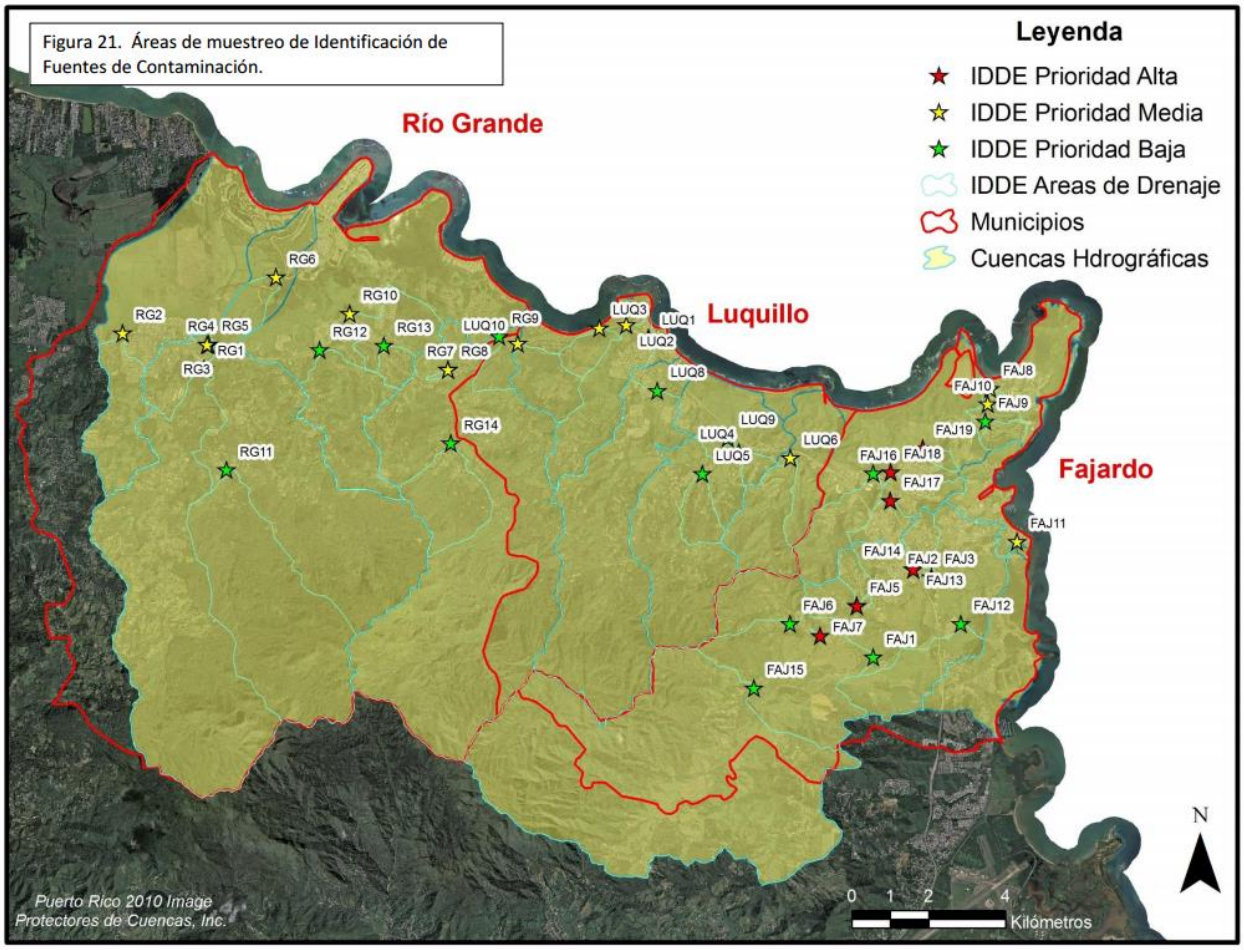
Cross Drain

Appendix J.

Information of pollution sources identified in the final report (September 2014) of "Estrategias para la identificación de fuentes de contaminación y el establecimiento de prácticas de control de erosión y sedimentación en los Municipios del Corredor Ecológico del Noreste, Puerto Rico"

The document was prepared by Protectores de Cuenca Inc. for the Department of Natural and Environmental Resources Coastal Zone Management Program.

Sampled Areas presented in the document.



Results of samples presented at “Estrategias para la identificación de fuentes de contaminación y el establecimiento de prácticas de control de erosión y sedimentación en los Municipios del Corredor Ecológico del Noreste, Puerto Rico” (September 2014).

SAMPLE	DATE	TEMP (°C)	PH	COND (MS)	SAL (MG/L)	TURB (NTU)	OP. BR. (RFU)	CHL. A (µG/L)	NH3 (MG/L)	ENTER (RAW COUNT	ENTER. (COUNT /100	TDS (PPT)	FLOW (CU. FT.)	NOTES	HOTSPOT	PRIORITY
FAJ1	10/10/2014	28.2	8.44	123.5	0.05	1.4	0.107	0	0.3	49	4900	61	360	Upstream of WWTP	No	n/a
FAJ10	10/11/2014	28.5	829	1.078	0.53	1.6	0.361	1.025	0.45	156	15600	528.6	7.5	Stream near gas station	Yes	Medium
FAJ11	10/11/2014	29.6	8.21	39.76	21.76	2.3	0.423	0.728	0.92	148	14800	19.3	n/a	Outlet of Rio Fajardo	Yes	Medium
FAJ12	10/11/2014	27	7.08	277.2	0.107	14.2	0.84	7.749	0.8	111	11100	n/a	n/a	Abandoned development site	No	n/a
FAJ13	10/11/2014	32.7	8.48	error	error	6.9	1.176	16.14	12.38	TNTC	TNTC	error	1.5	Channel in downtown Fajardo	Yes	High
FAJ14	10/11/2014	n/a	n/a	n/a	n/a	7.6	1.607	2.528	11.96	TNTC	TNTC	n/a	0.0025	Outfall draining to FAJ13	Yes	High
FAJ15	10/11/2014	30.5	8.29	122.4	0.05	0.7	0.081	0	0	13	1300	60.49	245.8	Mainstem in upper watershed	No	n/a
FAJ16	10/16/2014	n/a	n/a	n/a	n/a	n/a	0.704	6.677	0	160	16000	n/a	1.1	n/a	No	n/a
FAJ17	10/16/2014	n/a	n/a	n/a	n/a	n/a	0.665	2.633	6.7	TNTC	TNTC	n/a	28.5	Sewage	Yes	High
FAJ18	10/16/2014	n/a	n/a	n/a	n/a	n/a	0.616	1.09	1.62	TNTC	TNTC	n/a	1.5	Sewage	Yes	High
FAJ19	10/16/2014	n/a	n/a	n/a	n/a	n/a	1.535	9.732	5.39	TNTC	TNTC	n/a	0.0005	Sewage	Yes	High
FAJ2	10/10/2014	31.1	6.9	390.3	error	0.5	0.029	0	0.11	0	0	191.7	n/a	Pipe	No	n/a
FAJ3	10/10/2014	32.5	8.04	390.6	error	3.4	0.958	8.644	1.75	200	20000	191.9	2.5	Stream	Yes	High
FAJ4	10/10/2014	27.1	5	454.1	0.201	4	0.658	1.324	0	93	9300	233	2.0	Stream	No	n/a

SAMPLE	DATE	TEMP (°C)	PH	COND (MS)	SAL (MG/L)	TURB (NTU)	OP. BR. (RFU)	CHL. A (µG/L)	NH3 (MG/L)	ENTER (RAW COUNT	ENTER. (COUNT /100	TDS (PPT)	FLOW (CU. FT.)	NOTES	HOTSPOT	PRIORITY
FAJ5	10/10/2014	n/a	n/a	n/a	n/a	15.4	1.178	7.049	2.53	280	28000	n/a	0.0017	Sewage / septage	Yes	High
FAJ6	10/10/2014	26.5	7.2	206.2	0.06	2.9	0.306	0.624	0.15	88	8800	101.5	5.5	n/a	No	n/a
FAJ7	10/10/2014	29.4	6.79	255.2	0.095	10.2	0.369	1.981	>1*	TNTC	TNTC	125.9	n/a	Sewage stream	Yes	High
FAJ8	10/11/2014	26.6	8.3	954.6	0.469	3.5	0.425	2.604	0.6	148	14800	468.3	0.13	Near mobile home park at Seven Seas beach	Yes	Medium
FAJ9	10/11/2014	27.6	8.1	527.7	0.24	1.1	0.671	1.327	0	163	16300	n/a	0.0024	Near hotel / rooster pens	No	n/a

Appendix K Segments of soil resources reports of the study area.

Source of Maps: Natural Resources Conservation Service
Web Soil Survey
Soil Survey Area: Humacao Area, Puerto Rico Eastern Part Version 7, Sep 29, 2014.

Areas next to Landfill Soil analysis for reforestation alternatives

(Complete report can be downloaded at form projet folder in www.ccpaisaje.org)

Soil Information for All Uses Suitabilities and Limitations for Use

The Suitabilities and Limitations for Use section includes various soil interpretations displayed as thematic maps with a summary table for the soil map units in the selected area of interest. A single value or rating for each map unit is generated by aggregating the interpretive ratings of individual map unit components. This aggregation process is defined for each interpretation.

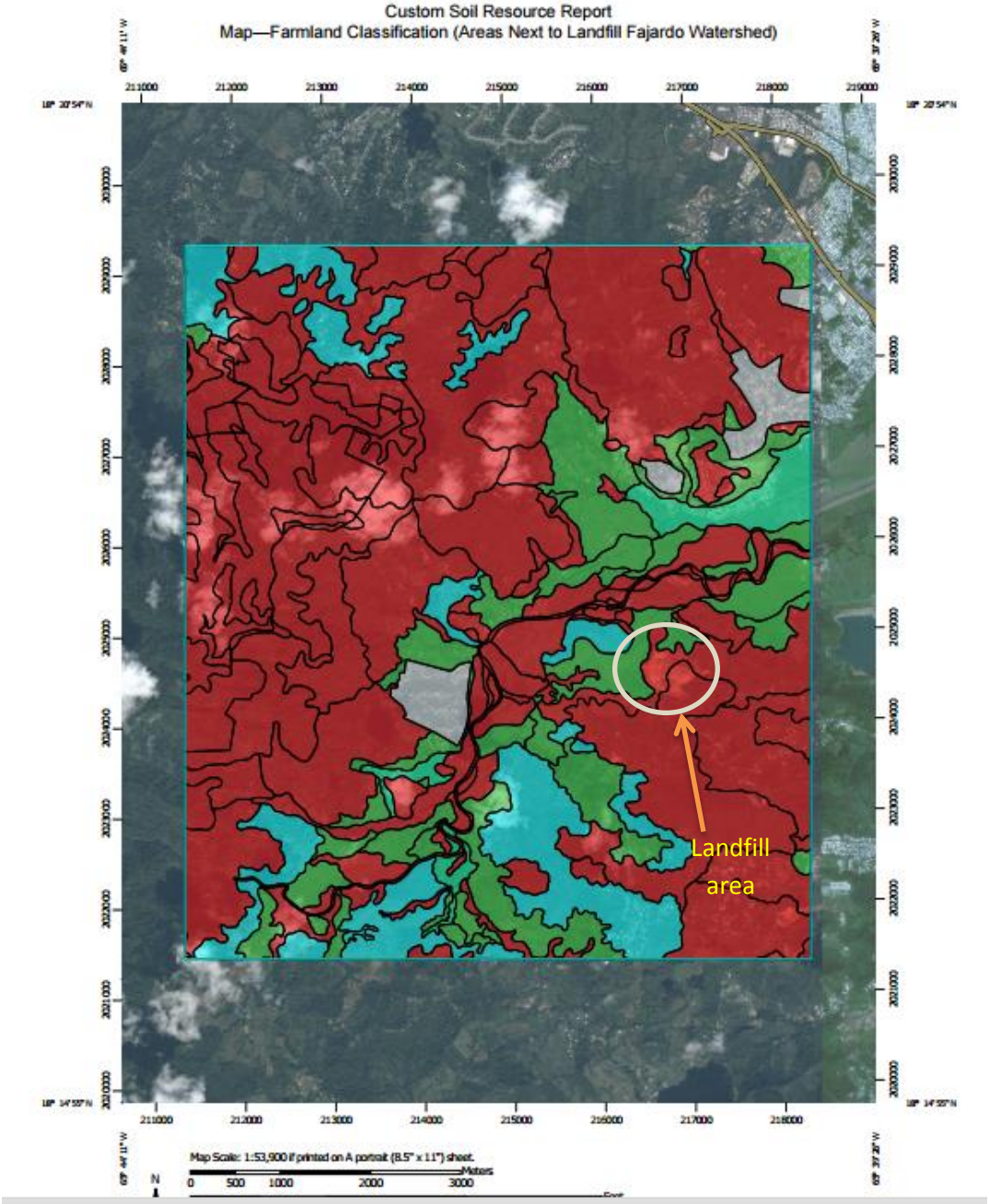
Land Classifications

Land Classifications are specified land use and management groupings that are assigned to soil areas because combinations of soil have similar behavior for specified practices. Most are based on soil properties and other factors that directly influence the specific use of the soil. Example classifications include ecological site classification, farmland classification, irrigated and nonirrigated land capability classification, and hydric rating.

Farmland Classification (Areas Next to Landfill Fajardo Watershed)

Farmland classification identifies map units as prime farmland, farmland of statewide importance, farmland of local importance, or unique farmland. It identifies the location and extent of the soils that are best suited to food, feed, fiber, forage, and oilseed crops. NRCS policy and procedures on prime and unique farmlands are published in the "Federal Register," Vol. 43, No. 21, January 31, 1978.

Custom Soil Resource Report
Map—Farmland Classification (Areas Next to Landfill Fajardo Watershed)



MAP LEGEND

Soil Rating Points

- Not prime farmland
- All areas are prime farmland
- Prime farmland if drained
- Prime farmland if protected from flooding or not frequently flooded during the growing season
- Prime farmland if irrigated
- Prime farmland if drained and either protected from flooding or not frequently flooded during the growing season

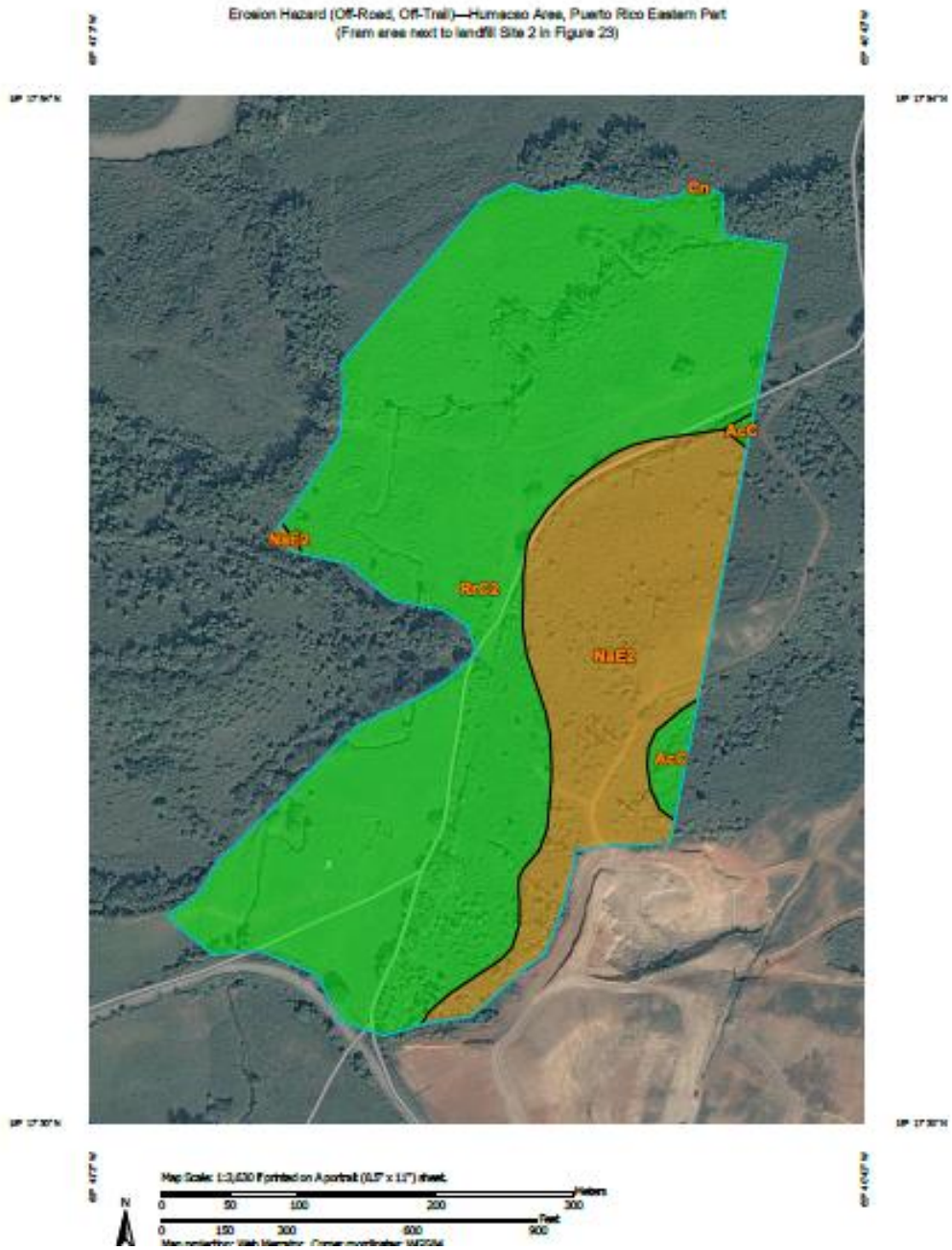
Table—Farmland Classification (Areas Next to Landfill Fajardo Watershed)

Farmland Classification— Summary by Map Unit — El Yunque National Forest, Puerto Rico (PR700)				
Map unit symbol	**Map unit name**	**Rating**	**Acres in AOI**	**Percent of AOI**
CzE	Cristal-Zarzal complex, 5 to 40 percent slopes	Not prime farmland	207.1	1.5%
HmE	Humatas-Zarzal complex, 5 to 40 percent slopes	Not prime farmland	400.7	3.0%
LuB	Luquillo-El Verde complex, 0 to 5 percent slopes, occasionally flooded	Not prime farmland	11.2	0.1%
ZaG	Zarzal very cobbly clay, 40 to 90 percent slopes	Not prime farmland	129.8	1.0%
ZcF	Zarzal-Cristal complex, 20 to 60 percent slopes	Not prime farmland	500.8	3.7%
Subtotals for Soil Survey Area			**1,249.5**	**9.2%**
Totals for Area of Interest			**13,575.1**	**100.0%**

Farmland Classification— Summary by Map Unit — Humacao Area, Puerto Rico Eastern Part (PR689)				
Map unit symbol	**Map unit name**	**Rating**	**Acres in AOI**	**Percent of AOI**
AcC	Aceitunas silty clay loam, 5 to 12 percent slopes	All areas are prime farmland	1,122.5	8.3%
CbF2	Caguabo clay loam, 20 to 60 percent slopes, eroded	Not prime farmland	973.4	7.2%
Cn	Cobbly alluvial land	Not prime farmland	172.2	1.3%
Co	Coloso silty clay loam, occasionally flooded	Prime farmland if drained	91.2	0.7%
CzE	Cristal-Zarzal complex, 5 to 40 percent slopes	Not prime farmland	132.8	1.0%
FaC	Fajardo clay, 2 to 10 percent slopes	All areas are prime farmland	6.6	0.0%
FaC2	Fajardo clay, 2 to 10 percent slopes, eroded	All areas are prime farmland	45.4	0.3%
Fo	Fortuna clay	Farmland of statewide importance	7.0	0.1%
HmE	Humatas-Zarzal complex, 5 to 40 percent slopes	Not prime farmland	269.7	2.0%
HtE2	Humatas clay, 20 to 40 percent slopes	Farmland of statewide importance	1,508.2	11.1%
HtF2	Humatas clay, 40 to 60 percent slopes	Not prime farmland	2,243.7	16.5%
HuF	Humatas-Stony land complex, 40 to 60 percent slopes	Not prime farmland	1.6	0.0%

Farmland Classification— Summary by Map Unit — Humacao Area, Puerto Rico Eastern Part (PR689)				
Map unit symbol	**Map unit name**	**Rating**	**Acres in AOI**	**Percent of AOI**
LuB	Luquillo-El Verde complex, 0 to 5 percent slopes, occasionally flooded	Not prime farmland	28.4	0.2%
LyF	Los Guineos-Yunque-Stony rock land association steep	Not prime farmland	222.6	1.6%
MaD2	Mabi clay, 12 to 20 percent slopes, eroded	Farmland of statewide importance	5.8	0.0%
MuE2	Mucara silty clay loam, 20 to 40 percent slopes, eroded	Not prime farmland	136.0	1.0%
NaE2	Naranjito silty clay loam, 20 to 40 percent slopes, eroded	Not prime farmland	665.2	4.9%
NaF2	Naranjito silty clay loam, 40 to 60 percent slopes, eroded	Not prime farmland	1,139.6	8.4%
NOTCOM	No Digital Data Available		330.7	2.4%
Re	Reilly soils	Not prime farmland	589.1	4.3%
RrB	Rio Arriba clay, 2 to 5 percent slopes	All areas are prime farmland	48.8	0.4%
RrC2	Rio Arriba clay, 5 to 12 percent slopes, eroded	All areas are prime farmland	357.0	2.6%
Rs	Rock land	Not prime farmland	31.9	0.2%
SaE2	Sabana silty clay loam, 20 to 40 percent slopes, eroded	Not prime farmland	40.1	0.3%
SaF2	Sabana silty clay loam, 40 to 60 percent slopes, eroded	Not prime farmland	314.2	2.3%
Tt	Toa silty clay loam	All areas are prime farmland	310.2	2.3%
VeC	Vega Alta silty clay loam, 5 to 12 percent slopes	All areas are prime farmland	123.3	0.9%
VgA	Vega Baja silty clay loam, 0 to 3 percent slopes	Prime farmland if drained	224.8	1.7%
W	Water	Not prime farmland	89.6	0.7%
Wa	Wet alluvial land	Not prime farmland	64.0	0.5%
YuF2	Yunes silty clay loam, 20 to 60 percent slopes, eroded	Not prime farmland	499.5	3.7%
ZaG	Zarzal very cobbly clay, 40 to 90 percent slopes	Not prime farmland	301.0	2.2%
ZcF	Zarzal-Cristal complex, 20 to 60 percent slopes	Not prime farmland	229.4	1.7%
Subtotals for Soil Survey Area			**12,325.6**	**90.8%**
Totals for Area of Interest			**13,575.1**	**100.0%**

Erosion hazard analysis for off-road, off-trails in site 3 Figure 23



MAP LEGEND

Soil rating Polygons

- Very severe
- Severe
- Moderate
- Slight
- Not rated

Erosion Hazard (Off-Road, Off-Trail)

Erosion Hazard (Off-Road, Off-Trail)— Summary by Map Unit — Humacao Area, Puerto Rico Eastern Part (PR689)						
Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
AcC	Aceitunas silty clay loam, 5 to 12 percent slopes	Slight	Aceitunas (100%)		0.5	1.3%
Cn	Cobbly alluvial land	Not rated	Cobbly alluvial land (95%)		0.0	0.0%
			Hydraquents (5%)			
NaE2	Naranjito silty clay loam, 20 to 40 percent slopes, eroded	Severe	Naranjito (100%)	Slope/erodibility (0.75)	9.3	24.6%
RrC2	Rio Arriba clay, 5 to 12 percent slopes, eroded	Slight	Rio Arriba (100%)		28.0	74.1%
Totals for Area of Interest					37.7	100.0%

Erosion Hazard (Off-Road, Off-Trail)— Summary by Rating Value		
Rating	Acres in AOI	Percent of AOI
Slight	28.5	75.4%
Severe	9.3	24.6%
Null or Not Rated	0.0	0.0%
Totals for Area of Interest	37.7	100.0%

Erosion Hazard (Off-Road, Off-Trail)—Humacao Area, Puerto Rico Eastern Part

Fram area next to landfill Site 2 in Figure 23

Description

The ratings in this interpretation indicate the hazard of soil loss from off-road and off-trail areas after disturbance activities that expose the soil surface. The ratings are based on slope and soil erosion factor K. The soil loss is caused by sheet or rill erosion in off-road or off-trail areas where 50 to 75 percent of the surface has been exposed by logging, grazing, mining, or other kinds of disturbance.

The ratings are both verbal and numerical. The hazard is described as "slight," "moderate," "severe," or "very severe." A rating of "slight" indicates that erosion is unlikely under ordinary climatic conditions; "moderate" indicates that some erosion is likely and that erosion-control measures may be needed; "severe" indicates that erosion is very likely and that erosion-control measures, including revegetation of bare areas, are advised; and "very severe" indicates that significant erosion is expected, loss of soil productivity and off-site damage are likely, and erosion-control measures are costly and generally impractical.

Numerical ratings indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the specified aspect of forestland management (1.00) and the point at which the soil feature is not a limitation (0.00).

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Rating Options

Aggregation Method: Dominant Condition

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "Dominant Condition" first groups like attribute values for the components in a map unit. For each group, percent composition is set to the sum of the percent composition of all components participating in that group. These groups now represent "conditions" rather than components. The attribute value associated with the group with the highest cumulative percent composition is returned. If more than one group shares the highest cumulative percent composition, the corresponding "tie-break" rule determines which value should be returned. The "tie-break" rule indicates whether the lower or higher group value should be returned in the case of a percent composition tie. The result returned by this aggregation method represents the dominant condition throughout the map unit only when no tie has occurred.

Component Percent Cutoff: *None Specified*

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.