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An economical feasibility study for the implementation of a PES scheme in the catchment area of the Río Yaque del Norte, Dominican Republic

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Acronyms and Abbreviations

GTZ	Deutsche Gesellschaft zur Technischen Zusammenarbeit (German Agency for Technical Cooperation)
DR	Dominican Republic
MARENA	Ministerio de Medio Ambiente y de Recursos Naturales, former: SEMARENA (Dominican Ministry of the Environment)
DIARENA	Dirección de Información Ambiental y de Recursos Naturales (Dominican ministry for environmental information and geography, belonging to MARENA)
PROGEREN	Programa de Gestión y Protección de Recursos Naturales en Cuencas Hidrográficas (GTZ Program to Protect and Manage the Sustainable Use of the Natural Resources in Hydrographic Basins)
EGEHID	Empresa de Generacion Hidroelectrica Dominicana (state-owned hydroelectric power generating company)
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
FAO	Food And Agriculture Organization
COP	Conference of the Parties
PES	Payment for Environmental Services
EGS	Ecological Goods and Services
ES	Environmental/Ecological Services
MA	UN Millennium Ecosystem Assessment
CAY	Cuenca Alta del Yaque del Norte (Upper watershed of the Yaque del Norte River)
KfW	Kreditanstalt für Wiederaufbau (German governmental development bank)
DED	Deutscher Entwicklungsdienst (German Development Service)
PROCARYN	Proyecto Manejo y Conservación de la Cuenca Alta del Río Yaque del Norte (Management and conservation project of the upper Yaque del Norte watershed)
CEDAF	Centro para el Desarrollo Agropecuario y Forestal, Inc. (Dominican development center for forestry and agriculture)

JBN	Jardín Botánico Nacional (National Botanic Garden)
GEF	Global Environmental Facility
USAID	United States Agency for International Development
ArcGIS	A suite consisting of a group of geographic information system (GIS) software products produced by Esri
CEP	USAID Country Environmental Profile
GNP	Gross National Product
CDEEE	Corporación Dominicana de Empresas Eléctricas Estatales (Dominican corporation of state owned electricity companies)
INAPA	Instituto Nacional de Aguas Potables y Alcantarillados (National institute of potable water and canalization)
CORAASAN	Corporación del Acueducto y Alcantarillado de Santiago (Corporation of the Santiago aqueduct and canalization)
NGO	Non-Governmental Organization
TEV	Total Economic Value
WTP	Willingness To Pay
WTA	Willingness To Accept
SPOT	Satellite Pour l'Observation de la Terre (French high-resolution, optical imaging Earth observation satellite system)
SSC	Sediment Storage Capacity
SY	Sediment Yield
A_d	Drainage Area
T_r	Reservoir lifetime

Abstract
The focus of this research is on the question whether an implementation of a PES scheme in a watershed is economically feasible or not. Of special interest in this case study is a state-run hydroelectric power plant in the Dominican watershed of the Northern Yaque River, which represents a potential direct benefiter of the theoretically implemented PES scheme. Three hypothetical scenarios will be compared with each other: the situation of the hydroelectric power plant complex without the implementation of a PES watershed protection program, the situation that would have occurred if such a program would have been installed contemporaneous with the commissioning of the hydroelectric complex and finally the situation that would occur if such a program would be installed now.

I. Introduction

1. Background of the Study
During my concluding internship with the GTZ in the Dominican Republic I visited the Rio Yaque del Norte catchment area. This watershed forms together with the watershed of the Rio Artibonito, the project area of the German Agency for Technical Cooperation (GTZ) PROGEREN program in the Dominican Republic. PROGEREN stands for “Programa de Gestión y Protección de Recursos Naturales en Cuencas Hidrográficas” and the long term objective is the sustainable management and protection of the natural resources in the Dominican watersheds in the catchment area of the two national headstreams.

As described in internal GTZ papers the major threat to this target is the erosion in the upper, mountainous “Cordillera Central”, the main mountain range of the island where the Yaque del Norte has its source. The erosion causes sedimentation in the Yaque del Norte which has a negative impact on the national supply of drinking water and on the production of hydroelectric power. Especially affected by the last concern is EGEHID (Empresa de Generación Hidroeléctrica Dominicana), a governmental hydroelectric power generating company, which is running a hydroelectric power plant that is fed by the Yaque del Norte.

The Dominican government is aware of these problems and a legal framework for environmental protection is set by the approval of the first general law on environment and natural resources, called Law 64-00, which passed the congress on the 18th of August 2000. The main objective of Law 64-00 is "to provide rules for the protection, improvement and restoration of the environment and natural resources, by ensuring the sustained development thereof" (Pellerano & Herrera, 2005).

Having the same target, the GTZ gives technical support by providing advice for the Dominican government and its ministries. One concrete activity is the support in the nationwide reforestation program, which also takes place in the Yaque del Norte catchment. To strengthen the cooperation between the GTZ and the ministry of environment (MARENA - Ministerio de Medio Ambiente y de Recursos Naturales) I worked closely together with the geographical department of the MARENA, the DIARENA (Dirección de Información

Ambiental y de Recursos Naturales), to develop a GIS based monitoring system for the reforestation activities in that very area.

During and before my internship the establishing of a pilot PES (Payment for environmental services) project was discussed. The idea was to generate an alternative financier for not only reforestations but also for a long lasting change from degrading land use forms to more sustainable and resource gentle ones.

2. Payments for Environmental Services

PES schemes are recently attracting more and more attention and were discussed in depth lately at the 15th Conference of the Parties (COP 15) in Copenhagen, at the United Nations Climate Change Conference of 2009. According to Pagiola et al. (2002) an environmental service (ES) is defined "as a positive environmental externality, which is provided through a natural- or human-managed ecosystem and normally is not taken into account in individual economic decisions". The term "environmental services" refers to the provision of these positive externalities. Giving these environmental externalities an economical value would strengthen the significance of ecological concerns in the economical decision making process.

Many studies already have been undertaken to estimate the economic value of ES and I will refer to them later in this study as well (de Groot, Wilson, & Boumans, 2002)(Farber, Costanza, & Wilson, 2002)(Limburg, O'Neill, Costanza, & Farber, 2002)(Loomis, Kent, Strange, Fausch, & Covich, 2000). For the entire biosphere, the value is estimated to be in the range of \$16 - 54 trillion/yr, with an average of \$33 trillion/yr (Costanza, et al., 1987). For comparison, the Global GNP was around \$18 trillion/yr at this time.

However, until now there are mainly four types of ES that have been sold already and which seem to be the most promising tradable services, from an economically point of view (Wunder, 2007):

1. *Carbon sequestration and storage* (e.g., northern electricity companies paying tropical farmers to plant or maintain additional trees),
2. *Biodiversity protection* (e.g., conservation donors paying landholders for creating set-aside areas for biological corridors),
3. *Watershed protection* (e.g., downstream water users or hydroelectric power plant owners paying upstream farmers for adopting land uses that limit soil erosion or flooding risks),
4. *Protection of landscape beauty* (e.g., tourism operators paying a local community not to hunt in a zone used for wildlife viewing).

3. Problem Description

3.1. Background

The DR is confronted with an ongoing deforestation and an inappropriate land use in the rural areas which are primarily located in the difficult to access, main mountain range of the island: the Cordillera Central (Peter, 2004). This region, located at the center of Hispaniola, is difficult to access and the source of all the rivers and streams in the DR. Among them, the longest stream of the nation: the river Yaque del Norte (296 km). The longest river of the island, the Artibonito or Artibonite River (320 km), which major part (252 km) is located in Haiti, also has its source in the Cordillera Central.

The ongoing degradation of this important watershed is a serious threat. As it can be seen in the neighboring country Haiti, degradation of soils and consequently sedimentation of streams and rivers leads to enormous impacts on the supply of drinking water, irrigation water and the production of hydroelectricity. Therefore, the resource water is of great importance for the stability of the whole island Hispaniola.

"Safe and clean drinking water and sanitation is an essential human right", declared the UN General Assembly[1] in July 2010, being deeply concerned about the fact that almost 900 million people worldwide do not have access to clean water(United Nations, 2010). A dramatic example that outlines the importance and the essential need for clean water supply could be observed in Haiti, 9 months after the disastrous earthquake, in October 2010, when a cholera disease broke out and spread through contaminated food and water. The official death toll actually stands at 1.200 (2010-11-25). Experts, however, act on the assumption of as many as 2.000 people, referring to supposable unreported fatalities in remote areas. The number of officially reported cases is currently approaching 50.000 (United Nations, 2010).

3.2. Cause of the Problem

3.2.1. Soil Erosion

In 1981, soil erosion was defined as the number one problem which affected the natural resources of the DR (USAID Country Environmental Profile). The main causes for this degradation were deforestation and small scale farming on steep slopes, a practice which occurs very frequently in the interior areas of the nation (Cordillera Central). It appeared that the extensive erosion resulted in degradation of soil fertility, diminishment of the life expectancy of reservoirs used for hydro power generation and irrigation and an increasing flood risk. In the next two decades, erosion continued and the areas classified as "arid and degraded" tripled from 402 km^2 in 1981 to 1,306 km^2 in 1998 (International Resources Group, Ltd., 2001). With a total land area of 48,320 km^2 (CIA, 2010) this means a portion of 2.7 %.

[1] The General Assembly is the main deliberative, policymaking and representative organ of the United Nations. Comprising all 192 Members of the United Nations, it provides a unique forum for multilateral discussion of the full spectrum of international issues covered by the Charter. (United Nations, 2010)

3.2.2. Land Fertility

According to the CEP of 1981, around 13% of the Dominican soils can be classified as having a high potential for intensive usage with only moderate limitations. About 20% have a limited cultivation potential (usable for rice and pasture), especially due to drainage issues, while more than 67% of Dominican soils are either so steep, rocky and/or shallow that they only can be considered as potentially good for silviculture or protection areas.

3.2.3. Political Issues

Another major problem is the lack of capacities at the state and civil-society level, which constraints an effectual respond to the described development. The centralistic Ministry of Environment operates from the capital (Santo Domingo) and has the absolute authority in budget, planning and staff issues. This means the local authorities and citizens cannot revert to the human and capital resources of the ministry. Consequently, they do not take any responsibility neither for a sustainable management nor for the protection of the natural resources.

3.2.4. Unsecure and Nonexistent Land Tenure

Many Dominican farmers have insecure or limited land tenure which discourages them from undertaking costly soil protection actions, even if those actions would guarantee an enhancement of the long term productivity. Even if they were willing to adopt more sustainable land use techniques, farmers with unsecure or inexistent land tenure have to face great difficulties in obtaining the needed credit to finance the conservation and protection strategies (Veloz, Southgate, Hitzhusen, & Macgregor, 1985). At the same time, the tendency to over-exploit rangeland, which is an open-access resource in the DR, is very strong.

4. Program Description

4.1. Conceptual Framework

PROGEREN is a GTZ drafted three phase program with a total duration of nine years. The first phase started in January, 2003 and the program will end in February, 2012. Each phase has a total duration of three years and consequently the program is now in its final phase.

4.2. Strategy

The emphasis of PROGEREN's advisory function lies on the institutional strengthening of national and local capacities. On a local scale, the main focus is on capacity building in improved land use technologies. Ecologically responsible production methods for coffee, timber and environmental friendly eco tourism are supported. This contributes directly to the improvement of the living standard of the local residents and to the maintenance of the biodiversity.

4.3. Counterparts

The official political counterparts are:

- The Ministry of the Environment (MARENA),
- The Ministry of Economics ("Ministerio de Economía, Planificación y Desarrollo")
- The Development Center for Forestry and Agriculture, Inc. (CEDAF)
- The communities of the concerned provinces.

4.4. PES

One of the activities of PROGEREN is to assist on an implementation approach of a PES pilot project in the upper catchment of the Yaque del Norte River, namely in the five municipalities Constanza, Jarabacoa, Jánico, Monción y San José de las Matas. The focus is on the provision of hydrological services through reforestation. Since June, 2009 the management of the PES project works together with the National Reforestation Program („Plan Nacional Quisqueya Verde") on the sowing of seeds in primary areas of the catchment basin. Together with the CDEF the GTZ developed an action plan for the initiative establishment of a PES project in the CAY. In this plan four potential PES buyers already showed their interest on participating in the planned PES scheme: CDEEE, INAPA, Juntas de Regantes[2] and CORAASAN.

The development of PES schemes in the DR and the role of German cooperation agencies in that context will be pointed out in the following chapter.

[2] The Junta de Regantes is a Dominican union of irrigation associations

4.5. The Role of PES in the Dominican Republic

The first concrete initiative for a PES scheme installation in the DR came up in 2002-2004, in the row of the PROCARYN[3] project. In the year 2005 the MARENA, the Development Center for Forestry and Agriculture, Inc. (CEDAF) and the National Botanic Garden (JBN) formulated a request at the Global Environmental Facility (GEF) for a sustainable management project of a protected area, Las Neblinas, which also included a PES component. The CEDAF requested the GTZ for technical assistance in the project design and this cooperation subsequently led to the idea of creating a PES project in the CAY, namely in the five municipalities Constanza, Jarabacoa, Jánico, Monción y San José de las Matas – the pilot project which I will use now as an example for this study.

[3] PROCARYN (Proyecto Manejo y Conservación de la Cuenca Alta del Río Yaque del Norte) was a project of MARENA which lasted from 2001-2007. It was technically and financially supported by German cooperation agencies (KfW, GTZ, DED) and addressed the development of ecologically and economically viable forestry, agriforestry and agricultural systems along with participatory measures for community development and securing land tenure arrangements.(Heindrichs, 2003)

5. Legal framework

5.1. Background

After the signature and ratification of several international agreements, such as the Vienna Convention (Ozone Layer Protection), the Rio Agreement (Biological Diversity) and the Kyoto Protocol of the United Nations Frame Convention on Climate Change the DR had to face the challenge of modernizing its policies and laws on environmental protection. The outcome of this approach is the law 64-00, which was passed in August 2000 and which is the first generally admitted Dominican law on environmental protection in history. Before the year 2000 the legal framework for environmental protection was comprised of several special laws, presidential decrees, resolutions and administrative measures, which were often contradictory and lacked a truly scientific character, thus, could not protect the natural resources efficiently.

5.2. Principles of Law 64-00

The law 64-00 recognizes the importance of the protection, preservation and sustained use of natural resources for the well-being of humanity, paying special attention on the issues of deforestation, land degradation and water deficiency. The effective protection of the environment is now an essential duty of the State and it thus has the responsibility to adopt an integral policy which can be executed participatory with all environment related institutions. This shall improve the environmental situation by concentrating all, until then scattered, efforts and thus provoke an effective work. Furthermore, the law recognizes the principle of precaution by providing that "lack of scientific absolute certainty shall not be called as a reason not to adopt preventive effective measures in any activities having a negative influence on the environment".

5.3. Objectives of Law 64-00

The main objective of Law 64-00 is "to provide rules for the protection, improvement and restoration of the environment and natural resources, by ensuring the sustained development thereof". It regulates soil, water and air contamination, dangerous products, elements and substances, domestic and municipal waste, human settlings and sonic contamination. It also regulates the granting of rights by the MARENA and/or municipal authorities for the use of natural resources, including the use of soil, water, coastal and sea resources, forests, caves and mineral resources (Pellerano & Herrera, 2005).

5.4. The Ministry of Environment and Natural Resources

The MARENA created the Law 64-00 and is responsible for the administration of the environment, ecosystems and natural resources. The registered office is situated in the capitol, Santo Domingo and it has the absolute authority in budget, planning and staff issues, hence MARENA is a centralist ministry. The tasks are to draft, execute and supervise the application of national policies on environment and natural resources and to ensure the preservation, protection and sustained use of natural resources, the improvement of soil, air and water contamination rules, the proper exploration and exploitation of mineral resources, the preservation of coastal and sea resources, and the establishment of general environmental rules for human settings and industries. The MARENA has an authorization, supervision, recommendation and consultation function, co-operating with other governmental, municipal and civil authorities and institutions.

5.5. Administrative instruments

Any industrial activities undertaken in the country must be provided with an environmental license, which certifies that the respective environmental impact evaluation has been made, and that the activity, work or project may be carried out under the conditions set in the environment administration program established therein.

Other instruments of environment administration are environmental planning, the national plan of territorial organization, the national system of protected areas, the national information system on environment and natural resources, environment supervision, environmental education, scientific and technical investigation, incentives, the national fund for environment and natural resources, and the declaration of emergency areas.

5.6. Obtaining Licenses and Permissions

Environmental licenses and permits must be obtained by companies interested in executing works or projects that may affect, in any manner whatsoever, natural resources, environmental quality or the health of the population.

The Resolution 05/2002 of March, 18^{th} 2002 creates the regulations of environmental permits and licenses, the classification of works, activities and projects, and the procedures for environmental permits for existing establishments and for studies of environmental impact.

II. Methods

6. Description of the Study Side

6.1. Geographical Aspects

The upper part of the CAY is located at the northern slope of the Dominican central mountain range, the "Cordillera Central". It covers a surface of approximately 840 km² and is located between the 18 55' and the 19 17' northern latitude and 70 31' to 70 50' western longitude. 70% of the total surface is located within the geographic limits of the municipality Jarabacoa between the provinces of Vega and Santiago. Forestry, agriculture and silvopastoral land use are the most dominant land use forms in this rural area. (Heindrichs, 2003)

The altitude varies between 400 m above sea level (dam of Taveras) and 1600 m above sea level (buffer zone of the National Park "Armando Bermúdez"). The temperature average is 21.4°C, the annual precipitation average is 1500 mm and the relative humidity is 80%.

6.2. Forest Cover in the CAY

Originally, the mountainous area was nearly entirely covered by endemic pine forests. A FAO's forest inventory of 1973 revealed that primeval forest originally covered about 99% of the Dominican Republic. At the beginning of the 20th century 85% of the original 99% forest cover was still left.

Figure 1 Location of the CAY (PROCARYN, 2007)

Nowadays, farmers have transformed over 50% of the Northern Yaque watershed's natural forests into different agricultural land use systems which trigger erosion, affecting the population downstream (Peter, 2004). The population today consists of approximately 37.400 inhabitants. In the CAY itself, forest cover still is the dominant land use form, followed by agriculture (GTZ, 2006).

6.3. Hydrological Aspects of the CAY

The Yaque del Norte River basin, the largest watershed in the Dominican Republic, is one of the most important water sources of the country, supplying two important reservoirs and providing drinking water for an estimated 1.2 million people (especially the city of Santiago, the second largest city in the Dominican Republic) and as well irrigation water for up to 80% of the country's most productive food-producing region, the Cibao Valley. The river drains an area of 7.053 km^2, i.e. 15% of the entire country (Witter & Carrasco, 1996). The river basin itself owns a rich biodiversity with various types of ecosystems and exceptional climatic conditions.

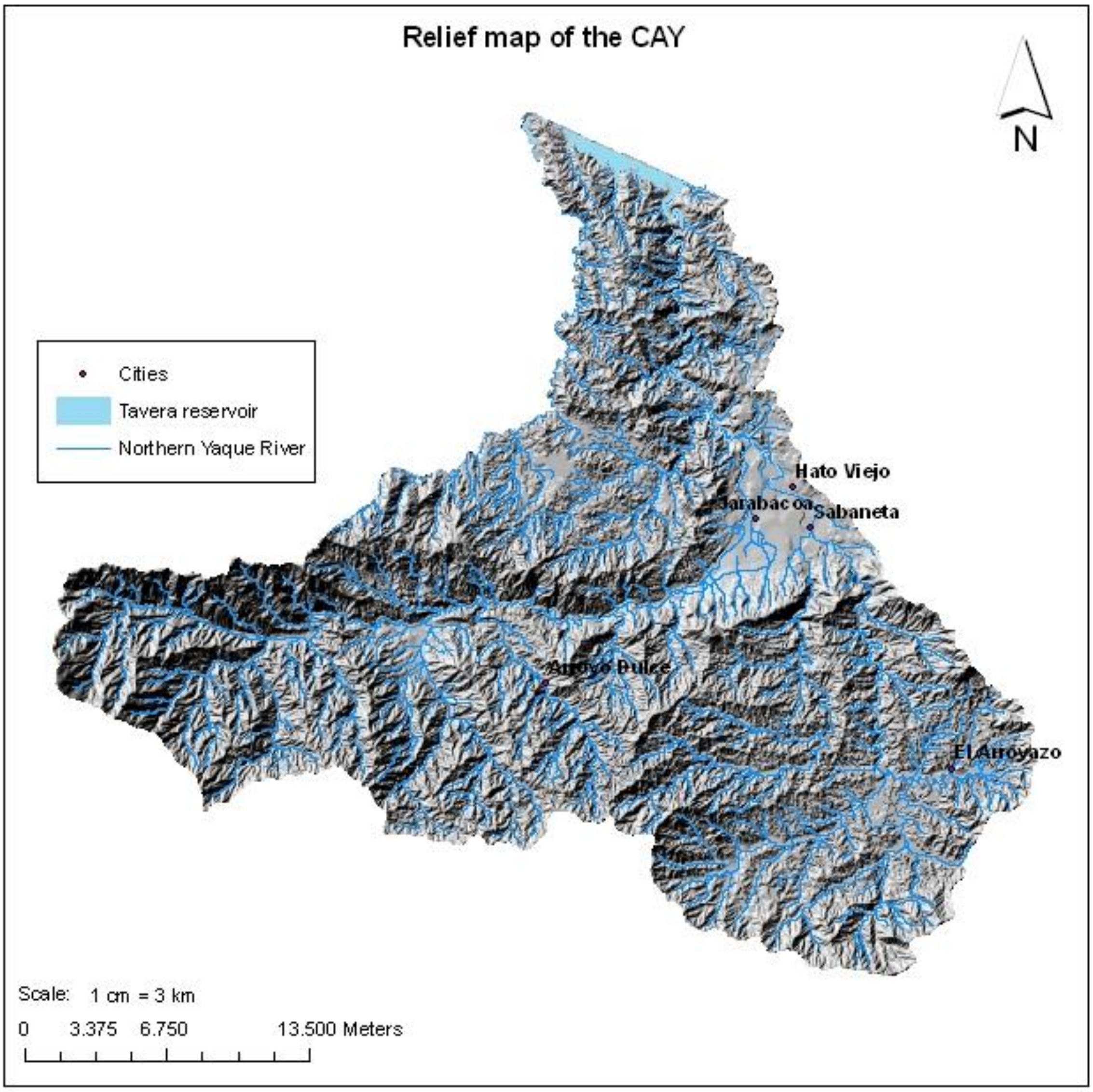

Figure 2 Relief map of the CAY, including the five major cities

6.4. Hydroelectric aspect

The river supplies a major hydroelectric complex, the Tavera-Bao-Lopéz-Angostura complex, consisting of two dams, a connecting channel, a flood control basin and two power houses. Together, the two reservoirs have got a water holding capacity of 417 million m^3 (Tavera 170 million m^3, Bao 247 million m^3) and the flood control basin of Lopéz has a capacity of 4.4 million m^3. The first power house, situated in Monte la Zanja, Sabana Iglesia has a production rate of 96 MW while the other one in Angostura has one of 18 MW. A major part of the energy supply and both the drinking and irrigation water supply is therefore provided by this complex.

7. Purpose of the Study

The purpose of this study is to give a well-founded recommendation whether or not a PES installation seems to be possible and reasonable in the catchment area of the Yaque del Norte River. I will use this study are and the pilot PES initiative in the CAY as an example and will thus focus on hydrological ES. The intent is to describe the major requirements, the cost-value ratio and finally the practical methods to provide the requested ES for a PES scheme installation. I will then go on by giving recommendations for the installation and monitoring of a possible PES scheme. The obtained information and outcome shall subsequently be seen as decision guidance for the adoption of watershed PES concepts in the DR and the undertaken calculations might serve as a model for analyzing comparable situations.

8. Research Questions

R.1. How are EGS defined and which typology can be used to classify EGS?

R.2. What are the basic characteristics of watershed protection markets? Who are potential buyers and providers for hydrological services in the CAY? Which EGS are relevant for the CAY, for the potential EGS buyers and -providers?

R.3. Which typology can be used to classify EGS? What are appropriate evaluation methods for the relevant EGS in the CAY?

R.4. How can the quantities of the relevant EGS be assessed? What are the quantitative values of the identified EGS on the provider and on the buyer side?

R.5. What are the economically values of the identified EGS on the provider side? How high are the costs of such an EGS provisioning PES project? What is the economical value of the hypothetical PES project for the buyer? Is such a PES scheme for watershed protection in the CAY economically reasonable for the buyer?

9. Methodology

M.1. To define EGS and to identify an appropriate typology for the classification of EGS I will study several scientific papers and publications dealing with that topic and give an overview of the different classification system.

M.2. To filter out the basic characteristics of watershed markets I will study several scientific papers and publications dealing with that topic and describe the concerned characteristics. I then will identify potential EGS buyers and -providers for the already described situation in the CAY. Concluding, I will point out the relevant EGS for the CAY on the buyer and provider side, focusing on EGS that have an effect on the watershed level.

M.3. To identify an appropriate evaluation typology for the defined EGS in the CAY I will study several scientific papers and publications dealing with that topic and give an overview of the different evaluation typologies and concepts. I then will finally point out a relevant evaluation method for the EGS in the CAY.

M.4. To identify the quantities of the relevant EGS on the provider side I will do a land use survey and identify the concerned sites that are relevant for the provision of the former defined EGS.

To identify the quantities of the relevant EGS on the buyer side I will first calculate the annual and total sedimentation yield in the Tavera basin for three hypothetical scenarios:

1. The situation of the Tavera dam without a watershed management project (Scenario No. 1),
2. the situation of the Tavera dam that would occur if such a program would have been installed contemporaneous with the commissioning of the hydroelectric complex (Scenario No. 2)
3. and finally the situation that would occur if such a program would be installed now, in the year 2010 (Scenario No. 3).

Based on these results I will calculate the hypothetical lifetime of the Tavera dam according to Einsele et al. (1997)for all three described scenarios.

M.5. To determine the economical value of the provided EGS I will use the opportunity costs that are calculated for the provision of the identified EGS on the provider side by the CEDAF and the GTZ in 2007.

To identify the economical value which a hypothetical PES scheme in the CAY might have for the operator of the hydroelectric power plant I will make a cost-benefit analysis for each of the three described scenarios, based on the former calculated difference in economic life-time of the hydroelectric power plant.

By comparing the costs and benefits of the hypothetical PES scheme in the CAY, a well founded statement about the economically feasibility can be made and recommendations can be given whether or not such a scheme should be carried into execution or not.

III. Results

10. Typology of EGS

10.1. Definition of EGS

Per definition, an ES is a positive environmental externality, which is provided through a natural- or human-managed ecosystem (Pagiola, Bishop, & Landell-Mills, 2002). As those externalities are not necessarily only “services” but also “goods” it is more accurate to talk about environmental goods and services.

EGS represent the benefits that human populations obtain, directly or indirectly, from ecosystems.

In this research the definition for PES by Wunder (2005) will be used as it is the most complete and actual definition dealing with that topic. According to Wunder, a PES is:

- a *voluntary* transaction where
- a *well-defined* ES (or a land-use likely to secure that service)
- is being ‘bought’ by at least one ES *buyer*
- from at least one ES *provider*
- if the ES provider secures ES provision (*conditionality*).

10.2. Classification of EGS

I will use the classification system which is also used in the UN Millennium Ecosystem paper of 2005. This typology system is adapted to great parts by de Groot et al. (2002).

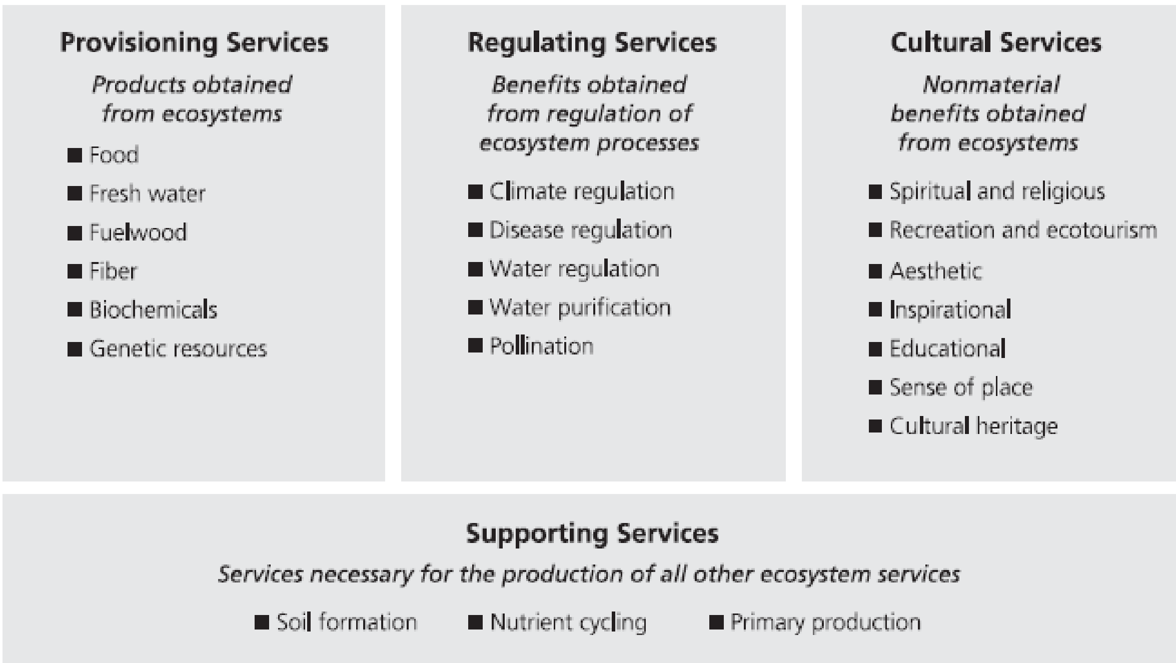

Figure 3 Typology of EGS (MA, 2005)

10.2.1. Provisioning Services

PS are products (or "goods") which are provided by ecosystems for (direct) human consumption. These are:

Food: All the edibles derived from plants (fruits and vegetables), animals (meat, dairy products) and microbes (mushrooms).

Fresh water: A PS that also overlaps with the category "regulating service".

Fiber: Such as wood, jute, hemp, silk and many other products which can be processed in a large variety.

Fuel: Wood, dung and other biological materials which are used as sources of energy.

Genetic resources: This includes the genes and genetic information used for animal and plant breeding and biotechnology.

Biochemicals, natural medicines and pharmaceuticals: Many medicines, biocides, food additives such as alginates and biological materials are derived from ecosystems.

Ornamental resources: These are animal products, such as skins and shells, and plant products, such as flowers which are used as ornaments. Here the direct value is mostly culturally determined which gives us another example of linkages between the different categories.

10.2.2. Regulating Services

RS are benefits which derive from the regulative functions of ecosystems. Examples are:

Climate regulation: Ecosystems have both, a local and a global influence on the climate. At the local scale, changes in land cover can affect both temperature and precipitation. At the global scale, ecosystems, in this case especially forests play an important role in climate by either sequestering or emitting greenhouse gases.

Regulation of human diseases: Changes in ecosystems can directly change the abundance of human pathogens, such as cholera, and can alter the abundance of disease vectors, such as mosquitoes.

Water regulation: The timing and magnitude of runoff, flooding and aquifer recharge can be strongly influenced by changes in land cover, including in particular alterations that change the water storage potential of the system, such as the conversion of wetlands or the replacement of forests with croplands or croplands with urban areas.

Water purification and waste treatment: Ecosystems can be a source of impurities in fresh water but also can help to filter out and decompose organic wastes introduced into inland waters and coastal and marine ecosystems.

Pollination: Ecosystem changes affect the distribution, abundance and effectiveness of pollinators.

Erosion control: Vegetative cover plays an important role in soil retention and the prevention of landslides.

Biological control: Ecosystem changes affect the prevalence of crop and livestock pests and diseases.

Storm protection: The presence of coastal ecosystems such as mangroves and coral reefs can dramatically reduce the damage caused by hurricanes or large waves.

Air quality maintenance: Ecosystems both contribute chemicals to and extract chemicals from the atmosphere, influencing many aspects of air quality.

10.2.3. Cultural Services

CS are nonmaterial benefits which people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences. These are:

Cultural diversity: The diversity of ecosystems is as well influencing the diversity of cultures.

Social relations: Ecosystems influence the types of social relations that are established in particular cultures. Fishing societies for example, differ in many respects in their social relations from nomadic herding or agricultural societies.

Spiritual and religious values: Many religions attach spiritual and religious values to ecosystems or their components, for example the peyote cult in regions of Mexico, strongly attached to the peyote cactus.

Knowledge systems: Ecosystems influence the types of knowledge systems developed by different cultures.

Educational values: Ecosystems and their components and processes provide the basis for both formal and informal education in many societies.

Inspiration: Ecosystems provide a rich source of inspiration for art, folklore, national symbols, architecture and advertising.

Aesthetic values: Many people find beauty or aesthetic value in various aspects of ecosystems, as reflected in the support for parks, "scenic drives" and the selection of housing locations.

Sense of place: Many people value the "sense of place" that is associated with recognized features of their environment, including aspects of the ecosystem.

Cultural heritage values: Many societies place high value on the maintenance of either historically important landscapes ("cultural landscapes") or culturally significant species.

Recreation and ecotourism: People often choose where to spend their leisure time based in part on the characteristics of the natural or cultivated landscapes in a particular area.

10.2.4. Supporting services

SS are necessary for the production of all other ecosystem services. They differ from provisioning, regulating and cultural services especially in their impact level on people. SS are either indirect or occur over a very long period of time, whereas changes in the other categories have relatively direct and short-term impacts on people. For example, humans do not directly use soil formation services, although changes in this would indirectly affect people through the impact on the provisioning service of food production. Some other examples of supporting services are primary production, production of atmospheric oxygen, soil formation and retention, nutrient cycling, water cycling and provisioning of habitat.

10.2.5. Alternative Classification

An ecosystem can as well be described by its structure and ongoing processes, i.e. its dynamic interactions between the biotic and abiotic factors. Those processes then can be categorized into different ecosystem functions. De Groot et al. (2002)did so and pointed out four different ecosystem functions, consisting of a regulating-, a production-, and a carrier- and a habitat function. As soon as these functions are valued by- and included in a social system they become services (Nasi, Wunder, & Campos A., 2002).

The following diagram points out the relationship between ecosystem functions, EGS, their possible value to society and the resulting role they play in political and economical decision making processes.

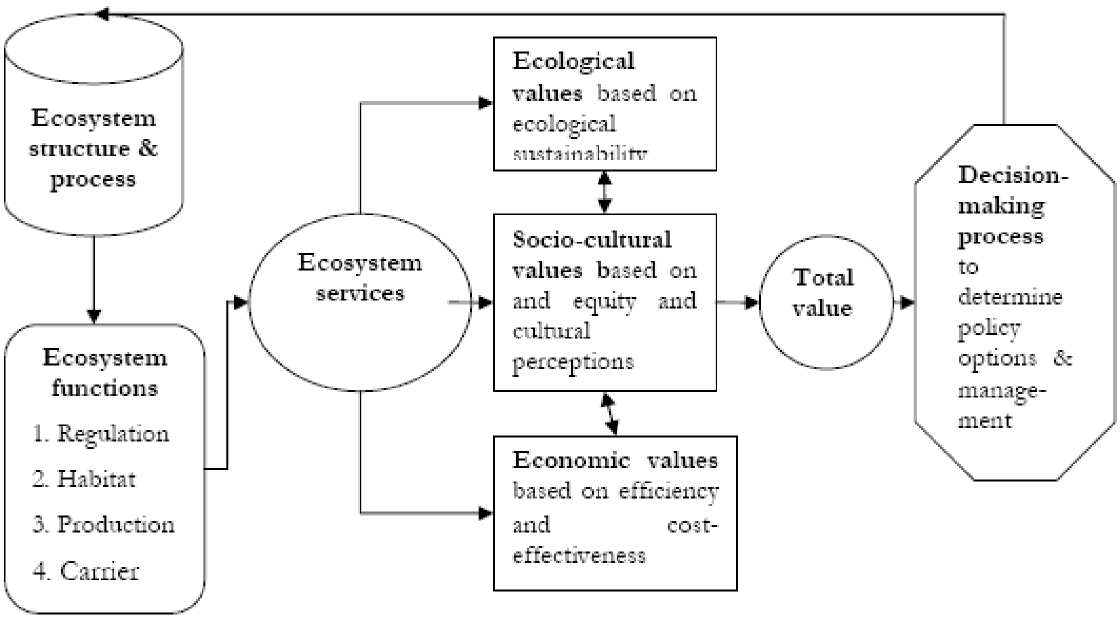

Figure 4 Framework for integrated Assessment and Valuation of Ecosystem Functions, Goods and Services (adapted from the Groot, 2002)

11. Identification of potential EGS Provider and Buyer

11.1. Characteristics of Watershed Protection Markets

Historically the protection of watersheds is rather a governmental task since water and forests are so called “public goods”. This means that they are by nature non-excludable and non-rival. Non-excludability means that consumers cannot be prevented from enjoying the goods or services in question, even if they do not pay for this privilege. For instance, it is almost impossible, to exclude downstream communities from benefiting from improved water quality caused by forest regeneration upstream. Non-rivalry means that the consumption of those goods and/or services does not reduce the available amount to others. In this situation there is no competition in consumption since an infinite number of consumers can use the given quantity supplied. A good example of a non-rival forest service is carbon sequestration. Once carbon is sequestered the global community benefits from this in terms of a reduced threat of global warming (Landell-Mills & Porras, 2002).

Nevertheless the role of private companies, NGOs, private landholders and communities in delivering and financing watershed services is growing and today the market is already dominated by the private sector. According to a comparative study of Landell-Mills et al. (2002), dealing with 61 watershed market cases worldwide, the private sector forms almost 60% of all recorded buyers and even over 65% of the recorded sellers. As the demand side is evenly split between private corporations and individuals, the supply-sides main actors are clearly the individual landowners.

Taken together public enterprises and government departments are the single most important buyers of watershed services. As a major landowner in watershed areas governmental enterprises, e.g. water boards, electricity suppliers and recreation agencies, have a clear interest in maintaining the supply of the quality and the continuously flow of water.

11.2. Potential Buyer and Provider of EGS

The possible ES providers are upstream farmers of the CAY. The degrading land use techniques like “slash and burn” and shifting cultivation, which are common practice in the upper watershed, are causing severe erosion and stream sedimentation. This does not only reduce the soil fertility, it also leads to stream and finally reservoir sedimentation of the dams.

The Tavera-Bao-Lopez Angostura hydroelectric complex, which is state-run by EGEHID has to face an economic loss due to this sedimentation problem and is therefore highly interested in reducing the negative sedimentation affects. EGEHID is therefore identified as the potential ES buyer.

11.3 Relevant EGS for the CAY on the Buyer Side

On the potential buyer side, the governmental operator of the Tavera-Bao-Lopéz-Angostura complex, the following regulating ES are relevant in the CAY.[4]

All of them are *regulating services*:

Water regulation: The timing and magnitude of runoff, flooding and aquifer recharge can be strongly influenced by changes in land cover including in particular alterations that change the water storage potential of the system, such as the conversion of wetlands or the replacement of forests with croplands or croplands with urban areas.

Water purification and waste treatment: Ecosystems can be a source of impurities in fresh water but can also help to filter out and decompose organic wastes introduced into inland waters and coastal and marine ecosystems.

Erosion control: Vegetative cover plays an important role in soil retention and the prevention of landslides.

11.4. Relevant EGS for the CAY on the Provider Side

On the potential provider side, the farmers of the CAY, the following ES are relevant in the CAY:

Provisioning services:

Food: All the edibles derived from plants (fruits and vegetables), animals (meat, dairy products) and microbes (mushrooms).

Fresh water: A PS that also overlaps with the category "regulating service".

Fiber: Such as wood, jute, hemp, silk and many other products which can be processed in a large variety.

Fuel: Wood, dung and other biological materials which are used as sources of energy

Regulating services:

Climate regulation: At the local scale, as changes in land cover can affect both temperature and precipitation.

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[4]Virtually all downstream benefits of soil conservation can be placed in one of the following three categories(Southgate & Macke, 1989):

1. Reducing sedimentation, eutrophication and other forms of nonpoint source pollution increases the flow and/or the value of services drawn from water resources, for instance hydroelectricity and recreation.
2. Watershed management reduces the remediation actions and -costs of downstream impacts, like dredging and water treatment.
3. Controlling soil erosion reduces damage done to machinery (e.g., turbines and pumps) used in water resource development projects.

Regulation of human diseases: Changes in ecosystems can directly change the abundance of human pathogens, such as cholera, and can alter the abundance of disease vectors, such as mosquitoes.

Water regulation: The timing and magnitude of runoff, flooding and aquifer recharge can be strongly influenced by changes in land cover, including in particular alterations that change the water storage potential of the system, such as the conversion of wetlands or the replacement of forests with croplands or croplands with urban areas.

Water purification and waste treatment: Ecosystems can be a source of impurities in fresh water but also can help to filter out and decompose organic wastes introduced into inland waters and coastal and marine ecosystems.

Erosion control: Vegetative cover plays an important role in soil retention and the prevention of landslides.

Biological control: Ecosystem changes affect the prevalence of crop and livestock pests and diseases.

Cultural services:

Inspiration: Ecosystems provide a rich source of inspiration for art, folklore, national symbols, architecture and advertising.

Aesthetic values: Many people find beauty or aesthetic value in various aspects of ecosystems, as reflected in the support for parks, "scenic drives" and the selection of housing locations.

Recreation and ecotourism: People often choose where to spend their leisure time based in part on the characteristics of the natural or cultivated landscapes in a particular area.

Supporting services:

Such as soil formation and retention, nutrient cycling, water cycling and provisioning of habitat.

12. Evaluation Typology of EGS

Each of the above described EGS can be categorized and structured by the specific values they have for society. The values of EGS can be divided into three types: ecological, socio-cultural and economical.

12.1. Ecologic Valuation

Evaluating EGS according to their "ecological value" is a very complex and delicate theme. Ecosystems and non-human species are presumed not to have any conscious goals and no "value system", at all. Likewise, one cannot talk about "value" as the degree to which an item contributes to achieving a goal in this context since there is no conscious goal being pursued (Farber et al. 2002). From an anthropological point of view, the ecological importance of ecosystems can be expressed through the causal relationships between its individual parts. At a local scale, for instance, the value can be described by the ability of a particular tree species to control erosion and to contribute to the survival of another species or of an entire ecosystem (Farber et al. 2002). At a global scale, different ecosystems and their species play different roles in the maintenance of essential life support processes such as energy conversion, biogeochemical cycling and evolution (MA, 2005).

However, to maintain the quantity and the quality of EGS it is crucial that the use of these goods and services has to be limited to a sustainable level and the limits of sustainable use are determined by ecological criteria. According to de Groot et al. (2006) those are:

- the *naturalness or integrity value*, which refers to the degree of human presence in terms of physical, chemical or biological disturbance,
- the *diversity value*, which refers to the variety of life in all its forms, including ecosystem, species and genetic diversity,
- the *uniqueness or rarity value*, which refers to local, national or global rarity of ecosystems and species,
- the *fragility or vulnerability value*, which refers to the sensitivity of ecosystems for human disturbance and
- the *renewability or recreatability value*, which refers to the possibility for (spontaneous) renewability or human restoration of ecosystems.

12.2. Socio-cultural Valuation

Based on different worldviews or conceptions of nature and society, one can as well value elements in ones environment in an ethical, religious, cultural and philosophical way. These values are expressed through, for example, designation of sacred species or places, development of social rules concerning ecosystem use (for instance "taboos") and inspirational experiences. For many people, socio-cultural identity is in part constituted by the ecosystems in which they live and on which they depend - these help determine not only how they live, but who they are (MA, 2005). According to de Groot et al. (2006) the main types of socio-cultural values include the following:

Therapeutic value: General therapeutic effects of nature on peoples' mental and physical well-being and the provision of medicines, clean air, water and soil, space for recreation and outdoor sports.

Amenity value: The importance of nature for cognitive development, mental relaxation, aesthetic enjoyment and recreational benefits.

Heritage value: The importance of nature as orientation to personal or collective history and cultural identity.

Spiritual value: The importance of nature in symbols and elements with sacred, religious and spiritual significance.

Existence value: The importance people attach to nature for ethical reasons (intrinsic value) and intergenerational equity (bequest value).

12.3. Economic Valuation

The concept of total economic value (TEV) has become a widely used framework for assessing the utilitarian value of ecosystems (de Groot et al., 2006). It differentiates between two major types of economic values: the *use value* and the *non-use value* (Pearce & Warford, 1993).

Use values

The *direct use values* derive from EGS that can be extracted, consumed or directly enjoyed by human beings (Dixon & Pagiola, 1998). They can either be consumptive (goods like food, timber etc.) or non-consumptive (cultural services like scuba-diving in a coral reef or hiking in a national park).

The *indirect use values* derive from the environmental services the ecosystem provides us with indirectly (Dixon & Pagiola, 1998). These values can be categorized under regulating- and supporting services. Common examples are the downstream benefiters, who take advantage out of the natural water filtration which takes place further upstream. Another actual example is carbon sequestration, contributing to the abatement of climate change even on a global level.

Option values derive from maintaining the option of taking advantage of something's use value at a later date.

Non-use values

Non-use values derive from the benefits the environment may provide but which do not involve using it in any way.

The *bequest value* derives from the desire to pass on values to future generations.

Existence value derives from the knowledge that something exists, even if anybody plans to use it.

12.3.1. Economic Valuation Methods

Economic valuation methods are differentiated into four basic types. According to de Groot et al. (2002) each of these categories is described as follows:

Direct market valuation

The exchange value that certain ecosystem services have in trade is used for the monetary evaluation. This method is mainly applicable for provisioning (timber and food production) and regulating services (recreation, ecotourism and carbon sequestration).

Indirect market valuation

If no direct market valuation is possible, the value has to be assessed indirectly. This value can either be expressed by the "Willingness To Pay" (WTP) for the maintenance of an EGS or by the "Willingness To Accept" (WTA) the compensation costs for the loss of an EGS.

For example, it is possible to pay either for the maintenance of an intact catchment area to take advantage of its regulating and supporting services like water regulation, -purification, -cycling and waste treatment or the compensation costs which derive from the loss of this ES have to be paid, in this case by the establishment of water treatment plants. This assessment can be done, using the following methods:

Avoided Cost (AC): Costs that can be avoided by the maintenance of ES and which occur with the loss of these ES. Examples are flood control (which avoids property damages) and waste treatment (which avoids health costs) by wetlands.

Replacement Cost (RC): ES can partly be replaced with human-made systems - the costs which occur through this replacement are called RC. One example is the natural waste treatment by marshes which can be (partly) replaced with artificial treatment systems.

Factor Income (FI): For many people, an intact ecosystem with all the ES it provides is the economic basis for their livelihood. One example is commercial fisheries: an improvement of the natural water quality leads as well to an increase catch and thereby increased incomes of fishermen.

Travel Cost (TC): The use/visit of foreign ecosystems (services) may require travel and therefore travel costs, which therefore are a part of the implied value of this service. Examples are recreation areas or special ecosystems that attract distant visitors: the value they award that area must be at least what they were willing to pay for travelling to it. A well known example for such an area is the Great Barrier Reef in Australia, attracting every year up to two million visitors (Australien Government, 2010).

Hedonic Pricing (HP): The demand on certain services may be reflected in the prices people will pay for associated goods. This idea is very common in real estate economics, where the prices of identical houses vary largely depending on the location of the property they are built on. Example: A house on the beach front usually exceeds prices of identical inland homes near less attractive scenery.

Contingent valuation (CV)

Service demands may be ascertained by posing hypothetical scenarios that involve the description of alternatives in a social survey questionnaire. For example, a survey questionnaire might ask respondents to express their WTP to increase the level of water quality in a stream, lake or river so that they might enjoy activities like swimming, boating or fishing (Wilson & Carpenter, 1999).

Group valuation

Another approach to ecosystem service valuation that has gained increasing attention involves group deliberation (Wilson & Howarth, 2002)(Jacobs, 1997). This valuation approach is based on the assumption that public decision making should result from open public debate to identify the holistic social demand on ES and not excluding one part of society. One example is a PES scheme in Costa Rica, where the financing of the ES (water quality maintenance) providers is assured by the interest of the ES users on the water tax.

12.4. Evaluation Method for the CAY

I will mainly focus on economical evaluation as I try to give the EGS of interest in the CAY a monetary value. This is of vital importance for two reasons:

1. It is one of the major tasks to completely convince a possible financier if he is supposed to pay for the provision of a certain ES. If you want to attract a private investor it is fundamental to have an economically well-founded argumentation that his or her investment will pay off.
2. Forest ecosystems help to sustain basic biogeochemical cycles on which local and global human survival depends. However, the majority of the direct forest users receive neither financial nor any other compensation for their contributions, thus having little motivation to protect the natural resources. Financial compensation can serve as such an essential incentive. (Guo, Xia, & Li, 2000)

As described in chapter 11.3. all relevant EGS in the CAY on the buyer are regulating services. I will therefore use indirect market valuation techniques in particular to define the possible economic value (WTP) a PES project might have for the different potential EGS buyers. The method of choice here is the avoided costs method.

13. Quantitative Evaluation on the Provider Side

13.1. Classification Typology of the Affected Sites

According to a FAO study dealing with erosion problems in subtropical areas (Weaver, 1979) a general recommendation can be made to decrease sedimentation levels. Weaver suggests that hilltops and upper slopes should remain forested or be afforested, medium-sloped lands should be managed as agroforestry systems and bottom lands should be used for crop production. Agronomists, foresters, soil scientists and others who have worked on soil erosion problems in the DR agree with these general land-use suggestions (Veloz, Southgate, Hitzhusen, & Macgregor, 1985). Based on this common knowledge, Veloz et al. (1985) developed a land use guideline for the Dominican Valdesia watershed management project by classifying the watershed in four slope classes. I will adopt this classification in my study since the conditions of those two Dominican watersheds are very similar.

The classification and the recommendations are as follows:

Class A: 3% - 20% slope**.** Traditional farming should continue. Mulching and contour plowing should be encouraged.

Class B: 21% - 35% slope. Mixed cropping and agroforestry systems should be established instead of traditional crop-farming. All pastures should be renovated.

Class C: 36% - 50% slope. Agroforestry should be established on existing cropland. All pasture should be renovated.

Class D: Greater than 50% slope. All cropland and pastures should be reforested.

13.2. Land Use Distribution in the CAY

In 2008, the GTZ did a land use survey based on a SPOT image from 2006 of the CAY for the PROCARYN. I processed these results in ArcGIS, creating a land use map and calculating the distribution of the different land use forms in the CAY. It turned out that nearly 70% of the CAY are covered with forest and that over 20% of the area are used for agricultural and livestock farming. A more detailed description can be found in table 1 and figure 5 presented below. The land use map is presented as figure 6 on the following page.

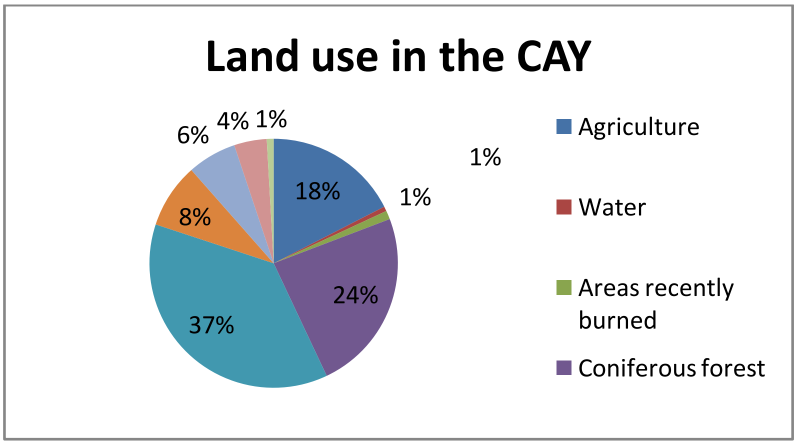

Figure 5 Land use distribution in the CAY

Land use type	Area (in ha)	Area (%)
Agriculture	14679	17%
Water	512	1%
Areas recently burned	946	1%
Coniferous forest	19979	24%
Deciduous forest	31142	37%
Mixed forest	7081	8%
Scrubland	5358	6%
Pasture	3561	4%
Urban area	748	1%
Total	84006	100%

Table 1 Land use distribution in the CAY

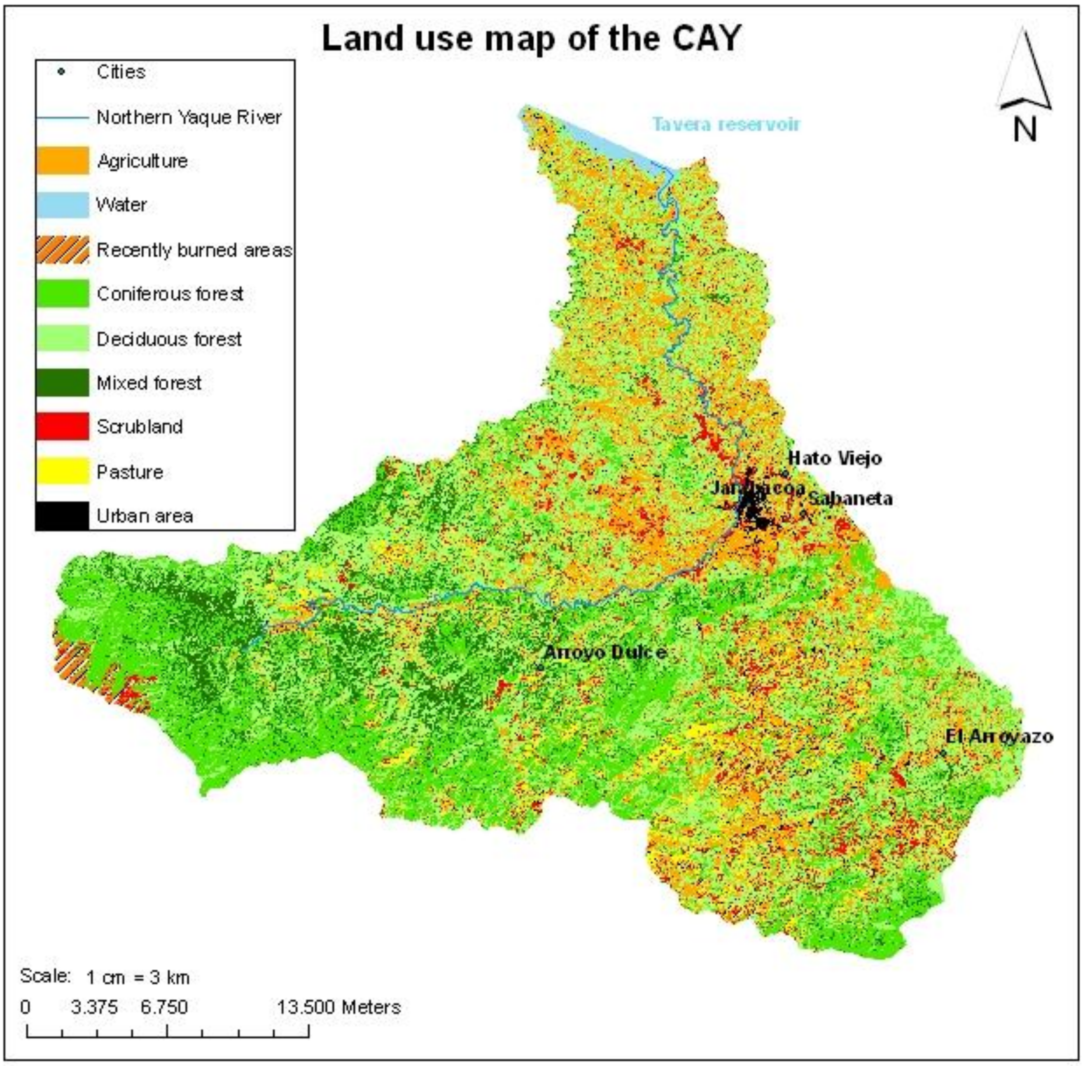

Figure 6 Land use map of the CAY with the five major cities, the Northern Yaque River and the Tavera reservoir

13.3. Slope Situation in the CAY

With ArcGIS I created a slope map of the CAY, categorizing all slopes into 4 slope classes according to the classification system described in chapter 13.1. The map can be seen in figure 7.

Slope class A: from 0 – 20 % rise

Slope class B: from 21 – 35 % rise

Slope class C: from 36 – 50 % rise

Slope class D: from 51 – 100% rise

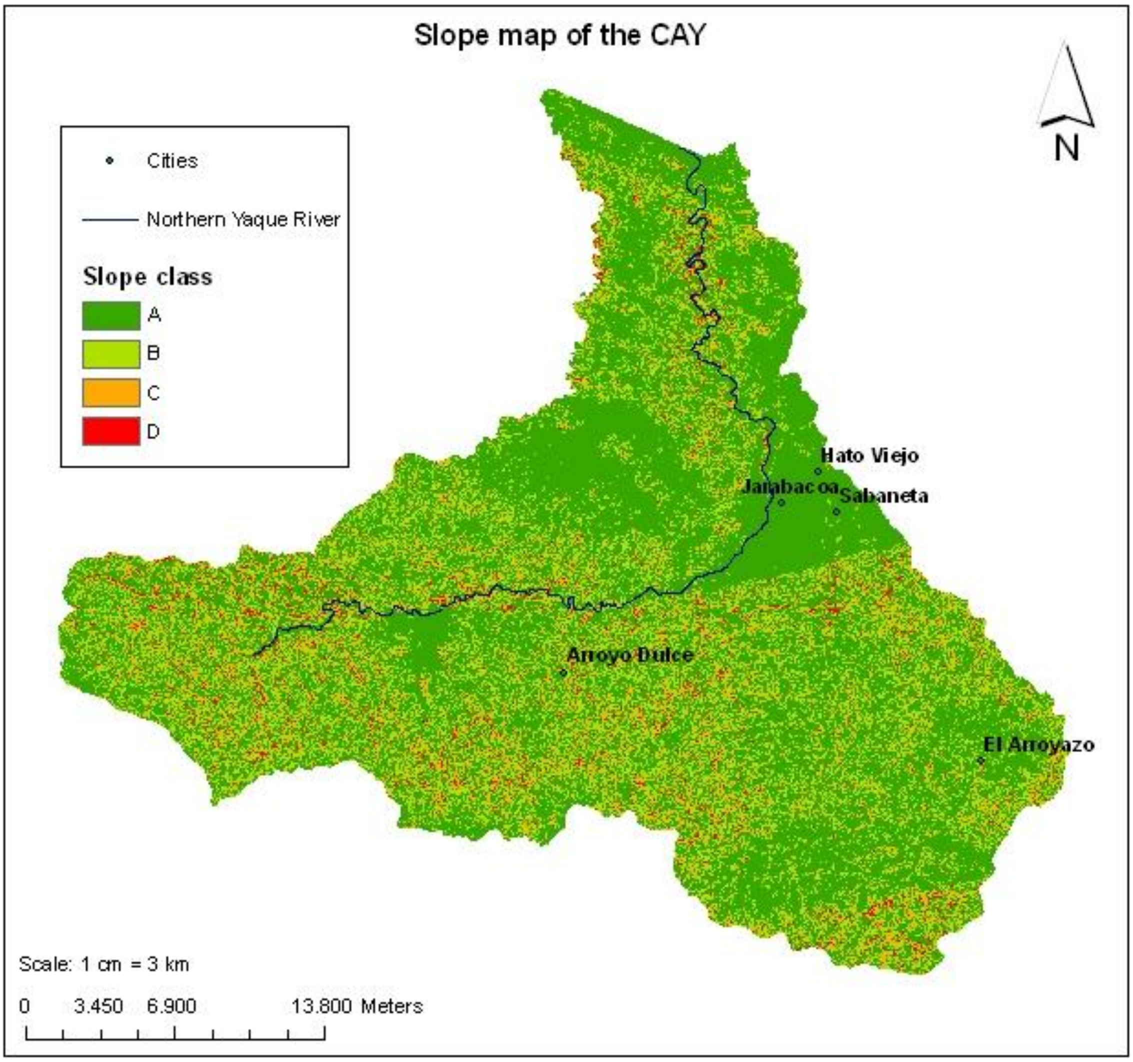

Figure 7 Slope map of the CAY, including the five major cities and the Northern Yaque River

In the CAY 66 % (55.000 ha) of the area can be categorized in slope class A, 23 % (20.000 ha) in slope class B, 8 % in slope class C (7.000 ha) and only 3 % (2.000 ha) in slope class D (see table 2 and figure 8).

Slope (%)	Area (in ha)	Area (%)
0 - 20	55.211	66%
21 - 35	19.661	23%
36 - 50	6.937	8%
51 - 100	2.128	3%
Total	83.938	100%

Table 2 Slope class distribution in the CAY

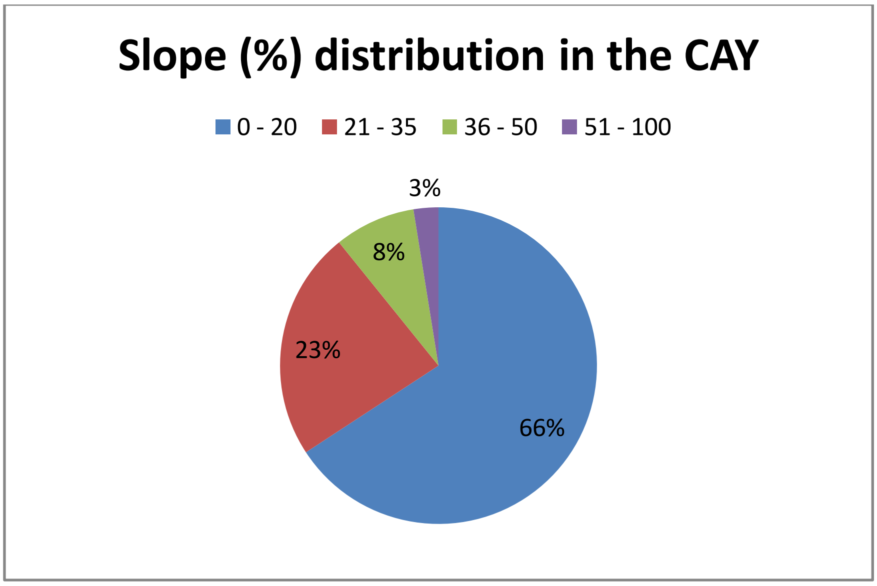

Figure 8 Slope class distribution in the CAY

13.4. Land Use Distribution According to Slope Classes

To find out to which quantity of the different land use types occur in each slope class, I generated four specific map layers, each one consisting out of only one slope class. I then intersected each of these layers with the land use map to find out to which extend the different slope classes are covered with agricultural farming and pasture.

It is noticeable that about 70% of the traditional agricultural farming and livestock ranching takes place in the first slope class and therefore has not to be changed. Only 20% of the traditional agricultural sites should be transformed into agroforestry systems and 30% of the pastures shall be renovated. Only 1% of the agricultural sides and 2% of the pastures are in absolutely inappropriate terrain and have to be afforested (see table 3 below and figure 9 and 10).

	Slope class A		Slope class B		Slope class C		Slope class D	
Land use	Area (in ha)	Area (%)	Area (in ha)	Area (%)	Area (in ha)	Area (%)	Area (in ha)	Area (%)
Agriculture	11.216	76%	2.528	17%	735	5%	189	1%
Pasture	2.425	68%	808	23%	260	7%	65	2%
Total	13.641		3.336		995		254	

Table 3 Land use distribution according to slope classes in the CAY

According to the land use guideline developed by Veloz et al. (1985) (see chapter 13.1.) this means that 3.263 ha of traditional agriculture systems (Slope class B and C) should be changed into agro-forestry systems and that 1.068 ha of pastures should be renovated (Slope class B and C). Finally, 189 ha of agricultural sites and 65 ha of pasture (Slope class D) have to be afforested.

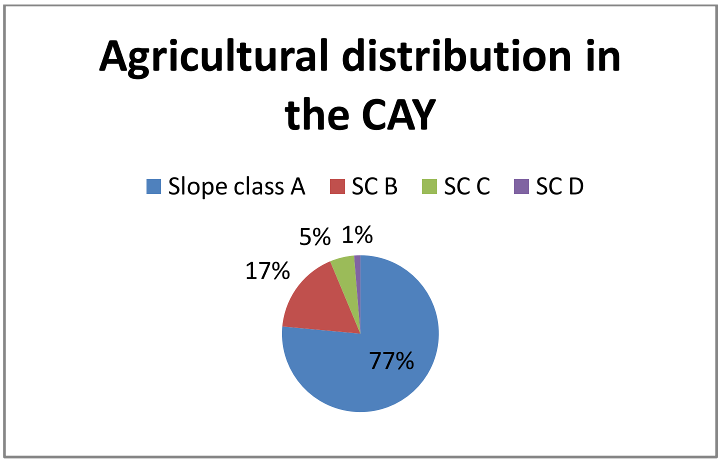

Figure 9 Agricultural distribution according to slope classes in the CAY

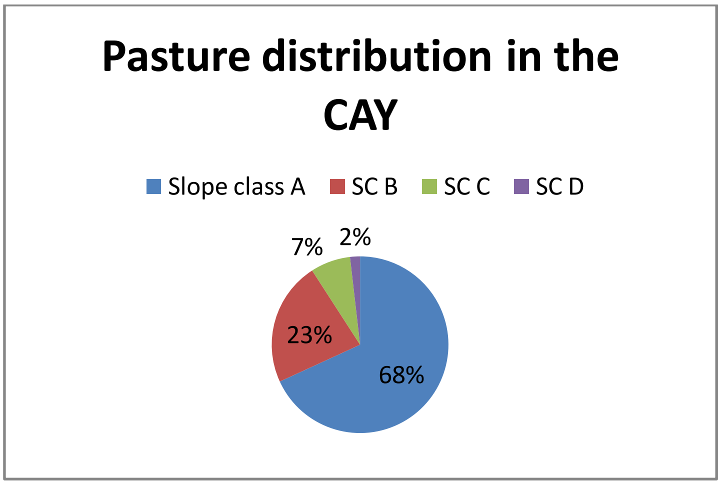

Figure 10 Pasture distribution according to slope classes in the CAY

14. Quantitative Evaluation on the Buyer Side

14.1. Technical Facts of the Tavera-Bao-Lopéz Angostura Complex

The storage capacity of the three reservoirs of the Taveras-Bao-Lopéz-Angostura complex has a total capacity of 421.40 million m^3 (Taveras: 173 Mm^3, Bao: 244 Mm^3, Lopéz: 4.4 Mm^3) and the drainage area of the Tavera basin is 785 km^2. Both the Tavera and the Lopez-Angostura dam are hydroelectric power generating dams. The Tavera dam is also used for the production of potable- and sanitary- and irrigation water and irrigation matters. The Bao dam is only constructed as irrigation and drink water reservoir (INDRHI, 2010). I will focus on the Tavera dam and its reservoir as this is the only part of the complex from which reliable data is available.

	Tavera	**Lopez Angostura**	**Bao**
Technical information:			
Type of dam	Earth	Earth	Earth
Purpose	Hydroelectricity, potable- and irrigation water	Hydroelectricity	Potable- and irrigation water
Dam height	80.00 m	22.50 m	110.00 m
River	Yaque del Norte	Bao	Bao
Altitude of weir crest	332.50 m a.s.l.	230.60 m a.s.l.	334.90 m a.s.l.
Length of the weir crest	320.00 m	180.00 m	425.00 m
Crest height of the over fall	315.50 m a.s.l.	225.00 m a.s.l.	327.50 m a.s.l.
Type of over fall	With 6 lock gates	With lock gates	/
Over fall capacity	1,000.00 m^3/s	3,410.00 m^3/s	/
Maximal operating level	327.50 m a.s.l.	225.00 m a.s.l.	327.50
Minimal operating level	295.00 m a.s.l.	217.50 m a.s.l.	311.00 m a.s.l.
Total storage capacity	173.00 million m^3	4.40 mm^3	244.00 mm^3
Dead storage capacity	7.6 Million m3		
Reservoir area	6.20 Km^2	0.04 Km^2	10.00 Km^2
Drainage/catchment area	785.00 Km^2	938.00 Km^2	887.00 Km^2
Generating capacity	96.00 MW	18.00 mw	
Other information:			
Irrigation area	9,100.00 ha		
Produced energy	220.00 GWH/a	128.00 GWH/a	
construction year	1973		1984

Table 4 The Tavera-Bao-Lopéz Angostura complex (Source: INDRHI, 2010)

14.2. Sedimentation in the Tavera Reservoir

The sedimentation yield in the Tavera basin is conducted with2.284 m^3/km^2/annually. This is an average value for the observed first 20 years since its completion in 1973. The projected amount which shall occur after an erosion control project is conducted with 725 m^3/km^2/annually, which equals a reduction of 68% (MARENA, 2010). In a comparative study of the Dominican Valdesia watershed a sediment yield reduction of 86% is estimated (Veloz, Southgate, Hitzhusen, & Macgregor, 1985).

The Tavera reservoir has a total storage capacity of 173 million m^3 from which 7.6 million $m^3$are dead storage capacity. In 1981, only 8 years after the Tavera completion, already 18 m of sediments occurred behind the dam (total height 80m) causing 40% reduction in the dead storage capacity and 10-14 m loss of active storage (International Resources Group, Ltd., 2001). In 1993 then, INDRHI stated out that the dead storage capacity was already completely filled and that roughly 17% of the active storage capacity was filled with sediments. Only after 20 years, the reservoir was filled to 20.7% with sediments which equals a total amount of 35.81 million m^3 of sediments.

14.3. Reservoir Lifetime of Tavera Reservoir

I will follow the method of Einsele et al.(1997) to calculate the lifetime of artificial reservoirs, using the acquired statistic data of INDRHI, MARENA and the International Resource Group, Ltd. Einsele et al. (1997) calculate the reservoir lifetime as a function of its sediment storage capacity, its drainage area and sediment yield (see figure 12).

The formula is as follows:

$$T_r = \frac{SSC}{SY \times A_d} \text{ (years)}$$

Where:

SSC is the sediment storage capacity (metric tons, *t*),

SY the specific sediment yield (t/km2/a)

A_d the drainage area (km2), and

T_r the reservoir lifetime (years).

In the case of the Tavera reservoir, this means:

SSC is 173 million m^3 (total storage capacity)

SY is 2.284 $m^3/km^2/a$, and

A_d is 785 km^2.

The probable duration of life of the Tavera basin is calculated for three different scenarios:

1. Scenario No. 1: no actions to decrease the soil erosion will be undertaken and the sediment yield of the Tavera basin will therefore not decrease.
2. Scenario No. 2: Soil erosion actions would have been implemented directly with the establishment of the Tavera dam and a decrease of sediment yield would have occurred permanently.
3. Scenario No. 3: Soil erosion actions will be undertaken from now on (2010) and an increase of sediment yield is about to occur.

For the calculations of Scenario No. 3 I further assume the following:

1. Effects on decreasing erosion and therefore reservoir sedimentation cannot be expected from the first year. I therefore calculated a period of five years with approximately no change in erosion behavior, following a watershed management study of Briones (1991).
2. Furthermore, I assumed that the expected effects will not occur immediately and to 100% directly after those first five years divided the expected reduction in sediment yield of 68% up in a three five-year periods. In the first five years I assume a reduction in SY of 23%, in the second one as well and finally a reduction of 22% in the last period. The expected effects can therefore only be seen as completely fulfilled 20 years after the initial establishment.

The predicted lifetime of the Tavera reservoir is 96 years (Scenario 1). If an erosion project with the expected decrease in sediment yield to 725 m^3/km^2/annually (MARENA, 2010), would have been implemented directly with the completion of the reservoir (Scenario 2) the lifetime would be increased up to 303 years. The calculated values become approved if one compares them with the data given by the International Resource Group in 1981 and the one of INDRHI from 1993.

If an erosion project would be implemented now (Scenario 3), the expected lifetime would still be 198 years (till the year 2171).

	Scenario 1	Scenario 2	Scenario 3
Remaining storage capacity in mm^3	0	0	0
Year	2069 (after 96 years)	2276 (after 303 years)	2171 (after 198 years)

Table 5 Duration of reservoir lifetime (until it is filled to 100%)

Still, this is a very optimistic value as the lifetime of a reservoir is very likely to end before it is completely filled with sediments. This becomes clear if the following technical fact is considered: If the reservoir is filled with sediments above the over fall level it will be completely clogged and therefore inoperative (see figure 11). The crest height of the Tavera over fall is at 63m dam height (see table 4) and I will therefore calculate with 80% of the total storage capacity for the SSC value.

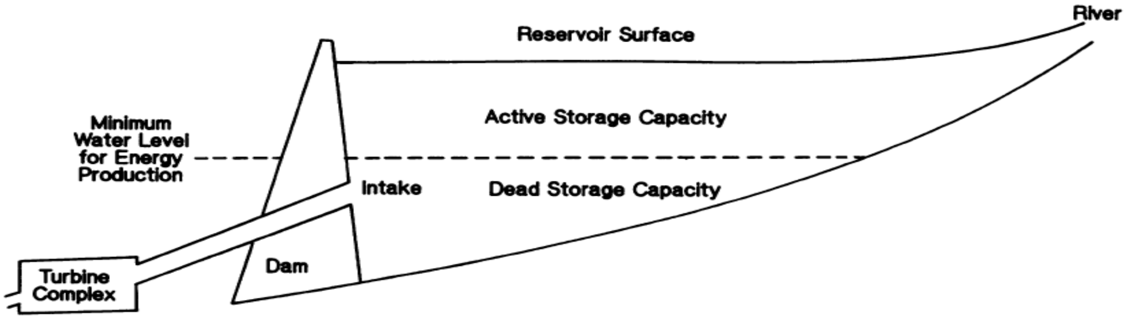

Figure 11 Profile of a hydroelectric reservoir (Southgate et al., 1989)

The probable duration of life of the Tavera reservoir is then reduced to 77 years without, 243 years with a directly implemented and 138 years with an erosion project starting in 2010.

	Scenario 1	Scenario 2	Scenario 3
Remaining storage capacity in mm^3	34.943.620	34.702.625	34.818.114
Year	2050 (after 77 years)	2216 (after 243 years)	2111 (after 138 years)

Table 6 Duration of reservoir lifetime (until it is filled to 80%)

Still this is a rather conservative value and some scientists state out that a dam will lose its efficiency when 50% of the active storage is lost. In this case, duration of lifetime would be:

	Scenario 1	Scenario 2	Scenario 3
Remaining storage capacity in mm^3	83.353.000	83.078.250	83.012.341
Year	2023 (after 50 years)	2131 (after 158 years)	2027 (after 54 years)

Table 7 Duration of reservoir lifetime (until the active storage capacity is filled to 50%)

The function is also shown in figure 12 which clearly demonstrates the strong influence of the sediment yield.

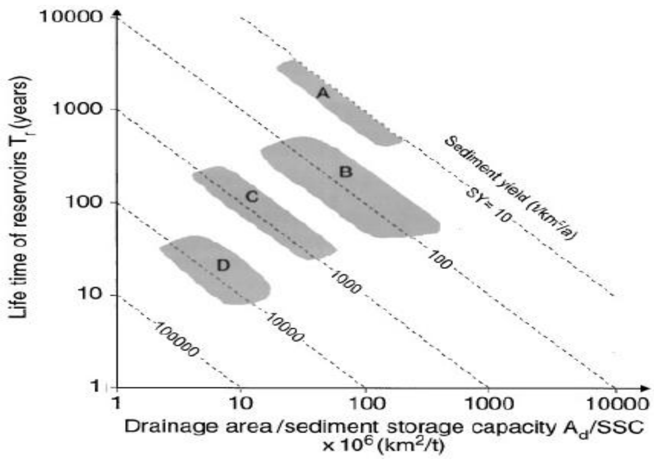

Figure 12 Lifetime of reservoirs (T_r) in relation to specific sediment yield and the ratio of drainage area (A_d) and sediment storage capacity (SSC).[5] (adopted from Einsele et al., 1997)

[5] Shaded fields signify: **A** Undisturbed catchments of moderaterelief under humid temperate climate;
B majority of reservoirs inregions of moderate relief with land use, different climates;
C majorityof reservoirs with alpine catchments; **D** reservoirs in regions ofextremely high sediment yield

15. Economical Valuation on the Provider Side - Opportunity Costs for Land Use Changes

A study of the Dominican agroforestry university Fernando Arturo de Meriño (UAFAM) calculated the opportunity cost for the extensive livestock farming on US$ 51 ha/year. Based on this study and on the experiences gained in the PROCARYN project, MARENA calculated the opportunity costs for reforestations with conservation purposes, to be US$ 137 ha/year. For the establishment of agro-forestry systems (with at least 140 trees/ha, for example "shaded coffee") a complementary amount of US$ 20/ha/year was conducted. For the renovation of pastures US$ 124 has been calculated. For all compensation payments, except for the pasture renovation, a duration of five years is suggested. This range derives from the assumption that there will be no or less benefits for the farmer directly one year after his land has been undertaken the land use change. (CEDAF; GTZ, 2007).

Land use change	**Opportunity costs per ha and year**
Pasture renovation	US$ 124
Reforestation with conservation purpose	US$ 137
Establishment of agro-forestry systems	US$ 157

Table 8 Opportunity costs for land use change

As already described in chapter 13.4.:

- 3.263 ha of traditional agriculture systems should be changed into agro-forestry systems
- 1.068 ha of pastures should be renovated
- 189 ha of agricultural sites and 65 ha of pasture (254 ha in total) have to be afforested.

This means that the opportunity costs that have to be paid for the land use change in one year would be US$ 679.521 in total. The costs consist of the following parts:

- US$ 512.291 for the change of traditional agriculture systems into agro-forestry systems
- US$ 132.432 for pasture renovation and
- US$ 34.798 for afforestation purposes.

Considering a total duration of five years, the costs would increase each year about another US$ 547.089, reaching the total costs of US$ 2.867.877.

16. Economical Valuation on the Buyer Side – Economical Value of the PES Project

After quantifying the physical loss of the Tavera reservoir in chapter 14.3. I will now monetize the losses. I will follow the method of Briones (1991) who considers every benefit obtained from a dam being a direct function of the storage capacity of its storage capacity volume. Therefore I bring the production capacity of hydroelectric power in direct relation to the actual active storage capacity of the Tavera reservoir, which means that a reduction in active storage capacity means as well a reduction in hydroelectric power production. Thus, it is possible to derive a unit benefit in terms of dollars per cubic meter of stored water. This unit value is then used to calculate the economical losses due to the loss of storage capacity. In the case of the Tavera dam we got an initial active storage capacity of 165 million m^3 and based on that a possible production of 220 GWh annually. The average price for a kWh in the DR is US$ 0,129. The ratio of the produced electricity to active storage volume thus is 1,33kWh per m^3. The investment- and operating costs of the Tavera dam are calculated according to Kruck et al. (2004) who base their statistics on the studies of Hirschl et al. (2002).

Capacity (kW)	New construction	Revitalization	Modernization
1 – 100	7.500 – 12.500	3.500 – 10.000	2.000 – 3.000
100 – 250	6.000 – 7.500	2.000 – 3.500	1.500 – 2.000
250 – 500	5.000 – 6.000	1.500 – 2.000	1.000 – 1.500
500 - 1000	4.500 – 6.000	1.500	1.000
1000 – 10.000	4.000 – 4.500	1.500	1.000

Table 9 Investment costs for hydroelectric power plants in US$/kW (Hirschl et al. 2002)

The investment cost for the Tavera dam are calculated with 4.000 US$/kW as the dam has a generating capacity of 96 MW and the total investment then is 384.000.000 US$.

The annual operating costs can be calculated over the investment costs. According to Kaltschmitt et al. (2003) the annual operating costs are 1 – 4% of the investment costs and according to Hirschl et al. (2002), the operation costs range from 2,5 – 4% of the investment costs. I will therefore calculate with a value of 3% of the investment costs, as this value fits into both the given cost ranges. Doing so, the annual expenditure would be 11.520.000 US$.

Taken these calculations into consideration the economic lifetime of the reservoir decreases and the economic value of the watershed management project is as follows.

	Scenario 1	Scenario 2	Scenario 3
Elimination of IC	After 29 years (2002)	After 24 years (1997)	After 29 years (2002)
Economic lifetime	59 years (till 2032)	185 years (till 2158)	82 years (till 2055)
Hypothetical NPV until end of economic lifetime	138.260.892 US$ 138 million US$	1.279.153.901 US$ 1,3 billion US$	180.266.633 US$ 180 million US$

Table 10 Economic lifetime and NPV (net present value) from the electricity production of the Tavera dam with operating costs of 3% of the IC (investment costs)

In this case, the economic lifetime of the Tavera reservoir (under electricity producing aspects) would be exaggerated for 23 years. This exaggeration would lead to an increase of 42 million US$ (42.005.741 US$) in total gain of NPV, which can here be seen as the WTP. However, it is important to clarify that these are only the benefits from hydroelectricity production and not from potable water production and irrigation water supply. Of course, an increase in lifetime means also a longer lasting supply of those two externalities and an additional increase of the socio-economic value of the Tavera dam.

IV. Discussion

17. Provider and Buyer of EGS and the Relevant EGS in the CAY

As I identified the potential EGS provider and –buyer I tried to allocate the former defined EGS according to their typology to both groups. In the case of the ES buyers, the state-run hydroelectric power plant, it was easy to allocate the EGS of interest, as the EGS that have to be provided are self-evident and clearly definable.

In the case of the EGS provider side, this was not so clear as expectations and opinions of such a large group of farmers about what is important and what not can vary to great parts. The method of choice to identify the important and unimportant EGS and finally put them into a well-founded ranking would be a series of interviews held with a representative part of the farmers. As I did not carried out such an interview during my internship and as I could not find any reliable data for the concerned area, I did an assumption, pointing out all possible EGS that might be of interest for the farmers of the CAY, according to my opinion. I know that this cannot be seen as fully representative and that further research is needed here. Nevertheless, the study focuses mainly on the question whether or not a PES project might be reasonable and economically feasible for the possible financier, the "buyer" of the provided EGS. On that account, this incorrectness should not carry too much weight and therefore can be neglected.

18. Evaluation Typology and Methods of EGS

Each of the described methods has its strengths and weaknesses and the applicability varies from situation to situation, depending on the practical on-site conditions. However, a synthesis study of over 100 scientific papers by Costanza et al. (1987), shows that for each EGS usually several valuation methods can be used. The study also shows that for each type of ES usually only one or two methods were used primarily.

The relationship between the main types of ES and the preferred valuation methods are presented below:

- *Regulation services* were mainly valued through indirect market valuation techniques (particularly avoided cost and replacement cost),
- *Regulating services and supporting services* (also referred to as Habitat functions) mainly through direct market pricing (for example, money donations for conservation purposes),
- *Provisioning services* through direct market pricing and factor income methods,
- *Cultural services* mainly through contingent valuation (for cultural and spiritual information), hedonic pricing (for aesthetic information) and market pricing (for recreation, tourism and science).

By matching the described typology against the best available valuation methods, de Groot et al. (2002) have shown that it is in principal possible to relate a monetary value to all types of EGS. This value depends on the human preferences for the availability and maintenance of the related EGS.

Nevertheless, conventional economic value is based on the goal of individual utility maximization, and a commodity is only valuable to the extent to which it contributes to the goals of individual welfare.

It is therefore still an urgent need to investigate more extending valuation concepts, especially with respect to ecological sustainability, and distributional fairness (Costanza & Folke, 1997) as valuations based alone on current individual preferences and utility maximization, do not necessarily lead to ecological sustainability or social fairness (Bishop, 1993).

19. Quantitative and Economical Evaluation on the Provider and Buyer side

It has to be out pointed that this study mainly focus on the hydroelectric production aspects of the hydroelectric power plant and that the production and storage of drinking- and irrigation water are not considered. Of course, those two functions will increase with an exaggeration of the reservoir lifetime as well and the economical benefits that will derive here have to be calculated as well. This calculation is missing in this study as it was not possible for me to get reliable data about those two aspects for the Tavera dam.

It also was not possible to find reliable data about the sedimentation level in the last reservoir of the Tavera-Bao-Lopéz-Angostura complex, the Lopez-Angostura reservoir. Therefore it was not possible to calculate the effects on reservoir lifetime and theoretical electric power production for this last part of the complex, like I did with the Tavera dam. Nevertheless, it should be clearly demonstrated with the example of the Tavera dam, that the effect would be positive and that an exaggeration of reservoir lifetime and an increase in benefits due to a plus in electric power production is highly expectable.

V. Conclusion

The total costs that would derive from the compensation costs which would have to be paid to the concerned farmers nearly reach the amount of US$ 3 million. This seems to be a very high payment but if one compares this amount with the possible extra benefits (US$ 42 million) that would derive from the economic lifetime exaggeration (23 years) of the Tavera dam calculated in chapter 16. it becomes clear that this spending would truly pay off. Still, an extra benefit of roughly US$ 39 million is possible.

However, watershed management should be initiated before a dam is put into operation because the economic lifetime of a reservoir and therefore of the hydroelectric power producing capacity depends highly on the sediment yield of the basin. As shown in this study a directly implemented watershed protection program would triple the economical lifetime of a hydroelectric complex and increase the benefits almost tenfold. Compared to this possible benefit and the high investment cost of US$ 384 million plus the annual operating costs of almost US$ 12 million, an extra initial spending of US$ 3 million could not be considered as a large quantity

The main cause for the soil degradation and sedimentation is inappropriate land use, especially on the steep slopes of the CAY. These degrading land use techniques might be a lack of knowledge but it is even more likely that they are the result of a generally open access to rangeland. There is no need to conserve a particular site if it is as well possible to simply leave the field and make another parcel agricultural usable. This technique is especially attractive for farmers with no land title as there is no reason for them to invest in something they do not posses. Also for farmers with land tenure, soil conservation techniques are often simply not affordable. The opportunity payments which could be paid during a possible PES scheme would serve as a financial incentive and would compensate the farmers for eventual loses due to the implementation of conservation techniques and/or the change from one land use system to another.

The legal framework for a sustainable and sensitive use of the DR natural resources is set with the law 64-00.The effective protection of the environment is now an essential duty of the State and it thus has the responsibility to adopt an integral policy which can be executed participatory with all environment related institutions. The MARENA, which created the Law 64-00, represents a responsible, executive and governmental authority for the administration of the environment, ecosystems and natural resources.

The GTZ is willing to support the establishment of a PES project and represents a possible counterpart, especially addressing technical assistance matters. The GTZ already has an assistant function on an implementation approach of a PES pilot project in the upper catchment of the Yaque del Norte River and therefore is the ideal counterpart due to its already gained experiences.

A possible financier or "buyer of EGS" is also identified and it would be in its own economical interest to pay for the implementation of a watershed management project, as it is already stated out in the beginning of this chapter. EGEHID already signalized its interest in promoting and financing a watershed protection program in the CAY and can be considered to be a reliable financier.

I therefore highly recommend the establishment of a PES scheme for the watershed protection of the CAY, as it addresses all involved parties in a positive way and represents a win-win situation for all the parties directly involved.

VI. Recommendations

As stated out before, I would highly recommend the implementation of a PES scheme for watershed protection in the CAY.

Furthermore, I would give the following recommendations for the execution of such a program:

1. A five year action plan should be developed with a strong involvement of all concerned parties, especially of the farmers. It would therefore be very helpful to support the foundation of a representative farmers organization to better address the doubts and needs they might have and to simplify negotiations. This would also have the advantage that environmental education and courses on improved land use technologies could be held in the communities and/or together with the founded farmers' organization.

2. A strong involvement of local groups and organizations into the decision making processes should be realized to avoid bureaucratic and long-winded formalities.

3. The emphasis of the advisory function of the involved counterparts should lie on the institutional strengthening of national and local capacities. On a local scale, the main focus of the possible counterparts shall lie on capacity building in improved land use technologies, and ecologically responsible production methods for coffee, timber and agroforestry-system shall be taught and supported. The GTZ could take a leading function here, due to its experience in the CAY and in advisory support.

4. An establishment of a monitoring system is needed, both for the monitoring of the land use changes and for the changes in erosion and sediment yield levels. I recommend a GIS based monitoring system to control the land use changes. DIARENA which is in charge of the production of environmental maps of the DR and which also works with ArcGIS, is highly recommendable here. For the monitoring of the sediment yield in the Tavera basin, already existing studies by MARENA and the International Resource Group should be continued for twenty years in a 5 year cycle, to proof the assumptions about sedimentation reduction given by MARENA.

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Appendices

Table of content

1. Calculations for scenario No. 1

	Remaining TSC		Remaining DSC		Remaining AST		Total SY		Produced Electricity	Benefit from Produced Electricity	Benefits minus operation costs
Year	m3	%	m3	%	m3	%	m3	%	kWh	$US	US$
0	173.000.000	100%	7.600.000	100%	165.400.000	100%	0	0%	0	0	
1	171.207.060	99%	6.703.530	88%	164.503.530	99%	1.792.940	1%	218.807.597	28.226.180	16.706.180
2	169.414.120	98%	5.807.060	76%	163.607.060	99%	3.585.880	2%	217.615.195	28.072.360	16.552.360
3	167.621.180	97%	4.910.590	65%	162.710.590	98%	5.378.820	3%	216.422.792	27.918.540	16.398.540
4	165.828.240	96%	4.014.120	53%	161.814.120	98%	7.171.760	4%	215.230.389	27.764.720	16.244.720
5	164.035.300	95%	3.117.650	41%	160.917.650	97%	8.964.700	5%	214.037.987	27.610.900	16.090.900
6	162.242.360	94%	2.221.180	29%	160.021.180	97%	10.757.640	6%	212.845.584	27.457.080	15.937.080
7	160.449.420	93%	1.324.710	17%	159.124.710	96%	12.550.580	7%	211.653.181	27.303.260	15.783.260
8	158.656.480	92%	428.240	6%	158.228.240	96%	14.343.520	8%	210.460.779	27.149.440	15.629.440
9	156.863.540	91%	0	0%	156.863.540	95%	16.136.460	9%	208.645.579	26.915.280	15.395.280
10	155.070.600	90%	0	0%	155.070.600	94%	17.929.400	10%	206.260.774	26.607.640	15.087.640
11	153.277.660	89%	0	0%	153.277.660	93%	19.722.340	11%	203.875.969	26.300.000	14.780.000
12	151.484.720	88%	0	0%	151.484.720	92%	21.515.280	12%	201.491.163	25.992.360	14.472.360
13	149.691.780	87%	0	0%	149.691.780	91%	23.308.220	13%	199.106.358	25.684.720	14.164.720
14	147.898.840	85%	0	0%	147.898.840	89%	25.101.160	15%	196.721.553	25.377.080	13.857.080
15	146.105.900	84%	0	0%	146.105.900	88%	26.894.100	16%	194.336.747	25.069.440	13.549.440
16	144.312.960	83%	0	0%	144.312.960	87%	28.687.040	17%	191.951.942	24.761.801	13.241.801
17	142.520.020	82%	0	0%	142.520.020	86%	30.479.980	18%	189.567.137	24.454.161	12.934.161
18	140.727.080	81%	0	0%	140.727.080	85%	32.272.920	19%	187.182.331	24.146.521	12.626.521
19	138.934.140	80%	0	0%	138.934.140	84%	34.065.860	20%	184.797.526	23.838.881	12.318.881
20	137.141.200	79%	0	0%	137.141.200	83%	35.858.800	21%	182.412.721	23.531.241	12.011.241
21	135.348.260	78%	0	0%	135.348.260	82%	37.651.740	22%	180.027.915	23.223.601	11.703.601
22	133.555.320	77%	0	0%	133.555.320	81%	39.444.680	23%	177.643.110	22.915.961	11.395.961
23	131.762.380	76%	0	0%	131.762.380	80%	41.237.620	24%	175.258.305	22.608.321	11.088.321

24	129.969.440	75%	0	0%	129.969.440	79%	43.030.560	25%	172.873.499	22.300.681	10.780.681
25	128.176.500	74%	0	0%	128.176.500	77%	44.823.500	26%	170.488.694	21.993.042	10.473.042
26	126.383.560	73%	0	0%	126.383.560	76%	46.616.440	27%	168.103.889	21.685.402	10.165.402
27	124.590.620	72%	0	0%	124.590.620	75%	48.409.380	28%	165.719.083	21.377.762	9.857.762
28	122.797.680	71%	0	0%	122.797.680	74%	50.202.320	29%	163.334.278	21.070.122	9.550.122
29	121.004.740	70%	0	0%	121.004.740	73%	51.995.260	30%	160.949.473	20.762.482	9.242.482
30	119.211.800	69%	0	0%	119.211.800	72%	53.788.200	31%	158.564.667	20.454.842	8.934.842
31	117.418.860	68%	0	0%	117.418.860	71%	55.581.140	32%	156.179.862	20.147.202	8.627.202
32	115.625.920	67%	0	0%	115.625.920	70%	57.374.080	33%	153.795.057	19.839.562	8.319.562
33	113.832.980	66%	0	0%	113.832.980	69%	59.167.020	34%	151.410.252	19.531.922	8.011.922
34	112.040.040	65%	0	0%	112.040.040	68%	60.959.960	35%	149.025.446	19.224.283	7.704.283
35	110.247.100	64%	0	0%	110.247.100	67%	62.752.900	36%	146.640.641	18.916.643	7.396.643
36	108.454.160	63%	0	0%	108.454.160	66%	64.545.840	37%	144.255.836	18.609.003	7.089.003
37	106.661.220	62%	0	0%	106.661.220	64%	66.338.780	38%	141.871.030	18.301.363	6.781.363
38	104.868.280	61%	0	0%	104.868.280	63%	68.131.720	39%	139.486.225	17.993.723	6.473.723
39	103.075.340	60%	0	0%	103.075.340	62%	69.924.660	40%	137.101.420	17.686.083	6.166.083
40	101.282.400	59%	0	0%	101.282.400	61%	71.717.600	41%	134.716.614	17.378.443	5.858.443
41	99.489.460	58%	0	0%	99.489.460	60%	73.510.540	42%	132.331.809	17.070.803	5.550.803
42	97.696.520	56%	0	0%	97.696.520	59%	75.303.480	44%	129.947.004	16.763.163	5.243.163
43	95.903.580	55%	0	0%	95.903.580	58%	77.096.420	45%	127.562.198	16.455.524	4.935.524
44	94.110.640	54%	0	0%	94.110.640	57%	78.889.360	46%	125.177.393	16.147.884	4.627.884
45	92.317.700	53%	0	0%	92.317.700	56%	80.682.300	47%	122.792.588	15.840.244	4.320.244
46	90.524.760	52%	0	0%	90.524.760	55%	82.475.240	48%	120.407.782	15.532.604	4.012.604
47	88.731.820	51%	0	0%	88.731.820	54%	84.268.180	49%	118.022.977	15.224.964	3.704.964
48	86.938.880	50%	0	0%	86.938.880	53%	86.061.120	50%	115.638.172	14.917.324	3.397.324
49	85.145.940	49%	0	0%	85.145.940	51%	87.854.060	51%	113.253.366	14.609.684	3.089.684
50	83.353.000	48%	0	0%	83.353.000	50%	89.647.000	52%	110.868.561	14.302.044	2.782.044
51	81.560.060	47%	0	0%	81.560.060	49%	91.439.940	53%	108.483.756	13.994.404	2.474.404
52	79.767.120	46%	0	0%	79.767.120	48%	93.232.880	54%	106.098.950	13.686.765	2.166.765
53	77.974.180	45%	0	0%	77.974.180	47%	95.025.820	55%	103.714.145	13.379.125	1.859.125

54	76.181.240	44%	0	0%	76.181.240	46%	96.818.760	56%	101.329.340	13.071.485	1.551.485
55	74.388.300	43%	0	0%	74.388.300	45%	98.611.700	57%	98.944.534	12.763.845	1.243.845
56	72.595.360	42%	0	0%	72.595.360	44%	100.404.640	58%	96.559.729	12.456.205	936.205
57	70.802.420	41%	0	0%	70.802.420	43%	102.197.580	59%	94.174.924	12.148.565	628.565
58	69.009.480	40%	0	0%	69.009.480	42%	103.990.520	60%	91.790.119	11.840.925	320.925
59	67.216.540	39%	0	0%	67.216.540	41%	105.783.460	61%	89.405.313	11.533.285	13.285
60	65.423.600	38%	0	0%	65.423.600	40%	107.576.400	62%	87.020.508	11.225.646	-294.354
61	63.630.660	37%	0	0%	63.630.660	38%	109.369.340	63%	84.635.703	10.918.006	
62	61.837.720	36%	0	0%	61.837.720	37%	111.162.280	64%	82.250.897	10.610.366	
63	60.044.780	35%	0	0%	60.044.780	36%	112.955.220	65%	79.866.092	10.302.726	
64	58.251.840	34%	0	0%	58.251.840	35%	114.748.160	66%	77.481.287	9.995.086	
65	56.458.900	33%	0	0%	56.458.900	34%	116.541.100	67%	75.096.481	9.687.446	
66	54.665.960	32%	0	0%	54.665.960	33%	118.334.040	68%	72.711.676	9.379.806	
67	52.873.020	31%	0	0%	52.873.020	32%	120.126.980	69%	70.326.871	9.072.166	
68	51.080.080	30%	0	0%	51.080.080	31%	121.919.920	70%	67.942.065	8.764.526	
69	49.287.140	28%	0	0%	49.287.140	30%	123.712.860	72%	65.557.260	8.456.887	
70	47.494.200	27%	0	0%	47.494.200	29%	125.505.800	73%	63.172.455	8.149.247	
71	45.701.260	26%	0	0%	45.701.260	28%	127.298.740	74%	60.787.649	7.841.607	
72	43.908.320	25%	0	0%	43.908.320	27%	129.091.680	75%	58.402.844	7.533.967	
73	42.115.380	24%	0	0%	42.115.380	25%	130.884.620	76%	56.018.039	7.226.327	
74	40.322.440	23%	0	0%	40.322.440	24%	132.677.560	77%	53.633.233	6.918.687	
75	38.529.500	22%	0	0%	38.529.500	23%	134.470.500	78%	51.248.428	6.611.047	
76	36.736.560	21%	0	0%	36.736.560	22%	136.263.440	79%	48.863.623	6.303.407	
77	34.943.620	20%	0	0%	34.943.620	21%	138.056.380	80%	46.478.817	5.995.767	
78	33.150.680	19%	0	0%	33.150.680	20%	139.849.320	81%	44.094.012	5.688.128	
79	31.357.740	18%	0	0%	31.357.740	19%	141.642.260	82%	41.709.207	5.380.488	
80	29.564.800	17%	0	0%	29.564.800	18%	143.435.200	83%	39.324.401	5.072.848	
81	27.771.860	16%	0	0%	27.771.860	17%	145.228.140	84%	36.939.596	4.765.208	
82	25.978.920	15%	0	0%	25.978.920	16%	147.021.080	85%	34.554.791	4.457.568	
83	24.185.980	14%	0	0%	24.185.980	15%	148.814.020	86%	32.169.985	4.149.928	

84	22.393.040	13%	0	0%	22.393.040	14%	150.606.960	87%	29.785.180	3.842.288	
85	20.600.100	12%	0	0%	20.600.100	12%	152.399.900	88%	27.400.375	3.534.648	
86	18.807.160	11%	0	0%	18.807.160	11%	154.192.840	89%	25.015.570	3.227.008	
87	17.014.220	10%	0	0%	17.014.220	10%	155.985.780	90%	22.630.764	2.919.369	
88	15.221.280	9%	0	0%	15.221.280	9%	157.778.720	91%	20.245.959	2.611.729	
89	13.428.340	8%	0	0%	13.428.340	8%	159.571.660	92%	17.861.154	2.304.089	
90	11.635.400	7%	0	0%	11.635.400	7%	161.364.600	93%	15.476.348	1.996.449	
91	9.842.460	6%	0	0%	9.842.460	6%	163.157.540	94%	13.091.543	1.688.809	
92	8.049.520	5%	0	0%	8.049.520	5%	164.950.480	95%	10.706.738	1.381.169	
93	6.256.580	4%	0	0%	6.256.580	4%	166.743.420	96%	8.321.932	1.073.529	
94	4.463.640	3%	0	0%	4.463.640	3%	168.536.360	97%	5.937.127	765.889	
95	2.670.700	2%	0	0%	2.670.700	2%	170.329.300	98%	3.552.322	458.249	
96	877.760	1%	0	0%	877.760	1%	172.122.240	99%	1.167.516	150.610	
Total									10.948.849.707	1.412.401.612	

Table 11 Calculations for Scenario No. 1

2. Calculations for Scenario No. 2

	Remaining TSC		Remaining DSC		Remaining AST		Total SY without project		Produced Electricity (KWh)	Benefit from Produced Electricity	Benefit minus operating costs
Year	m3	%	m3	%	m3	%	m3	%	kWh	US$	US$
0	173.000.000	100%	7.600.000	100%	165.400.000	100%	0	0%	0	$0	
1	172.430.875	99%	7.315.438	96%	165.115.438	100%	569.125	0%	219.603.532	$28.328.856	$16.808.856
2	171.861.750	98%	7.030.875	93%	164.830.875	100%	1.138.250	1%	219.225.064	$28.280.033	$16.760.033
3	171.292.625	98%	6.746.313	89%	164.546.313	99%	1.707.375	1%	218.846.596	$28.231.211	$16.711.211
4	170.723.500	98%	6.461.750	85%	164.261.750	99%	2.276.500	1%	218.468.128	$28.182.388	$16.662.388
5	170.154.375	97%	6.177.188	81%	163.977.188	99%	2.845.625	2%	218.089.659	$28.133.566	$16.613.566
6	169.585.250	97%	5.892.625	78%	163.692.625	99%	3.414.750	2%	217.711.191	$28.084.744	$16.564.744
7	169.016.125	97%	5.608.063	74%	163.408.063	99%	3.983.875	2%	217.332.723	$28.035.921	$16.515.921
8	168.447.000	96%	5.323.500	70%	163.123.500	99%	4.553.000	3%	216.954.255	$27.987.099	$16.467.099
9	167.877.875	96%	5.038.938	66%	162.838.938	98%	5.122.125	3%	216.575.787	$27.938.277	$16.418.277
10	167.308.750	96%	4.754.375	63%	162.554.375	98%	5.691.250	3%	216.197.319	$27.889.454	$16.369.454
11	166.739.625	95%	4.469.813	59%	162.269.813	98%	6.260.375	4%	215.818.851	$27.840.632	$16.320.632
12	166.170.500	95%	4.185.250	55%	161.985.250	98%	6.829.500	4%	215.440.383	$27.791.809	$16.271.809
13	165.601.375	95%	3.900.688	51%	161.700.688	98%	7.398.625	4%	215.061.914	$27.742.987	$16.222.987
14	165.032.250	94%	3.616.125	48%	161.416.125	98%	7.967.750	5%	214.683.446	$27.694.165	$16.174.165
15	164.463.125	94%	3.331.563	44%	161.131.563	97%	8.536.875	5%	214.304.978	$27.645.342	$16.125.342
16	163.894.000	94%	3.047.000	40%	160.847.000	97%	9.106.000	5%	213.926.510	$27.596.520	$16.076.520
17	163.324.875	93%	2.762.438	36%	160.562.438	97%	9.675.125	6%	213.548.042	$27.547.697	$16.027.697
18	162.755.750	93%	2.477.875	33%	160.277.875	97%	10.244.250	6%	213.169.574	$27.498.875	$15.978.875
19	162.186.625	93%	2.193.313	29%	159.993.313	97%	10.813.375	6%	212.791.106	$27.450.053	$15.930.053
20	161.617.500	92%	1.908.750	25%	159.708.750	97%	11.382.500	7%	212.412.638	$27.401.230	$15.881.230
21	161.048.375	92%	1.624.188	21%	159.424.188	96%	11.951.625	7%	212.034.169	$27.352.408	$15.832.408
22	160.479.250	92%	1.339.625	18%	159.139.625	96%	12.520.750	7%	211.655.701	$27.303.585	$15.783.585
23	159.910.125	91%	1.055.063	14%	158.855.063	96%	13.089.875	8%	211.277.233	$27.254.763	$15.734.763

24	159.341.000	91%	770.500	10%	158.570.500	96%	13.659.000	8%	210.898.765	$27.205.941	$15.685.941
25	158.771.875	91%	485.938	6%	158.285.938	96%	14.228.125	8%	210.520.297	$27.157.118	$15.637.118
26	158.202.750	90%	201.375	3%	158.001.375	96%	14.797.250	9%	210.141.829	$27.108.296	$15.588.296
27	157.633.625	90%	0	0%	157.633.625	95%	15.366.375	9%	209.652.721	$27.045.201	$15.525.201
28	157.064.500	90%	0	0%	157.064.500	95%	15.935.500	9%	208.895.785	$26.947.556	$15.427.556
29	156.495.375	89%	0	0%	156.495.375	95%	16.504.625	10%	208.138.849	$26.849.911	$15.329.911
30	155.926.250	89%	0	0%	155.926.250	94%	17.073.750	10%	207.381.913	$26.752.267	$15.232.267
31	155.357.125	89%	0	0%	155.357.125	94%	17.642.875	10%	206.624.976	$26.654.622	$15.134.622
32	154.788.000	88%	0	0%	154.788.000	94%	18.212.000	11%	205.868.040	$26.556.977	$15.036.977
33	154.218.875	88%	0	0%	154.218.875	93%	18.781.125	11%	205.111.104	$26.459.332	$14.939.332
34	153.649.750	88%	0	0%	153.649.750	93%	19.350.250	11%	204.354.168	$26.361.688	$14.841.688
35	153.080.625	87%	0	0%	153.080.625	93%	19.919.375	12%	203.597.231	$26.264.043	$14.744.043
36	152.511.500	87%	0	0%	152.511.500	92%	20.488.500	12%	202.840.295	$26.166.398	$14.646.398
37	151.942.375	87%	0	0%	151.942.375	92%	21.057.625	12%	202.083.359	$26.068.753	$14.548.753
38	151.373.250	86%	0	0%	151.373.250	92%	21.626.750	13%	201.326.423	$25.971.109	$14.451.109
39	150.804.125	86%	0	0%	150.804.125	91%	22.195.875	13%	200.569.486	$25.873.464	$14.353.464
40	150.235.000	86%	0	0%	150.235.000	91%	22.765.000	13%	199.812.550	$25.775.819	$14.255.819
41	149.665.875	86%	0	0%	149.665.875	90%	23.334.125	13%	199.055.614	$25.678.174	$14.158.174
42	149.096.750	85%	0	0%	149.096.750	90%	23.903.250	14%	198.298.678	$25.580.529	$14.060.529
43	148.527.625	85%	0	0%	148.527.625	90%	24.472.375	14%	197.541.741	$25.482.885	$13.962.885
44	147.958.500	85%	0	0%	147.958.500	89%	25.041.500	14%	196.784.805	$25.385.240	$13.865.240
45	147.389.375	84%	0	0%	147.389.375	89%	25.610.625	15%	196.027.869	$25.287.595	$13.767.595
46	146.820.250	84%	0	0%	146.820.250	89%	26.179.750	15%	195.270.933	$25.189.950	$13.669.950
47	146.251.125	84%	0	0%	146.251.125	88%	26.748.875	15%	194.513.996	$25.092.306	$13.572.306
48	145.682.000	83%	0	0%	145.682.000	88%	27.318.000	16%	193.757.060	$24.994.661	$13.474.661
49	145.112.875	83%	0	0%	145.112.875	88%	27.887.125	16%	193.000.124	$24.897.016	$13.377.016
50	144.543.750	83%	0	0%	144.543.750	87%	28.456.250	16%	192.243.188	$24.799.371	$13.279.371
51	143.974.625	82%	0	0%	143.974.625	87%	29.025.375	17%	191.486.251	$24.701.726	$13.181.726
52	143.405.500	82%	0	0%	143.405.500	87%	29.594.500	17%	190.729.315	$24.604.082	$13.084.082
53	142.836.375	82%	0	0%	142.836.375	86%	30.163.625	17%	189.972.379	$24.506.437	$12.986.437

54	142.267.250	81%	0	0%	142.267.250	86%	30.732.750	18%	189.215.443	$24.408.792	$12.888.792
55	141.698.125	81%	0	0%	141.698.125	86%	31.301.875	18%	188.458.506	$24.311.147	$12.791.147
56	141.129.000	81%	0	0%	141.129.000	85%	31.871.000	18%	187.701.570	$24.213.503	$12.693.503
57	140.559.875	80%	0	0%	140.559.875	85%	32.440.125	19%	186.944.634	$24.115.858	$12.595.858
58	139.990.750	80%	0	0%	139.990.750	85%	33.009.250	19%	186.187.698	$24.018.213	$12.498.213
59	139.421.625	80%	0	0%	139.421.625	84%	33.578.375	19%	185.430.761	$23.920.568	$12.400.568
60	138.852.500	79%	0	0%	138.852.500	84%	34.147.500	20%	184.673.825	$23.822.923	$12.302.923
61	138.283.375	79%	0	0%	138.283.375	84%	34.716.625	20%	183.916.889	$23.725.279	$12.205.279
62	137.714.250	79%	0	0%	137.714.250	83%	35.285.750	20%	183.159.953	$23.627.634	$12.107.634
63	137.145.125	78%	0	0%	137.145.125	83%	35.854.875	21%	182.403.016	$23.529.989	$12.009.989
64	136.576.000	78%	0	0%	136.576.000	83%	36.424.000	21%	181.646.080	$23.432.344	$11.912.344
65	136.006.875	78%	0	0%	136.006.875	82%	36.993.125	21%	180.889.144	$23.334.700	$11.814.700
66	135.437.750	77%	0	0%	135.437.750	82%	37.562.250	22%	180.132.208	$23.237.055	$11.717.055
67	134.868.625	77%	0	0%	134.868.625	82%	38.131.375	22%	179.375.271	$23.139.410	$11.619.410
68	134.299.500	77%	0	0%	134.299.500	81%	38.700.500	22%	178.618.335	$23.041.765	$11.521.765
69	133.730.375	76%	0	0%	133.730.375	81%	39.269.625	23%	177.861.399	$22.944.120	$11.424.120
70	133.161.250	76%	0	0%	133.161.250	81%	39.838.750	23%	177.104.463	$22.846.476	$11.326.476
71	132.592.125	76%	0	0%	132.592.125	80%	40.407.875	23%	176.347.526	$22.748.831	$11.228.831
72	132.023.000	75%	0	0%	132.023.000	80%	40.977.000	24%	175.590.590	$22.651.186	$11.131.186
73	131.453.875	75%	0	0%	131.453.875	79%	41.546.125	24%	174.833.654	$22.553.541	$11.033.541
74	130.884.750	75%	0	0%	130.884.750	79%	42.115.250	24%	174.076.718	$22.455.897	$10.935.897
75	130.315.625	74%	0	0%	130.315.625	79%	42.684.375	25%	173.319.781	$22.358.252	$10.838.252
76	129.746.500	74%	0	0%	129.746.500	78%	43.253.500	25%	172.562.845	$22.260.607	$10.740.607
77	129.177.375	74%	0	0%	129.177.375	78%	43.822.625	25%	171.805.909	$22.162.962	$10.642.962
78	128.608.250	73%	0	0%	128.608.250	78%	44.391.750	26%	171.048.973	$22.065.317	$10.545.317
79	128.039.125	73%	0	0%	128.039.125	77%	44.960.875	26%	170.292.036	$21.967.673	$10.447.673
80	127.470.000	73%	0	0%	127.470.000	77%	45.530.000	26%	169.535.100	$21.870.028	$10.350.028
81	126.900.875	73%	0	0%	126.900.875	77%	46.099.125	27%	168.778.164	$21.772.383	$10.252.383
82	126.331.750	72%	0	0%	126.331.750	76%	46.668.250	27%	168.021.228	$21.674.738	$10.154.738
83	125.762.625	72%	0	0%	125.762.625	76%	47.237.375	27%	167.264.291	$21.577.094	$10.057.094

84	125.193.500	72%	0	0%	125.193.500	76%	47.806.500	28%	166.507.355	$21.479.449	$9.959.449
85	124.624.375	71%	0	0%	124.624.375	75%	48.375.625	28%	165.750.419	$21.381.804	$9.861.804
86	124.055.250	71%	0	0%	124.055.250	75%	48.944.750	28%	164.993.483	$21.284.159	$9.764.159
87	123.486.125	71%	0	0%	123.486.125	75%	49.513.875	29%	164.236.546	$21.186.514	$9.666.514
88	122.917.000	70%	0	0%	122.917.000	74%	50.083.000	29%	163.479.610	$21.088.870	$9.568.870
89	122.347.875	70%	0	0%	122.347.875	74%	50.652.125	29%	162.722.674	$20.991.225	$9.471.225
90	121.778.750	70%	0	0%	121.778.750	74%	51.221.250	30%	161.965.738	$20.893.580	$9.373.580
91	121.209.625	69%	0	0%	121.209.625	73%	51.790.375	30%	161.208.801	$20.795.935	$9.275.935
92	120.640.500	69%	0	0%	120.640.500	73%	52.359.500	30%	160.451.865	$20.698.291	$9.178.291
93	120.071.375	69%	0	0%	120.071.375	73%	52.928.625	31%	159.694.929	$20.600.646	$9.080.646
94	119.502.250	68%	0	0%	119.502.250	72%	53.497.750	31%	158.937.993	$20.503.001	$8.983.001
95	118.933.125	68%	0	0%	118.933.125	72%	54.066.875	31%	158.181.056	$20.405.356	$8.885.356
96	118.364.000	68%	0	0%	118.364.000	72%	54.636.000	32%	157.424.120	$20.307.711	$8.787.711
97	117.794.875	67%	0	0%	117.794.875	71%	55.205.125	32%	156.667.184	$20.210.067	$8.690.067
98	117.225.750	67%	0	0%	117.225.750	71%	55.774.250	32%	155.910.248	$20.112.422	$8.592.422
99	116.656.625	67%	0	0%	116.656.625	71%	56.343.375	33%	155.153.311	$20.014.777	$8.494.777
100	116.087.500	66%	0	0%	116.087.500	70%	56.912.500	33%	154.396.375	$19.917.132	$8.397.132
101	115.518.375	66%	0	0%	115.518.375	70%	57.481.625	33%	153.639.439	$19.819.488	$8.299.488
102	114.949.250	66%	0	0%	114.949.250	69%	58.050.750	34%	152.882.503	$19.721.843	$8.201.843
103	114.380.125	65%	0	0%	114.380.125	69%	58.619.875	34%	152.125.566	$19.624.198	$8.104.198
104	113.811.000	65%	0	0%	113.811.000	69%	59.189.000	34%	151.368.630	$19.526.553	$8.006.553
105	113.241.875	65%	0	0%	113.241.875	68%	59.758.125	35%	150.611.694	$19.428.908	$7.908.908
106	112.672.750	64%	0	0%	112.672.750	68%	60.327.250	35%	149.854.758	$19.331.264	$7.811.264
107	112.103.625	64%	0	0%	112.103.625	68%	60.896.375	35%	149.097.821	$19.233.619	$7.713.619
108	111.534.500	64%	0	0%	111.534.500	67%	61.465.500	36%	148.340.885	$19.135.974	$7.615.974
109	110.965.375	63%	0	0%	110.965.375	67%	62.034.625	36%	147.583.949	$19.038.329	$7.518.329
110	110.396.250	63%	0	0%	110.396.250	67%	62.603.750	36%	146.827.013	$18.940.685	$7.420.685
111	109.827.125	63%	0	0%	109.827.125	66%	63.172.875	37%	146.070.076	$18.843.040	$7.323.040
112	109.258.000	62%	0	0%	109.258.000	66%	63.742.000	37%	145.313.140	$18.745.395	$7.225.395
113	108.688.875	62%	0	0%	108.688.875	66%	64.311.125	37%	144.556.204	$18.647.750	$7.127.750

114	108.119.750	62%	0	0%	108.119.750	65%	64.880.250	38%	143.799.268	$18.550.106	$7.030.106
115	107.550.625	61%	0	0%	107.550.625	65%	65.449.375	38%	143.042.331	$18.452.461	$6.932.461
116	106.981.500	61%	0	0%	106.981.500	65%	66.018.500	38%	142.285.395	$18.354.816	$6.834.816
117	106.412.375	61%	0	0%	106.412.375	64%	66.587.625	38%	141.528.459	$18.257.171	$6.737.171
118	105.843.250	60%	0	0%	105.843.250	64%	67.156.750	39%	140.771.523	$18.159.526	$6.639.526
119	105.274.125	60%	0	0%	105.274.125	64%	67.725.875	39%	140.014.586	$18.061.882	$6.541.882
120	104.705.000	60%	0	0%	104.705.000	63%	68.295.000	39%	139.257.650	$17.964.237	$6.444.237
121	104.135.875	60%	0	0%	104.135.875	63%	68.864.125	40%	138.500.714	$17.866.592	$6.346.592
122	103.566.750	59%	0	0%	103.566.750	63%	69.433.250	40%	137.743.778	$17.768.947	$6.248.947
123	102.997.625	59%	0	0%	102.997.625	62%	70.002.375	40%	136.986.841	$17.671.303	$6.151.303
124	102.428.500	59%	0	0%	102.428.500	62%	70.571.500	41%	136.229.905	$17.573.658	$6.053.658
125	101.859.375	58%	0	0%	101.859.375	62%	71.140.625	41%	135.472.969	$17.476.013	$5.956.013
126	101.290.250	58%	0	0%	101.290.250	61%	71.709.750	41%	134.716.033	$17.378.368	$5.858.368
127	100.721.125	58%	0	0%	100.721.125	61%	72.278.875	42%	133.959.096	$17.280.723	$5.760.723
128	100.152.000	57%	0	0%	100.152.000	61%	72.848.000	42%	133.202.160	$17.183.079	$5.663.079
129	99.582.875	57%	0	0%	99.582.875	60%	73.417.125	42%	132.445.224	$17.085.434	$5.565.434
130	99.013.750	57%	0	0%	99.013.750	60%	73.986.250	43%	131.688.288	$16.987.789	$5.467.789
131	98.444.625	56%	0	0%	98.444.625	60%	74.555.375	43%	130.931.351	$16.890.144	$5.370.144
132	97.875.500	56%	0	0%	97.875.500	59%	75.124.500	43%	130.174.415	$16.792.500	$5.272.500
133	97.306.375	56%	0	0%	97.306.375	59%	75.693.625	44%	129.417.479	$16.694.855	$5.174.855
134	96.737.250	55%	0	0%	96.737.250	58%	76.262.750	44%	128.660.543	$16.597.210	$5.077.210
135	96.168.125	55%	0	0%	96.168.125	58%	76.831.875	44%	127.903.606	$16.499.565	$4.979.565
136	95.599.000	55%	0	0%	95.599.000	58%	77.401.000	45%	127.146.670	$16.401.920	$4.881.920
137	95.029.875	54%	0	0%	95.029.875	57%	77.970.125	45%	126.389.734	$16.304.276	$4.784.276
138	94.460.750	54%	0	0%	94.460.750	57%	78.539.250	45%	125.632.798	$16.206.631	$4.686.631
139	93.891.625	54%	0	0%	93.891.625	57%	79.108.375	46%	124.875.861	$16.108.986	$4.588.986
140	93.322.500	53%	0	0%	93.322.500	56%	79.677.500	46%	124.118.925	$16.011.341	$4.491.341
141	92.753.375	53%	0	0%	92.753.375	56%	80.246.625	46%	123.361.989	$15.913.697	$4.393.697
142	92.184.250	53%	0	0%	92.184.250	56%	80.815.750	47%	122.605.053	$15.816.052	$4.296.052
143	91.615.125	52%	0	0%	91.615.125	55%	81.384.875	47%	121.848.116	$15.718.407	$4.198.407

144	91.046.000	52%	0	0%	91.046.000	55%	81.954.000	47%	121.091.180	$15.620.762	$4.100.762
145	90.476.875	52%	0	0%	90.476.875	55%	82.523.125	48%	120.334.244	$15.523.117	$4.003.117
146	89.907.750	51%	0	0%	89.907.750	54%	83.092.250	48%	119.577.308	$15.425.473	$3.905.473
147	89.338.625	51%	0	0%	89.338.625	54%	83.661.375	48%	118.820.371	$15.327.828	$3.807.828
148	88.769.500	51%	0	0%	88.769.500	54%	84.230.500	49%	118.063.435	$15.230.183	$3.710.183
149	88.200.375	50%	0	0%	88.200.375	53%	84.799.625	49%	117.306.499	$15.132.538	$3.612.538
150	87.631.250	50%	0	0%	87.631.250	53%	85.368.750	49%	116.549.563	$15.034.894	$3.514.894
151	87.062.125	50%	0	0%	87.062.125	53%	85.937.875	50%	115.792.626	$14.937.249	$3.417.249
152	86.493.000	49%	0	0%	86.493.000	52%	86.507.000	50%	115.035.690	$14.839.604	$3.319.604
153	85.923.875	49%	0	0%	85.923.875	52%	87.076.125	50%	114.278.754	$14.741.959	$3.221.959
154	85.354.750	49%	0	0%	85.354.750	52%	87.645.250	51%	113.521.818	$14.644.314	$3.124.314
155	84.785.625	48%	0	0%	84.785.625	51%	88.214.375	51%	112.764.881	$14.546.670	$3.026.670
156	84.216.500	48%	0	0%	84.216.500	51%	88.783.500	51%	112.007.945	$14.449.025	$2.929.025
157	83.647.375	48%	0	0%	83.647.375	51%	89.352.625	52%	111.251.009	$14.351.380	$2.831.380
158	83.078.250	47%	0	0%	83.078.250	50%	89.921.750	52%	110.494.073	$14.253.735	$2.733.735
159	82.509.125	47%	0	0%	82.509.125	50%	90.490.875	52%	109.737.136	$14.156.091	$2.636.091
160	81.940.000	47%	0	0%	81.940.000	50%	91.060.000	53%	108.980.200	$14.058.446	$2.538.446
161	81.370.875	46%	0	0%	81.370.875	49%	91.629.125	53%	108.223.264	$13.960.801	$2.440.801
162	80.801.750	46%	0	0%	80.801.750	49%	92.198.250	53%	107.466.328	$13.863.156	$2.343.156
163	80.232.625	46%	0	0%	80.232.625	49%	92.767.375	54%	106.709.391	$13.765.511	$2.245.511
164	79.663.500	46%	0	0%	79.663.500	48%	93.336.500	54%	105.952.455	$13.667.867	$2.147.867
165	79.094.375	45%	0	0%	79.094.375	48%	93.905.625	54%	105.195.519	$13.570.222	$2.050.222
166	78.525.250	45%	0	0%	78.525.250	47%	94.474.750	55%	104.438.583	$13.472.577	$1.952.577
167	77.956.125	45%	0	0%	77.956.125	47%	95.043.875	55%	103.681.646	$13.374.932	$1.854.932
168	77.387.000	44%	0	0%	77.387.000	47%	95.613.000	55%	102.924.710	$13.277.288	$1.757.288
169	76.817.875	44%	0	0%	76.817.875	46%	96.182.125	56%	102.167.774	$13.179.643	$1.659.643
170	76.248.750	44%	0	0%	76.248.750	46%	96.751.250	56%	101.410.838	$13.081.998	$1.561.998
171	75.679.625	43%	0	0%	75.679.625	46%	97.320.375	56%	100.653.901	$12.984.353	$1.464.353
172	75.110.500	43%	0	0%	75.110.500	45%	97.889.500	57%	99.896.965	$12.886.708	$1.366.708
173	74.541.375	43%	0	0%	74.541.375	45%	98.458.625	57%	99.140.029	$12.789.064	$1.269.064

174	73.972.250	42%	0	0%	73.972.250	45%	99.027.750	57%	98.383.093	$12.691.419	$1.171.419
175	73.403.125	42%	0	0%	73.403.125	44%	99.596.875	58%	97.626.156	$12.593.774	$1.073.774
176	72.834.000	42%	0	0%	72.834.000	44%	100.166.000	58%	96.869.220	$12.496.129	$976.129
177	72.264.875	41%	0	0%	72.264.875	44%	100.735.125	58%	96.112.284	$12.398.485	$878.485
178	71.695.750	41%	0	0%	71.695.750	43%	101.304.250	59%	95.355.348	$12.300.840	$780.840
179	71.126.625	41%	0	0%	71.126.625	43%	101.873.375	59%	94.598.411	$12.203.195	$683.195
180	70.557.500	40%	0	0%	70.557.500	43%	102.442.500	59%	93.841.475	$12.105.550	$585.550
181	69.988.375	40%	0	0%	69.988.375	42%	103.011.625	60%	93.084.539	$12.007.905	$487.905
182	69.419.250	40%	0	0%	69.419.250	42%	103.580.750	60%	92.327.603	$11.910.261	$390.261
183	68.850.125	39%	0	0%	68.850.125	42%	104.149.875	60%	91.570.666	$11.812.616	$292.616
184	68.281.000	39%	0	0%	68.281.000	41%	104.719.000	61%	90.813.730	$11.714.971	$194.971
185	67.711.875	39%	0	0%	67.711.875	41%	105.288.125	61%	90.056.794	$11.617.326	$97.326
186	67.142.750	38%	0	0%	67.142.750	41%	105.857.250	61%	89.299.858	$11.519.682	-$318
187	66.573.625	38%	0	0%	66.573.625	40%	106.426.375	62%	88.542.921	$11.422.037	
188	66.004.500	38%	0	0%	66.004.500	40%	106.995.500	62%	87.785.985	$11.324.392	
189	65.435.375	37%	0	0%	65.435.375	40%	107.564.625	62%	87.029.049	$11.226.747	
190	64.866.250	37%	0	0%	64.866.250	39%	108.133.750	63%	86.272.113	$11.129.103	
191	64.297.125	37%	0	0%	64.297.125	39%	108.702.875	63%	85.515.176	$11.031.458	
192	63.728.000	36%	0	0%	63.728.000	39%	109.272.000	63%	84.758.240	$10.933.813	
193	63.158.875	36%	0	0%	63.158.875	38%	109.841.125	63%	84.001.304	$10.836.168	
194	62.589.750	36%	0	0%	62.589.750	38%	110.410.250	64%	83.244.368	$10.738.523	
195	62.020.625	35%	0	0%	62.020.625	37%	110.979.375	64%	82.487.431	$10.640.879	
196	61.451.500	35%	0	0%	61.451.500	37%	111.548.500	64%	81.730.495	$10.543.234	
197	60.882.375	35%	0	0%	60.882.375	37%	112.117.625	65%	80.973.559	$10.445.589	
198	60.313.250	34%	0	0%	60.313.250	36%	112.686.750	65%	80.216.623	$10.347.944	
199	59.744.125	34%	0	0%	59.744.125	36%	113.255.875	65%	79.459.686	$10.250.300	
200	59.175.000	34%	0	0%	59.175.000	36%	113.825.000	66%	78.702.750	$10.152.655	
201	58.605.875	33%	0	0%	58.605.875	35%	114.394.125	66%	77.945.814	$10.055.010	
202	58.036.750	33%	0	0%	58.036.750	35%	114.963.250	66%	77.188.878	$9.957.365	
203	57.467.625	33%	0	0%	57.467.625	35%	115.532.375	67%	76.431.941	$9.859.720	

204	56.898.500	33%	0	0%	56.898.500	34%	116.101.500	67%	75.675.005	$9.762.076	
205	56.329.375	32%	0	0%	56.329.375	34%	116.670.625	67%	74.918.069	$9.664.431	
206	55.760.250	32%	0	0%	55.760.250	34%	117.239.750	68%	74.161.133	$9.566.786	
207	55.191.125	32%	0	0%	55.191.125	33%	117.808.875	68%	73.404.196	$9.469.141	
208	54.622.000	31%	0	0%	54.622.000	33%	118.378.000	68%	72.647.260	$9.371.497	
209	54.052.875	31%	0	0%	54.052.875	33%	118.947.125	69%	71.890.324	$9.273.852	
210	53.483.750	31%	0	0%	53.483.750	32%	119.516.250	69%	71.133.388	$9.176.207	
211	52.914.625	30%	0	0%	52.914.625	32%	120.085.375	69%	70.376.451	$9.078.562	
212	52.345.500	30%	0	0%	52.345.500	32%	120.654.500	70%	69.619.515	$8.980.917	
213	51.776.375	30%	0	0%	51.776.375	31%	121.223.625	70%	68.862.579	$8.883.273	
214	51.207.250	29%	0	0%	51.207.250	31%	121.792.750	70%	68.105.643	$8.785.628	
215	50.638.125	29%	0	0%	50.638.125	31%	122.361.875	71%	67.348.706	$8.687.983	
216	50.069.000	29%	0	0%	50.069.000	30%	122.931.000	71%	66.591.770	$8.590.338	
217	49.499.875	28%	0	0%	49.499.875	30%	123.500.125	71%	65.834.834	$8.492.694	
218	48.930.750	28%	0	0%	48.930.750	30%	124.069.250	72%	65.077.898	$8.395.049	
219	48.361.625	28%	0	0%	48.361.625	29%	124.638.375	72%	64.320.961	$8.297.404	
220	47.792.500	27%	0	0%	47.792.500	29%	125.207.500	72%	63.564.025	$8.199.759	
221	47.223.375	27%	0	0%	47.223.375	29%	125.776.625	73%	62.807.089	$8.102.114	
222	46.654.250	27%	0	0%	46.654.250	28%	126.345.750	73%	62.050.153	$8.004.470	
223	46.085.125	26%	0	0%	46.085.125	28%	126.914.875	73%	61.293.216	$7.906.825	
224	45.516.000	26%	0	0%	45.516.000	28%	127.484.000	74%	60.536.280	$7.809.180	
225	44.946.875	26%	0	0%	44.946.875	27%	128.053.125	74%	59.779.344	$7.711.535	
226	44.377.750	25%	0	0%	44.377.750	27%	128.622.250	74%	59.022.408	$7.613.891	
227	43.808.625	25%	0	0%	43.808.625	26%	129.191.375	75%	58.265.471	$7.516.246	
228	43.239.500	25%	0	0%	43.239.500	26%	129.760.500	75%	57.508.535	$7.418.601	
229	42.670.375	24%	0	0%	42.670.375	26%	130.329.625	75%	56.751.599	$7.320.956	
230	42.101.250	24%	0	0%	42.101.250	25%	130.898.750	76%	55.994.663	$7.223.311	
231	41.532.125	24%	0	0%	41.532.125	25%	131.467.875	76%	55.237.726	$7.125.667	
232	40.963.000	23%	0	0%	40.963.000	25%	132.037.000	76%	54.480.790	$7.028.022	
233	40.393.875	23%	0	0%	40.393.875	24%	132.606.125	77%	53.723.854	$6.930.377	

234	39.824.750	23%	0	0%	39.824.750	24%	133.175.250	77%	52.966.918	$6.832.732	
235	39.255.625	22%	0	0%	39.255.625	24%	133.744.375	77%	52.209.981	$6.735.088	
236	38.686.500	22%	0	0%	38.686.500	23%	134.313.500	78%	51.453.045	$6.637.443	
237	38.117.375	22%	0	0%	38.117.375	23%	134.882.625	78%	50.696.109	$6.539.798	
238	37.548.250	21%	0	0%	37.548.250	23%	135.451.750	78%	49.939.173	$6.442.153	
239	36.979.125	21%	0	0%	36.979.125	22%	136.020.875	79%	49.182.236	$6.344.508	
240	36.410.000	21%	0	0%	36.410.000	22%	136.590.000	79%	48.425.300	$6.246.864	
241	35.840.875	20%	0	0%	35.840.875	22%	137.159.125	79%	47.668.364	$6.149.219	
242	35.271.750	20%	0	0%	35.271.750	21%	137.728.250	80%	46.911.428	$6.051.574	
243	34.702.625	20%	0	0%	34.702.625	21%	138.297.375	80%	46.154.491	$5.953.929	
244	34.133.500	20%	0	0%	34.133.500	21%	138.866.500	80%	45.397.555	$5.856.285	
245	33.564.375	19%	0	0%	33.564.375	20%	139.435.625	81%	44.640.619	$5.758.640	
246	32.995.250	19%	0	0%	32.995.250	20%	140.004.750	81%	43.883.683	$5.660.995	
247	32.426.125	19%	0	0%	32.426.125	20%	140.573.875	81%	43.126.746	$5.563.350	
248	31.857.000	18%	0	0%	31.857.000	19%	141.143.000	82%	42.369.810	$5.465.705	
249	31.287.875	18%	0	0%	31.287.875	19%	141.712.125	82%	41.612.874	$5.368.061	
250	30.718.750	18%	0	0%	30.718.750	19%	142.281.250	82%	40.855.938	$5.270.416	
251	30.149.625	17%	0	0%	30.149.625	18%	142.850.375	83%	40.099.001	$5.172.771	
252	29.580.500	17%	0	0%	29.580.500	18%	143.419.500	83%	39.342.065	$5.075.126	
253	29.011.375	17%	0	0%	29.011.375	18%	143.988.625	83%	38.585.129	$4.977.482	
254	28.442.250	16%	0	0%	28.442.250	17%	144.557.750	84%	37.828.193	$4.879.837	
255	27.873.125	16%	0	0%	27.873.125	17%	145.126.875	84%	37.071.256	$4.782.192	
256	27.304.000	16%	0	0%	27.304.000	17%	145.696.000	84%	36.314.320	$4.684.547	
257	26.734.875	15%	0	0%	26.734.875	16%	146.265.125	85%	35.557.384	$4.586.903	
258	26.165.750	15%	0	0%	26.165.750	16%	146.834.250	85%	34.800.448	$4.489.258	
259	25.596.625	15%	0	0%	25.596.625	15%	147.403.375	85%	34.043.511	$4.391.613	
260	25.027.500	14%	0	0%	25.027.500	15%	147.972.500	86%	33.286.575	$4.293.968	
261	24.458.375	14%	0	0%	24.458.375	15%	148.541.625	86%	32.529.639	$4.196.323	
262	23.889.250	14%	0	0%	23.889.250	14%	149.110.750	86%	31.772.703	$4.098.679	
263	23.320.125	13%	0	0%	23.320.125	14%	149.679.875	87%	31.015.766	$4.001.034	

264	22.751.000	13%	0	0%	22.751.000	14%	150.249.000	87%	30.258.830	$3.903.389	
265	22.181.875	13%	0	0%	22.181.875	13%	150.818.125	87%	29.501.894	$3.805.744	
266	21.612.750	12%	0	0%	21.612.750	13%	151.387.250	88%	28.744.958	$3.708.100	
267	21.043.625	12%	0	0%	21.043.625	13%	151.956.375	88%	27.988.021	$3.610.455	
268	20.474.500	12%	0	0%	20.474.500	12%	152.525.500	88%	27.231.085	$3.512.810	
269	19.905.375	11%	0	0%	19.905.375	12%	153.094.625	88%	26.474.149	$3.415.165	
270	19.336.250	11%	0	0%	19.336.250	12%	153.663.750	89%	25.717.213	$3.317.520	
271	18.767.125	11%	0	0%	18.767.125	11%	154.232.875	89%	24.960.276	$3.219.876	
272	18.198.000	10%	0	0%	18.198.000	11%	154.802.000	89%	24.203.340	$3.122.231	
273	17.628.875	10%	0	0%	17.628.875	11%	155.371.125	90%	23.446.404	$3.024.586	
274	17.059.750	10%	0	0%	17.059.750	10%	155.940.250	90%	22.689.468	$2.926.941	
275	16.490.625	9%	0	0%	16.490.625	10%	156.509.375	90%	21.932.531	$2.829.297	
276	15.921.500	9%	0	0%	15.921.500	10%	157.078.500	91%	21.175.595	$2.731.652	
277	15.352.375	9%	0	0%	15.352.375	9%	157.647.625	91%	20.418.659	$2.634.007	
278	14.783.250	8%	0	0%	14.783.250	9%	158.216.750	91%	19.661.723	$2.536.362	
279	14.214.125	8%	0	0%	14.214.125	9%	158.785.875	92%	18.904.786	$2.438.717	
280	13.645.000	8%	0	0%	13.645.000	8%	159.355.000	92%	18.147.850	$2.341.073	
281	13.075.875	7%	0	0%	13.075.875	8%	159.924.125	92%	17.390.914	$2.243.428	
282	12.506.750	7%	0	0%	12.506.750	8%	160.493.250	93%	16.633.978	$2.145.783	
283	11.937.625	7%	0	0%	11.937.625	7%	161.062.375	93%	15.877.041	$2.048.138	
284	11.368.500	6%	0	0%	11.368.500	7%	161.631.500	93%	15.120.105	$1.950.494	
285	10.799.375	6%	0	0%	10.799.375	7%	162.200.625	94%	14.363.169	$1.852.849	
286	10.230.250	6%	0	0%	10.230.250	6%	162.769.750	94%	13.606.233	$1.755.204	
287	9.661.125	6%	0	0%	9.661.125	6%	163.338.875	94%	12.849.296	$1.657.559	
288	9.092.000	5%	0	0%	9.092.000	5%	163.908.000	95%	12.092.360	$1.559.914	
289	8.522.875	5%	0	0%	8.522.875	5%	164.477.125	95%	11.335.424	$1.462.270	
290	7.953.750	5%	0	0%	7.953.750	5%	165.046.250	95%	10.578.488	$1.364.625	
291	7.384.625	4%	0	0%	7.384.625	4%	165.615.375	96%	9.821.551	$1.266.980	
292	6.815.500	4%	0	0%	6.815.500	4%	166.184.500	96%	9.064.615	$1.169.335	
293	6.246.375	4%	0	0%	6.246.375	4%	166.753.625	96%	8.307.679	$1.071.691	

294	5.677.250	3%	0	0%	5.677.250	3%	167.322.750	97%	7.550.743	$974.046	
295	5.108.125	3%	0	0%	5.108.125	3%	167.891.875	97%	6.793.806	$876.401	
296	4.539.000	3%	0	0%	4.539.000	3%	168.461.000	97%	6.036.870	$778.756	
297	3.969.875	2%	0	0%	3.969.875	2%	169.030.125	98%	5.279.934	$681.111	
298	3.400.750	2%	0	0%	3.400.750	2%	169.599.250	98%	4.522.998	$583.467	
299	2.831.625	2%	0	0%	2.831.625	2%	170.168.375	98%	3.766.061	$485.822	
300	2.262.500	1%	0	0%	2.262.500	1%	170.737.500	99%	3.009.125	$388.177	
301	1.693.375	1%	0	0%	1.693.375	1%	171.306.625	99%	2.252.189	$290.532	
302	1.124.250	1%	0	0%	1.124.250	1%	171.875.750	99%	1.495.253	$192.888	
303	555.125	0%	0	0%	555.125	0%	172.444.875	100%	738.316	$95.243	
Total									34.725.848.382	$4.479.634.441	

Table 12 Calculations for Scenario No. 2

3. Calculations for Scenario No. 3

	Remaining TSC		Remaining DSC		Remaining AST (m3)		Total SY without project		Produced Electricity	Benefit from Produced Electricity	Benefits minus operation costs
Year	m3	%	m3	%	m3	%	m3	%	kWh	US$	US$
0	173.000.000	100%	7.600.000	100%	165.400.000	100%	0	0%	0	0	
1973	171.207.060	99%	6.703.530	88%	164.503.530	99%	1.792.940	1%	218.789.695	28.223.871	16.703.871
1974	169.414.120	98%	5.807.060	76%	163.607.060	99%	3.585.880	2%	217.597.390	28.070.063	16.550.063
1975	167.621.180	97%	4.910.590	65%	162.710.590	98%	5.378.820	3%	216.405.085	27.916.256	16.396.256
1976	165.828.240	96%	4.014.120	53%	161.814.120	98%	7.171.760	4%	215.212.780	27.762.449	16.242.449
1977	164.035.300	95%	3.117.650	41%	160.917.650	97%	8.964.700	5%	214.020.475	27.608.641	16.088.641
1978	162.242.360	94%	2.221.180	29%	160.021.180	97%	10.757.640	6%	212.828.169	27.454.834	15.934.834
1979	160.449.420	93%	1.324.710	17%	159.124.710	96%	12.550.580	7%	211.635.864	27.301.026	15.781.026
1980	158.656.480	92%	428.240	6%	158.228.240	96%	14.343.520	8%	210.443.559	27.147.219	15.627.219
1981	156.863.540	91%	0	0%	156.863.540	95%	16.136.460	9%	208.628.508	26.913.078	15.393.078
1982	155.070.600	90%	0	0%	155.070.600	94%	17.929.400	10%	206.243.898	26.605.463	15.085.463
1983	153.277.660	89%	0	0%	153.277.660	93%	19.722.340	11%	203.859.288	26.297.848	14.777.848
1984	151.484.720	88%	0	0%	151.484.720	92%	21.515.280	12%	201.474.678	25.990.233	14.470.233
1985	149.691.780	87%	0	0%	149.691.780	91%	23.308.220	13%	199.090.067	25.682.619	14.162.619
1986	147.898.840	85%	0	0%	147.898.840	89%	25.101.160	15%	196.705.457	25.375.004	13.855.004
1987	146.105.900	84%	0	0%	146.105.900	88%	26.894.100	16%	194.320.847	25.067.389	13.547.389
1988	144.312.960	83%	0	0%	144.312.960	87%	28.687.040	17%	191.936.237	24.759.775	13.239.775
1989	142.520.020	82%	0	0%	142.520.020	86%	30.479.980	18%	189.551.627	24.452.160	12.932.160
1990	140.727.080	81%	0	0%	140.727.080	85%	32.272.920	19%	187.167.016	24.144.545	12.624.545
1991	138.934.140	80%	0	0%	138.934.140	84%	34.065.860	20%	184.782.406	23.836.930	12.316.930
1992	137.141.200	79%	0	0%	137.141.200	83%	35.858.800	21%	182.397.796	23.529.316	12.009.316
1993	135.348.260	78%	0	0%	135.348.260	82%	37.651.740	22%	180.013.186	23.221.701	11.701.701
1994	133.555.320	77%	0	0%	133.555.320	81%	39.444.680	23%	177.628.576	22.914.086	11.394.086
1995	131.762.380	76%	0	0%	131.762.380	80%	41.237.620	24%	175.243.965	22.606.472	11.086.472

1996	129.969.440	75%	0	0%	129.969.440	79%	43.030.560	25%	172.859.355	22.298.857	10.778.857
1997	128.176.500	74%	0	0%	128.176.500	77%	44.823.500	26%	170.474.745	21.991.242	10.471.242
1998	126.383.560	73%	0	0%	126.383.560	76%	46.616.440	27%	168.090.135	21.683.627	10.163.627
1999	124.590.620	72%	0	0%	124.590.620	75%	48.409.380	28%	165.705.525	21.376.013	9.856.013
2000	122.797.680	71%	0	0%	122.797.680	74%	50.202.320	29%	163.320.914	21.068.398	9.548.398
2001	121.004.740	70%	0	0%	121.004.740	73%	51.995.260	30%	160.936.304	20.760.783	9.240.783
2002	119.211.800	69%	0	0%	119.211.800	72%	53.788.200	31%	158.551.694	20.453.169	8.933.169
2003	117.418.860	68%	0	0%	117.418.860	71%	55.581.140	32%	156.167.084	20.145.554	8.625.554
2004	115.625.920	67%	0	0%	115.625.920	70%	57.374.080	33%	153.782.474	19.837.939	8.317.939
2005	113.832.980	66%	0	0%	113.832.980	69%	59.167.020	34%	151.397.863	19.530.324	8.010.324
2006	112.040.040	65%	0	0%	112.040.040	68%	60.959.960	35%	149.013.253	19.222.710	7.702.710
2007	110.247.100	64%	0	0%	110.247.100	67%	62.752.900	36%	146.628.643	18.915.095	7.395.095
2008	108.454.160	63%	0	0%	108.454.160	66%	64.545.840	37%	144.244.033	18.607.480	7.087.480
2009	106.661.220	62%	0	0%	106.661.220	64%	66.338.780	38%	141.859.423	18.299.866	6.779.866
2010	104.868.280	61%	0	0%	104.868.280	63%	68.131.720	39%	139.474.812	17.992.251	6.472.251
2011	103.075.340	60%	0	0%	103.075.340	62%	69.924.660	40%	137.090.202	17.684.636	6.164.636
2012	101.282.400	59%	0	0%	101.282.400	61%	71.717.600	41%	134.705.592	17.377.021	5.857.021
2013	99.489.460	58%	0	0%	99.489.460	60%	73.510.540	42%	132.320.982	17.069.407	5.549.407
2014	97.696.520	56%	0	0%	97.696.520	59%	75.303.480	44%	129.936.372	16.761.792	5.241.792
2015	95.903.580	55%	0	0%	95.903.580	58%	77.096.420	45%	127.551.761	16.454.177	4.934.177
2016	94.523.016	55%			94.523.016	57%	78.476.984		125.715.612	16.217.314	4.697.314
2017	93.142.452	54%			93.142.452	56%	79.857.548		123.879.462	15.980.451	4.460.451
2018	91.761.889	53%			91.761.889	55%	81.238.111		122.043.312	15.743.587	4.223.587
2019	90.381.325	52%			90.381.325	55%	82.618.675		120.207.162	15.506.724	3.986.724
2020	89.000.761	51%			89.000.761	54%	83.999.239		118.371.012	15.269.861	3.749.861
2021	88.032.573	51%			88.032.573	53%	84.967.427		117.083.323	15.103.749	3.583.749
2022	87.064.386	50%			87.064.386	53%	85.935.614		115.795.633	14.937.637	3.417.637
2023	86.096.198	50%			86.096.198	52%	86.903.802		114.507.944	14.771.525	3.251.525
2024	85.128.011	49%			85.128.011	51%	87.871.989		113.220.254	14.605.413	3.085.413
2025	84.159.823	49%			84.159.823	51%	88.840.177		111.932.565	14.439.301	2.919.301

2026	83.586.082	48%			83.586.082	51%	89.413.918		111.169.489	14.340.864	2.820.864
2027	83.012.341	48%			83.012.341	50%	89.987.659		110.406.414	14.242.427	2.722.427
2028	82.438.601	48%			82.438.601	50%	90.561.399		109.643.339	14.143.991	2.623.991
2029	81.864.860	47%			81.864.860	49%	91.135.140		108.880.264	14.045.554	2.525.554
2030	81.291.119	47%			81.291.119	49%	91.708.881		108.117.188	13.947.117	2.427.117
2031	80.717.378	47%			80.717.378	49%	92.282.622		107.354.113	13.848.681	2.328.681
2032	80.143.637	46%			80.143.637	48%	92.856.363		106.591.038	13.750.244	2.230.244
2033	79.569.897	46%			79.569.897	48%	93.430.103		105.827.962	13.651.807	2.131.807
2034	78.996.156	46%			78.996.156	48%	94.003.844		105.064.887	13.553.370	2.033.370
2035	78.422.415	45%			78.422.415	47%	94.577.585		104.301.812	13.454.934	1.934.934
2036	77.848.674	45%			77.848.674	47%	95.151.326		103.538.737	13.356.497	1.836.497
2037	77.274.933	45%			77.274.933	47%	95.725.067		102.775.661	13.258.060	1.738.060
2038	76.701.193	44%			76.701.193	46%	96.298.807		102.012.586	13.159.624	1.639.624
2039	76.127.452	44%			76.127.452	46%	96.872.548		101.249.511	13.061.187	1.541.187
2040	75.553.711	44%			75.553.711	46%	97.446.289		100.486.436	12.962.750	1.442.750
2041	74.979.970	43%			74.979.970	45%	98.020.030		99.723.360	12.864.313	1.344.313
2042	74.406.229	43%			74.406.229	45%	98.593.771		98.960.285	12.765.877	1.245.877
2043	73.832.489	43%			73.832.489	45%	99.167.511		98.197.210	12.667.440	1.147.440
2044	73.258.748	42%			73.258.748	44%	99.741.252		97.434.135	12.569.003	1.049.003
2045	72.685.007	42%			72.685.007	44%	100.314.993		96.671.059	12.470.567	950.567
2046	72.111.266	42%			72.111.266	44%	100.888.734		95.907.984	12.372.130	852.130
2047	71.537.525	41%			71.537.525	43%	101.462.475		95.144.909	12.273.693	753.693
2048	70.963.785	41%			70.963.785	43%	102.036.215		94.381.834	12.175.257	655.257
2049	70.390.044	41%			70.390.044	43%	102.609.956		93.618.758	12.076.820	556.820
2050	69.816.303	40%			69.816.303	42%	103.183.697		92.855.683	11.978.383	458.383
2051	69.242.562	40%			69.242.562	42%	103.757.438		92.092.608	11.879.946	359.946
2052	68.668.821	40%			68.668.821	42%	104.331.179		91.329.532	11.781.510	261.510
2053	68.095.081	39%			68.095.081	41%	104.904.919		90.566.457	11.683.073	163.073
2054	67.521.340	39%			67.521.340	41%	105.478.660		89.803.382	11.584.636	64.636
2055	66.947.599	39%			66.947.599	40%	106.052.401		89.040.307	11.486.200	-33.800

2056	66.373.858	38%			66.373.858	40%	106.626.142		88.277.231	11.387.763	
2057	65.800.117	38%			65.800.117	40%	107.199.883		87.514.156	11.289.326	
2058	65.226.377	38%			65.226.377	39%	107.773.623		86.751.081	11.190.889	
2059	64.652.636	37%			64.652.636	39%	108.347.364		85.988.006	11.092.453	
2060	64.078.895	37%			64.078.895	39%	108.921.105		85.224.930	10.994.016	
2061	63.505.154	37%			63.505.154	38%	109.494.846		84.461.855	10.895.579	
2062	62.931.413	36%			62.931.413	38%	110.068.587		83.698.780	10.797.143	
2063	62.357.673	36%			62.357.673	38%	110.642.327		82.935.705	10.698.706	
2064	61.783.932	36%			61.783.932	37%	111.216.068		82.172.629	10.600.269	
2065	61.210.191	35%			61.210.191	37%	111.789.809		81.409.554	10.501.832	
2066	60.636.450	35%			60.636.450	37%	112.363.550		80.646.479	10.403.396	
2067	60.062.709	35%			60.062.709	36%	112.937.291		79.883.404	10.304.959	
2068	59.488.969	34%			59.488.969	36%	113.511.031		79.120.328	10.206.522	
2069	58.915.228	34%			58.915.228	36%	114.084.772		78.357.253	10.108.086	
2070	58.341.487	34%			58.341.487	35%	114.658.513		77.594.178	10.009.649	
2071	57.767.746	33%			57.767.746	35%	115.232.254		76.831.102	9.911.212	
2072	57.194.005	33%			57.194.005	35%	115.805.995		76.068.027	9.812.776	
2073	56.620.265	33%			56.620.265	34%	116.379.735		75.304.952	9.714.339	
2074	56.046.524	32%			56.046.524	34%	116.953.476		74.541.877	9.615.902	
2075	55.472.783	32%			55.472.783	34%	117.527.217		73.778.801	9.517.465	
2076	54.899.042	32%			54.899.042	33%	118.100.958		73.015.726	9.419.029	
2077	54.325.301	31%			54.325.301	33%	118.674.699		72.252.651	9.320.592	
2078	53.751.561	31%			53.751.561	32%	119.248.439		71.489.576	9.222.155	
2079	53.177.820	31%			53.177.820	32%	119.822.180		70.726.500	9.123.719	
2080	52.604.079	30%			52.604.079	32%	120.395.921		69.963.425	9.025.282	
2081	52.030.338	30%			52.030.338	31%	120.969.662		69.200.350	8.926.845	
2082	51.456.597	30%			51.456.597	31%	121.543.403		68.437.275	8.828.408	
2083	50.882.857	29%			50.882.857	31%	122.117.143		67.674.199	8.729.972	
2084	50.309.116	29%			50.309.116	30%	122.690.884		66.911.124	8.631.535	
2085	49.735.375	29%			49.735.375	30%	123.264.625		66.148.049	8.533.098	

2086	49.161.634	28%			49.161.634	30%	123.838.366		65.384.973	8.434.662	
2087	48.587.893	28%			48.587.893	29%	124.412.107		64.621.898	8.336.225	
2088	48.014.153	28%			48.014.153	29%	124.985.847		63.858.823	8.237.788	
2089	47.440.412	27%			47.440.412	29%	125.559.588		63.095.748	8.139.351	
2090	46.866.671	27%			46.866.671	28%	126.133.329		62.332.672	8.040.915	
2091	46.292.930	27%			46.292.930	28%	126.707.070		61.569.597	7.942.478	
2092	45.719.189	26%			45.719.189	28%	127.280.811		60.806.522	7.844.041	
2093	45.145.449	26%			45.145.449	27%	127.854.551		60.043.447	7.745.605	
2094	44.571.708	26%			44.571.708	27%	128.428.292		59.280.371	7.647.168	
2095	43.997.967	25%			43.997.967		129.002.033		58.517.296	7.548.731	
2096	43.424.226	25%			43.424.226		129.575.774		57.754.221	7.450.294	
2097	42.850.485	25%			42.850.485		130.149.515		56.991.146	7.351.858	
2098	42.276.745	24%			42.276.745		130.723.255		56.228.070	7.253.421	
2099	41.703.004	24%			41.703.004		131.296.996		55.464.995	7.154.984	
2100	41.129.263	24%			41.129.263		131.870.737		54.701.920	7.056.548	
2101	40.555.522	23%			40.555.522		132.444.478		53.938.845	6.958.111	
2102	39.981.781	23%			39.981.781		133.018.219		53.175.769	6.859.674	
2103	39.408.041	23%			39.408.041		133.591.959		52.412.694	6.761.238	
2104	38.834.300	22%			38.834.300		134.165.700		51.649.619	6.662.801	
2105	38.260.559	22%			38.260.559		134.739.441		50.886.543	6.564.364	
2106	37.686.818	22%			37.686.818		135.313.182		50.123.468	6.465.927	
2107	37.113.077	21%			37.113.077		135.886.923		49.360.393	6.367.491	
2108	36.539.337	21%			36.539.337		136.460.663		48.597.318	6.269.054	
2109	35.965.596	21%			35.965.596		137.034.404		47.834.242	6.170.617	
2110	35.391.855	20%			35.391.855		137.608.145		47.071.167	6.072.181	
2111	34.818.114	20%			34.818.114		138.181.886		46.308.092	5.973.744	
2112	34.244.373	20%			34.244.373		138.755.627		45.545.017	5.875.307	
2113	33.670.633	19%			33.670.633		139.329.367		44.781.941	5.776.870	
2114	33.096.892	19%			33.096.892		139.903.108		44.018.866	5.678.434	
2115	32.523.151	19%			32.523.151		140.476.849		43.255.791	5.579.997	

2116	31.949.410	18%			31.949.410		141.050.590		42.492.716	5.481.560	
2117	31.375.669	18%			31.375.669		141.624.331		41.729.640	5.383.124	
2118	30.801.929	18%			30.801.929		142.198.071		40.966.565	5.284.687	
2119	30.228.188	17%			30.228.188		142.771.812		40.203.490	5.186.250	
2120	29.654.447	17%			29.654.447		143.345.553		39.440.415	5.087.813	
2121	29.080.706	17%			29.080.706		143.919.294		38.677.339	4.989.377	
2122	28.506.965	16%			28.506.965		144.493.035		37.914.264	4.890.940	
2123	27.933.225	16%			27.933.225		145.066.775		37.151.189	4.792.503	
2124	27.359.484	16%			27.359.484		145.640.516		36.388.113	4.694.067	
2125	26.785.743	15%			26.785.743		146.214.257		35.625.038	4.595.630	
2126	26.212.002	15%			26.212.002		146.787.998		34.861.963	4.497.193	
2127	25.638.261	15%			25.638.261		147.361.739		34.098.888	4.398.757	
2128	25.064.521	14%			25.064.521		147.935.479		33.335.812	4.300.320	
2129	24.490.780	14%			24.490.780		148.509.220		32.572.737	4.201.883	
2130	23.917.039	14%			23.917.039		149.082.961		31.809.662	4.103.446	
2131	23.343.298	13%			23.343.298		149.656.702		31.046.587	4.005.010	
2132	22.769.557	13%			22.769.557		150.230.443		30.283.511	3.906.573	
2133	22.195.817	13%			22.195.817		150.804.183		29.520.436	3.808.136	
2134	21.622.076	12%			21.622.076		151.377.924		28.757.361	3.709.700	
2135	21.048.335	12%			21.048.335		151.951.665		27.994.286	3.611.263	
2136	20.474.594	12%			20.474.594		152.525.406		27.231.210	3.512.826	
2137	19.900.853	12%			19.900.853		153.099.147		26.468.135	3.414.389	
2138	19.327.113	11%			19.327.113		153.672.887		25.705.060	3.315.953	
2139	18.753.372	11%			18.753.372		154.246.628		24.941.984	3.217.516	
2140	18.179.631	11%			18.179.631		154.820.369		24.178.909	3.119.079	
2141	17.605.890	10%			17.605.890		155.394.110		23.415.834	3.020.643	
2142	17.032.149	10%			17.032.149		155.967.851		22.652.759	2.922.206	
2143	16.458.409	10%			16.458.409		156.541.591		21.889.683	2.823.769	
2144	15.884.668	9%			15.884.668		157.115.332		21.126.608	2.725.332	
2145	15.310.927	9%			15.310.927		157.689.073		20.363.533	2.626.896	

2146	14.737.186	9%			14.737.186		158.262.814		19.600.458	2.528.459	
2147	14.163.445	8%			14.163.445		158.836.555		18.837.382	2.430.022	
2148	13.589.705	8%			13.589.705		159.410.295		18.074.307	2.331.586	
2149	13.015.964	8%			13.015.964		159.984.036		17.311.232	2.233.149	
2150	12.442.223	7%			12.442.223		160.557.777		16.548.157	2.134.712	
2151	11.868.482	7%			11.868.482		161.131.518		15.785.081	2.036.275	
2152	11.294.741	7%			11.294.741		161.705.259		15.022.006	1.937.839	
2153	10.721.001	6%			10.721.001		162.278.999		14.258.931	1.839.402	
2154	10.147.260	6%			10.147.260		162.852.740		13.495.856	1.740.965	
2155	9.573.519	6%			9.573.519		163.426.481		12.732.780	1.642.529	
2156	8.999.778	5%			8.999.778		164.000.222		11.969.705	1.544.092	
2157	8.426.037	5%			8.426.037		164.573.963		11.206.630	1.445.655	
2158	7.852.297	5%			7.852.297		165.147.703		10.443.554	1.347.219	
2159	7.278.556	4%			7.278.556		165.721.444		9.680.479	1.248.782	
2160	6.704.815	4%			6.704.815		166.295.185		8.917.404	1.150.345	
2161	6.131.074	4%			6.131.074		166.868.926		8.154.329	1.051.908	
2162	5.557.333	3%			5.557.333		167.442.667		7.391.253	953.472	
2163	4.983.593	3%			4.983.593		168.016.407		6.628.178	855.035	
2164	4.409.852	3%			4.409.852		168.590.148		5.865.103	756.598	
2165	3.836.111	2%			3.836.111		169.163.889		5.102.028	658.162	
2166	3.262.370	2%			3.262.370		169.737.630		4.338.952	559.725	
2167	2.688.629	2%			2.688.629		170.311.371		3.575.877	461.288	
2168	2.114.889	1%			2.114.889		170.885.111		2.812.802	362.851	
2169	1.541.148	1%			1.541.148		171.458.852		2.049.727	264.415	
2170	967.407	1%			967.407		172.032.593		1.286.651	165.978	
2171	393.666	0%			393.666		172.606.334		523.576	67.541	
										2.184.800.474	

Table 13 Calculations for Scenario No. 3

4. Explanations

4.1. Abbreviations

TSC: Total storage capacity = DSC + ASC

DSC: Dead storage capacity

ASC: Active storage capacity

SY: Sediment yield

4.2. Calculations

Remaining TSC = Initial TSC - Total sediment yield

Total SY = specific SY of the Tavera watershed ($t/km^2/a$) x specific drainage area of the Tavera watershed (km^2) x years of existence of the Tavera dam (a)

Remaining DSC = Initial DSC - 50% of the annual total SY (until DSC is completely filled with sediments)

Remaining ASC = Initial ASC - 50% of the annual total SY (until DSC is completely filled with sediments, from this point on: - 100% of the annual total SY)

Produced electricity = RAS x production unit (kWh/m^3)

Production unit = Initially, annual produced energy (220.000.000 kWh) / Initial ASC (165.400.000 m^3) = 1,33 kWh/m^3

Benefit from produced electricity = Produced electricity (kWh) x Price of kWh (0, 129 US$/kWh)

Benefits minus operation costs = Benefit from produced electricity – annual operation costs

Annual operation costs = 3% of investment costs (384.000.000 US$) = 11.520.000 US$