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IR 1

Financial or Socio-Economic Mechanisms Controlling the Constructed Wetlands Service Chain in Tanzania

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VLIR PROJECT

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Literature Review, Mobilization of the Available data and Cost Benefit Analysis

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List of Abbreviations and Acronyms

Abbreviation	Description
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
CW	Constructed Wetland
FWS	Free Water Surface
SSF	Subsurface Flow
CBA	Cost Benefit Analysis
UDSM	University of Dar Es Salaam
SBR	Sludge Blanket Reactor
RSS	Ruaha Secondary School
SFP	Single Farm Payment
CAPEX	Capital Expenditure
NPV	Net Present Value
OPEX	Operational Expenditure
US	United States
Tsh	Tanzanian Shilling
PBP	Payback Period
SN	Semi Natural
ARI	Accounting Rate of Interest
IRR	Internal Rate of Return
WSP	Waste Stabilization Ponds

1 Background Information

1.1 General Introduction

There is no even a single city or town in Tanzania with adequate sewage treatment facilities (Mohammed 2002). In normal circumstances urban centres would be served by wastewater treatment plants and regulated septic disposal facilities, while peri urban areas would experience un-regulated dumping and waste burial. In Tanzania however, a very small portion of the urban centres are served with adequate wastewater facility. Coverage by sewerage services in major cities such as Dar es Salaam, Arusha and Mwanza is less than 15%, an exception is Moshi with 40% coverage (Zephania Mihayo and Cyrus Njiru (2005)). About 60-70% of the urban population (Mato, 2002), in Tanzania, currently lives in unplanned peri-urban areas, relying mostly on pit latrines and septic tank soak away systems for sanitation. Major problems with pit latrines and septic tanks in Tanzania are leakages caused by poor construction, flooding of low lying areas, and lack of maintenance. Soak away pits fill up due to poor infiltration when built in clay soil areas. Possibility of conventional systems polluting drinking water sources is great due to building the systems in close proximity to shallow water wells and rivers. In urban areas there is generally lack of adequate wastewater treatment resulting from rapid population growth, lack of funds to implement centralized wastewater treatment and lack of commitment among policy makers to adequately deal with the problem.

To tackle these problems good solutions for improving sanitation systems in Tanzania have to be identified. A sustainable low cost solution for hygienic sanitation identified is implementing constructed wetland systems. The use of constructed wetlands (CW) for domestic wastewater treatment in Tanzania has gained much popularity over the last ten years since the early pioneering works by Kimwaga et al., 2004, Senzia et al., 2003

1.2 Introduction to Constructed Wetlands

Constructed wetlands (CW) are natural systems in which wastewater is treated with plants and bacteria using natural processes such as filtering, sedimentation, natural die-off of pathogens, biodegradation, radiation of sunlight etc. to treat the wastewater in a controlled environment (Reed 1995, Gray 1999). There are different types of wetlands, in Free Water Surface (FWS) constructed wetlands, the plants float on the water while in Sub Surface Flow (SSF) constructed wetlands the plants are growing in a substrate, for instance sand or gravel. In these systems the wastewater level is kept below the surface. The advantage of keeping the water below the surface is that breeding of malaria mosquitoes is prevented, therefore the SSF system is favourable in Tanzania. When treating urban or mixed domestic wastewater, constructed wetlands are always preceded by primary treatment, in for instance a septic tank or waste stabilization ponds (WSP), as otherwise the loading with organic solids is too high and will cause clogging and malfunctioning of the system. The main advantage of constructed wetlands is that these systems are relatively easy to construct and to operate and maintain, furthermore, little input in terms of energy and no chemicals are needed. This means that also costs, both investment and recurrent, are generally low. In addition constructed wetlands can produce some biomass, in some cases also fish. Social acceptance of the wetland is generally good, as wetlands can be integrated in the natural landscape easily and when well designed there will not be any nuisance by smell or insects. Disadvantage may be the relatively large land area required compared to more intensive wastewater treatment plants. However, in many cases, such as implementation of constructed wetlands at schools and hospitals in Tanzania, land area is not a restricting factor.

This article analyses the economics (costs and benefits) of Constructed Wetlands. The analysis is based on the identifying the financial cost and benefits categories with the view of providing and insight of the cost benefit analysis (CBA). Moreover the article is meant to provide cost model for constructed such when one knows some aspects of CW design and construction, then one can easily estimate the costs of the CW.

2. Evolution of Constructed Wetlands Technology in Tanzania

The evolution of Constructed Wetlands technology dates back as far as 1995 when the University of Dar Es Salaam, College of Engineering and Technology Tanzania and two Danish Universities, namely the Royal Danish School of Pharmacy (Currently known as The Pharmaceutical University of Denmark) and The University of Copenhagen, The Technical University of Denmark started a collaborative research project focusing on Waste Stabilizations Ponds (WSP). The emphasis for WSP research was placed on revealing the processing taking place with the WSP system through the use of ecological modeling approach so as as to improve the design approach for WSP as the earlier design approach didn't take into consideration the processes taking place within the system.

Since September 1998, the project started research on "Constructed Wetlands (CW)" in addition to WSP with the view of polishing/upgrading the WSP effluents. The research project started with pilot scale which was meant to establish design guidelines and criteria and other related information including construction and operation for use of CW in Tanzania. The research on CW focused on using ecological modeling using STELLA software. The areas that were research on included the following;

(i) Modeling of Nitrogen Transformation and Removal in CW
(ii) Modeling of coupled Dynamic Roughing Filters and CW
(iii) Selection of Suitable Media for CW in Tanzania
(iv) Selection of Suitable Indigenous Macrophytes for CW in Tanzania
(v) Modeling of BOD removal in CW

As an output to the research project, the following were achieved

- Better understanding of the processes taking place in WSP and CW has been documented
- A holistic ecological model for the design of WSPs and a model for nutrient removal have been formulated, validated, calibrated and verified

Based on the success of the research project, the results from the pilot studies were then transformed into practical application where a number of full scale projects both nationally and internationally have been implemented.

Despite the wide spread and application of this technology in Tanzania, the successful implementation and adaptation of constructed wetlands in Tanzania is still hindered by socio-economic aspects meaning that there is a lack of understanding of the economics (costs and benefits) associated with use of CW. Moreover, there is a lack of knowledge and commitment of users, responsible government institutions and international development agencies. It is in this background that this component of study is trying to address.

3. Implemented Projects for Constructed Wetlands in Tanzania

3.1 Introduction

The "Waste Stabilization Pond & Constructed Wetland Research Project" of the University of Dar es Salaam (UDSM) has successfully introduced constructed wetland technology for wastewater treatment mainly to institutions such as schools, prisons and colleges since 2002. A total of 10 units of variable sizes have been built to treat domestic wastewater. These systems have been built in Iringa (at schools for 1,200 p.e. (population equivalent) and 1,000 p.e.), Shinyanga prison (2,500 p.e.), Malya prison (3,500 p.e), Bariadi prison (2,000 p.e.), Moshi Municipality (45,000 p.e.), Kibaha (2,500 p.e.) and Dar es Salaam (2 households).

These units were introduced because of serious wastewater treatment and disposal problems that the institutions were facing. The CW's were meant to provide decentralised wastewater treatment to these institutions to meet Tanzanian effluent standards. The problems faced by are typical of many such institutions in Tanzania and in the Eastern Africa region. In addition to the systems built in Tanzania one system has been built in Kenya at Shimo la Tewa Prison, one in Uganda for treating abattoir wastewater in combination with Sludge Blanket Reactor (SBR) system and one in Ethiopia at Modjo Tanneries for treating tanneries wastewater also in combination with SBR system. Below is the description of only 2 selected projects in Tanzania.

3.2 The Constructed Wetland at Kleruu Teacher's College

Before the introduction of the CW system Kleruu Teachers College was treating its wastewater through a combination of mechanical aeration system and an oxidation pond. However, operation of the mechanical system failed because of high running costs and lack of regular maintenance. Figure 1 shows the failed mechanical system. The pond was malfunctioning, ignored, lacked de-sludging and released untreated effluent to the downstream communities. The communities downstream were subjected to health risks and bad odour resulting from anaerobic decomposition of organic matter.

Figure 1. Conditions of failed mechanical system in Kleruu

Figure 2. Conditions of Rehabilitated System at Kleruu

After consultation with UDSM “WSP & Constructed Wetland Research Project”, a Horizontal Subsurface Flow CW was installed to replace the pond. Baffled system was introduced as seen in Figure 2. The need for intensive operation of the mechanical system ceased and the condition of the wetland after full growth of the plants.

3.3 The Constructed Wetland at Ruaha Secondary School

Ruaha Secondary School (RSS) approached the UDSM for advice on their sanitation system. RSS is built in a high water table area and during rainy seasons their leaking septic tank system overflowed into the environment. The nearby communities complained about the situation and the Iringa Municipality ordered the school to deal with the problem. One option that was being considered was to use vacuum tankers to empty the septic tanks but this was too expensive. After a visit UDSM suggested the implementation of a CW system. Due to financial limitations of the school, a self help approach was used whereby the UDSM designed the system and the school through their resident civil engineer looked after the construction. Despite instructions on the requirements of the CW construction, several errors were committed during construction which resulted in 30% extra costs.

The first CW designed for 600 people was inaugurated in May 2003 and a year after another similar unit was added in parallel. From the experience gained in the construction of the first unit, the second unit was constructed with no flaws. This brought the treatment capacity to 1200 people. In one way capacity to construct a wetland was gained by this school. The school is using the treated water for growing elephant grass for their cow project. They are also using the wetland for training their students (see Figure 3). The performance of the system is excellent.

Figure 3. Fully Grown Constructed Wetlands at RSS

4. Financial Cost Categories for Constructed Wetlands

Having reviewed various aspects and milestones of the constructed wetlands in Tanzania, in order for one to understand its economics, it is important to look into different cost categories of CW. The following sections describe different categories associated with constructed. The description of these categories will form the basis for cost benefit analysis as it will be explained later. The overall cost for CW implementation includes capital and operating cost. For the sake of easing the report, these categories will be discussed separately. It has however to be taken into account that these cost categories will be used to establish the total financial costs for selected CW in Tanzania that will be subjected to CBA. On the other hand, table 4.1 provides the average amount of money for the various cost categories which form part of CW investment costs. The costs (per square meter) have been established based on the typical CW units designed and constructed in Tanzania.

4.1 Investment/capital cost

The capital costs consist of six (6) items as follows;

4.1.1 Land Costs

Under this cost, the following items will have the cost implications; cost of land, loss of productivity, loss of Single Farm Payments (SFP). The value of the land lost depends both on the surface area and land use. The larger the farmyard, the larger the wetland required and the land taken. In addition, a buffer area is recommended between wetland cells (e.g. 5 m wide) and between cells and grazed areas/water bodies (≥ 10 m) for maintenance and contingency, which considerably increases the overall area needed.

4.1.2 Site assessment, planning, design, supervision

In this phase of the CW project, the costs that will be incurred will be for preliminary hydrological, soil, ecological, archaeological surveys investigations as well as for design plans and supervision.

4.1.3 Discharge permit

In some countries (e.g. Ireland) there is a cost associated with discharge permit license fee, water sampling and expert advice. However in other countries (e.g. Tanzania), this is not required and hence there is no cost.

4.1.4 Construction

Overall construction costs are site-specific linked to the materials costs, piping work, excavation works, reworking of topsoil, fencing and concrete structures, etc. There is also a cost associated to the labor and the media.

4.1.5 Planting

The cost for planting depend mainly on the planting density and species used (reeds, bulrushes, grasses), and on plant or seed availability (e.g. if plants can be transplanted from an existing wetland or pond and if the area was already a wet grassland before construction). Guidance on transplanting usually recommends sourcing from accredited nurseries, to avoid damage to existing habitats and inadvertent introduction of exotic species. The recommended planting density is about 2 plants m^2.

Table 4.1: Typical amount for the various cost categories of CW

Item	Units	Average Amount (Tshs)
Site assessment, planning, design, supervision	M^2	32,785
Construction materials	M^2	36,800
Labour charges for construction works	M^2	23,950
Substrates (Aggregates)	M^2	53,850
Macrophytes (Plants)	M^2	2,550

4.1.6 Decommissioning

In some cases, for example, if CW land use activity ceases, land is sold, the CW reaches the end of its life time, or legislation changes, it might be necessary to decommission the wetland, carrying out simple earthworks to fill the CW or to transform it. In such a case, sediment can be left in situ, cells can be filled using available material, pipes and liners have to be removed and properly disposed of, and vegetation can be harvested to use in other CFWs or left in situ. The CW can also be transformed into an amenity wetland, if a permanent source of water is available.

4.2 Operational and maintenance cost

Under this sub-category, there are only two items as follows;

4.2.1 Maintenance

Maintenance activities appeared to be neglected for the CWs investigated, mainly due to the absence of regulatory requirements, lack of financial incentives and lack of information and understanding of the maintenance needed. Indeed, regular maintenance activities are needed to ensure CW integrity and function, such as removal of material obstructing pipes, grass cutting on the edges, removal of sediment, replanting areas where establishment failed, and level control on a regular basis.

4.2.2 Monitoring

Most of the CWs are indeed completely unmonitored after construction, resulting in poor performance being undetected and in the lack of corrective actions. Due to absence of regulation and enforcement in the field, the cost of monitoring which could be borne by farmers or local authorities is currently unknown, and could be significant if the “polluter pays” principle is fully applied and farmers are required to address this issue.

However, water sampling and analysis is necessary to ensure that the effluent is not impacting negatively on the receiving water body, especially in sensitive areas, and during rainy periods when peak pollution occurs.

5. Financial Benefit Categories of Constructed Wetlands

Constructed wetlands may provide, to a certain extent, most of the benefits associated with natural wetlands. This section aims at developing a framework for the identification of the benefits associated to the use of constructed wetlands for wastewater treatment. An economic perspective is embraced throughout the section and the possibility of using economic valuation methods to estimate the benefits in monetary terms is discussed. It has however to be taken into account that these benefits categories will be used to establish the total financial benefits for selected CW in Tanzania that will be subjected to CBA.

5.1 Functions and Benefits of Constructed Wetlands

Constructed wetlands perform many functions that provide goods and services to society. Following a classification proposed by a Wetland Reserve Program report for natural wetlands (WRP, 1994a) wetland functions can be grouped into the four broad categories of (i) hydrology/water quality, (ii) landscape enhancement, (iii) fish and wildlife habitat, (iv) recreational and educational activities. The wetland function related to hydrology and water quality includes supply of treated water suitable to be reused in several applications, increase of surface quality and recharge of aquifers.

The development of a habitat for fish and wildlife may provide benefits related to production of food and fiber through harvesting, protection of fisheries, aquaculture as well as educational and cultural activities. According to the land context in which they are placed, free water surface constructed wetlands can also significantly enhance landscape aesthetics by introducing a pleasant natural element in the landscape. Closely related to the habitat and landscape functions is the provision of opportunities for recreationists.

Economic goods and services provided by constructed wetlands through the four main functions are grouped in Table below into goods and services to which a price is attached in relevant markets and goods and services for which no relevant market exists (non-market benefits). The former include supply of reusable water, food and fiber production, protection of fisheries and aquaculture. The latter are increase of surface- and groundwater quality, aquifer recharge, educational, cultural and recreational activities, land development and existence and bequest of biodiversity. Lambert (2003) points out that "market failures related to ecosystems include the fact that many wetlands (1) provide services that are public goods, (2) many wetlands services are affected by externalities and (3) property rights related to ecosystems and their services are often not clearly defined". The following table provides wetlands functions and goods and services from which the valuation method is based on;

Table 1. Constructed wetland functions, related economic values and suggested valuation methods.

		Wetland function	Good or service provided	Valuation Method
Market benefits		Hydrology / Water Quality	Supply of reusable water	market price
		Fish and Wildlife Habitat	Food and fiber production (harvesting)	market price
			Protection of fisheries / Aquaculture	market price
Non-market benefits	Use Values	Hydrology / Water Quality	Increase of surface water quality	contingent valuation, avoided cost analysis
			Groundwater recharge	contingent valuation, avoided cost analysis
		Fish and Wildlife Habitat	Educational/cultural activities	contingent valuation, travel cost
		Recreation and aesthetics	Recreational activities	contingent valuation, travel cost
		Landscape enhancement	Land development	stated preference methods, hedonic method
	Non-use values	Fish and Wildlife Habitat	Existence and bequest value of biodiversity and biological resources	contingent valuation

5.2 Framework for evaluation of economic benefits of constructed wetlands

This section critically discusses the possibility of valuating in monetary terms each of the benefits identified in Table 1 above. The focus will be on two of the basic steps in CBA proposed by Boardman et al. (1996), namely on (i) identifying the functions of constructed wetlands that lead to welfare impacts and selecting appropriate measurement indicators (measurement units) and (ii) assessing the applicability of economic valuation methods to the monetization of the impacts. It is stressed that in this section only methods for primary valuation studies are taken into account.

5.2.1 Hydrology/water quality

Supply of reusable water

Constructed wetlands are already in use in many wastewater reclamation and reuse schemes worldwide (see Bixio et al., 2004). The good quality of the polished effluent makes it suitable for various forms of reuse including agriculture, industry and in general for medium to low contact applications.

Measurement indicators

The most obvious indicator of the benefits provided is the quantity of wastewater reused. The residual concentration of polluting substances (like nutrients, toxic elements or suspended solids) can however highly affect the benefit from reusing the wastewater. When the polished effluent is used in agriculture, a high concentration of nutrients can induce the positive effect of reducing (or eliminating) the need to use fertilizers. These cost savings need to be included in the economic valuation. Hussain et al. (2001) point out, however, that in some cases the nutrients might be supplied in excess of crop requirements, and thus nutrient content value approach results may overestimate actual economic worth of nutrients in the wastewater. When the reuse application involves contact with human beings, considerations about risk to human health induced by the possible presence of toxic elements in the wastewater cannot be avoided in the valuation. Finally, for applications in industrial processes, residual concentration of suspended solids may lead to problems with sedimentation and clogging and thus to a reduction of the benefits.

Valuation considerations

Even when a price of water exists and it is assumed to be an appropriate indicator on which to base the valuation, difficulties in valuating the benefits arise from the fact that water price is often not the result of market transactions but it is kept to a sub-optimal level by political, legal or historical factors. In other words the price of water may not reflect the true value of water to the consumer but, typically, it underestimates it. When this is the case, Hussain et al. (2001) suggest deriving the shadow price for water using hedonic price analysis or assuming the cost of energy required to use an alternative technology to deliver the same quantity of water.

Increase of surface water quality

Constructed wetlands provide a tool to reanimate the “dead” treated wastewater and transform it into usable natural surface water. This aspect of the treatment with constructed wetland has been extensively studied in the “Waterharmonica” project in the Netherlands (see for instance Kampf and Claassen, 2004). The key point of the “Waterharmonica” concept is that free water surface constructed wetlands not only provide a significant reduction of key contaminants (like chemical oxygen demand, pathogens, nutrients etc.) but their effluent is much more similar to a natural healthy surface water than the effluent of a conventional mechanical treatment plant. A more natural daily trend in the dissolved oxygen concentration is observed and suspended solids are of a different kind, biomass instead of activated sludge flocks.

Measurement indicators

The key point of the analysis in this case is the identification of appropriate water quality standards to be used as indicators of the water quality status of the receiving surface water body. The already cited Wetland Reserve Program (1994a) reports a range of variables that have been used in 17 different methods to evaluate natural wetlands functions. The variables linked to the downstream water quality status include chemical parameters like dissolved oxygen, heavy metals nutrients, bacteria and sediments concentrations, conductivity, alkalinity and temperature in the effluent.

Valuation considerations

Moons (2003) reports a series of studies concerning the economic valuation of several water quality parameters. In particular nitrates, sulphates, chemical oxygen demand (COD) are valued. Most of the studies use a contingent valuation approach to assess the value of a certain improvement in the water quality standard (i.e. reduction of mean nitrate concentration) or of the safeguard of existing water quality. The results refer to different water uses (drinking water supply, ground- and surface water quality). In general the results of the studies show a high variability according to the level of information provided to the respondents and to the probability of the occurrence of the prospected pollution event. Some authors (Breaux et al., 1995) suggest an alternative valuation technique based on avoided cost analysis to evaluate the costs related to the water quality improvement occurring in the wetland compared the costs of traditional treatment.

Groundwater recharge

The polishing step of treatment provided by constructed wetlands can make the treated wastewater suitable for recharging the aquifers in areas of over-exploitation of groundwater resources and thus provide a beneficial effect in the water resources management. It must be observed that the groundwater recharge does not occur in the location of the constructed wetland itself since the permeability of the wetland bottom is typically very low to avoid infiltration of polluted wastewater into the soil.

Valuation methods

Engineering costs for providing groundwater recharge with alternative technologies are generally available and can be used to value the benefits of groundwater recharge by means of constructed wetlands. The benefit from the constructed wetland will equal the difference between the costs of supplying the water for the recharge by means of the constructed wetland and with the alternative source.

5.2.2 Fish and wildlife habitat

Protection of fisheries / Aquaculture – Food and fiber production (harvesting)

Application of wastewater treated in polishing constructed wetlands for creating conditions suitable to aquaculture activities can be found in several installations worldwide (see for instance the Arcata Marsh and Wildlife Sanctuary, California). Research conducted on the island of Texel (Netherlands) by Kampf et al. (1999) shows that toxicity effects due to biomagnification of heavy metals like copper and zinc in the food chain from zooplankton to fishes are limited under normal loading conditions. The possibility of linking constructed wetlands to aquaculture schemes and to use the material harvested for different applications in developing countries has been discussed by Yana (2004).

Valuation methods

Economic valuation in this case is determined by market conditions. The value of the wetland for production is given by the difference between net returns from production from wetland harvest and net returns from production from next best alternative (WRP, 1994b).

Existence and bequest of biodiversity and biological resources

The development of a complex ecosystem rich in biodiversity within constructed wetlands is reported in many studies worldwide. Plant and animal communities can carry a significant economic value for their mere existence and/or to ensure that future generations might enjoy this biodiversity. It must be noted, however, that plant and animal communities in a constructed wetland have generally a reduced habitat value if compared to natural wetlands because of the high load of nutrients carried by the influent wastewater (Tanner, 2002) and the presence of toxic substances.

Valuation considerations

The economic valuation of biodiversity and biological resources has been object of a large number of studies. In a survey and evaluation of empirical studies, Nunes et al. (2001) report that contingent valuation is by far the most used method since it is the only method able to estimate non-use values of biodiversity like existence, option and bequest. Contingent valuation is one of the most controversial non-market valuation methods. One of the most important critics is that there cannot be the certainty that people would actually pay the amount stated. Nevertheless the importance of contingent valuation is given by the fact that it is one of the few methods that allow estimating nonuse values.

5.2.3 Recreational and educational activities

Recreational activities

Recreational activities that may potentially take place in a constructed wetland include consumptive and non-consumptive uses. In the former mainly hunting is included, while the latter refers to bird and wildlife watching. Bird watching is probably the most important recreational activity related to constructed wetlands. Birds often use wetlands as nesting places or as feeding and resting place during the migration and constructed wetlands are often considered optimal spots for bird watching. This recreational function of constructed wetlands is obviously closely linked to the wildlife habitat function. Recreational and cultural activities can assume a very relevant economic value.

Valuation considerations

The most commonly used valuation method to assess the economic value of recreational activities is the travel cost method. This method has been recently applied to evaluate the recreational benefits produced by the free water surface constructed wetlands in Empuriabrava (Spain). In this installation, the wetland effluent feeds the otherwise drying out Laguna del Cortalet in the Empordà Park (Seguì, 2004). It must be observed that the use of this method involves the risk to overestimate the value of the recreational service since visiting the site may not be the only reason for travelling to the wetland area. The existence of substitutes for the recreational activities must be taken into account in the analysis

Educational and cultural activities

Constructed wetlands may provide opportunities for environmental education and for raising awareness among citizens. Information centres are often created to welcome visitors and explain the scientific background of the wastewater treatment processes and the value of wetland ecosystem. An example of educational activities successfully taking place in a constructed wetland is given by the WSP and CW Research Group of UDSM, in which information about wastewater treatment functions of the wetlands and publications are handed out to the visitors.

Valuation considerations

The already cited Wetland Reserve Report (1994a) points out that economic valuation is seldom attempted for these values, since "it is often difficult to separate educational/cultural services from the provision of other goods and services". Accessibility of the site and existence of substitutes in the region are key elements that determine the educational value of a wetland.

5.2.4 Landscape enhancement

Constructed wetlands can carry high landscape values when they are integrated with recreational areas in water parks. This landscape values are higher in urban development sites than in rural areas since in urban areas free water surface constructed wetlands and water parks introduce a valuable natural element. To assess this value the existence of substitutes in the region under consideration is a key aspect that must be included in the analysis. The higher price of land in urban areas is a limitation to the implementation of such schemes.

Measurement indicators

According to the Wetland Reserve Program report (1994b), information needs to be taken into account for the valuation are size and configuration of the wetland, proximity to roads and to other infrastructures. For what concerns the configuration of the wetland, according to the same authors open water and marshy wetlands are generally preferred from an aesthetic viewpoint to thickly vegetated swamps where visual access is impaired. Similarly, irregular edges and mosaic patterns of vegetation are generally considered of a higher visual value.

6. Key Concepts in Financial Cost Benefit Analysis

Before embarking into CBA it is imperative to understand some of the key concepts that are used in CBA. This section explains some of these concepts.

Annuitization is the process of converting an investment into a series of periodic payments.

Assets include all forms of constructed facility and infrastructure.

Capital expenditure (CAPEX) is the money required at the beginning of a project to finance or purchase materials, land, labor and any other costs related to construction and project implementation.

Cost benefit analysis (CBA) takes into account both financial and socio-economic costs and benefits to assess the comparative advantage of different options in monetary terms.

Design life is the estimated lifespan of an asset.

Discounting is a method used to convert future costs or benefits to present values using a discount rate.

Discount rate is the annual percentage rate at which the present value of a future dollar (or other currency) is estimated to lose its value over time.

Net Present Value (NPV) is an aggregated value used in whole life cycle analysis to measure the resultant financial and economic benefit of a good or service when all costs and benefits are taken into consideration. A positive NPV indicates a net benefit and a negative NPV a net loss.

Operational expenditure (OPEX) is the money that is required to sustain a facility or activity (including labor, fuel, and all other operation and maintenance costs).

Planning horizon is the duration over which the whole life cycle costs are evaluated.

Whole life-cycle analysis involves a long-term perspective taking into account all the costs incurred and the benefits received over the total duration of a project up until the planning horizon is reached

7 Cost Benefit Analysis (CBA)

As discussed in previous sections the constructed wetlands are a good solution for hygienic and sustainable sanitation for schools in Tanzania. However, finding investment capital is still a major barrier in dissemination of the constructed wetland technology in developing countries, such as Tanzania. To strengthen the argument pro-dissemination and to select potentially attractive implementation opportunities, we include a cost-benefit analysis. This analysis is split into two parts first elaborating on financial attractiveness from investor's point of view and second on cost and benefits from societal point of view. It has however to be noted that NOT all the costs and benefits categories identified in sections 4 and 5 have been included in this CBA. It has not possible to have all categories because of lack of data information availability. But again the CBA results presented below only gives an indication of CB of CW.

7.1 Financial Cost Benefit analysis

The CBA analysis that was carried out in this study was based on only one constructed wetlands project in Tanzania, namely at RSS. We base our financial CBA on the following data and assumptions (Balkema, et al., 2010):

- The project life time is set to 10 years, assuming that a constructed wetland (CW) will in fact last longer than that, the residual value of the CW at the end of the project life-time is set to half the construction value in year 0.
- The average expected inflation rate in Tanzania is set to 8.7%.
- The interest on a commercial loan for a period longer than 5 years is 15.7%.
- The following cash outflows for the non-financial operations for a constructed wetland project are distinguished: (1) design costs of the Constructed Wetland (in year 0); (2) building materials (in year 0); (3) other construction costs such as wages (in year 0) and (4) Operation and Maintenance costs (in year 1 through 9).
- The cash inflows of the non-financial operations of the project consist of all direct and indirect cash inflows caused by implementing the project, in this case: the reduction of sanitation costs caused by the constructed wetland. For instance avoidance of costs of waste dumping; or avoidance of cleaning costs of the existing system which is replaced by or extended with the newly constructed wetlands. In most cases these are avoided costs by not having to empty the septic tank as often as before. For the case study of constructed wetlands at Ruaha Secondary School in Iringa,

In Tanzania, the following data was collected:

- The initial costs of the project are completely covered by grants.
- The total construction costs for the CW are relatively low, because the university (UDSM) does not charge for the design of the wetland, furthermore the construction is taken care of by students and employees of the school. Therefore, the only construction costs are the TSh. 3,121,250 (US$ 2,500) for construction materials.
- Operation & Maintenance of the Wetland is TSh. 420,000 (US$ 340) per year for wage costs and costs of measuring the water quality on various indicators.
- The introduction of the CW reduces the cleaning cost of the school's septic tank that was its dominant sanitation technology until then: instead of emptying the tank 4 times a month, it now needs to be emptied only once a year. Emptying the septic tank costs TSh. 25,000 (US$ 20).

In the case of Ruaha Secondary School the constructed wetland is financial feasible because of the relatively high avoided costs of not having to empty the septic tank as often as before implementing the wetland. The calculated Net Present Value (NPV) is 2,807,000 TSh. (US$ 2,250), the Internal Rate of Return (IRR) 33% (compare to nominal interest rate of 16%) and the Pay Back Period (PBP) lies between 4 and 5 years. As a sensitivity analysis, switching values are calculated indicating at what rise investment or maintenance costs or a drop in benefits (less avoided costs) the NPV will become zero. In the case of the Ruaha Secondary School investment costs higher than 7,047,000 TSh. (5,640 US$) (2,3 times the realized investment costs) would make the project financially unattractive (NPV = 0). Similarly, doubling the operation and maintenance costs would make the project financially unfeasible (NPV = 0) and

35% lower avoided costs would make the project financially unfeasible as (NPV = 0). From these indicators for sensitivity we conclude that the project is a rather safe investment in financial terms. In addition, the investment costs for the Ruaha Secondary School constructed wetland project were granted, as such the project was without a doubt a financial success.

Based on the Ruaha case study we conclude that in cases where relatively high cost can be avoided by implementing a constructed wetland the investment will be financial feasible. In Ruaha the avoided cost, on yearly basis, was as high as 38% of the initial investment In the literature no comparable analyses were found using similar avoided cost situations, although reference can be found on comparison of costs for different wastewater treatment systems. For instance, in his economic analysis (Chapter 7) Okurut (2000) compares the costs for a constructed wetland with a waste stabilisation pond for the treatment of wastewater for 4000 p.e. in Uganda and concludes that constructed wetlands are economically competitive. Land costs for the WSP was estimated to be 30% higher as a larger area is required, while the operating and maintenance costs are similar for both systems (Okurut 2000, p149), therefore making constructed wetlands the most attractive option.

Mannino et al. (2008) compare the costs of semi natural free water surface wetlands (SN FWS) to activated sludge wastewater treatment plants, and conclude that the wetlands were more economical. Despite high development costs, estimated to be six- to nine-fold higher for the wetlands than for the activated sludge plants (Mannino (2009) p.125, note: excluding land costs!). The total cost needed to give an annual wastewater treatment service per i.e. were calculated to be two- to eight-fold lower over the entire 20 years lifespan, respectively based on a discount rate of 5 and 10% (Mannino (2008) p.124 and p.127). Mainly due to lower maintenance costs, the higher development costs where more than offset in 2 to 3 years (Mannino 2008, p.127). These finding are a bit more promising but in the same range as our results.

7.2 Societal Cost Benefit Analysis

All data in the previous section, supporting the implementation of constructed wetlands, refer to direct and indirect costs for the investor, but as for any water and sanitation project the main benefits are societal. Since fewer people get sick and fewer children die of diarrhoeal diseases the benefits for the society are much larger. This should be taken into account on national and international level. To strengthen the arguments for the discussions on policy making and setting soft loans and subsidies we include a societal cost benefit analysis. In the Ruaha School project the student population at the school is the target population. This is a secondary school (children aged between 12 and 18), there are no children under five which are most likely to die of diarrhoeal diseases, and therefore no mortality rate needs to be calculated for this CBA.

- The total population at the Ruaha Secondary School is 750. The table summarizes the estimated health impacts caused by the construction of a constructed wetland. The technology is estimated to prevent between 9 and in 28 diarrhoeal incidents (low and high case see Hutton 2004). Assuming an average of three days off school per case of diarrhoea there are 27 to 84 days of school attendance gained.

These health benefits need to be transformed into economic benefits with the help of the following statistics:

- Patient expenses avoided due to avoided illness: The avoided costs of treatment of ill children involve the cost of medicine (ORS). The average cost of diarrhoea treatment per child in Sub Sahara Africa is TSh. 7,200 (US$5.50)4.
- Value of child days gained of those with avoided illness. When a child is ill (assumed to be 3 days on average) at least one of the parents has to stay at home to take care of the child; assuming that this parent is usually working, this would lead to income losses. The average daily wage of one parent is set to Tsh.4,000 (US$ 3.2) per day.
- The societal Accounting Rate of Interest (ARI) can be calculated based on the long-term interest rate on Tanzanian government bonds, which is approximately 4% ex-inflation.
- For the socio-economic CBA, the actual costs for the design of the constructed wetland which the university (UDSM) provided for free are also needed. These costs are estimated to be10% of the wetland construction costs.
- The shadow wage rate is approximately zero in Tanzania.

If taking these societal benefits in account in the CBA makes the project even more attractive to invest in, the NPV calculated is as high as 11,100,000 TSh. (8,880 US$) and the real IRR is 493% (compare with the real ARI of 4%) and the pay back period is as short as 1 year!Even if the avoided costs of the frequent emptying of the septic tank before constructing the wetland is set to zero, the NPV calculated remains positive namely 2,200,000 TSh. (1,760 US$) and the IRR remains high (106%) and the investment can still be paid back within one year. From this it is safe to conclude that investments in water and sanitation facilities should be facilitated by governments and international institutions as the cost of not financing these projects is high not only in terms of suffering but even in terms of money.

We are not the only ones concluding that not investing in water and sanitation in developing countries costs money. Hutton and Haller (2004) report that the total annual economic benefits of water and sanitation interventions in the East African region are estimated to be 52 US$ (2000) per person when realizing access to improved water supply and sanitation for all, and 72 US$ (2000) with addition of minimal water disinfected at point of use (Hutton and Haller (2004), p.34, p.46). Benefit Cost ratio's for the East Africa Region are estimated to be 12 when realizing access to improved water supply and sanitation for all, and 15 for addition of minimal water disinfected at point of use (Hutton and Haller (2004) p. 85). These Benefit Cost ratios drop to 2 and 3 when high costs and low benefits are assumed (Hutton and Haller (2004) p.87). So even for the lowest estimates benefits are twice as high as the costs. Investments in water and sanitation in developing countries are not only needed from humanitarian point of view but are also paying back.

8. Financial Mechanisms for Funding the Construction and Operation of Constructed Wetlands in Tanzania

In order for the CW technology to be effectively adapted, there are must be financial mechanisms in place. Financial mechanisms, in this context, mean sources of funds for both capital costs and operation and maintenance costs. This study has identified some financial mechanism available in Tanzania for easy adaptation of CW technology. The financial mechanisms can be available at different levels as explained below;

8.1 National Level

At national is National government through Municipal Councils whose functions will be;

- Allocate funds for sanitation and hygiene education,
- Lobby external support agencies for discretionary terms for financing waste management, hygiene promotion and sanitation,
- Provide financial incentives to local governments which can deliver efficient and effective sanitation and hygiene promotion programmes,
- Develop and finance micro-credit schemes managed by Non-Governmental organization (e.g. SACOSS) or the private sector to target households and work with private sector leaders and product manufacturers to create programmes for extending credit to members of the most vulnerable communities.
- Provide loan security to households that have no collaterals

8.2 Local Level

At local level are Local governments (participating wards) whose functions will be;

- Review the effectiveness of sanitation and hygiene promotion programmes and ensure that funds are not used to finance high-cost, low-impact investments,
- Make subsidy programmes clear and transparent;
- Create incentives to develop new technologies to reduce cost;
- Create micro-credit and credit guarantee programmes to target households and provide incentives for local manufacturers to extend credit to the poorest households

8.3 Communities and Civil Societies Level

At this level, the communities and societies will have the following functions;

- Scrutinize public accounts and check on reported spending on sanitation and hygiene promotion to help increase accountability and reduce wastage;
- Propose alternative institutional and technical approaches that could reduce costs and ensure that these are well-known and well publicized,
- Develop micro-credit schemes to fund household sanitation improvements and create mechanisms for generating user fees for funding continuing operation and maintenance of facilities.

8.4 Household Level

The household level will have the following roles in funding;

- Participate in community schemes and/or micro-credit schemes,
- Pay back loans to loan providers
- Contribute maintenance fee to user groups.

8.5 Entrepreneurship Level

The functions for this level will be;

- Offer poor households with low-interest credit to purchase their products (e.g. CW etc)
- Work with local governments, No–governmental organization and/or banks to develop micro-credit schemes
- Develop cost-effective products and services for poor communities and households.

8.6 Financial Institutions Level

These financial institutions will give soft loans for sanitation (e.g. CW) activities and investments (services and facilities installation)

8.7 International organizations and external funding agencies Level

These agencies will have the following functions;

- Allocate sufficient resources to the sector
- Mobilize other development partners to contribute funds.
- Compile and disseminate information on a variety of cost effective sanitation alternatives and effective behaviour change strategies
- Compile and disseminate information on effective programmes for mobilizing financial resources, including micro-credit schemes, targeted subsidies etc.

It has to be noted that, there is no any single financial mechanism that has been explained above that can be used alone meaning that different financial mechanisms have been looked at together to create the complementarily of one another.

References

Balkema, Annelies, Karoli N. Njau, dr Henny Romijna, ir Ralph de Ruijter: Socio-economic analysis of constructed wetlands systems for hygienic sanitation in Tanzania, Water Practice & Technology Vol 5 No 1 © IWA Publishing 2010 doi:10.2166/WPT.2010.022

Bixio D., De Heyder B., Chikurel H., Muston M., Miska V., Joksimovic D., Schäfer A.I., Ravazzini A., Aharoni A., Savic D. and C. Thoeye (2004) In: Proc. 4th IWA World Congress; 19-24 September 2004, Marrakech, Morocco.

Boardman, A., D. Greenberg, A. Vining, and D. Weimer (1996), Cost-benefit analysis: concepts and practice, Upper Saddle River, N.J.: Prentice-Hall).

Breaux, Andree., Stephen Farber, and John Day., "Using Natural Coastal Wetlands to Wastewater Treatment: An Economic Benefit Analysis.", Journal of Environmental Management, Vol. (44), pp. 285-291. , 1995

Hussain, I.; L. Raschid; M.A. Hanjra; F. Marikar; and W. van der Hoek. 2001. A framework for analyzing socioeconomic, health and environmental impacts of wastewater use in agriculture in developing countries: Working Paper 26. Colombo, Sri Lanka: International Water Management Institute. IWMI.

Hutton G. and Haller L. (2004), Evaluation of the Costs and Benefits of Water and Sanitation Improvements at Global Level, World Health Organisation, Geneva 2004, report no.: WHO/SDE/WSH/04.04.

Kampf R, Jak R, Groot M (1999) “Growing daphnia on effluent to improve the food situation of spoonbills on the island of Texel”, 4th international conference on ecological engineering for wastewater treatment, As, Norway, 7-11 June 1999.

Kampf R and Claassen THL (2004) “The use of treated wastewater for nature: the Waterharmonica, a sustainable solution as an alternative for separate drainage and treatment), IWA_Leading-Edge Technology, LET2004, WW5, 3 June 2004, Prague, Czech Republic.

Kimwaga, R. J., Mbwette, T.S.A., Mashauri, D.A. Katima, J.H.Y. and Jorgensen, S.E.(2004) Use of coupled Dynamic Roughing Filters and subsurface horizontal flow constructed wetlands system as appropriate technology for upgrading WSP effluents in Tanzania. Physics and Chemistry of Earth 29: 1243 – 1251

Lambert A (2003) “Economic valuation of wetlands: an important component of wetland management strategies at the river basin scale”, available online at http://www.ramsar.org.

Mannimo I., Franco D., Picionni E., Favero L., Mattiuzzo E., Zanetto G. (2008), A Cost Effectiveness Analysis of Seminatural Wetlands and Activated Sludge Wastewater Treatment Systems, Environmnetal Management (2008) 41-118-129.

Mato, R. (2001), “Groundwater Pollution in Urban Dar es Salaam”, Tanzania, Technical University Eindhoven.

Mohammed, 2002

Moons E (2003) “The development and application of economic valuation techniques and their use in environmental policy – A survey”, Working Paper Series n° 2003-7, Faculty of Economics and Applied Economic Sciences, Katholieke Universiteit Leuven, Belgium.

Nunes P.A.L.D. and van den Bergh J.C.J.M. (2001) “Economic valuation of biodiversity: sense or nonsense?”, Ecological Economics 39 (2001) 203-222.

Okurut Tom Okia (2000), A pilot Study on Municipal Wastewater Treatment Using a Constructed wetland in Uganda, PhD Thesis Wageningen University and the International Institute for Infrastructure, Hydraulic and Environmental Engineering, Published by A.A. Balkema in Rotterdam, the Netherlands, ISBN 9054104244.

Reed S.C., Crites R.W., and Middlebrooks E.J. (1995). Natural systems for wastewater management and treatment, McGraw-Hill, ISBN 0-07-060982-9.

Seguì Amòrtegui, LA (2004) “Sistemas de regeneraciòn y reutilizaciòn de agues residuals. Metodologìa para el anàlisis técnico-econòmico y casos “, Departament de Enginyeria Agroalimetària i Biotecnologia, Universitat Politècnica de Catalunya.

Senzia, A.M., Mashauri, D.A., and Mayo, A.W. 2003: Suitability of Constructed Wetlands and waste stabilization ponds in wastewater treatment: nitrogen transformation and removal, Phys. Chem. Earth **28**: 1117-1124

Tanner CC, Sukias JPS (2002) “Status of wastewater treatment wetlands in New Zealand”, EcoEng Newsletter, 1 April 2002.

WRP, Wetland Reserve Program (1994a) “Methods for evaluating wetland functions”, WRP Technical note WG-EV2.2, May 1994.

WRP, Wetland Reserve Program (1994b) “Procedures for evaluating wetlands non-market values and functions”, WRP Technical Note WG-EV-2.1, May 1994.

Yana B.B. (2004) “Could the Waterharmonica play its role in the developing world? A review of practical experiences, successful, and less successful experiences”, presentation at the 7th INTECOL International Wetlands Conference in Utrecht, The Netherlands, 25-30 July 2004.

Zephania Mihayo and Cyrus Njiru (2005), “Improving Utility Management at MWAUWASA, Mwanza Tanzania” 31st WEDC International Conference, Kampala, Uganda, on Maximizing the Benefits from Water and Environmental Sanitation.

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