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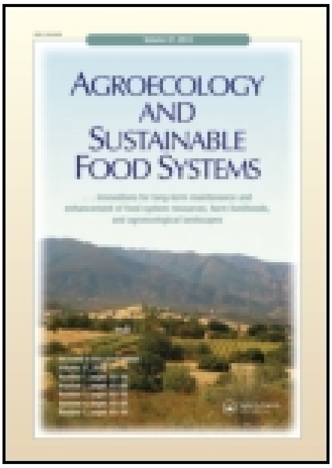

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Economics of Grass Strips Used as Sediment Filters in the Riparian Zones of Lake Victoria, Uganda

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Economics of Grass Strips Used as Sediment Filters in the Riparian Zones of Lake Victoria, Uganda

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Land-use change in the riparian zones has lead to flow of sediments and nutrients into Lake Victoria. Using net present value (NPV) and sensitivity analysis techniques, economic viability of Paspalum, lemon, and elephant grasses as sediment filters under maize production are determined. Findings reveal that grass strips in maize production generates NPVs of 1,620 €ha^{-1}, 1,736 €ha^{-1}, and 1,766 €ha^{-1} for maize + Paspalum, maize + lemon and maize + elephant grass, respectively, at 5% discount rate. Sensitivity analyses show, NPVs are stable to varying discount rates but not to yield declines in maize and grasses. Overall, integrated land use to reduce sediment and nutrient fluxes is a more acceptable solution to land-constrained farmers.

KEYWORDS *net present value, grass strips, soil erosion, Lake Victoria, Uganda*

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1. INTRODUCTION

Land degradation mainly through soil erosion and nutrient mining is one of the most important environmental problems in the Lake Victoria Basin. Soil erosion, a natural process commonly accelerated by human activities is a major non-point source sediment pollutant and is reported to have significantly affected the geomorphology, ecology as well as water quality in the Lake Victoria Basin (Lufafa et al. 2003; Majaliwa et al. 2003; Majaliwa 2004; Kimaro et al. 2005; World Agroforestry Centre 2006; Isabirye et al. 2010; De Meyer et al. 2011). The sediments transported by the runoff are rich in fixed soil nutrients and organic carbon, and can be considered losses that otherwise are vital for sustainable agricultural production. Stocking (1986), reports that land degradation is partly responsible for the increasing cost of agricultural production and that the eroded sediments have higher concentrations of nitrogen and phosphorus than the original soils (due to higher enrichment ratios).

The quest for increased agricultural output through both intensive and extensive margins, settlements, urban centers, and industrial development coupled with inappropriate agricultural production methods have largely contributed to the sedimentation and eutrophication of the lake (East African Community 2004; Lake Victoria Environment Management Programme 2004; East African Community 2006; Isabirye et al. 2010). Moreover, the legislation limiting activities to a 100 to 200 m distance from major water bodies has remained largely unimplemented. Alteration of the natural transition/riparian zones around Lake Victoria has rendered the buffering capacity of these areas ineffective or even detrimental to the quality of the lake waters. The buffering capacity can be improved by managing or restoring vegetative riparian buffer zones around the Lake (Blanco-Canqui et al. 2004), which will contribute toward reduction in sediment and nutrient delivery from intensively cultivated areas (Wanyama et al. 2012).

In their pristine condition, riparian areas provide an extensive list of benefits to both humans and the environment (Rein 1999). Because of their unique position between land and water, riparian areas act as a buffer between upland terrestrial activities and the water. Filter strips favor infiltration and reduce soil detachment by rain and runoff, recharge groundwater, reduce erosion rates and trap sediment and other pollutants, provide shelter and food for wildlife, and help mitigate the effects of non-point source pollution (Welsch 1991; Muscutt et al. 1993; Uri et al. 1998 Lovell and Sullivan 2006; Qiu 2009). Buffer zones of dense permanent vegetation situated along the bank of a stream or lake (the riparian zone) are a simple and generally cost-effective method that can be used to protect water from polluting effects of sediment-generating land uses (Dabney et al. 2006; Lovell and Sullivan 2006). Vegetative filter strips (VFSs) have also been reported as a best management practice for reducing runoff of some agricultural non-point source contaminants, such as soil nutrients, organic materials and pesticides bound to soil particles and other suspended sediments entering surface waters (Muscutt et al. 1993; Franti 1997; Bouldin et al. 2004; Lovell and Sullivan 2006). A VFS is an area along a ditch, gully, stream, pond, lake, or sink hole that is covered permanently by vegetation such as grasses, wetland plants, shrubs, or forest (Muscutt et al. 1993; Chesapeake Bay Program 1995). A buffer strip's location and design can influence its pollutant-trapping efficiency (Chang et al. 2011). Therefore, buffer strips may be situated at various points within, along and after the field. Dabney et al. (2006) highlighted the use of in-field, edge-of-field, and after-field buffers in the United States. According to Parsons et al. (1994), grass filters and riparian buffers were effective in removing about 80–90% of sediment from storm runoff in the piedmont and coastal plains of North Carolina (USA). Buffer strips are most effective when the flow is uniform, slow, and shallow and the sediment trapping efficiency increases as the particle size of the sediments increases (Muscutt et al. 1993; Chang et al. 2011). Grass filters, however, cannot remove all runoff contaminants, and they are particularly less effective at removing nutrients and pesticides in solution, that is, those that dissolve in water and are not attached to soil particles (Franti 1997; Wanyama et al. 2012).

The smallholder farmers in the riparian zones of Lake Victoria may perceive the establishment of grass filter strips as alternative land uses which certainly entail opportunity costs (Uri et al. 1998). Moreover, the portion of land planted to grasses may be taken as loss of cultivable area if there are no tangible benefits to offset the perceived loss to the smallholder farmers (Tenge et al. 2005). Therefore, in order to ensure efficiency in smallholder land reallocation decisions, the present and future streams of benefits and costs need to be identified, valued, and evaluated (Balana et al. 2012). However, quantitative comparison of the benefits and costs of implementing grass strips in terms of establishment cost, maintenance cost, and costs associated with loss of cultivable area (Leeds et al. 1999), is lacking in Uganda.

The integrated use of grass strip filters in agricultural production in the lake basin can be acceptable to the farmers if they are assured of realizing a multiplicity of benefits. These grasses may be used as fodder, mulch, and extracting essential oils in addition to trapping sediments. Moreover, the smallholder farmers are conscious of the incremental costs and benefits that accrue from a given investment and thus adopt technologies with positive net benefits (CIMMYT 1988; Crawford and Kamuanga 1988). Whereas the results reported by Wanyama et al. (2012) from an on-farm experiment in the Iguluibi micro-catchment had tested four tropical grass species as sediment filters (sugar cane, Paspalum, lemon, and elephant grass), the smallholder farmers, through their own assessment, did not select sugar cane as a suitable candidate. Therefore, this study sought to investigate and compare the economics of Paspalum, lemon, and elephant grasses when used as sediment filters in smallholder maize production systems in Iguluibi micro-catchment of Lake Victoria, Uganda. The important questions addressed were: Which grass types are economically viable when integrated with maize production in the Iguluibi micro-catchments and how sensitive are the net benefits to variations in maize yield, grass biomass, prices of maize grain and grass and real discount rates?

2. MATERIALS AND METHODS

2.1. Description of the Study Area

The study was conducted at Iguluibi micro-catchment in Mayuge district, southeastern Uganda, along the Lake Victoria shoreline (Figure 1). The catchment is located between 33°15′ to 33°25′E and 0°25′ to 0°30′N and occupies an area of ca 10,000 ha in the sub-catchment of Thruston bay along Lake

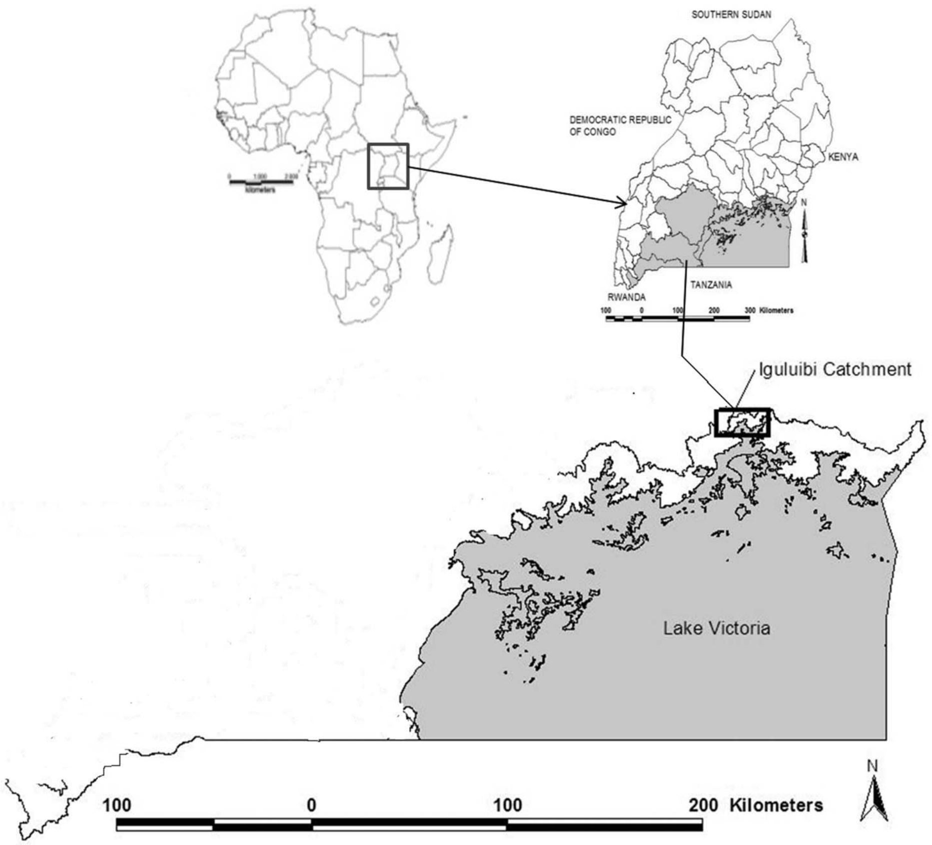

FIGURE 1 Location of Iguluibi micro-catchment, Lake Victoria Uganda.

TABLE 1 Selected chemical properties of Iguluibi soil horizons, Uganda used to estimate nutrient losses

Depth (cm)	0–22	22–51	51–80
Organic carbon (%)	1.8	1.0	0.9
Avail.P Bray (mg/kg)	6.0	7.0	6.0
Exch. K (cmol(+)/kg)	0.7	0.7	0.5

Source: Isabirye 2005; Isabirye et al. 2010.

Victoria shoreline. The major soil types are very deep, sandy clay loam luvisols on moderately sloped ridges in an undulating topography (Isabirye et al. 2010). Some of the chemical properties of the soils in this area are given in (Table 1). The relevant root-able soil depth of 0–22 cm is specially targeted in calculating the nutrients lost in the sediments.

Mean annual rainfall is 1283 mm with a bimodal rainfall distribution, having the first rainy season from March up to May, and a second rainy season occurring between September and December. The rainfall episodes induce substantial soil erosion since some rainfall intensities exceed 25 mm/hr (Isabirye 2005). The natural vegetation consists of aquatic grassland, aquatic tree savannah, savannah grassland, semi-deciduous forest and thicket, and swamp forest. The area is dominated by an intensive crop agriculture consisting of banana-coffee systems with sugarcane, maize, beans, and sweet potatoes as predominant crops, and also with some livestock mostly in the new emerging peri-urban “zero grazing/cut and carry” stall system of livestock production (Mwebaze 2002).

Maize production is an important economic activity, with maize serving both as food for humans and livestock and cash crop in the region. Eastern Uganda is one of the major maize producing regions in Uganda, with a mean parcel size of 0.32 ha of maize either in pure or mixed stand totaling 1.1 million metric tons/yr (47% of national production) with the highest yield of 2.9 tons/ha/yr for the year 2008–2009 (Uganda Census of Agriculture 2008–2009). Maize production is, therefore, a smallholder dominated activity (Isabirye 2005). The distribution of mean maize parcels, area (ha), production (tons), and yield in (t/ha) by region for the production year 2008–2009 is presented in (Table 2).

2.2. Data Collection and Evaluation

The data used in this study were collected from various studies previously conducted in the Iguluibi micro-catchment. These studies generated data used to calculate soil nutrient losses in trapped sediments. Yield of the different grass species used as strip filters under maize production on a 10% slope were obtained from an on-farm experiment conducted between 2007 and 2009 as detailed in Wanyama et al. (2012) (Table 3 and Figure 2). These data are used to quantify the amount of inorganic fertilizer that the smallholder farmers would have to apply in order to replace the lost nutrients if no grass strips are incorporated (estimated using the replacement cost approach).

TABLE 2 Area, number of parcels, mean parcel sizes, and yield for maize by region in Uganda 2008–2009

Region	Total number parcels	Area (ha)	Mean-parcel size (ha)	Production (tons)	% of national production	Yield (t/ha)
Central	505,301	189,135	0.37	449,859	19	2.4
Eastern	1,203,481	388,762	0.32	1,108,554	47	2.9
Northern	629,795	247,780	0.39	305,798	13	1.2
Western	535,077	188,583	0.35	497,745	21	2.6
Uganda	2,873,654	1,014,260	0.35	2,361,956	100	2.3

Source: Uganda Census of Agriculture Report 2008/2009.

TABLE 3 Annual values of nutrients lost (€/ha), mean maize and grass biomass yields from strip filters in Iguluibi, Uganda

Grass strip	Value of nutrient lost (NPK) €/ha/yr	Mean Maize yield (kg/ha)	Grass biomass kg/ha (fresh weight)
Paspalum grass	5.2	4,442	150
Lemon grass	4.8	4,442	10,000
Elephant grass	5.9	4,442	10,000
Control	30.0	4,676	0

Source: Calculations based on Isabirye 2005; Isabirye et al. 2010; Wanyama et al. 2012.

FIGURE 2 Maize field planted with lemon grass strip sediment filter in Igulubi Uganda (Wanyama et al. 2012) (color figure available online).

Although the on-farm experiment results reported by Wanyama et al. (2012), tested three grass strip widths (i.e., 2.5 m, 5 m, and 10 m), and four tropical grasses (Paspalum, sugar cane, lemon, and elephant grass), the farmers through participatory ranking preferred the 5 m strip width and 3 grasses (Paspalum, lemon, and elephant grass). To the farmers, the 5 m strip width was considered a better choice because it did not compromise so much on the cultivable area for maize and, at the same time, they also reported that they could harvest sufficient quantities of grass biomass. Therefore, the data reported in this study corresponds to the 5 m strip widths, maize, and three grass combinations of Paspalum, lemon, and elephant grass (as the preferred choices through farmers' own selection). In the study area and most of Uganda, there are two growing seasons per year and, therefore, farmers harvest two maize crops per year. Once established the grasses are harvested four times per year, throughout their lifetime of five years.

In addition, data were collected through a random farmer survey and brainstorming with local maize farmers who hosted and managed the on-farm experiments on soil erosion control using grass strip filters in the second season of 2009. Through a questionnaire, these farmers provided data on the costs of all the activities involved in establishment, maintenance, and harvesting of maize and grass biomass along with the prevailing farm-gate and market prices of inputs and outputs. These data were recorded and used in the valuation of the various costs and benefits in this study. In valuing unpaid family labor, the farmers in the focus group discussions were asked two equivalent questions: how much they would pay to someone to do an equivalent task and how much they would have accepted as payment for themselves to carryout the same task. Where the amounts were at variance, the average of the two was taken to arrive at the value for family labor.

Data on commercial lending interest rates and consumer price indices (CPI) were obtained from the research department, Bank of Uganda (2010) (Table 4). The CPI and the nominal commercial lending rates were used to compute the inflation rate and then later the real rate of interest. The real rate of interest is then used as a real discount rate to determine the present values of costs and benefits that accrue at different time periods.

Even though at the edge of the field, the area occupied by the grass strip filter, was considered a cost, as it reflected the opportunity foregone to plant it with maize and the use of smallholder farmers' labor to plant and maintain the grasses. However, this cost in terms of lost cultivable area may be directly

TABLE 4 Price index and interest rates in Uganda for the years 2006 to 2011 (General Price Index of 2005–2006 was used as the base and set equal to 100)

	2006	2007	2008	2009	2010	2011
General price index	100.00	110.24	123.52	139.60	145.18	172.29
Lending rate	18.70	19.11	20.45	20.96	20.17	20.64

Source: http://www.bou.or.ug/bou/rates_statistics/Inflation/ (accessed March 9, 2012).

offset by the value of the vegetation harvested from the grass strips and the value of soil and nutrients trapped by the grass strips. The area occupied by one grass strip at the edge of the field was equal to 500 m^2/ha (0.05 ha).

Maize being an annual crop enables the smallholder farmer to plant two crops of maize in the same field twice a year for five consecutive years, making two maize crop harvests possible per year. In addition, the farmers also plant and maintain one grass strip of 5 m width at the edge of the field. The grasses used as strips are perennial tropical grasses with an excellent ability to re-sprout after harvesting. The grasses are also expected to remain effective and productive for the entire duration of five years. However, the smallholder farmer periodically removes the trapped sediments, soils, and nutrients and reapplies them on the upslope portion of the farm to ensure the strips do not get clogged. Franti (1997) recommends that periodic maintenance is important for effectiveness and durability of filter strips. Key maintenance requirements include: a) frequent inspection after intense rainfall or long runoff events and removal or regrading of deposited sediments; b) minimizing development of rill and gully erosion channels—repairing, re-seeding, and inter-seeding any bare spots immediately; c) cutting back vegetation two to three times per year if growth is vigorous; d) testing soils periodically to assure continued plant health; and e) controling unwanted trees, shrubs, and noxious weeds.

The project costs include cost of land preparation, cost of planting materials (maize and grass seeds), cost of labor to plant, cost of labor to weed, and cost of labor to harvest the grasses and maize. The benefits include the maize crop yield, biomass harvested from grasses, and value of nutrients and soils trapped by the grass strips. The benefits and costs were valued using the prevailing local prices while the value of the nutrients trapped by the sediments were valued using the equivalent cost of commercial inorganic fertilizer that would have been used to replace the lost nutrients (replacement cost method) (Pearce and Turner 1990; Bojö 1996). The aggregate amount of the trapped sediments is used to infer the value of the protective function of the grass strip filters. The indirect cost of the lost cultivable area (foregone production) due to planting the grass strips is compensated for by the value of the biomass harvested from grasses, and the value of soil nutrients and sediments trapped. It can also be computed from the number and yield of maize plants that would have been planted in such an area. All costs and benefit values were adjusted using the appropriate real discount rate calculated from the consumer price indices and nominal interest rates in (Table 4) and converted into euro equivalent using the exchange rate at the time of the study (1€ = 2500 UGX) (Bank of Uganda 2010).

2.3. Data Analysis

The cost benefit analysis (CBA) criterion is a widely used tool for project evaluation (Jagger and Pender 2003; Tilahun et al. 2007; Balana et al. 2012) and it provides a coherent framework for integrating information on the biophysical and economic environments faced by farmers (Lutz and Munasinghe 1994; Lutz et al. 1994). CBA is the social appraisal of projects and has traditionally been used to evaluate government policy interventions and projects of a public nature. It can also be used to assess private-sector projects that have externality dimensions in terms of costs and benefits (Perman et al. 2011). CBA analysis quantifies the monetary value of all policy and/or project consequences taking into account the time value of money and the intertemporal nature of returns from such investments. CBA can also been used to appraise alternative land uses, highlighting those that have adverse environmental consequences to both individuals (private agents) and society (Tilahun et al. 2007).

In this study, we conducted a financial analysis of costs and benefits in a typical way a private sector agent would appraise investments using market prices and market interest rates as opposed to the economic perspective of the social planner (Lutz and Munasinghe 1994; Lutz et al. 1994; Bojö 1996). This is because the smallholder farmers in Uganda are the key actors when land-use decisions are made. Farmers as private agents are motivated by self interest and decide how to use their land in light of their own objectives, production possibilities, and constraints, not on the basis of any theory of the social good (Lutz and Munasinghe 1994; Lutz et al. 1994; Balana et al. 2012). The project benefits and costs were discounted to enable comparison of project effects that occur at different points in time. Discounting is the procedure whereby gains and losses to individuals or society are valued less the more distant they are in the future, acknowledging that individuals discount the near future at a higher rate than the very distant future (Pearce and Turner 1990; Rein 1999; Perman et al. 2011). Given that the costs and benefits relate to different time periods and because of high inflation of the Uganda's economy, a real discount rate is preferred compared to a nominal discount rate that relates to nominal prices and inflation.

Cash flow analysis techniques were employed to determine the various costs and benefits of producing one hectare of maize under the with and without the three grass strip filters (traditional maize production, maize + Paspalum grass strips, maize + lemon grass strips, and maize + elephant grass strips). The various costs involved were captured and valued in monetary units along with the associated benefits from the maize production with and without grass combinations. A comparison of total costs and total benefits was made and is presented in (Tables 5 and 6).

Whereas various investment decision criteria exist for appraising alternative investment projects, in this study we used the NPV method to compare

TABLE 5 Calculation of costs (€/ha) of maize production with and without grass strips (Exchange rate 1 € equivalent to 2500 UGX)

Variable	Maize (control)	Maize+ Paspulum	Maize+ lemon grass	Maize+ elephant grass
Year 1				
Land preparation (€)	63.00	63.00	63.00	63.00
Maize seed (€)	62.00	59.00	59.00	59.00
Labor to plant maize (€)	150.00	142.00	142.00	142.00
Labor to plant grass (€)	0.00	6.00	12.00	12.00
Labor first weeding (€)	100.00	95.00	95.55	95.00
Labor second weeding (€)	78.75	74.82	74.82	74.82
Labor maintain grass strip (€)	0.00	7.50	7.50	7.50
Labor to harvest grass (€)	0.00	7.88	19.70	19.70
Labor to harvest maize (€)	63.00	59.00	59.00	59.00
Value of nutrients (NPK) (€)	30.00	5.20	4.80	5.90
Sum of costs Year 1 (€)	545.75	519.40	536.82	537.92
Years 2–5 costs (€)				
Land preparation (€)	200.00	180.00	180.00	180.00
Maize seed (€)	248.00	236.00	236.00	236.00
Labor to plant maize (€)	600.00	568.00	568.00	568.00
Labor first weeding (€)	400.00	380.00	380.00	380.00
Labor second weeding €)	315.00	299.28	299.28	299.28
Labor maintain grass strip (€)	0.00	30.00	30.00	30.00
Labor to harvest grass (€)	0.00	31.52	78.80	78.80
Labor to harvest maize (€)	248.00	236.00	236.00	236.00
Value of nutrients (NPK) (€)	120.00	20.80	19.20	23.60
Sum of costs Years 2–5 (€)	2,131.00	1,981.60	2,027.28	2,031.68

the economic attractiveness of the with-grass-strip and without-grass-strip filters in maize production. The NPV of a project is the present value of the net cash flow/net benefit associated with it (Tenge et al. 2005). The decision rule is that projects that result in nonnegative NPVs (NPV $\geq$ 0) should be considered for investment (Perman et al. 2011). By looking at the different management regimes, it would be in the smallholder's financial interest to adopt the production system if the net present value of the incremental returns from switching were positive (Lutz and Munasinghe 1994; Lutz et al. 1994). Compared to the other criteria such benefit-cost ratio and internal rate of return (IRR), the NPV criterion is the most straightforward and easy to interpret.

In order to analytically test the robustness of our results to variations in key estimates and also to account for risk and uncertainty, we performed a sensitivity analysis on our results. The sensitivity analysis results are based on variation of the real discount rates, variation of maize yield, and grass biomass production and determination of break-even farm gate price of maize.

In order to conduct a cost benefit analysis, one needs to have the year by costs and benefits along with an appropriate discount rate. According

TABLE 6 Calculation of benefits (€/ha) of maize production with and without grass strips

Variable	Maize (control)	Maize+ Paspulum	Maize+ lemon grass	Maize+ elephant grass
Year 1	–	–	–	–
Maize yield tons/ha	4.676	4.442	4.442	4.442
Price per ton of maize (€)	196.880	196.880	196.880	196.880
Value of maize yield (€)	920.610	874.540	874.540	874.540
Grass yield tons/ha	0.000	0.025	2.000	2.000
Price of grass (€/ton)	0.000	7.880	19.690	23.630
Value of grass yield (€)	0.000	0.197	39.380	47.260
Total benefits Year 1	920.610	874.740	913.920	921.800
Year 2	–	–	–	–
Maize yield tons/ha	4.442	4.442	4.442	4.442
Price per ton of maize (€)	196.880	196.880	196.880	196.880
Value of maize yield (€)	874.540	874.540	874.540	874.540
Grass yield tons/ha	0.000	0.025	3.000	3.000
Price of grass (€/ton)	0.000	7.880	19.690	23.630
Value of grass yield (€)	0.000	0.197	59.070	70.890
Total benefits Year 2	874.540	874.740	933.610	945.430
Year 3	–	–	–	–
Maize yield tons/ha	4.220	4.442	4.442	4.442
Price per ton of maize (€)	196.880	196.880	196.880	196.880
Value of maize yield (€)	830.830	874.540	874.540	874.540
Grass yield tons/ha	0.000	0.050	2.000	2.000
Price of grass (€/ton)	0.000	7.880	19.690	23.630
Value of grass yield (€)	0.000	0.393	39.380	47.260
Total benefits Year 3	830.830	874.930	913.920	921.800
Year 4	–	–	–	–
Maize yield tons/ha	4.009	4.442	4.442	4.442
Price per ton of maize (€)	196.880	196.880	196.880	196.880
Value of maize yield (€)	789.290	874.540	874.540	874.540
Grass yield tons/ha	0.000	0.025	1.500	1.500
Price of grass (€/ton)	0.000	7.880	19.690	23.630
Value of grass yield (€)	0.000	0.197	29.540	35.450
Total benefits Year 4	789.290	874.740	904.080	909.990
Year 5	–	–	–	–
Maize yield tons/ha	3.810	4.442	4.442	4.442
Price per ton of maize (€)	196.88	196.880	196.880	196.880
Value of maize yield (€)	750.11	874.540	874.540	874.540
Grass yield tons/ha	0.00	0.025	1.500	1.500
Price of grass (€/ton)	0.00	7.880	19.690	23.630
Value of grass yield (€)	0.00	0.197	29.540	35.450
Total benefits Year 5	750.11	874.740	904.080	909.990

to Perman et al. (2011), the real discount rate can be calculated from the prevailing nominal interest rate and inflation using Equation (1):

$$r = \frac{i - \pi}{1 + \pi} \tag{1}$$

where r is the real discount rate, i is the nominal rate of interest, and π is the inflation rate.

In the absence of adequate statistical data on the inflation rate, the CPI can be used as an estimate for inflation (Tilahun et al. 2007). The inflation rate is calculated from the geometric mean of the CPI as follows:

$$\pi = \left\{\frac{p_2}{p_1} \times \frac{p_3}{p_2} \times .... \times \frac{p_n}{p_{n-1}}\right\}^{\frac{1}{n-1}} - 1 \tag{2}$$

where p is the price index and the subscript indicates the specific year. The average inflation rate of $\pi \approx 11.5\%$ and a nominal interest rate of 16.5% were obtained based on the data from Table 4. Therefore, the real interest rate of $r = 5\%$ was subsequently determined and applied when discounting costs and benefits of the respective years. The NPV is calculated from

$$NPV = NB_0 + \frac{NB_1}{(1+r)^1} + \frac{NB_2}{(1+r)^2} + ... + \frac{NB_n}{(1+r)^n} \tag{3}$$

Equation (3) can be simplified as

$$NPV = \sum_{t=0}^{T} \{(NB_t)(1+r)^{-t}\} \tag{4}$$

where NPV is the net present value (€/ha), NB_t is the net benefits at time t (€/ha), that is, the difference between benefits and costs at a particular time, r is the real discount rate, and t is {0, 1, 2, . . . T}.

3. RESULTS AND DISCUSSION

3.1. Calculation of Costs and Benefits

The input costs for production of one hectare of maize under farmers' traditional practice (control) and three grass strip filter combinations in Iguluibi micro-catchment Mayuge district are presented in (Table 5). These input costs were estimated using prevailing local market prices, opportunity cost for family labor and the exchange rate of the euro to Uganda shillings at the time of the study (1 € equivalent to UGX 2500) (Bank of Uganda 2010). The value of land is not included as the farmers used their own land and that maize production was their primary enterprise and, thus, the opportunity cost of allocating land to maize production was zero.

In Table 5, the maize-control scenario represents the traditional farmer's practice without incorporation of grass strip filters in the maize production system. This is compared with the maize + grass strip filter combinations using three tropical grasses. The value of nutrients is estimated in terms of macro-nutrients (nitrogen, phosphorus, and potassium) using the following relations: 5 mg/kg of soil for phosphorus, exchangeable K (cmol(+)/kg) is 0.7, and organic matter is 1.72 of available organic carbon and 1–2% of organic matter is nitrogen (Table 1) (Isabirye et al. 2010). This value of nutrients is captured as a cost since it is lost in the sediments and never available for plant uptake. Therefore, the smallholder farmers incur this cost indirectly through reduced crop yields and society incurs the cost of pollution of Lake Victoria waters due sediment deposition. The value of nutrients lost is highest in the maize-control scenariowhere there is no grass buffer strips and this loss is cumulative for the five years, leading to a continued decline in maize yield. In addition, since the trapping effectiveness of the grass strips is on average 70%, some sediment is still lost even where grass strips are applied (Wanyama et al. 2012). This implies that some nutrients are lost in the with-grass-strip combinations as well, and this is shown in Table 5. Therefore, the sum of costs for the without-grass-strip is the highest reflecting the high loss of nutrients in sediments. The differences in costs between the different grass types is due to differences in trapping effectiveness and differences in costs of establishment, maintenance and harvesting the grass biomasses. However, the costs in Year 1 for the with-grass-strips combination differ from those in subsequent years due to the fact that, in Year 1, a cost to plant grass is incurred while in other years there are no grass planting costs but there are strip maintenance costs. Additionally, land preparation costs in subsequent years are relatively smaller compared to those of Year 1 that involve initial land opening (Table 5).

3.2. Present Value of Net Benefits (PNB) of Maize Production With and Without Grass Strips

In Table 6, the benefits that accrue to the smallholder farmers in the production of maize from the with- and without-grass-strip filters are given. These benefits are expected to flow for the entire duration of the project life that is tied to the lifespan of the grasses of five years. In the maize control scenario, the only benefit that the smallholder farmers obtain is in terms of the value of maize yield. This, however, declines from year to year due to the fact that the lost nutrients in sediments reduce the fertility of the land thus leading to declining yields (Table 6). In the with-grass-strip filters, since the grass strip occupies 5% (0.05ha) and maize is planted on the remaining 0.95 ha of the area, the value of maize yield obtained in Year 1 is smaller compared to maize control. However, in the subsequent years, due to conservation of soils and nutrients in the with-grass-strips scenario, the value of maize yield remains stable over time and exceeds that obtained in then without-grass-strip scenario. Moreover, the harvest and sale of grass biomass also adds to the total value of benefits that accrue to the smallholder farmers in the with-grass-strips scenario, thus, acting as an inducement and incentive for the smallholder farmers (Table 6).

Whereas in the without-grass-strip scenario, the total benefits decline from Year 1 until Year 5, in the with-grass-strip scenario, the total benefits increase from Year 1 to Years 2 and 3 and only begin to decline in the last year. This change in total benefits in the with-grass-strip scenario is attributable to the fact that the grasses establish slowly in year, reach peak harvest in year 3 to 4 and declines thereafter. The detailed calculation of the total benefits is given in Table 6.

The net benefits per hectare are obtained by taking the sum of benefits minus the sum of costs in respective years. The net benefits are then discounted on a year by year basis to obtain the present values in euro for the control and the maize + grass combinations. The value of discounted net benefits (PNB) for the without-grass-strips declines from Year 1 to Year 5, reflecting the continued loss of soil fertility due to soil erosion and sediment removal (Table 7A). The discounted benefits for the maize with-grass-strips combination are shown in the corresponding sections of Tables 7 (sections B, C, and D, respectively) for maize + Paspalum, maize + lemon and maize + elephant grass.

Sections A–D of Table 7 further show the NPV on a year by year basis and an overall NPV for the five years at a 5% real discount rate for the control and the maize + grass strip combinations. The maize + elephant grass combination returns the highest NPV of 1,766 € ha^{-1} followed by maize + lemon grass at 1,736 € ha^{-1}, followed by maize + Paspalum at 1,620 € ha^{-1}, and, last, the control at 1,306 € ha^{-1}. The differences in NPVs obtained from the with-grass-strip scenarios are mainly attributable to the differences in market prices and demand for the biomass harvested from the grasses. Elephant grass has a high local demand as fodder for livestock on the zero grazing-feeding production system. In peri-urban areas of Uganda, dairy farmers have resorted to stall-feeding of their livestock on fodder harvested from fodder banks and roadsides especially elephant grass due to limited land (Mwebaze 2002). Therefore, in terms of socioeconomic importance to the smallholder farmers, elephant grass ranks number one, followed by lemon grass, and Paspalum last. This contrasts with the technical findings of trapping effectiveness that ranked Paspalum number one, followed by lemon grass, and elephant grass last (Wanyama et al. 2012). These findings demonstrate the relevance of putting into consideration the interest of the end users/smallholder farmers in any technological recommendations. These socioeconomic results imply that if these grass strips are recommended to the smallholder farmers as strip sediment filters, the farmers most probably will adopt elephant grass first, followed by lemon grass, and Paspalum will come last, assuming the local conditions remain constant as implied by the NPV calculations and the demand for grass biomasses.

TABLE 7 Net present value (€) at 5% real discount rate for maize production with and without grass strip filters

Year	Benefits	Costs	Net benefit	Discount factor (5%)	NPV
A: Maize without grass strips					
1	920.61	545.75	374.86	0.9524	357
2	874.54	532.75	341.79	0.9070	310
3	830.83	532.75	298.08	0.8638	257
4	789.29	532.75	256.54	0.8227	211
5	750.11	532.75	217.36	0.7835	170
Total (€)	4165.38	2676.75	1488.63		1,306
B: Maize with Paspalum grass					
1	874.74	519.40	355.34	0.9524	338
2	874.93	495.40	379.53	0.9070	344
3	874.94	495.40	379.53	0.8638	328
4	874.94	495.40	379.53	0.8227	312
5	874.94	495.40	379.53	0.7835	297
Total (€)	4374.49	2501.00	1873.49		1,620.00
C: Maize with Lemon grass					
1	913.92	536.82	377.10	0.9524	359
2	933.61	506.82	426.79	0.9070	387
3	913.92	506.82	407.10	0.8638	352
4	904.08	506.82	397.26	0.8227	327
5	904.08	506.82	397.26	0.7835	311
Total (€)	4,569.61	2,564.10	2,005.51		1,736
D: Maize with Elephant grass					
1	921.80	537.92	383.88	0.9524	366
2	945.43	507.92	437.51	0.9070	397
3	921.80	507.92	413.88	0.8638	358
4	909.99	507.92	402.07	0.8227	331
5	909.99	507.92	402.07	0.7835	315
Total (€)	4,609.01	2,569.60	2,039.41		1,766

Tables 8 and 9 present and compare the present values at 1% and 10% real discount rates for the with- and without-grass-strip scenarios. From these Tables 8 and 9, it can be seen that all the three maize + grass combinations are financially superior to the control (traditional practice). The maize + lemon and maize + elephant grass treatments consistently had higher and positive NPVs, with the maize + elephant grass strip returning the highest NPV at 1%, 5%, and 10% discount rates. The PNBs for lemon and elephant grasses are highest in Years 2 and 3 when the grasses are fully established and, therefore, at peak biomass harvest. The PNB for Paspalum also increases in Year 2, but remains almost constant thereafter. This is attributable to the fact that Paspalum grass biomass does not have high market values because of its low price and low yields (Table 8).

Our results in Table 9 reveal the implications of the higher cost of capital on the sum of NPV at the end of the five-year period. The high cost of capital is reflected by the high discount rate of 10%. From these calculations, it can

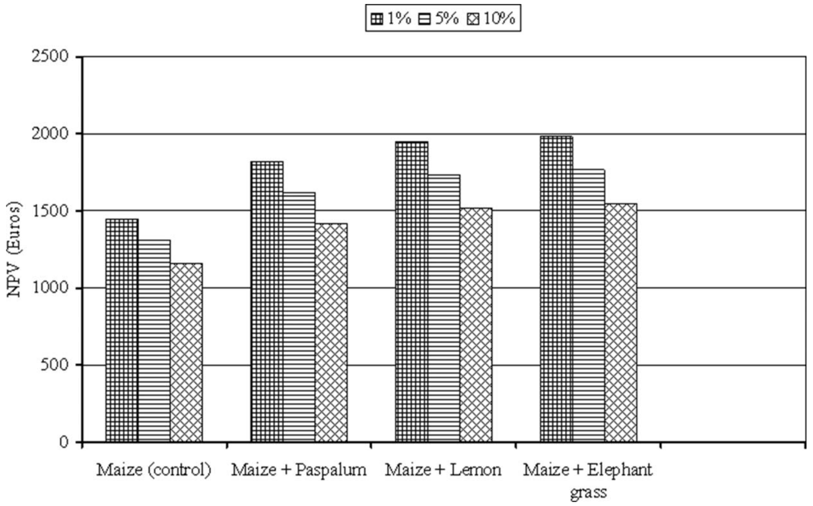

FIGURE 3 Net present values of maize-control and maize-grass strips at 1%, 5%, and 10% real discount rates.

be seen that the sum of NPVs decline in magnitude compared to those obtained at 1% and 5% discount rates. However, the order of magnitude remains unchanged, with the maize + elephant grass returning the highest NPV of 1,546 € ha^{-1}, followed by maize + lemon at 1,520 € ha^{-1}, followed by maize + Paspalum at 1,417 € ha^{-1}, and last, the without-grass-strip at 1,158 € ha^{-1} (Table 9).

In Figure 3, the respective NPV values of the projected five-year maize production period under the with- and without-grass-strip scenarios at 1%, 5%, and 10% real discount rates are plotted. The discount rates are chosen to reflect the lower and upper bounds to determine the overall effect on the five-year investment plan for maize production in combination with grass strips. As can be seen from (Figure 4), the maize + grass strips combinations financially outperform the control at the three discount rates considered. The

TABLE 8 Net present value (€) at 1% real discount rate for maize production with and without grass strips

Year	Maize (control) PNB (€)	Maize + Paspalum PNB (€)	Maize + lemon grass PNB (€)	Maize + elephant grass PNB (€)
1	371	352	373	380
2	335	372	418	429
3	289	368	395	402
4	247	365	382	386
5	207	361	378	383
NPV (€)	1,449	1,818	1,947	1,980

TABLE 9 Net present value (€) at 10% real discount rate for maize production with and without grass strips

Year	Maize (control) PNB (€)	Maize + Paspalum PNB (€)	Maize+ lemon grass PNB (€)	Maize+ elephant grass PNB (€)
1	341	323	343	349
2	282	314	353	362
3	224	385	306	311
4	175	260	272	275
5	135	236	247	250
NPV (€)	1,158	1,417	1,520	1,546

PNB = present value of net benefits; NPV = net present value.

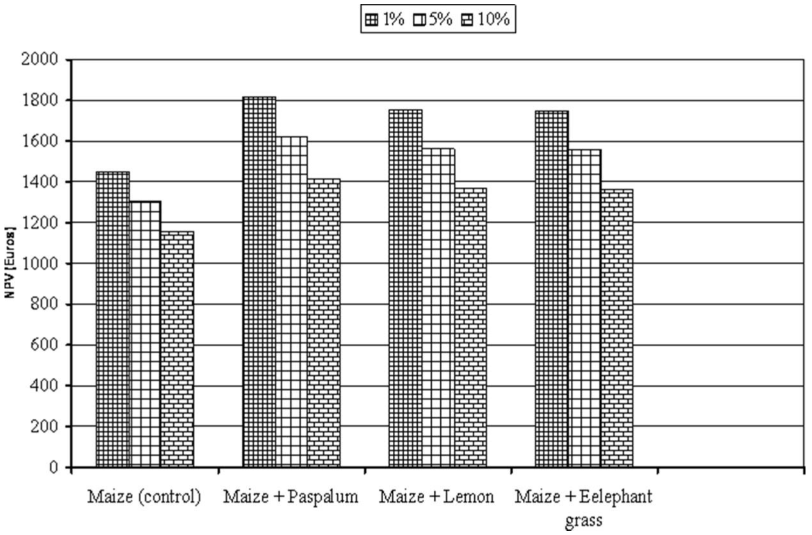

FIGURE 4 Net present values of maize (control) and maize + grass strips at 1%, 5%, and 10% discount rates and zero prices of grasses.

lack of soil conservation measures in the without-grass-strip scenario leads to a continued loss of nutrients through sediment discharge and this translates into lower maize yields over time.

Among the three grasses, there are differences in NPV at all the three discount rates. This is attributed to the fact that the Paspalum grass has low biomass yield and fetches a lower market price compared to lemon and elephant grasses (Figure 3). However, despite the low biomass yield and market value of Paspalum, it substantially reduces the loss of soil nutrients by trapping sediments. Paspalum has been reported to be an excellent grass filter strip because of its extensive above ground canopy cover and belowground root network. The root cohesion of Paspalum further reinforces the topsoil thus reducing detachment and soil erosion (Wanyama et al. 2012).

3.3. Other Benefits from Grass Filter Strips

Grass filter strips incorporated in crop production are beneficial to the farmers in a variety of ways. The grasses trap sediments loaded with nutrients and organic matter thereby preventing pollution of water bodies and eventual loss of vital plant nutrients. Given the changing land uses in the riparian zones of Lake Victoria, agricultural production activities are carried out close to shoreline. This presents a serious threat of pollution from sediments and nutrients from eroded materials. Therefore, the incorporation of grass strip buffers can reduce this pollution threat.

On the other hand, the grasses themselves are beneficial for they provide a number of uses to the smallholder farmers. Lemon grass is used as a nontoxic insect repellent and as an ingredient in citronella oil for pesticides, toothpaste, tea flavors, and perfume. Because of the importance of lemon grass in the area, many farmers have promoted it as a separate crop enterprise. Elephant grass is harvested and used as animal fodder in the "cut-and-carry" grazing system (Mwebaze 2002), while Paspalum is mostly harvested for mulch (Wanyama et al. 2012).

3.4. Sensitivity Analysis

In addition to varying the discount rates, we also conduct a sensitivity analysis on the price of the grass biomasses. When the price of the grass biomass reduces to zero, that is, assuming the demand for grass biomass is nonexistent in the study area, then the smallholder farmers may have no immediate tangible incentives to plant grasses except those with their own livestock to feed. The results of zero prices on the grass biomasses at the three discount rates are shown in Table 10. These results further reveal that the NPV are now highest for the maize + Paspalum combination, followed by maize + lemon, followed by maize + elephant grass, and, last, the maize (control) (Table 10). At a zero price of grass biomass, the true effect of the soil conserving effect of the grass strips is depicted as the results in Figure 4.

TABLE 10 Net present values (€) at 1%, 5%, and 10% discount rates and zero prices for grass biomass

Yield decline 10%	Maize + control	Maize + Paspalum	Maize + lemon	Maize + elephant grass
NPV (1%)	1,449	1,816	1,755	1,750
NPV (5%)	1,306	1,619	1,563	1,559
NPV (10%)	1,158	1,416	1,367	1,363

3.5. Break-Even Price of Maize Grain

The breakeven farm gate price of maize is determined based on the inputs and output of the maize control scenario (traditional maize production without grass strips). The smallholder farmers using the traditional management to produce maize would break-even at 128.50 € per ton of maize grain (or UGX 321.25 per kilogram of maize grain) at the prevailing exchange rate of 1€ = UGX 2500 at the time of the study (Bank of Uganda 2010). At this break-even price, the maize + Paspalum combination returns a positive NPV of 305 € ha^{-1}, the maize + lemon combination has a positive NPV of 554 € ha^{-1} and maize + elephant grass has a positive NPV of 611 € ha^{-1}; all discounted at 5% in five years. This implies that a decline in the farm gate price of maize affects the smallholder farmers using the traditional production practice much more than those who incorporate grass strips in maize production. This is contributed by the high loss of soil nutrients due to soil erosion which reduces the maize yield over time in the without-grass-strips scenario. In the maize + Paspalum combination, the reduction of nutrient loss afforded by Paspalum grass enables the farmer to obtain a positive NPV despite the low market value of Paspalum biomass. On the other hand, the high marketable value of elephant grass and lemon grass biomass combined with the diminished loss of nutrients through sediment transportation cushions the farmers against the low farm-gate prices of maize. This explains the relatively high and positive net present values of 554 € ha^{-1} and 611 € ha^{-1} for maize + lemon and maize + elephant grass at the maize grain break-even price respectively.

4. CONCLUSIONS

In this article, we use data from an on-farm experiment and household surveys to evaluate the economics of three grass types used as sediment strip filters in maize production in the Iguluibi micro-catchment. We employ a NPV criterion and a real discount rate calculated using CPI and nominal commercial interest rates. Sensitivity analyses are also conducted on the lower and upper real discount rates and also on the price of the grass biomasses.

From our results presented and given the fact that maize crop has a poor ground cover, it is shown that in the traditional method of maize production, a substantial amount of soil nutrients are lost both in the runoff (dissolved nutrients) and also as sediment-fixed nutrients. Conservatively, this amount of sediment-fixed nutrients lost—in terms of the macro nutrients nitrogen, phosphorus and potassium—implies that the smallholder maize farmers without incorporating grass strips on average incur an equivalent of 30 €/ha/yr or 150 €/ha in five years in terms of lost nutrients. In other words, in terms of replacement costs, the smallholder farmer would need an extra 150 €/ha in five years to replace the lost macronutrients (nitrogen, phosphorous and potassium). Moreover, the other nutrients both macro- and micro- that may be dissolved and lost in the runoff are not accounted for, which would probably increase the magnitude of the loss and hence the corresponding replacement costs incurred by the smallholder farmers. Additionally, the biggest social cost in terms pollution of Lake Victoria has not been captured in this private agent oriented study.

By incorporating one grass strip filter at the edge of the field, the smallholder maize farmer greatly reduces the value of sediment fixed nutrients lost to 5.20 €/ha, 4.80 €/ha, and 5.91 €/ha/yr for Paspalum, lemon, and elephant grass, respectively. In five years, the smallholder maize farmer saves up to 124 €, 126 €, and 120.47 € by incorporating Paspalum, lemon, and elephant grass, respectively. This monetary saving in relative terms is substantial given the fact that a ton of maize fetches only 196.88 € at the farm gate. These findings on the approximate cost in terms of lost nutrients are in comparable range with other findings elsewhere. For example, Stocking (1986) reported that the financial cost of erosion on arable lands in Zimbabwe ranged from USD 20/ha/yr to USD 50/ha/yr (in comparable terms, this is equivalent to 15.75 €/ha/yr to 39.77 €/ha/yr), depending on the extent of soil erosion and other factors.

In a nutshell, our findings in this article show the economic relevance of the three grass strips as sediment filters in the Lake Victoria catchment at a 5 m strip width and average slope of 10%. The smallholder farmers have a win-win situation if they embrace the grass strips as sediment filters in maize production systems. They will achieve the twin objectives of the grass strips trapping sediments, reduction of pollution of Lake Victoria and also reaping benefits from the biomass harvested from the grasses. This situation can further be improved by integrating livestock production in the system. The livestock feed on the fodder harvested from grass strips and animal wastes are returned to fertilize the fields. In this way the strips of land allocated to grasses are optimally utilized by the farmers. However, in contrast to the technical findings on sediment trapping effectiveness, the smallholder farmers' preference ranking is maize + elephant grass, followed by maize + lemon grass, and, last, maize + Paspalum. The fourth grass type sugarcane is disregarded by the smallholder farmers because the narrow strip planted to sugarcanes can not guarantee sufficient revenues due to the fact that the canes are not harvested as regularly as the other three grasses. The smallholder farmers' choices and preference ordering is justified by consideration of the market values, frequency of harvests and the local prices of the grass biomass as our results have demonstrated. Overall, practices that allow simultaneous use of the land; reduce the direct transfer of sediments and nutrients into the lake are a more equitable solution, acceptable to smallholder land constrained farmers in the riparian zones.

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