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An ecological economics framework for assessing environmental flows: the case of inter-basin water transfers in Lesotho

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Abstract

This paper used the Lesotho Highlands Water Project (LHWP) that transfers water from the Orange River Basin in Lesotho to the Vaal River Basin in South Africa as a case study to show how environmental sustainability aspects can be integrated into economic development planning. Using the Ecological Social Accounting Matrix (ESAM) for Lesotho that integrates ecological implications of the LHWP with economic benefits of the project, the paper analysed the impact of lost ecological services downstream the LHWP dams in Lesotho on the well-being of households directly affected by the project (riparians) and the general economy of the country. The results revealed that despite significant economic benefits, the project has unintended impacts on ecological resources and services with resultant deleterious well-being implications for riparians. The results from the ESAM analysis indicated that not only the income of riparians is likely to suffer, but also that of other households and social groups, as well as the general economy of Lesotho. While results of the ESAM analysis did not indicate large income impacts on the economy at large, they were significant for riparians. The importance of integrating ecological consequences into impact assessment of IBWT before such transfers can be implemented to ensure sustainable development and considering economy-wide impacts associated with IBWT was proven necessary for a holistic impact assessment of IBWT.

Keywords: sustainability; Ecological Social Accounting Matrix (ESAM); inter-basin water transfers (IBWT); human well-being; Lesotho Highlands Water Project (LHWP)

1. Introduction

Water is scarce in many regions of the world. But even in countries with an overall abundance of water, demand exceeds supply in many areas. To overcome water deficits, water is often imported through inter-basin water transfers (IBWT) at international, national, regional and local levels to meet increasing off-stream demands in agriculture, industry, hydro-power and household for economic and social development. However, offstream gains from IBWT are achieved at high ecological costs downstream. This is because transferring water from one basin to

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the other can enormously reduce water required for instream uses leading to negative impacts on ecological resources and processes, which provide direct and indirect benefits to riparians.

Environmental Impact Assessments (EIAs) for inter-basin transfer projects usually leave out instream ecological effects of such projects. The assessments are also often done after important projects' elements have been designed (Hirji, 1998). The Lesotho Highlands Water Project (LHWP) that transfers water from the Orange River in Lesotho to the Vaal River Basin in South Africa is one good example. Recently, the Lesotho Highlands Development Authority (LHDA) commissioned a study to determine Instream Flow Requirements (IFRs) necessary to sustain riverine ecology of rivers downstream the dams of the project in Lesotho (LHDA, 2002a). However, this was done after important elements of the project had been implemented, e.g. part A of the first phase of the project had already been completed and part B had already commenced. It is important that instream impacts of IBWT are measured and included in IBWT impact assessments before such projects are implemented, and that mitigation and compensation measures against possible losses are put in place to ensure sustainable flow of instream benefits to riparians. Otherwise, IBWT may result in unintended negative impacts that threaten the sustainability of such projects in the long run.

The major objective of this paper is to develop and apply an ecological economics framework that integrates ecological considerations into economic assessments models to enable more comprehensive evaluation and analysis of the sustainability of IBWT. The LHWP is used as a case study to empirically apply the developed model. The paper is divided into five sections. The next section gives a brief background to the case study area. The analytical framework for assessing economic and ecological impacts of IBWT is discussed in Section 3. Section 4 presents the data and results of the study and conclusions are drawn in Section 5.

2. Background to case study area

The prime objective of the LHWP is to abstract water from rivers in the Highlands of Lesotho, store it in reservoirs and transfer it, through gravity, to the water deficient Vaal region in SA. Before transferred, the water is used to generate hydropower in Lesotho. The transferred water is aimed at augmenting water supply for industrial and residential use in the Vaal region. SA pays for the full cost of the project except the hydropower component and also pays US$45–47 million annually in royalties for the water delivered (World Bank, 1998). The royalties bring valued foreign earnings to Lesotho. Fig. 1 shows the location of the project in Lesotho including the main dams and rivers supplying the dams. The figure also shows sites where populations deriving livelihoods from the LHWP Rivers downstream the project dams reside. These are marked as IFR sites in the figure.

In the IFR sites reside 150 000 riparians who depend on a host of ecological resources found within the reaches of the affected rivers for livelihoods (LHDA, 2002b). These resources depend on the flows of the river system (streamflows) and include wild vegetables, medicinal plants, crafts grass, fire wood, fish, sand deposits and forage for grazing. The rivers are also the source of drinking water for riparians and their livestock. They also provide cultural/recreational/religious services to riparians. All these benefits were estimated to value 45 million Maloti at 2000 prices[2] (LHDA, 2002c). LHDA (2002c) also estimated that, due to the modification of streamflows downstream the LHWP dams, availability of aforementioned ecological resources and services will decline with deleterious impacts on the welfare of riparians. However, these were not included in the EIA of the scheme.

Because inter-basin water transfers affect many sectors of an economy, a social accounting matrix (SAM) framework is considered most appropriate for assessing impacts of inter-basin water transfers. Also, the SAM is an important tool for analysing social concerns (e.g. welfare implications of an exogenous change in institutional income) because it emphasises origins and distribution of income, as well as distribution of expenditure (Adelman, 1975; Pyatt and Round,

[2] Maloti (M) is the local currency of Lesotho which is pegged on SA Rand (R) on par basis. The M/R value in the year 2000 in relation to the US dollar was US$1 ≅ M12.00.

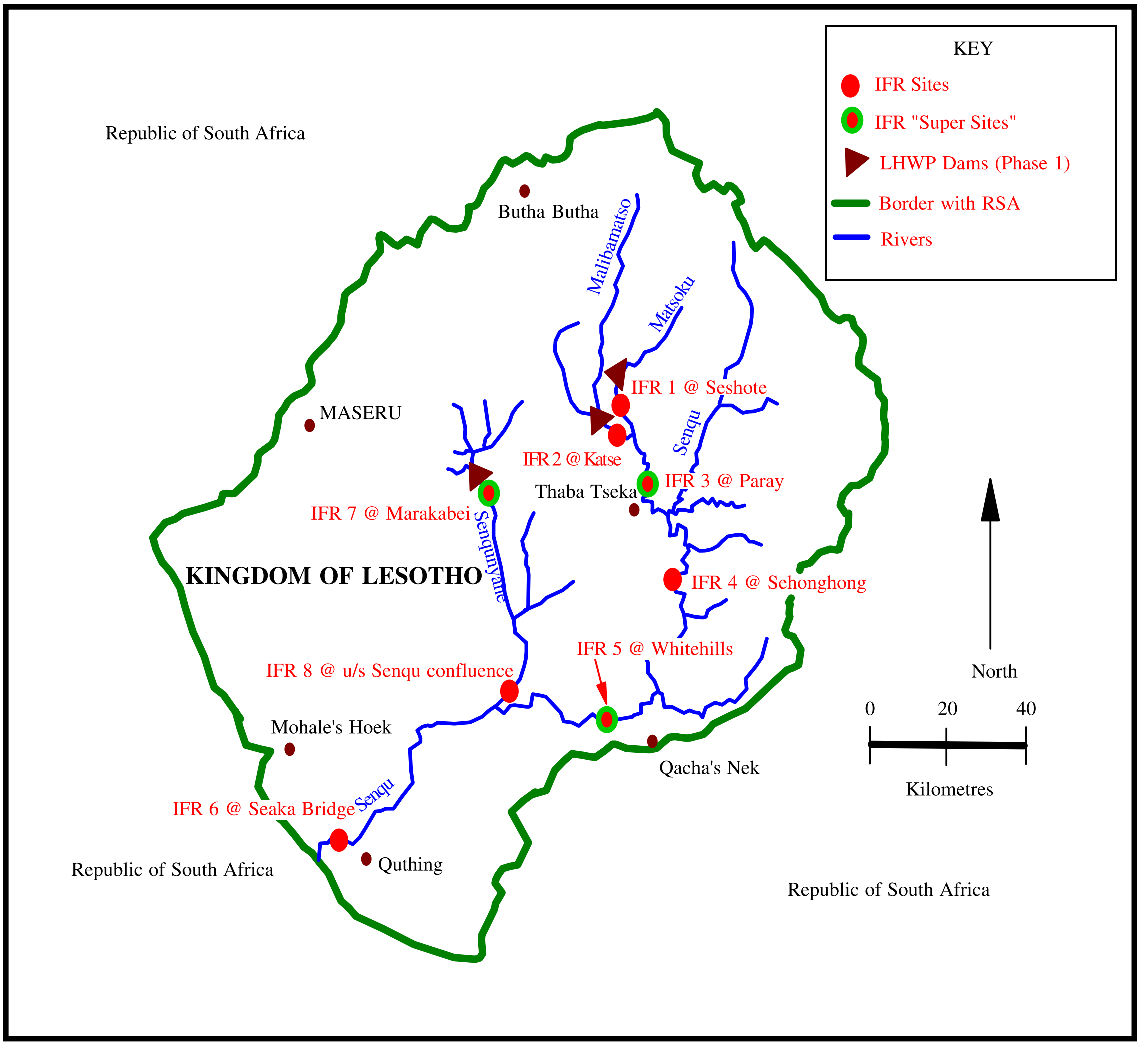

Fig. 1. The LHWP location in Lesotho and areas affected by modified river flow downstream the project dams. Source: LHDA (2002a).

1985; Adelman and Robinson, 1989; Thorbeck, 2002). Therefore, the SAM can help assess impacts of IBWT projects on different households and social groups.

The SAM models have been mainly applied in the literature to water management issues: Pan (2000) in China, Kumar and Young (1996) in Thailand and Daren et al. (1998) in Canada. Recently, SAM analysis has been applied to assess impacts of IBWT (Conningarth Consultants, 2000a,b). In these studies a multi-regional-country level approach to the measurement of water benefits was used for the Komati and Thukela IBWT in SA, respectively. All the above studies however did not include ecological considerations of water transfer schemes (instream impacts). As a result, benefits measured do not capture the full costs and benefits of the schemes. The present study therefore made an attempt to contribute to improving currently used methodology for assessing IBWT impacts by developing an ecological economy-wide framework that integrates ecological costs and benefits for socially and environmentally sustainable development.

3. The integrated ecological economics analytical framework

River flows (streamflows/instream/natural water) provide a myriad of important services necessary for economic production and sustenance of livelihoods. Fig. 2 presents the conceptual framework that shows the flow of services from streamflows to economic production, ecological production and households, and vice versa. The dotted lines in the figure denote unpaid benefits (i.e. subsidy from nature). These flows are later formally modeled and presented in the Ecological Social Accounting Matrix (ESAM) presented in Table 1.

In Fig. 2 the streamflow/natural water includes the water resource (water quantity) and water quality attributes. In the system of integrated environmental and economic accounting (SEEA) language, quality is referred to as water environmental assets (Pan, 2000; United Nations, 2003). Water environmental assets consist of environmental attributes of water including biochemical oxygen demand (BODs), chemical oxygen demand (CODs) and ammonium ion (NH_4^+) concentrations (United Nations, 2003). Water quantity and quality form the natural capital and provide three types of services: (i) freshwater to support ecological production, (ii) freshwater as intermediate input and waste sink in economic production (this includes freshwater abstracted from nature by water authorities for distribution to other sectors and water directly abstracted by different sectors, e.g. irrigation and livestock-watering) and (iii) freshwater for human consumption and cultural/spiritual purposes.

Economic and ecological production do not pay for streamflow, hence they receive a subsidy from nature (unpaid rent). Households receive two types of benefits from streamflows: (i) ecological resources supported by streamflows and (ii) freshwater directly consumed by households, or used by households for cultural/recreational/religious purposes. Households provide labor to access these benefits and receive remuneration in the form of the value of resources/benefits received. The unpaid value of services received includes the ecological resources rent, water resource rent and labor wages contributed by streamflow/ecological production. Since the SAM uses the system of national accounts (SNA) as data base, some streamflow values identified above are not included in the SNA as they are not marketed, i.e. ecological resources and natural water directly consumed or used by households for direct consumption or for cultural/recreational or religious purposes. Streamflow used as intermediate inputs in economic production is part of the SNA but is included as profits of sectors that

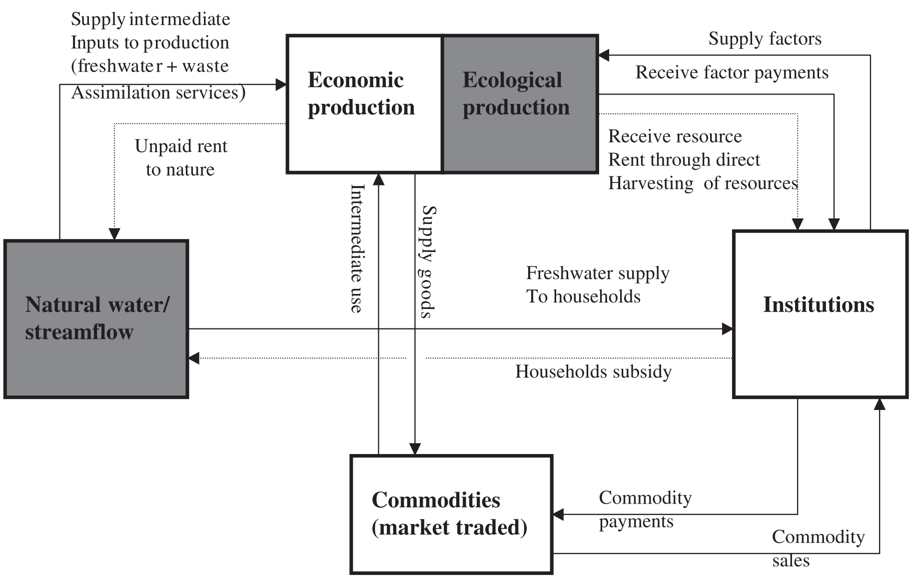

Fig. 2. Flow diagram of ecological and socio-economic flows.

Table 1
ESAM for Lesotho

	Endogenous accounts				Exogenous accounts			
	Water	Other activities	Capital	Households	Government	ROW	Ecological production	Natural water
Water	X_W	X_{WE}	I_W	C_W	G_W	E_W		
Other activities	X_{EW}	X_E	I_E	C_E	G_E	E_E		
Capital				S_H	S_G	S_R		
Households	W_W	W_E		Tr	Tr	Tr	W_N,R_N	W_Q,R_{QC}, R_{QE}
Government	T_W	T_E		T		Tr		
ROW	M_W	M_E	I_R	Tr				
Ecological production				C_N				
Natural water	X_{QW}	X_{QE}		C_Q				

derive these benefits. In the ESAM these benefits are isolated and allocated to the source sector (i.e. streamflow).

To account for the changes discussed above, the ESAM (Table 1) is augmented with two accounts: (i) ecological production, and (ii) natural water/streamflow. In the ESAM, the white block represents a highly simplified conventional SAM and the shaded block represents the ecological system that augments the conventional SAM to built the ESAM.

Let the value of ecological resources harvested and consumed by households equals C_N, remuneration received from harvesting ecological products be W_N, biological resources rent dissipating to households R_N. Then C_N must equal the sum of W_N and R_N according to the SAM double entry principle (Table 1). Further, let C_Q be the value of freshwater consumed by households, W_Q remuneration received from collecting water and R_{QC} freshwater rent dissipating to households directly consuming freshwater services. Then C_Q must equal the sum of W_Q and R_{QC} according to the SAM double entry principle.

To assess the value of streamflow in economic production we split economic production into two activities: (i) the water producing (W) and (ii) other economic (E) activities. Therefore, we split the value of intermediate use of raw water between these two activities as: (i) the value of water used as intermediate input by the water supply sector (X_{QW}) and, (ii) the value of natural water used as intermediate input by other economic sectors (X_{QE}). If use of water for economic production reduces water (quality and quantity) available for ecological production and human consumption, it means that the opportunity cost of water use in economic production is positive, implying a negative externality or a cost to society. Economic production activities must then pay nature the water resource rent (R_{QE}) to internalize the water quantity/quality loss. In this case $R_{QE}=R_W+R_E$, where R_W and R_E are water rents to be paid by the water supply sector and other economic sectors, respectively. If paid, R_{QE} should form part of households' income (as owners of natural resources) in Table 1. In this paper we assume that the external cost of the water transfer from the rivers in the highlands of Lesotho is the value of lost biological/ecological resources and services, and harmful effects that insufficient and polluted water resulting from abstraction of water from the rivers by the project may have on riparians.

4. Data and results of the empirical analysis

The study used the Lesotho SAM for the year 2000. Since the riparians reside in the highlands of Lesotho, and the main focus of this paper is on welfare impacts of riparians due to the LHWP, the households account in the Lesotho SAM was

Table 2
Ecological resources and services values

Resource/service	Total value (million Maloti at 2000 prices)	% Loss in resource/ service	Value of lost resource/service (million Maloti at 2000 prices)
Fish	10.77	4.6	1.95
Forage	1.6	0.2	0.09
Medicinal plants	0.52	0.2	0.09
Wild vegetables	4.93	1.7	0.74
Trees and shrubs	24.54	13.5	5.70
Crafts and thatch grass	0.92	+	0
Sand	2.14	+	0
Public health			0.26
Animal health			0.17
Total	45.43	20.2	8.99

disaggregated into four groups: (i) high-income mountain households, (ii) low-income mountain households, (iii) other high-income households and (iv) other low-income household. To built the ESAM, the values of ecological resources and services supported by flows of the Lesotho Highlands Rivers as well as the value of streamflow in maintaining the health and cultural values of riparians calculated by the Lesotho Highlands Water Authority (LHDA) was used to estimate C_{N} and C_{Q} in the ESAM (LHDA, 2002c). Productivity/cost measures were used to value those ecological resources that riparians use directly or sell in informal markets and where instream water serves as an input in their production. For streamflow health and cultural services, mitigation and transport costs, respectively, were used to value the services. Valuation details can be obtained from LHDA (2002c). LHDA (2002c) did not calculate the value of streamflow in economic production. Hence, X_{QW} and X_{QE} could not be isolated from economic production profits. Also, the study did not explicitly calculate W_{N} and R_{N}; and W_{Q}, and R_{QC}. As a result, these could not be isolated from C_{N} and C_{Q}, respectively.

The value of the loss of ecological resources and services due to the LHWP was calculated from the biophysical changes resulting from the project, socio-economic and economic information collected by LHDA. The same techniques used in valuing streamflow services in biological production and direct human consumption were used (see LHDA, 2002c for details). The derived value is used as a proxy for R_{QE} in the ESAM. This is however, introduced as an external decrease in households income in the ESAM to analyse the impact of the LHWP, through the loss of ecological resources and services, on the households' welfare. The data on ecological resources and services relevant for riparian livelihoods, their values and impact value of the LHWP is reported in Table 2.

For impact analysis, the SAM uses the multiplier matrix. Therefore, to analyse the impact of the loss in ecological resources and services due to the LHWP, the value impact is multiplied by the multiplier matrix derived from the ESAM to calculate the total impact on income of different activities and household groups in the SAM using the equation $\mathrm{d}Y_n=(I-A)^{-1}\mathrm{d}F=M_{\mathrm{a}}\mathrm{d}F$ (see Appendix A for the derivation of SAM multiplier analysis), where $\mathrm{d}Y_n$ is change in endogenous income of activity/household n, $(I-A)^{-1}$ is the ESAM multiplier matrix and $\mathrm{d}F$ is an exogenous change in households income resulting from loss in ecological resources and services. The results of the multiplier analysis are reported in Table 3.

Adjusting the SAM with ecological resources and services values (from Table 2) in the ESAM shows that by excluding ecological resource and service values, the SNA underestimates Lesotho's GDP by

Table 3
Impact of the LHWP on ecological services provision and households welfare

	Initial income (million Maloti at 2000 prices)	Change in income (million Maloti at 2000 prices)	% Change
All sectors	23 686.86	−16.61	−0.07
Factors	7097.97	−3.02	−0.04
Enterprises	1073.98	−0.67	−0.06
Mountain households—high income	240.19	−1.90	−0.79
Mountain households—low income	154.43	−7.43	−4.81
Other households—high income	4362.7	−1.59	−0.04
Other households—low income	545.95	−0.17	−0.00
Total	37 162.08	−31.39	−0.08

M45 million (at 2000 prices). From Table 2, it is clear that streamflows downstream the LHWP dams have significant role in sustaining riparian livelihoods and that the total value of services provided by streamflows is M45 million Maloti (at 2000 prices). This comprised 24% of riparian total income in 2000 (LHDA, 2002c). Due to the LHWP, the benefits of streamflows downstream the LHWP are likely to fall by approximately 9 million Maloti (at 2000 prices), thus affecting households depending on these resources for livelihoods. This comprises 10% of total income of households directly affected by the project (LHDA, 2002c). For the total mountain households population, the loss is M1.8 million and M7.19 million for high- and low-income mountain households, respectively, and is equivalent to 0.75% and 4.66% of total income of the two groups of households, respectively.

The ESAM multiplier analysis shows that, due to multiplier effects, the total fall in income is M1.90 and M7.43 million for high- and low-income mountain households, respectively. This fall represents 0.79 and 4.81 percentage loss in total income of the two groups of households. Although other households are not directly affected by the loss in ecological resources and services resulting from the LHWP, their income also falls to M1.59 and M.017 million for high- and low-income households, respectively, due to multiplier effects. The resultant total fall in national output is 32 million Maloti, which is 0.08% of the total national income in Lesotho.

5. Conclusions

Although the magnitudes of the fall in income are small, they are significant for households directly affected by the project. Also, the results clearly show the significance of integrating instream impacts of IBWT in an economy-wide impact assessment. Leaving out instream impacts of IBWT may lead to un-intended deleterious impacts on availability of ecological resources and services direly needed by riparians for survival and hence unsustainable livelihoods in the long term. Because of multiplier effects, instream impacts are not only felt by riparians directly affected by the project, but by the whole economy. Hence, for sustainable development, instream impacts of IBWT have to be measured and compensated or mitigated against to ensure sustainable development.

Notations glossary

Notation	Explanation
X_W	Intermediate use of produced water by water producing activity
X_{EW}	Intermediate use of produced water by other activities
W_W	Factor income from water producing activity
T_W	Production tax from water producing activity
M_W	Imports by water producing activity
X_{QW}	Intermediate use of natural water by water producing activity
X_{WE}	Intermediate use of other commodities by water producing activity
X_E	Intermediate use of other commodities by own activity
W_E	Factor payments by other activities
T_E	Tax payments by other activities
M_E	Imports by other activities
X_{QE}	Intermediate use of natural water by other activities
I_W	Investment consumption of water
I_E	Investment consumption of other commodities
I_R	Foreign capital investment
C_W	Households consumption of produced water
C_E	Households consumption of other commodities
S_H	Households savings
Tr	Transfers
T	Income tax
C_N	Households consumption of ecological products
C_Q	Households consumption of natural water
G_W	Government consumption of water
G_E	Government consumption of other commodities
SG	Government savings
E_W	Water exports
E_E	Exports from other activities
S_R	Foreign savings
W_N	Contribution of ecological production to value added
W_Q	Contribution of natural water to value added

Appendix A. ESAM multiplier analysis

For analytical purposes, the ESAM is partitioned into endogenous and exogenous accounts. The endogenous part of the ESAM accounts is converted into the corresponding matrix of average expenditure propensities or coefficients. This is obtained by dividing each element in a given column of endogenous accounts (T_{ij}) by the sum total of that column (Y_n). Thus

$$A_{n=}T_{ij}Y_n^{-1} \quad (1)$$

For endogenous accounts, the total income Y_n can therefore be computed as

$$Y_n = A_nY_n + F \quad (2)$$

which implies that row totals of endogenous accounts can be obtained by multiplying the average expenditure propensities for each row by the corresponding column sum and adding exogenous income F. Eq. (2) can be rewritten as

$$Y_n = (I - A_n)^{-1}F = M_aF \quad (3)$$

The inverse $(I–A_n)^{-1}$ is the accounting multiplier matrix M_a which relates endogenous incomes Y_n to injections, F. Thus, endogenous incomes Y_n can be derived by pre-multiplying injection F by a multiplier matrix. Changes in endogenous incomes (dY_n) resulting from changes in injections (dF) can be expressed as

$$dY_n = (I - A)^{-1}dF = M_adF \quad (4)$$

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