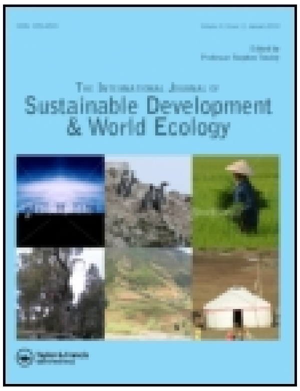

International Journal of Sustainable Development & World Ecology
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/tsdw20

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Available online: 27 Jun 2011

To cite this article: E.P.N. Udayakumara & R.P. Shrestha (2011): Assessing livelihood for improvement: Samanalawewa reservoir environs, Sri Lanka, International Journal of Sustainable Development & World Ecology, 18:4, 366-376

To link to this article: http://dx.doi.org/10.1080/13504509.2011.562740

International Journal of Sustainable Development & World Ecology
Vol. 18, No. 4, August 2011, 366–376

Assessing livelihood for improvement: Samanalawewa reservoir environs, Sri Lanka

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This paper explores household (HH)-level livelihood dynamics and determinants since construction of the Samanalawewa Hydroelectricity Reservoir (SHER) in the Samanalawewa watershed, Sri Lanka. The research is based on data from a structured questionnaire survey of 201 randomly selected households (HHs) in upstream and downstream areas. Livelihood dynamics at two separate points in time (1988 and 2008) were assessed based on a sustainable livelihood framework (SLF). Impact of livelihood determinants on livelihood was analysed using factor and regression analysis techniques, followed by an optimisation procedure to suggest requirements in selected significant determinants to improve the livelihood of various categories of farm HH. In both upstream and downstream areas, livelihood assets, viz. physical, social and human capital, increased significantly, while access to natural and financial capital decreased significantly and slightly, respectively, during last two decades. The factor analysis extracted six factors in the upstream area and seven in the downstream area. The derived regression models show that nine variables in the upstream area and ten in the downstream area are major determinants of HH livelihood. Based on optimisation results, policy implications are discussed in relation to needed improvements in livelihood determinants to improve overall livelihood of HHs.

Keywords: farm households; livelihood assessment; determinants; optimisation

Introduction

Livelihood can be defined as comprising ‘capabilities, assets and activities required for a means of living.’ Thus, livelihood sustainability refers to the ability of a household (HH) to deal with shocks and stresses, and to maintain or enhance its capabilities and assets without jeopardising the natural resources base (Chambers and Conway 1992). However, changes in livelihood affect the environment and vice versa (Rosen and Roberts 2000; Dupar and Badenoch 2002). The use of the term vulnerability context draws attention to the fact that the complex influences of assets are directly or indirectly responsible for many of the hardships faced by the poorest people in the world, although all vulnerability contexts are not necessarily negative (DFID 1999). On some occasions, people’s livelihoods and the wider availability of assets are fundamentally affected by critical trends (e.g. population, resources, economic, governance, technology) as well as by shocks (e.g. natural, human health, conflict between crops and livestock) and seasonality (price, production, etc.) over which they have limited or no control (DFID 1999). Thus, to examine livelihood changes and to understand livelihood sustainability in response to vulnerability context, livelihood assessment is executed. The results are immensely helpful to understand the present status of livelihoods, particularly those of the poor. Hence, livelihood results are imperative in formulating policies, plans and projects for betterment of the poor.

The Samanalawewa Hydroelectricity Reservoir (SHER) in the watershed started in 1988 and was completed in 1992. The Samanalawewa dam was constructed during this period to divert the Walawe River for electricity generation. This represents a vulnerability context in the area. No environmental impact assessment (EIA) was undertaken in the feasibility phase of the SHER, a single purpose hydropower project, although this was a requirement of the National Environmental (Amended) Act No. 56 of 1988 (TEAMS 1992) and thus environmental and socioeconomic impacts since its early stages are not well documented.

Environmental problems include depletion of most of the natural dense forests below 430 m above sea level (asl) and riverine vegetation along the Walawe River and its tributaries in the watershed. Spatially environmental impacts are felt in a reservoir area and its immediate environs; the water table drain-down area is affected by the power supply tunnel system; the area downstream of the dam between the dam site and the confluence of Walawe River and Diyawini tributary is affected, as is the wider catchment area and host areas of settlement (TEAMS 1992); and also the existing reservoir leaks (about 1.8 m^3s^{-1}) at its right bank (Laksiri et al. 2005). Socioeconomic problems caused by the inundation of agricultural lands including paddy result in loss of livelihoods on the one hand and traders losses of their clientele on the other. Downstream or the lower area of the catchment from the dam, HHs incur loss of earnings due to lack of irrigation water for their agricultural lands because the Walawe River was diverted for the dam construction. In addition to problems of water scarcity downstream, other problems, such as inadequate

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ISSN 1350-4509 print/ISSN 1745-2627 online

DOI: 10.1080/13504509.2011.562740
http://www.informaworld.com

pre-planning of re-settlements for evacuees and their livelihood basis requires a shift from rice to tea cultivation. The resettlement programme also did not take account of the original social structure, caste and kinship system (CECB 1991).

In general, the construction of a large dam will inevitably have adverse environmental and socioeconomic impacts in both the long and short term on the immediate environs and to a lesser extent on surrounding areas. Improving livelihoods of local people has received more attention during the last two decades and is one of the main goals of watershed management (Mitchell 2002, 2005; Shivakoti and Shrestha 2005; Mahdi et al. 2009). In terms of construction of SHER, it is arguable that people's livelihoods have been changed dramatically and they have undergone numerous environmental and socioeconomic hardships. Thus, the objectives of this study were to assess livelihood dynamics of dwellers in the vicinity of Samanalawewa Reservoir during the last two decades, identify factors influencing livelihood and suggest the required level of effort needed to improve current livelihood of farm HHs.

Study area

The study is situated in Ratnapura District of Sri Lanka (80.58°–80.92°N, 6.56°–6.80°E) covering an area of about 536 km^2 (Figure 1). The upstream area of the catchment from the dam lies along the southern face of the Horton Plains and Peak Wilderness in the Nuwara-eliya Divisional Secretariat Division (DSD) of Nuwara-eliya District, the lower part, inclusive of SHER (897 ha) that is, major water body of the study area, lies within the DSD of Imbulpe and Balangoda, while the hydropower station is situated in the DSD of Weligepola and accounts for about 10% of country's hydroelectricity supply (CEB 2006). Population in the study area is not evenly distributed because of terrain and land-use pattern. The studied area of the Nuwara-eliya DSD is not populated, hence all population of Imbulpe and 30% of Balangoda DSD's, about 86,954 according to DCS (2008), constitute the total study area population.

The study area consists of seven agro-ecological regions, viz. WU_1, WU_2, WU_3, IU_2, IU_3, WM_3 and IM_2 (W-Wet, I-Intermediate, U-Up country, M-Mid country and 1, 2 and 3 are ranking orders according to rainfall amount and distribution patterns) (TEAMS 1992; Udayakumara et al. 2010). The mean annual rainfall varies from 900 to 3175 mm in the study area. Different soil groups can be found: WU_1, WU_2, WU_3, IU_2 and IU_3 zones are having red yellow podzolic soils and mountain regosols as major soil groups; WM_3 comprises of the reddish brown latosols, red yellow podzols and immature brown loams; while IM_2 comprises reddish brown earth and immature loams as major soil groups (TEAMS 1992).

Agriculture is the predominant occupation in the study area. Upstream, 50.2% HHs are engaged in agriculture, followed by employment in either the government or private sector (21.5%), small-scale enterprises (11.0%), small-scale trading (9.0%) or wage labour (8.3%), while these occupations involve 62.8%, 10.9%, 9.0%, 13.5% and 3.8%, respectively, in the downstream area (Table 1). Irrigated paddy is the major crop in the downstream area,

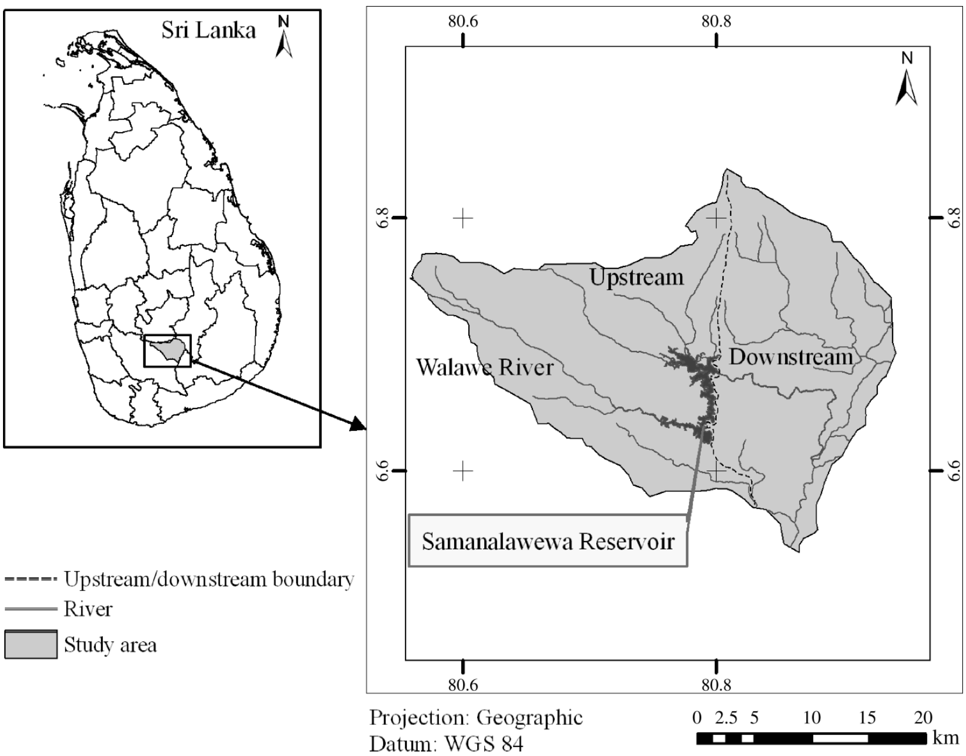

Figure 1. Location map of the study area.

Table 1. Summary of HH characteristics.

Characteristics	Upstream	Downstream
Family size	4.06	4.34
Average landholding (ha)	2.03	2.44
Occupation (% HH income)		
Agriculture	50.2	62.8
Employment	21.5	10.9
Small-scale enterprises	11.0	9.0
Small-scale trading	9.0	13.5
Wage labour	8.3	3.8

while in the upstream area tea and irrigated paddy are the major crops, and tomato and beans are grown by HHs (Udayakumara 2011). More than 84% of HHs in the study area have five family members. Upstream and downstream average family sizes and male:female ratios are 4.06, 1:99 and 4.34, 1:1, respectively. The average landholding per HH is 2.13 ha, with an average of 2.03 ha upstream and 2.44 ha downstream.

Methods

Data collection

The questionnaire study is mainly based on HH level data and assessed livelihoods of people in the area in two time periods (1988 and 2008) in terms of perceptions on the dynamics due to construction of the reservoir and farming systems and livelihood strategies. Data were also collected from other sources, such as interviews of key informants including village leaders, members of the Commune's People Committee and traders; map information on land use and topography (1:50,000) from the Department of Survey; tabular data from DSDs, the DCS of Sri Lanka and other reference material.

The study area consisted of 23,304 HHs of 67 upstream villages of which 15 were randomly selected, and 4638 HHs of nine selected downstream villages (DCS 2007). There was a total of 7269 HHs in the selected villages, that is, 5458 and 1811 upstream and downstream, respectively. Using Equation (1) (Yamane 1967), at 7% significance, the calculated sample size (n) required was 201. Thus, for the HH survey, 151 upstream and 50 downstream HHs ($n = 201$) were selected. Most questionnaires were filled during interviews with randomly selected HH heads of 28–72 years old; on the few occasions where HH heads were unavailable, the next most experienced person was interviewed. In general, an interview was lasted 1.5–2.0 h, between 16 February and 15 April 2009.

$$n = \frac{N}{(1 + N \times e^2)}, \qquad (1)$$

where n is the sample size, N the total HHs and e the significance (7%).

Assessment of livelihood

The sustainable livelihood framework (SLF), developed by Chambers and Conway (1992), and later expanded by the Department for International Development (DFID 1999) schematically formulates the interaction between internal and external factors of livelihood, which determine HH livelihood strategies and outcomes (Köeberlein 2003; Mahdi et al. 2009). Internal factors are the five capital assets, human, natural, financial, physical and social (DFID 1995). In general, the human asset (HA) represents skills, knowledge, ability to work and good health. The natural asset (NA) comprises the land, water, forests, wildlife resources, air quality, waste assimilation, erosion protection and biodiversity degree and rate of change. The financial asset (FA) consists of available stocks and regular inflows of money. The physical asset (PA) contains affordable transport, secure shelter and buildings, adequate water supply and sanitation, affordable energy and access to information. The social asset (SA) includes networks, connectedness and membership of more formalised groups (DFID 1999). External factors are vulnerability and transforming structures and process. Vulnerability consists of risks, stresses, emergencies and contingencies to which a HH is exposed (Bebbington 1999). Access to assets and scope for their application are influenced by the structural context, which encompasses laws, policies, institutions and governance. The structural context also has an impact on livelihood strategies (Mahdi et al. 2009).

As there was no EIA when SHER was constructed between 1988 and 1992, and given that numerous environmental and socioeconomic issues are associated with this, this study assessed livelihood for 1988 and 2008 separately for upstream and downstream HHs and also at the study area level to understand the change in the livelihood conditions of farms. The analytical framework followed for livelihood assessment was based on the SLF developed by international agencies, such as DFID, CARE, Oxfam and the United Nations Development Program (Carney 1998; Carney et al. 1999). We considered five livelihood assets (human, natural, financial, physical and social) as suggested in the framework. Each asset was represented by two to three selected indices, each of which was based on a number of individual decision variables ranging from one to four (Table 2). Livelihood index (LI) was computed as five capital assets: human asset index (HAI), natural asset index (NAI), financial asset index (FAI), physical asset index (PAI) and social asset index (SAI). Each of which was divided into sub-indices for each asset class using factor analysis, while decision variables were directly used in multiple regression and optimisation procedures, as these are important in policy interventions. Table 2 also contains the value category of each decision variable used to compute an individual index.

The skill and knowledge index consists of level of education, experience in training, knowledge gained from training and farmers' ability to solve farm problems (Table 2). Since production efficiency is positively related

Table 2. Livelihood capital assets, decision variables and index to measure their change.

Capital asset	Index	Decision variable	Value category
Human asset index	X_1 Skill and knowledge index	$X_{1.1}$ Level of education	Illiterate = 0, primary = 0.33, secondary = 0.66, tertiary = 1
		$X_{1.2}$ Experience in training	No = 0, 1/year = 0.33, 2–3/year = 0.66, >3/year = 1
		$X_{1.3}$ Knowledge gained from training	No = 0, low = 0.33, moderate = 0.66, high = 1
		$X_{1.4}$ Ability to solve farm problems alone	No = 0, sometimes = 0.33, usually = 0.66, always = 1
	X_2 Leadership potential index	$X_{2.1}$ Representative of community	No = 0, 1/year = 0.33, 2–3/year = 0.66, >3/year = 1
		$X_{2.2}$ Facilitator in community	No = 0, 1/year = 0.33, 2–3/year = 0.66, >3/year = 1
	X_3 Family labour index	$X_{3.1}$ Family labour	≤14 years = 0, ≥65 years = 0.5, 15–64 years = 1
Natural asset index	X_4 Soil potential index	$X_{4.1}$ Rating current soil fertility	Very bad = 0, bad = 0.33, fair = 0.66, good = 1
		$X_{4.2}$ Trend of soil fertility change	Rapid decrease = 0, decrease = 0.25, no change = 0.5, increase = 0.75, rapid increase = 1
	X_5 Water potential index	$X_{5.1}$ Water sufficiency for crops	Usually deficient = 0, often deficient = 0.33, sometime deficient = 0.66, always sufficient = 1
		$X_{5.2}$ Flood damage to crops	Usually = 0, often = 0.33, sometimes = 0.66, rarely = 1
		$X_{5.3}$ Drought damage of crops	Usually = 0, often = 0.33, sometimes = 0.66, rarely = 1
Financial asset index	X_6 Savings index	$X_{6.1}$ Savings	Available annual savings of *i*th farmer/highest available annual savings
	X_7 Income index	$X_{7.1}$ HH income	Annual HH income of *i*th farmer/highest annual HH income
Physical asset index	X_8 Transportation potential index	$X_{8.1}$ Transport potential to farm	None = 0, difficult = 0.33, sometimes difficult = 0.66, easy = 1
	X_9 Access to machinery index	$X_{9.1}$ Access agric. machinery for farm	None = 0, difficult = 0.33, sometimes difficult = 0.66, easy = 1
Social asset index	X_{10} Access to agric. information index	$X_{10.1}$ Access to agric. information	None = 0, <1/week = 0.25, 1/week = 0.5, 2–4 d/week = 0.75, >4 d/week = 1
	X_{11} Participation index	$X_{11.1}$ Participation in soil and water conservation organisations/committees	None = 0, rare = 0.25, sometimes = 0.5, often = 0.75, always = 1
	X_{12} Membership index	$X_{12.1}$ Membership in group/committee	None = 0, low = 0.33, high = 0.66, committee member = 1

Notes: Indices were calculated based on Miah (1993): Index $= \sum X_i W_i / N$, where X_i is the individual level; W_i is the respective weight; and N is the number of responses in each group.

to education (Chaudhry 2001), this is an important variable governing decision-making in farm production. Education is also associated with access to new information on farm production, consequences of soil erosion and conservation (Ervin CA and Ervin DE 1982; Abeygunawardena 1983; Norris and Batie 1987; McDowell and Sparks 1989; Illukpitiya and Gopalakrishnan 2004). Better education leads to easier adoption of modern agricultural technologies, and more educated farmers with technical skills follow agricultural intensification.

The leadership potential index consists of being a representative and facilitator in the community (Table 2). For example, in cooperatives and social coherence, which reflect farmers' ability to organise into groups, influence development, planning and budgeting activities or obtain formal credit or market access, which is conductive to increased farm production with decreased soil erosion (Wahid et al. 2008).

The family labour index is the active labour force of HHs in the economically active age range 15–64 years (CBSL 2007), indicating the importance of family labour in farming activities (Illukpitiya and Gopalakrishnan 2004). As a farmer ages, it is reasonable to assume that he pays less attention to long-term investment and may be more interested in short-term agricultural activities without harming the environment.

The soil potential index consists of soil fertility rating and trend of change in soil fertility as perceived by farmers. Soil nutrients are indispensable for crop growth and production. Crops require nitrogen (N), phosphorus (P) and potassium (K) macronutrients, together with several micronutrients (Shrestha 2004).

The water potential index is also a basic factor that plays a crucial role in crop growth. Understanding how water is added to and extracted from soil helps in managing the required moisture for crops (Shrestha 2004). This index consists of three variables, water sufficiency, events of flood damage and drought damage to crops.

The savings and income index considers credit availability for farming activities, where the higher the HH income from agriculture, the greater is agricultural expansion (Wahid et al. 2008). If availability of credit is high, a farmer can invest more in soil conservation (Illukpitiya and Gopalakrishnan 2004), resulting in increased farm production.

The transportation potential index refers to physical accessibility of transport to fields for transportation of inputs and harvest.

The access to machinery index refers to accessibility to field machinery, for example, tractors and harvesters important in farming activities that influence farm production.

The access to agricultural information index refers to accessibility to information on farming methods through the media or extension officers to facilitate better farming practices leading to increased production.

The participation index refers to level of participation in other activities, for example, community activities or government meetings. This is an important SA.

The membership index refers to involvement of HHs in group or committee participation and membership. This is also an important SA.

The assessment of livelihood was carried out to compare ecological units (upstream, downstream) and time periods (1988 and 2008). Various scaling and indexing techniques (Table 2) were used to analyse the survey data using SPSS™ 16.0 software.

Identification of livelihood determinants

Multivariate analyses, that is, factor analysis and multiple linear regression, were carried out to examine the relationship of underlying factors of livelihood in the study area. To examine underlying patterns or relationships for a large number of variables and determine the state of factors in livelihoods, factor analysis was used (Hair et al. 1992). For regression analysis, the dependent variable (Y) was individual household livelihood index (HHLI) and independent variables were 19 livelihood decision variables (Table 2; $X_{1.1} - X_{12.1}$). First, using Pearson's correlation test, significant variables attributed to HHs' LI were identified; then stepwise regression identified the most important variables for LI for each of ecological unit, following Equation (2):

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_{12} X_{12}, \tag{2}$$

where Y is the vector of explained indicator; β_0 the intercept to be estimated; $X_1 \ldots X_{12}$ the vector of explanatory indicators; and $\beta_1 \ldots \beta_{12}$ the coefficients to be estimated.

Optimisation for livelihood improvement

Numerous quantitative mathematical tools have been developed to analyse and support decision-making in agricultural research (Agrawal and Heady 1972; Bohlmann 2006). Linear programming (LP) optimises some linear objective functions subject to certain linear constraints in order to explore the optimum solution (Minh et al. 2007). For this study, LP was selected to formulate the appropriate composition of livelihood-related decision variables with potential to increase current LI. The LP models can have maximising or minimising functions (Hillier and Lieberman 2001). The maximising model in Equation (3) and model characteristics are given below. For this analysis, decision variables were selected from obtained results of the step-wise multiple regression analysis. Finally, non-negative constraint is considered for the selected decision variables, and Solver in Microsoft Excel was used for optimisation modelling (Ragsdale 1998). The objective function

$$LI_{\max} = \beta_0 + \sum_{i=1}^{n} \beta_i X_i, \tag{3}$$

was subjected to non-negative constraints; $0 \le X_i \le 1$, for $i\{1, 2, \ldots, n\}$, where $LI_{\max}$ is the maximum LI; β_0 the intercept; β_i the coefficients; and X_i the decision variables.

Results and discussion

Socioeconomic characteristics of study area

Out of the total surveyed population, 53.5% were 15–64 years old or economically active, 19.2% were below 15 years, 27.3% were 65 years and above. In general higher education is low in the area as only 10% of the population had attended university and about 5% are illiterate. Nearly three-quarters have grade 6–12 education and 10% attended grade 1–5. The proportion of HHs owning the land was higher upstream (88.8%) compared to downstream (74.6%). The proportion of HHs renting land for cultivation was lower upstream (7.6%) compared to downstream (14.9%). Similarly, HHs who rented out land were also lower upstream (1.8%) compared to downstream (4.5%). Other types of land tenure, such as land procured from parents, relatives or encroached crown land with no formal ownership or ambiguous property rights, were not accounted for. The annual average HH income for upstream and downstream HHs was US$2794 and US$3197, respectively, in 2008.

Livelihood dynamics

The average LI upstream and downstream was 0.55 and 0.62, respectively, in 1988 (Table 3), indicating relatively better livelihood downstream than upstream, although the

Table 3. Livelihood asset index and decision variables in 1988 and 2008.

Livelihood asset index	Year	Upstream		Downstream		*t*-Value	Significance
		Average	SD	Average	SD		
HAI	1988	0.35	0.15	0.37	0.15	0.90	0.37
	2008	0.43	0.15	0.41	0.15	0.83	0.41
X_1 Skill and knowledge index	1988	0.31	0.20	0.28	0.22	0.90	0.34
	2008	0.34	0.15	0.28	0.16	2.54	0.01*
X_2 Leadership potential index	1988	0.35	0.27	0.42	0.28	−1.42	0.16
	2008	0.54	0.27	0.50	0.25	0.87	0.39
X_3 Family labour index	1988	0.39	0.17	0.15	0.23	−1.05	0.30
	2008	0.40	0.18	0.44	0.24	−1.29	0.20
NAI	1988	0.81	0.09	0.75	0.13	3.02	0.01**
	2008	0.60	0.15	0.68	0.17	−3.11	0.01**
X_4 Soil potential index	1988	0.68	0.16	0.66	0.19	0.98	0.33
	2008	0.39	0.24	0.49	0.29	−2.53	0.012*
X_5 Water potential index	1988	0.93	0.12	0.86	0.16	3.55	0.001**
	2008	0.81	0.16	0.85	0.13	−2.08	0.04*
FAI	1988	0.64	0.16	0.74	0.13	−3.88	0.01**
	2008	0.64	0.16	0.69	0.13	−2.33	0.01*
X_6 Savings index	1988	0.62	0.22	0.75	0.12	−3.97	0.01**
	2008	0.62	0.20	0.69	0.13	−2.40	0.02*
X_7 Income index	1988	0.64	0.18	0.70	0.15	−2.59	0.01**
	2008	0.64	0.17	0.69	0.13	−1.85	0.07
PAI	1988	0.59	0.31	0.88	0.23	−6.14	0.01**
	2008	0.70	0.31	0.96	0.10	−5.69	0.01**
X_8 Transportation potential index	1988	0.61	0.36	0.89	0.23	−5.17	0.01**
	2008	0.75	0.35	0.96	0.09	−4.29	0.01**
X_9 Access to machinery index	1988	0.56	0.33	0.87	0.25	−6.15	0.01**
	2008	0.66	0.34	0.95	0.14	−6.06	0.01**
SAI	1988	0.38	0.13	0.35	0.11	1.47	0.14
	2008	0.50	0.13	0.47	0.11	1.12	0.26
X_{10} Access to agric. information index	1988	0.29	0.16	0.21	0.16	3.05	0.01**
	2008	0.43	0.22	0.35	0.19	2.49	0.02*
X_{11} Participation index	1988	0.65	0.27	0.66	0.28	−0.10	0.99
	2008	0.66	0.25	0.68	0.25	−0.56	0.57
X_{12} Membership index	1988	0.19	0.07	0.18	0.06	0.98	0.33
	2008	0.40	0.07	0.39	0.06	0.62	0.54

Notes: SD = standard deviation. ** and *significant at the 0.01 and 0.05 levels, respectively.

range of LI was slightly wider downstream (SD 0.24 compared to 0.19, respectively). By 2008, average LI increased in both areas (0.57 upstream and 0.64 downstream). Other trends, such as proportionate change in average LI and range within each group did not differ much between the two areas. Upstream, during the last 20 years, HAI, PAI and SAI increased, while NAI decreased and FAs were unchanged (Table 3). Increase in overall HAI was due to an increase in the indices of skill and knowledge, leadership potential and family labour. PAI variables, indices of transport potential and access to machinery, increased; SAI variables, access to agricultural information, participation and membership, increased; a decrease in NAI was due to a decrease in indices of soil and water potential (Table 3). Downstream, HAI, PAI and SAI also increased in the last two decades, while NAI and FAI (Table 3). A substantial increase in family labour index (193%) contributed to an overall HAI increase. Similarly, access to agricultural information (67%) and membership (117%) were major contributors to SAI. A decrease in soil potential index was the major reason for the decrease in NAI. With regard to dynamics of livelihood assets in upstream and downstream areas, HAI and SAI increased in both areas between 1988 and 2008, with slightly higher rate upstream, whereas PAI showed an opposite trend (Table 3). NAI decreased in both cases, implying natural resources depletion, which was higher upstream.

Determinants of livelihood

The factors influencing LI, a measure of livelihood, were identified using factor analysis, followed by multiple regression. In the surveyed HHs upstream, 19 variables representing livelihood asset indices of farm HH were analysed, and all showing significant covariance (>0.3) at a 0.05 significance were identified and entered into the factor model. Varimax with Kaiser normalisation rotation method (Hair et al. 1998) extracted six sets of uncorrelated variables in convergence of five iterations (Table 4). The communality, expressing the linear association between a particular variable and another variables in the model, was >0.50 for all included variables. An eigenvalue >1.0 was set to limit the number of factors to be extracted. The extracted factors cumulatively explained 65.46% of total variance associated with factors for LI in the upstream area.

Table 4. Rotated factor matrix of livelihood asset indices in upstream HHs.

Decision variable	Factor 1	2	3	4	5	6	Communality
$X_{1.3}$	0.90						0.51
$X_{1.4}$	0.90						0.70
$X_{1.2}$	0.82						0.86
$X_{10.1}$	0.68						0.86
$X_{2.2}$	0.63						0.52
$X_{11.1}$	0.61						0.67
$X_{2.1}$	0.58						0.74
$X_{8.1}$		0.85					0.64
$X_{9.1}$		0.83					0.79
$X_{7.1}$		0.76					0.60
$X_{6.1}$		0.68					0.80
$X_{4.2}$			0.85				0.62
$X_{4.1}$			0.77				0.74
$X_{5.1}$				0.72			0.73
$X_{5.3}$				0.62		0.43	0.63
$X_{12.1}$				0.56			0.50
$X_{3.1}$					0.84		0.54
$X_{1.1}$					0.50		0.51
$X_{5.2}$						0.89	0.75
Eigenvalue	4.25	2.60	1.55	1.39	1.32	1.32	
% Variance	22.35	13.69	8.16	7.33	6.97	6.96	
% Cumulative	22.35	36.04	44.21	51.53	58.50	65.46	

Note: Sample size (n) = 151.

The first factor comprised seven decision variables with higher factor loadings (>0.5), knowledge gained from training ($X_{1.3}$), ability to solve farm problems ($X_{1.4}$), experience in training ($X_{1.2}$), access to agricultural information ($X_{10.1}$), facilitator in the community ($X_{2.2}$), participation in soil conservation committees ($X_{11.1}$) and representative of community ($X_{2.1}$), which mostly represent awareness and responsibility elements of the human and social index. Four variables were associated with the second factor namely, transport potential to farmland ($X_{8.1}$), access to field machinery ($X_{9.1}$), HH income ($X_{7.1}$) and savings ($X_{6.1}$), representing infrastructure and economic well-being of HHs for PAs and FAs. Likewise, the third factor consisted of two variables, namely trends of soil fertility ($X_{4.2}$) and rating of current soil fertility ($X_{4.1}$), and the fourth factor contained water sufficiency for crops ($X_{5.1}$), drought damage to crops ($X_{5.3}$) and membership in committees ($X_{12.1}$). The fifth factor comprised availability of labour ($X_{3.1}$) and education level ($X_{1.1}$), and the sixth factor contained only one variable – flood damage to crops ($X_{5.2}$).

In the surveyed HHs downstream, factor analysis extracted seven sets of uncorrelated variables in convergence of eight iterations (Table 5). The communalities for all variables were >0.56, indicating the appropriateness of the included variables. The extracted seven factors cumulatively explained 73.75% of total variance, with the first factor explaining 17.77% (Table 5). There was a positive correlation among all factor loadings. The first factor included five variables, namely ability to solve farm problems ($X_{1.4}$), knowledge gained from training ($X_{1.3}$), experiences in training ($X_{1.2}$), participation in soil conservation committees ($X_{11.1}$) and facilitator in the community ($X_{2.2}$). These variables were similar to upstream HHs, indicating awareness and responsibility of HA and SA. Four variables associated with the second factor, namely savings ($X_{6.1}$), HH income ($X_{7.1}$), current soil fertility ($X_{4.1}$) and soil fertility change ($X_{4.2}$). The third factor contained family labour ($X_{3.1}$), drought damage of crops ($X_{5.3}$) and water sufficiency for crops ($X_{5.1}$); the fourth factor comprised transport potential to farmland ($X_{8.1}$) and access field machinery ($X_{9.1}$); the fifth factor consisted of representative of community ($X_{2.1}$) and access to agricultural information ($X_{10.1}$); the sixth factor contained the variables flood damage to crops ($X_{5.2}$) and membership in committees ($X_{12.1}$); and the seventh factor contained only one variable, level of education ($X_{1.1}$).

Based on the variables extracted in both cases, there is some similarity in terms influencing livelihoods in both areas; this was analysed with multiple regression (Tables 6 and 7). Upstream, out of 19 variables, only nine were statistically highly significant predictors of HHLI, ranging from 36% to 71% (Table 6). The first decision variable was experience in training, followed by HH income, transportation potential to farmland, knowledge gained from training, level of education, participation in soil conservation committees, membership in committees, rating of soil fertility and water sufficiency for crops. Although all models were significant, those with more predictor variables had higher adjusted R^2 implying superiority in terms of predictive power. All the predictor variables were positively related with HHLI except $X_{12.1}$, which may due to low membership in committees in upland HHs (Table 3).

Table 5. Rotated factor matrix of livelihood asset indices in downstream HHs.

Decision variable	Factor							Communality
	1	2	3	4	5	6	7	
$X_{1.4}$	0.94							0.72
$X_{1.3}$	0.94							0.73
$X_{1.2}$	0.73							0.91
$X_{11.1}$	0.71							0.91
$X_{2.2}$	0.49				0.40		0.42	0.73
$X_{6.1}$		0.94						0.75
$X_{7.1}$		0.93						0.69
$X_{4.1}$		0.76						0.63
$X_{4.2}$		0.75						0.64
$X_{3.1}$			0.80					0.56
$X_{5.3}$			0.77					0.80
$X_{5.1}$			0.68					0.82
$X_{8.1}$				0.78				0.67
$X_{9.1}$				0.78				0.68
$X_{2.1}$					0.76			0.64
$X_{10.1}$					0.69			0.60
$X_{5.2}$						0.87		0.70
$X_{12.1}$						0.60		0.92
$X_{1.1}$							0.75	0.91
Eigenvalue	3.38	3.06	1.79	1.60	1.51	1.40	1.28	
% Variance	17.77	16.08	9.43	8.43	7.96	7.35	6.74	
% Cumulative	17.77	33.84	43.28	51.71	59.66	67.00	73.75	

Note: Sample size (n) = 50.

Table 6. Regression estimates of determinants of LI of upstream HHs.

Predictor decision variable	Coefficients of models								
	1	2	3	4	5	6	7	8	9
β_0	0.43	0.23	0.23	0.23	0.23	0.20	0.29	0.26	0.23
$X_{1.2}$	0.21	0.16	0.17	0.11	0.10	0.08	0.08	0.09	0.08
$X_{7.1}$		0.36	0.25	0.21	0.18	0.16	0.16	0.14	0.12
$X_{8.1}$			0.09	0.10	0.12	0.12	0.12	0.12	0.12
$X_{1.3}$				0.09	0.09	0.08	0.08	0.08	0.08
$X_{1.1}$					0.08	0.08	0.08	0.07	0.08
$X_{11.1}$						0.08	0.08	0.09	0.09
$X_{12.1}$							−0.21	−0.20	−0.18
$X_{4.1}$								0.05	0.05
$X_{5.1}$									0.05
R	0.60	0.75	0.77	0.79	0.82	0.83	0.83	0.84	0.84
R^2	0.36	0.56	0.59	0.63	0.66	0.68	0.69	0.70	0.71
Adjusted R^2	0.35	0.55	0.58	0.62	0.65	0.67	0.68	0.69	0.69
Significance	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Notes: β_0, intercept; $X_{1.2}$, experience in training; $X_{7.1}$, HH income; $X_{8.1}$, transport potential to farm; $X_{1.3}$, knowledge gained from training; $X_{1.1}$, level of education; $X_{11.1}$, participation in soil conservation committees; $X_{12.1}$, membership in committees; $X_{4.1}$, rating of current soil fertility; $X_{5.1}$, water sufficiency for crops.

In downstream HHs, 10 decision variables as highly significant predictors of HHLI were included in models (Table 7). The first variable was knowledge gained from training, followed by trend of soil fertility change, facilitator in the community, experience in training, savings, access to agricultural information, participation in soil conservation committees, level of education, representative of community and water sufficiency for crops (Table 7). The variance explained by the models ranged from 54% to 95%, which was higher than in upstream HHs.

Options for livelihood improvement

Improvement in livelihood needs manipulation of variables related to LI. Most variables are positively related with HHLI and thus HHLI can be raised by improvement in these variables. A final model for upstream (model 9) and downstream (model 10) areas was selected to identify level of improvement needed in the decision variables. First, the HHs in each category, that is, upstream and downstream, were grouped into five to six groups and an LI target set for each group. Since, a radical improvement in current LI is rather impractical, a slightly higher LI for each group

Table 7. Regression estimates of determinants of LI of downstream HHs.

	Coefficients of models									
Predictor decision variable	1	2	3	4	5	6	7	8	9	10
β_0	0.56	0.52	0.52	0.51	0.40	0.37	0.33	0.33	0.31	0.29
$X_{1.3}$	0.15	0.16	0.14	0.09	0.09	0.08	0.08	0.07	0.08	0.08
$X_{4.2}$		0.11	0.10	0.09	0.05	0.05	0.05	0.06	0.05	0.05
$X_{2.2}$			0.08	0.08	0.08	0.07	0.06	0.06	0.06	0.06
$X_{1.2}$				0.07	0.08	0.08	0.07	0.05	0.04	0.04
$X_{6.1}$					0.19	0.19	0.21	0.20	0.21	0.20
$X_{10.1}$						0.09	0.09	0.09	0.08	0.08
$X_{11.1}$							0.06	0.06	0.06	0.06
$X_{1.1}$								0.04	0.04	0.04
$X_{2.1}$									0.03	0.03
$X_{5.1}$										0.04
R	0.73	0.84	0.89	0.91	0.94	0.95	0.96	0.97	0.97	0.97
R^2	0.54	0.71	0.79	0.83	0.88	0.91	0.92	0.93	0.94	0.95
Adjusted R^2	0.53	0.70	0.77	0.82	0.87	0.90	0.91	0.92	0.93	0.93
Significance	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Notes: β_0, intercept; $X_{1.3}$, knowledge gained from training; $X_{4.2}$, trend of soil fertility change; $X_{2.2}$, facilitator in community; $X_{1.2}$, experience in training; $X_{6.1}$, savings; $X_{10.1}$, access to agric. information; $X_{11.1}$, participation in soil conservation committees; $X_{1.1}$, level of education; $X_{2.1}$, representative of community; $X_{5.1}$, water sufficiency for crops.

Table 8. Current and optimised LI values for upstream HHs.

		Current values of decision variables								
Current range	% HHs	$X_{1.2}$	$X_{7.1}$	$X_{8.1}$	$X_{1.3}$	$X_{1.1}$	$X_{11.1}$	$X_{12.1}$	$X_{4.1}$	$X_{5.1}$
<0.40	8.0	0.14	0.42	0.23	0.06	0.06	0.40	0.39	0.52	0.64
0.40–<0.50	19.9	0.35	0.53	0.67	0.28	0.02	0.42	0.42	0.52	0.65
0.50–<0.60	23.2	0.66	0.60	0.68	0.66	0.20	0.73	0.41	0.45	0.66
0.60–<0.65	19.9	0.85	0.70	0.78	0.84	0.22	0.77	0.39	0.54	0.76
0.65–<0.70	26.5	0.96	0.77	0.96	0.89	0.35	0.76	0.39	0.63	0.72
0.70–<0.75	2.5	1.00	0.81	1.00	1.00	0.75	0.81	0.49	0.75	1.00
		Optimised values of decision variables								
Current range	Target LI	$X_{1.2}$	$X_{7.1}$	$X_{8.1}$	$X_{1.3}$	$X_{1.1}$	$X_{11.1}$	$X_{12.1}$	$X_{4.1}$	$X_{5.1}$
<0.40	0.55	0.50	0.64	0.47	0.41	0.43	0.66	0.26	0.61	0.70
0.40–<0.50	0.60	0.60	0.72	0.80	0.51	0.39	0.54	0.27	0.59	0.72
0.50–<0.60	0.65	0.78	0.76	0.75	0.73	0.39	0.82	0.29	0.54	0.70
0.60–<0.65	0.70	0.90	0.86	0.83	0.87	0.38	0.87	0.30	0.58	0.80
0.65–<0.70	0.75	0.97	0.94	0.99	0.92	0.49	0.87	0.30	0.67	0.76
0.70–<0.75	0.80	1.00	0.93	1.00	1.00	0.77	0.92	0.31	0.76	1.00

Notes: $X_{1.2}$, experience in training; $X_{7.1}$, HH income; $X_{8.1}$, transport potential to farm; $X_{1.3}$, knowledge gained from training; $X_{1.1}$, level of education; $X_{11.1}$, participation in soil conservation committees; $X_{12.1}$, membership in committees; $X_{4.1}$, rating of current soil fertility; $X_{5.1}$, water sufficiency for crops; LI, livelihood index.

average was set as the target LI. In upstream HHs, current LIs ranged from 0.29 to 0.74 (Table 8); among surveyed upstream HHs, 8% had minimum LI of 0.29–0.40, and about 28% of these HHs were below average LI. There were no HHs with the upper level of livelihood assets, that is, >0.75. It was assumed that all HHs should achieve at least above average LI (>0.5; Table 8). With the target of improving LI to 0.55, optimisation showed improvement needed in the current state of decision variable experience in training is about 3.6-fold, HH income is 1.5-fold, transport potential to farmland is twofold, knowledge gained from training is 6.8-fold, level of education is 7.2-fold, participation in soil conservation committees is 1.7-fold, current soil fertility is 1.2-fold and water sufficiency for crops is 1.1-fold. While improvement in each category is needed, substantial improvement in education level is required.

Similarly in downstream HHs, the current LI ranged from 0.51 to 0.79, indicating relatively better livelihood compared to upstream HHs (Table 9). In downstream areas 30% of HHs belonged to 0.51 to <0.60 LI category, 24% to 0.6–0.65, 26% HH to 0.65–0.7 and 16% to 0.7–0.75 (Table 9); only 4% had an LI value of 0.75–0.80. Optimisation showed that to achieve a target LI of 0.65 in case of HH with <0.6 LI, improvements in the decision variables access to agricultural information, representative of community, knowledge gained from training, soil fertility change, facilitator in community, experience in training, savings, participation in soil conservation committees and level of education require increases of 1.1, 1.1,

Table 9. Current and optimised LI values for downstream HHs.

		Current values of decision variables									
Current range	% HHs	$X_{1.3}$	$X_{4.2}$	$X_{2.2}$	$X_{1.2}$	$X_{6.1}$	$X_{10.1}$	$X_{11.1}$	$X_{1.1}$	$X_{2.1}$	$X_{5.1}$
<0.60	30.0	0.02	0.35	0.01	0.04	0.69	0.24	0.45	0.01	0.69	0.80
0.60–<0.65	24.0	0.75	0.17	0.08	0.47	0.62	0.32	0.70	0.14	0.72	0.77
0.65–<0.70	26.0	0.74	0.46	0.28	0.59	0.68	0.39	0.80	0.20	0.92	0.79
0.70–<0.75	16.0	1.00	0.54	0.37	0.75	0.68	0.53	0.86	0.29	0.76	0.72
0.75–<0.80	4.0	0.83	0.83	1.00	0.66	0.75	0.35	0.88	0.33	1.00	0.83
		Optimised values of decision variables									
Current range	Target LI	$X_{1.3}$	$X_{4.2}$	$X_{2.2}$	$X_{1.2}$	$X_{6.1}$	$X_{10.1}$	$X_{11.1}$	$X_{1.1}$	$X_{2.1}$	$X_{5.1}$
<0.60	0.65	0.29	0.44	0.21	0.18	0.94	0.26	0.53	0.14	0.73	0.83
0.60–<0.65	0.70	0.81	0.26	0.24	0.52	0.84	0.35	0.76	0.23	0.75	0.80
0.65–<0.70	0.75	0.78	0.51	0.37	0.62	0.88	0.43	0.85	0.28	0.93	0.81
0.70–<0.75	0.80	1.00	0.55	0.42	0.76	0.89	0.56	0.87	0.32	0.96	0.92
0.75–<0.80	0.85	0.90	0.86	1.00	0.72	1.00	0.38	0.92	0.34	1.00	0.85

Notes: $X_{1.3}$, knowledge gained from training; $X_{4.2}$, trend of soil fertility change; $X_{2.2}$, facilitator in community; $X_{1.2}$, experience in training; $X_{6.1}$, savings; $X_{10.1}$, access to agric. information; $X_{11.1}$, participation in soil conservation committees; $X_{1.1}$, level of education; $X_{2.1}$, representative of community; $X_{5.1}$, water sufficiency for crops.

14.5, 1.3, 21.0, 4.5, 1.4, 1.2 and 14.0 times, respectively. Slight improvement is needed in all categories to achieve the targeted LI is respective categories (Table 9).

Conclusions and policy implications

Livelihood of HHs in the watershed in general has slightly improved in the last two decades, however livelihood of downstream HHs was slightly better than that of upstream HHs. On the other hand, livelihood assets, such as HA, PA and SA have increased for both upstream and downstream HHs. The upstream HHs have more HA and SA but fewer PAs compared to downstream HHs. FAs are unchanged upstream but slightly decreased downstream. Moreover, NAs have declined in both areas, notably in the upstream area. This manifests the ever declining natural resource stocks and their degradation in the study area.

A number of determinants influence HH livelihoods. Knowledge gained from the training, education, participation in soil and water conservation committees and water sufficiency for crops are common determinants in both upstream and downstream areas. Other determinants, such as HH income, transport potential to farmland, participation as members in soil and water conservation committees and current soil fertility are specifically important in upstream area, whereas representative of community, savings, access to agriculture information, soil fertility change and participation as a facilitator in the community are significant determinants in downstream area.

It is evident that slight changes in livelihood assets coincide with the period of reservoir construction in the Samanalawewa watershed. Negative change in natural and FAs and slow growth of livelihood are major concerns in the area as these can be constrained by factors such as education level, which is generally low and thus poses as a constraint for livelihood improvement. Hence, the potentials for improving livelihood of HHs in both upstream and downstream areas include raising awareness, providing training and increasing education level, besides bringing improvements in other decision variables. However, the level of effort required is higher in the upstream area due to a comparatively low level of livelihoods. Given that majority of upstream HHs have their own land and tenure security, developing better land conservation practices for supporting on-farm based livelihoods will also help to reduce natural resource depletion through reduced dependency of HHs on common property resources. This is one important area for policy intervention to reduce natural resource depletion and improve HH livelihoods.

Acknowledgements

Financial support is acknowledged from the Improving Relevance and Quality of Undergraduate Education (IRQUE) – a World Bank Project implemented by Sabaragamuwa University of Sri Lanka, academic and partial scholarships provided by the Asian Institute of Technology (AIT) for the first author's doctoral studies. Thanks are also due to Professor Shivakoti for suggestions and literature support on livelihood assessment, to Dr. Schmidt-Vogt and Dr. Samarakoon for discussion during the course of the study. We sincerely appreciate constructive comments of the editor and reviewers, which helped to improve the quality of the manuscript.

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