Energy & Environment: Micro Hydroelectric Power Generation as an Integral Component of Participatory Watershed Management[1]

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INTRODUCTION

This paper examines a participatory and "market oriented" natural resources conservation effort. In this effort the International Irrigation Management Institute, IIMI, catalysed a process of mobilising resource users, Non Government Organizations (NGOs) and Government Agencies to **develop a micro hydro-electric power plant, MHPP, and to establish a participatory conservation program in the catchment**. This joint venture was initiated by the Shared Control of Natural Resources, SCOR Project. SCOR is being implemented jointly by IIMI and the Sri Lankan Government and financed by the United States Agency for International Development, USAID.

SCOR is a participatory **watershed management** project aimed at developing and testing a holistic interdisciplinary approach to **integrate environmental and conservation concerns with production goals.** The conservation strategy being tested in SCOR is different from traditional approaches. SCOR hypothesizes that a **package** of measures -- such as type of vegetation/crops, appropriate land and water saving and conservation practices, user rights to earn economic and other benefits from the (participatory) conservation of natural resources -- are more effective in protecting environmentally fragile lands in water basins and watersheds. The "package" should be selected in consultation with (or jointly with) the users and both conservation and production or other profitable uses of natural resources should be incorporated into the package. This means that the package provides adequate incentives -- such as profits, desired cash flow as well as non-monetary benefits -- to the user to motivate her/him to

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[1] Paper presented at the First Philippine International Conference and Exhibition on Agricultural Engineering and Related Technologies under the theme "Energy and Environment: Sustainability and Development Challenges", 22-26 April, 1996, Central Luzon State University, Philippines.
A Preliminary analysis of this Micro/Hydroelectric Power Project was presented by this author jointly with Nishantha Edirisinghe, D Wijenayake and Oscar Amarasinghe, to the Symposium on Rehabilitation of the Nilwala Basin, jointly organised by The Institution of Engineers, Sri Lanka and Engineering Research Unit, Faculty of Engineering Technology, The Open University of Sri Lanka, 26 & 27 January, 1996.

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protect natural resources. Unless the "actors" are informed by the knowledge of potential impact and unless the profitable alternatives exist, environmentally inappropriate decisions will continue to be made.

SCOR approach is being tested and demonstrated in two pilot watersheds in Sri Lanka, namely Huruluwewa in the North Central Province (dry zone) and **Nilwala** in the Southern Province (wet zone). Micro Hydroelectric Power Generation, discussed in this paper, is included as an integrated component of watershed management in the **Nilwala** area.

The Nilwala watershed is located in the low country wet-zone agro-ecological region. The Nilwala river starts at an elevation of 1050 meters. The area covered by the watershed is about 1000 sq. kilometers while the river itself is 70km long. The annual rainfall within the watershed ranges from 2000 mm near the coast and about 4000 mm in the hilly areas. The upper watershed comprises of about 6000 ha of forest in two reserved areas. It has recommended that felling operations should not be undertaken in these two reserves as well as in the areas reserved along the river banks. However, illicit felling and clearing of the boundary of these reserves for plantation crops - especially tea - are taking place. Tea plantations exist even in the middle of forest reserves. Improper selection of sites for tea planting combined with improper planting and other agronomic operations have resulted in severe soil erosion and fast degradation of the land areas. Unplanned extraction of non-timber products such as rattan, bamboo, and medicinal products, although illegal, is taking place at a rate! The reservations along the banks of the river have been encroached by the people living by its source. Poor agronomic practices, partly related to insecurity of tenure, have resulted in a high degree of soil erosion. Both illicit and legitimate gemming take place along the river thus accelerating bed scour and river bank erosion. These have resulted in faster flow of the river and drying up of adjacent areas. People living downstream complain of water problems not only for cultivation but even for drinking. This process of drying up the land is common in the lower reach of the river where the Nilwala flood protection program is in operation. The program involves the operation of flood protection dikes and the pumping of flood water from the land area into the river which is ultimately discharges into the sea. Because of the intense pumping operation, the fresh water is taken out of the land which results in faster drying up of the land.

The terrain is steep only in the upper catchment of the Nilwala watershed and the river flows across a flat landscape for most part of its length. Hence, micro hydroelectric power generation is expected to be profitable only in the upper catchment.

Illukpitiya villagers are the primary beneficiaries of the Micro Hydro-electric Power Project (MHPP). The village is located in the Bovitiya Dola sub watershed of the Nilwala Watershed/basin. The viliage consist of about 100 families.

2. THE PARTICIPATORY DEVELOPMENT PROCESS OF MICRO HYDRO-ELECTRIC POWER PROJECT

In January 1994, SCOR facilitated a participatory appraisal of natural resource use in the Bovitiya Dola Sub Watershed (BSW). In the sub-watershed, participatory appraisal of the characteristic of resource uses and users as well as mapping of **current** resource use were done by groups comprising of resource users/farmers, local officials of government agencies such as Tea Small Holdings Authority, Agriculture, Forestry and Agrarian Services departments, IIMI-SCOR professionals and catalysts. The SCOR catalysts took the lead role in preparing the resource use maps and recording information. General objectives of this Participatory Rapid Appraisal were to:

a) Prepare a **detailed** map of the sub watershed or tank ecosystem indicating: the land use pattern of **individual holdings** in the entire sub-watershed, cropping/vegetation patterns, type and quality of cropping/vegetation cover, natural drainage system, road network, residential pattern.

b) Develop a database, including basic data such as: type and membership of user organizations, if any, land fragmentation, ownership and tenurial patterns, cropping patterns and intensities (current and in the recent past), slope category, apparent degree of soil erosion, conservation practices, cultivation practices, input use of agriculture, production and productivity, and constraints to production and conservation, yield performance, profits derives from different holdings in different zones. Social organizations including farmers organizations, conflicts, assistance from government support services and NGOs.

c) Establish a "baseline" for the resource use pattern using (a) and (b).

d) Sensitize the officials of relevant government agencies/NGOs, and resource users on the importance and need for this exercise and obtain their active participation in future work.

For this purpose, each group was provided with a line diagram/sketch map of 1:3000 scale with land marks indicating roads and streams for guidance. The groups collected data and mapped each land plot of the sub watershed. Refining of the map to maintain accuracy to scale was done subsequently by the draftsman supporting the group and the *map was used for participatory planning of resources management of the sub watershed.* Land and water use as well as other information collected through the participatory mapping exercise have been incorporated into the SCOR spatial database using a Geographic Information System (GIS). For example, Figure 1 shows the pre-project land use (as of April 1994) of the sub-watershed. Table 1 shows the pre-project land use pattern in the sub watershed.

Figure 1.

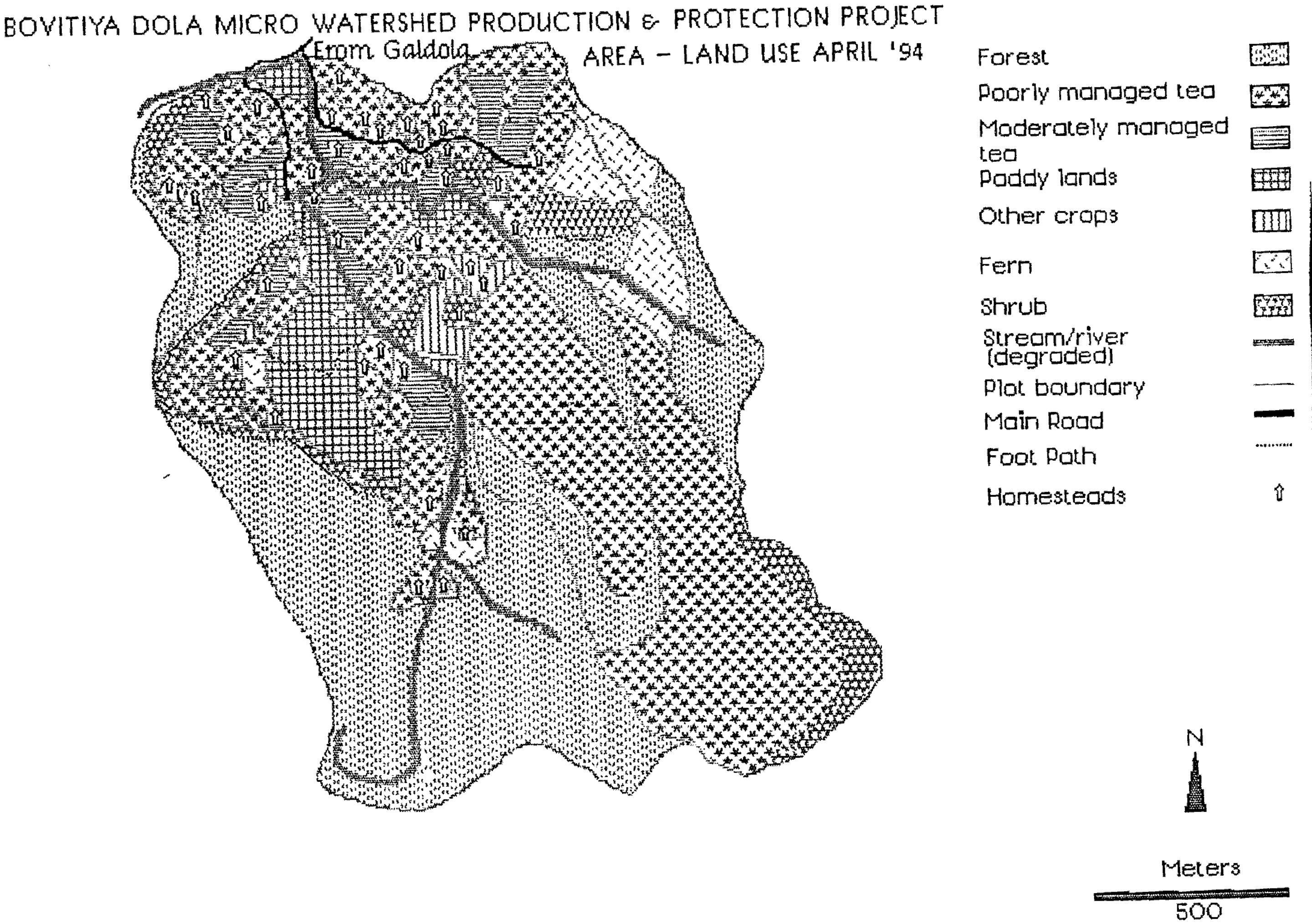

BOVITIYA DOLA MICRO WATERSHED PRODUCTION & PROTECTION PROJECT
From Galdola
AREA – LAND USE APRIL '94
Forest
Poorly managed tea
Moderately managed tea
Paddy lands
Other crops
Fern
Shrub
Stream/river (degraded)
Plot boundary
Main Road
Foot Path
Homesteads
N
Meters
500

Table 1 Pre-Project Land Use Pattern - Bovitiya Dola Sub Watershed

Land Use	Area (ha)	% Area
Forest		
high forest	18	10.3
degraded forest	12	7.0
fern & shrub etc.	14	8.1
Tea	102	58.5
Homestead	11	6.3
Paddy	7	4.0
Other	10	5.8
	174	100.0

Subsequently a participatory planning exercise was conducted and a resource management plan was formulated for the sub watershed. This was aimed at changing land and water use pattern to a more diversified resource use combining production (including hydroelectric power generation) and conservation using appropriate technologies; novel shared control arrangements. This means that the villagers have "action-plans" that guide them along a path to the planned future from the current status of resource use. For example, planned change of land use indicated the following:

Forest cover	-	25% high forest
	-	05% well conserved "stream gardens" (horticultural crops & bamboo etc. with conservation measured)
Tea & Homegardens	-	70% (conservation farming)

Changes in land and water use and other developments related to planned future land use is illustrated in Figure 2. Production and conservation as of January 1996 are indicated in Figure 3.

During the planning sessions itself, the villagers expressed deep interest and concern in harnessing the Bovitiya Dola waterfall for generating electricity for both domestic consumption and small industries. Moreover, the need for protecting the catchment to ensure the sustainability of the hydroelectric power plant too was emphasized. It was noted that the village was located 2.5 km away from the main grid transmission and that the estimated cost of supply was about Rs.3-4 million. Even the

Figure 2.

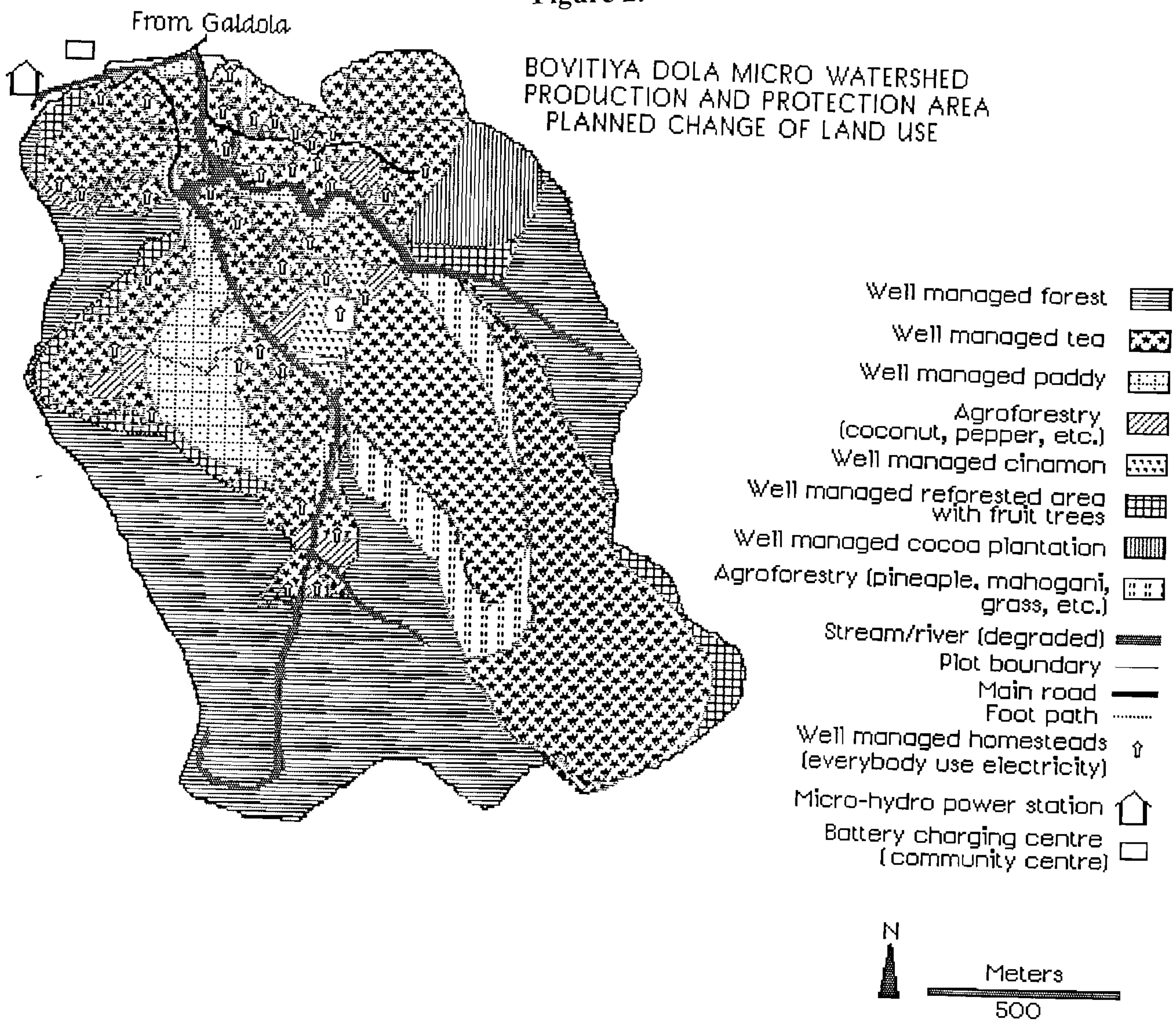
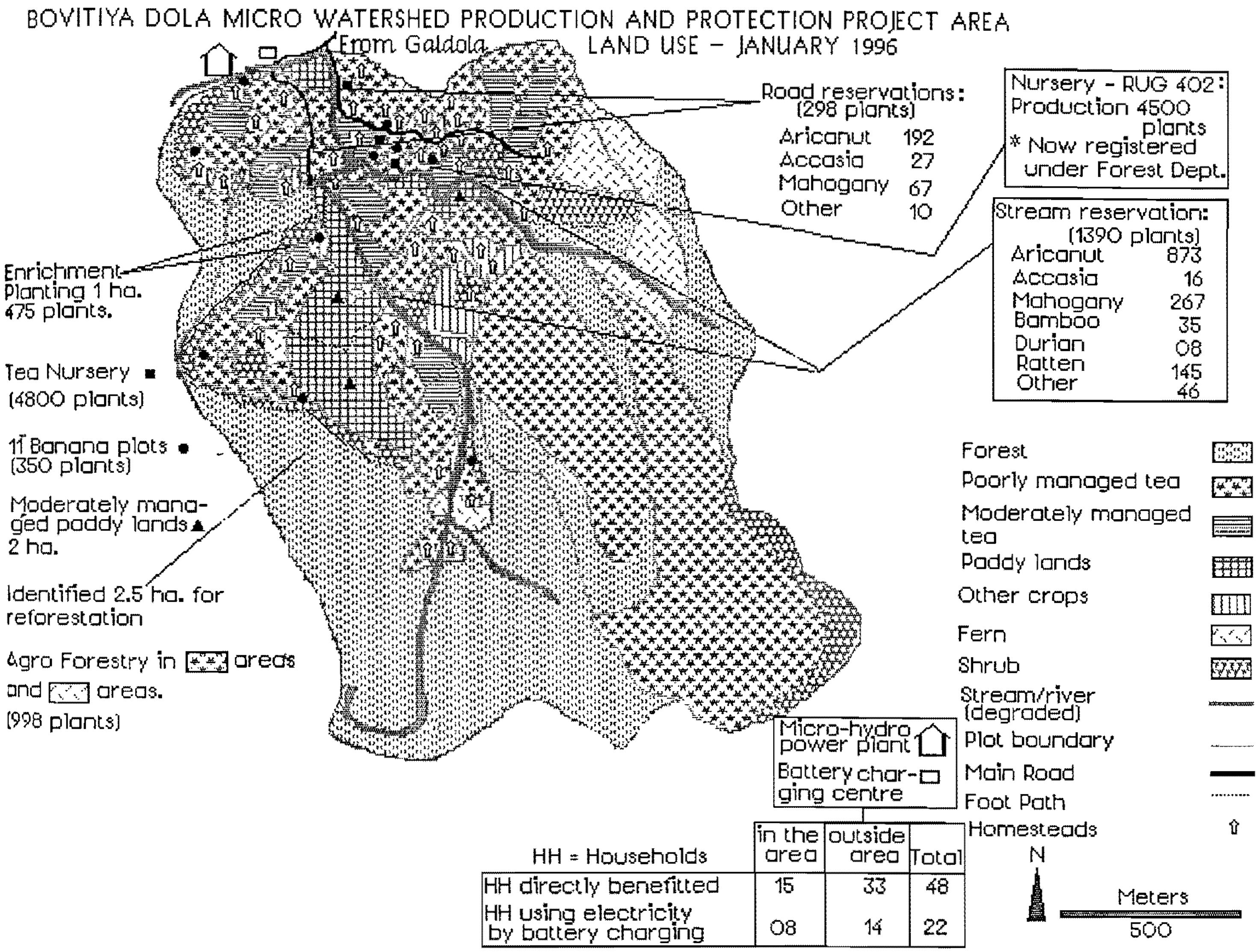

From Galdola
BOVITIYA DOLA MICRO WATERSHED
PRODUCTION AND PROTECTION AREA
PLANNED CHANGE OF LAND USE
Well managed forest
Well managed tea
Well managed paddy
Agroforestry
(coconut, pepper, etc.)
Well managed cinamon
Well managed reforested area
with fruit trees
Well managed cocoa plantation
Agroforestry (pineaple, mahogani,
grass, etc.)
Stream/river (degraded)
Plot boundary
Main road
Foot path
Well managed homesteads
(everybody use electricity)
Micro-hydro power station
Battery charging centre
(community centre)
N
Meters
500

Figure 3.



HH = Households	in the area	outside area	Total
HH directly benefitted	15	33	48
HH using electricity by battery charging	08	14	22

future possibility of grid connection remained weak. An average family spent about Rs.145.00 (US$3) per month for energy use; the main sources being kerosene and car batteries.

Because of its remote location and difficult accessibility, villagers had less contacts with government departments and projects. Even though the villagers were aware of micro- hydro- electric power generation, they did not know how to obtain technical know-how, financial resources etc. There was no government agency directly responsible for micro- hydroelectric power generation.

Formation of User Organization

As decided during the planning sessions, the villagers were organized into a cohesive group to develop and use the water fall/stream as the source of electricity **without having adverse effects on the existing minor irrigation deliveries**. The IIMI/SCOR catalyst facilitated this process. The organization, among other things, decided and designed action-plans for the following:

i. take collective measures to conserve and maintain the catchment;
ii. construct the hydro-electric power plant and supply electricity **directly** to 48 families;
iii. establish a "battery charging center" and supply electricity **indirectly** to another 22 families;[3]
iv. invite the ITDG to provide mainly the technical assistance;
v. share a considerable portion of capital costs of construction in the form of (limited) capital and offer voluntary and organized labor;
vi. plan and take over the responsibility of post-construction operation and maintenance of the hydro electric power plant;
vi. undertake necessary post-project rehabilitation.

The roles and the responsibilities of the office bearers of the organizations have been defined and a nine-member committee was established as a day-to-day decision making body to expedite the construction process. Each member in this committee represented a small group of farmers.

"A Rights Issue"

Paddy farmers whose fields were located further downstream had two irrigation lines installed at the point where the weir was constructed. They feared that the construction of weir and the diversion of part of the Bovitiya Dola through the fore bay tank would reduce the flow of irrigation water to their fields. As a compromise, the members of the micro-hydroelectric power group, at a negotiation process, agreed to

[3] Anticipated power supply is limited to 5 KW and consumption will be confined to 5 pm to 7 am during week days and 2 pm to 7 pm over the weekends and holidays. The battery re-charging will be done by using the electricity generated during day time.

assign priority for irrigation and **fixed two irrigation lines, six inches** below the existing levels. After this arrangement, no complaint has been made by the paddy farmers downstream concerning irrigation difficulties indicating that the project had not given rise to negative externalities (implying zero external costs).

In order to maintain equity and also to optimize the limited power generated, the organization **decided to limit the supply to only 100 W per household.**

Resources for the Construction of Micro Hydroelectric Power Plant

Members were requested to contribute Rs.1,500 (US$28) each in cash and supply their share of construction material and labor equitably for construction. The organization borrowed Rs.11,000 (US$204) at 2% annual interest rate from their apex farmer organization[4]. This organization expects to recover the loan within two years after the completion of the power plant.

The proposal for hydroelectric power development was submitted to Watershed Resources Management Team, WRMT[5]. The forest department official (who had participated in the design of catchment development efforts) commended that the users for their motivation on conserving the forest. The representative of Agrarian Services Department agreed to the project as it was clear that irrigation water rights had been protected. WRMT discussed the possibility of linking the proposal with the Matara Integrated Rural Development Project (MIRDP) mainly to obtain funding for electro mechanical equipment. This proposal was well within the scope of MIRDP and the Director of that program, who was also a member of the WRMT, agreed to provide the balance funding.

In addition to the consultancy services, ITDG also volunteered to supply a battery charger free.

Hydrological Considerations and the Design of Power Plant

IIMI watershed management coordinator, being an engineer, joined ITDG in providing technical assistance. He assisted the organization in the hydrological analysis.

The discharge of the stream was computed based on the stream flow during the dry months of the year and studying the variations during the rest of the months. The "design flow" of the stream was 35 lit/sec. Several elders in the area reported that they

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[4] This apex organization, namely the Horagala Service Farmer Organization was formed as a result of SCOR intervention.

[5] WRMT is a working group established under the SCOR project to: guide and assist SCOR implementation, provide technical assistance, prepare workplans, develop close links with government programs, agencies and donor funded projects and help resolve conflicts. WRMT consists of IIMI technical experts, heads and experts from key government agencies, user representatives and divisional secretaries.

experienced continuous flow (implying the perennial nature of the stream) before the destruction of forest in the catchment.

The location of the diversion weir, inlet canals, forebay tank, penstock and power house were decided collectively by the users, the ITDG and the IIMI Watershed Management Co-ordinator. A low level spillway incorporated with a regulating device was also provided in the diversion weir close to left bank in difference to the users' opinion to protect the right banks from collapsing. The team decided to provide silt exclusion devices at the diversion weir and at the forebay tank to protect turbine vanes from impacts of silt particles. Complying to the requirements laid down by the Central Environmental Authority of Sri Lanka and the Forest Department, user organization decided to build a stone terraced leader drain to discharge outflow of the turbine back to the same stream to minimize damages to the environment.

The main components of the design are shown in Figure 4.

3. ECONOMIC ANALYSIS OF THE PROJECT

A. Cost of Micro Hydroelectric Power Generation Plant

Capital Costs

This includes the cost of micro-hydropower generation plant, cost of transmission of electricity and cost of internal wiring.

Labor cost

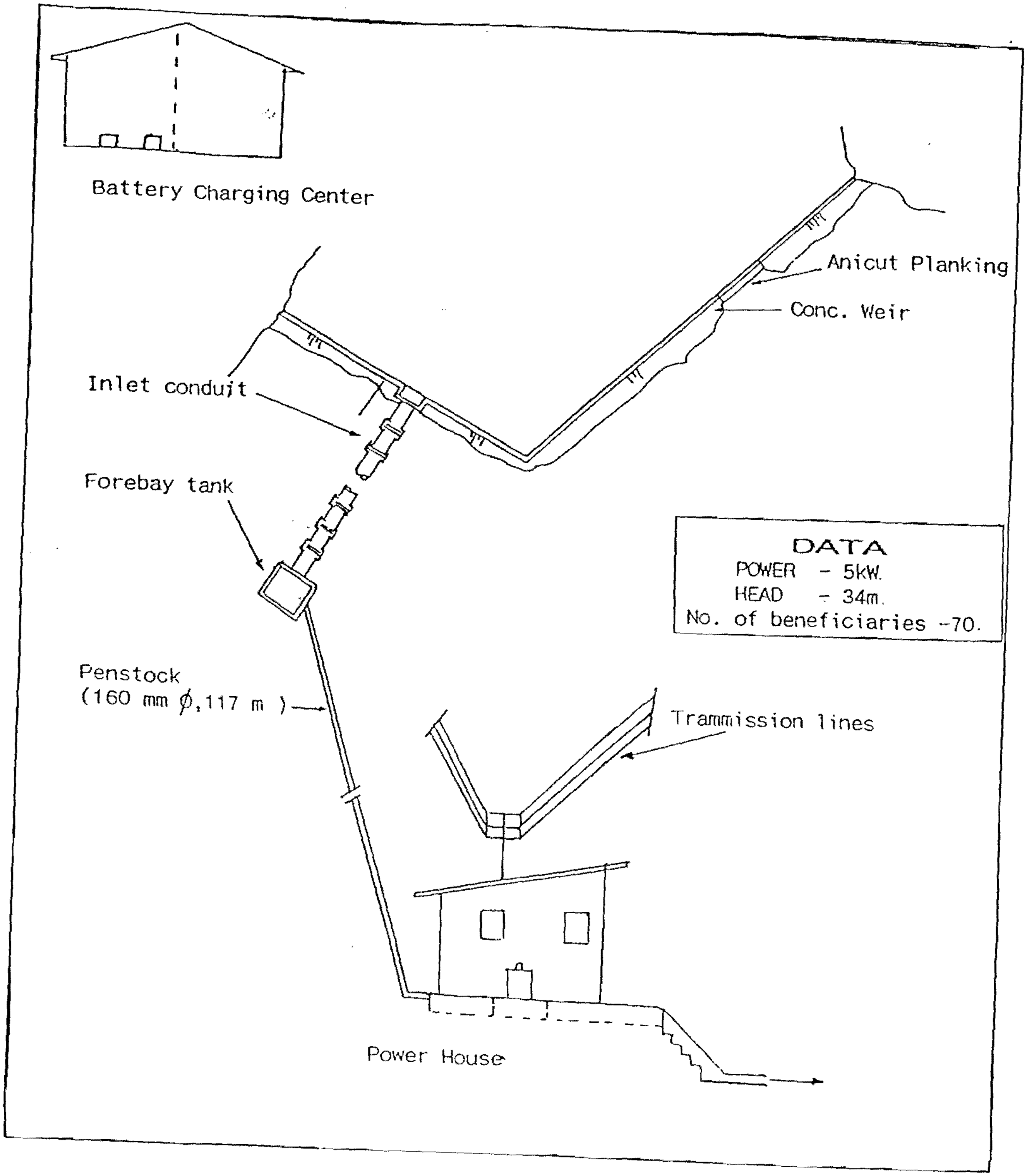
The labor contribution by the consumers of electricity for the civil construction works, installation of electromechanical equipment and transmission facilities was 647.5 labor days (Illukpitiya ECS records). Out of this, 146 (22.5%) days were Sundays and holidays when no green leaf transactions took place. The labor involvement for house connections of the transmission facilities was 14.7 labor days (per household) in total, with about 2 hours for completion of the connections to each house. For the internal house wiring, skilled labor was used on contract basis at the rate of Rs.60 to Rs.70 (US$1.1 - 1.3)[6] per point (survey data, 1995).

Material cost

Total material cost for electromechanical equipment, transmission vires and internal wiring was Rs.780,727 (US$14,460) (Table A2 in appendix).

[6] Conversion rate 1US$ = Rs.54.

Figure 4. Bovitiyadola Micro Hydroelectric Power Project.



Operation and Maintenance costs

Operation & Maintenance costs include the following:

⇒ Cost of de-silting the channel bed. De-silting is scheduled to be performed twice a year on ***Shramadana***[7] basis by the consumers of electricity. For this operation, 96 man days would be required annually.
⇒ Cost of Operation. The electricity consumers society have agreed to pay Rs.500 (US$9.30) per month for the operation and maintenance of power house and battery charging center.
⇒ Cost of replacement of bulbs. The total bulb requirement per year is 288 and the cost of bulb replacement is Rs.7200 (US$135).
⇒ Replacement of the generator and the turbine. Life time of the turbine is 10 years and its cost is Rs.65,000 (US$1200).
⇒ Maintenance cost of the hydropower plant is Rs.4000 (US$74) per year.
⇒ Credit for loan repayment Rs.2200 (US$41).

B. Cost of the Battery Charging Center

Capital Costs

The total cost of battery charging center was Rs.30,000 (US$555) (Table A3 in appendix).

Operation and maintenance costs of the battery charger

It would be Rs.1,200 (US$22) per year and the life time of the battery charger is taken as 10 years.

External Costs

a. Reforestation and "enrichment planting".

The electricity consumers proposed to protect the catchment in order to ensure continuous power generation throughout the year and also to reduce soil erosion. With that in view they arranged a reforestation program for 3.5 ha. enrichment planting for 0.5 ha. planting trees along 3 km of stream reservation and conserving 49 ha of tea lands. The cost of reforestation was Rs.59,500 (US$1100) and of maintenance for the first year through the third year was Rs.21,000 (US$389), Rs.14,000 (US$259) and Rs.8750 (US$162) respectively. Enrichment planting has been already completed in the degraded forest and the cost involved in the first year was Rs.4588.00 (US$85) and the maintenance cost was Rs.3000 (US$56), Rs.2000 (US$37) and Rs.1250 (US$23) for the second third and fourth years respectively. The initial cost of enrichment of stream reservation was

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[7] Voluntary group work by people.

Rs.10,750 (US$199) (Rs.6750 [US$125] for plants and Rs.4000 [US$74] for labor) and maintenance cost was Rs.6000 (US$111), Rs.4000 (US$74) and Rs.2500 (US$46) respectively for the second, third and fourth years.

b. Tea land conservation

The total extent of the tea lands in the watershed was 102 ha and out of which 49 ha belonged to the small holders who were the direct and indirect beneficiaries of the micro-hydropower project. Therefore this 49 Ha. was expected to be conserved by them to arrest the soil erosion. Assuming that nearly 5% of this land area is undertaken for replanting every year, all the costs were estimated for 46 ha. The cost of planting material for soil conservation was Rs.18,880 (US$350) in the first year and Rs.10,000 (US$185) during the second year. The labor requirement for maintaining the soil conservation practices was Rs.64,000 (US$1185) in the first year and Rs.50,000 (US$926) thereafter. It was expected that the farmers would attend to the infilling annually and 10000 tea plants to be planted during each year. The cost of infilling is given in table A4 in appendix.

As a result of the soil conservation practices adopted, the expected yield increment was 6% and additional labor cost involved in plucking an assumed annual yield increment of 24541 kg of green leaves was Rs.110,434 (US$2,045) per year. However, this ("expected") benefit was not included in the financial and economic analyses.

BENEFITS OF THE PROJECT

i. Cost savings accrued by the introduction of electricity in place of kerosene oil use.

The main source for domestic lighting was kerosene oil and according to a survey conducted the average kerosene oil consumption was 7.9 liters per month per family. The total kerosene oil consumption by 48 families of the area was 4550l liters per year and it will cost Rs.40,950 (US$758). (Subsidized price of kerosene was Rs.9/liter) and Rs.48,093 (US$891). (Shadow price as Rs.10.57/liter.) Assuming the people to reduce kerosene oil consumption by 95% after getting electricity, the cost saving was Rs.38,902 (US$720) (the Subsidized price of 9/liter was used for the financial analysis) its. Considering the shadow price the saving was Rs.45,688 (US$846).

ii. Cost saving through reduced car battery utilization for operating radios and TVs and savings of the battery recharging costs.

People use car batteries to operate radios and televisions and the batteries were recharged at regular intervals from the facilities available at Waralla and Galdola. There are 20 battery owners among the direct micro hydropower consumers. The average

battery charging cost was Rs.34 and battery charging frequency was 3.5 weeks. After receiving the electricity supply , the batteries were l be used only during day time and therefore re-charging frequency was reduced to an interval of 4.5 weeks. The re-charging cost therefore was reduced to Rs.20 through the use of the Electricity consumer's battery charging center. The life time of a battery is generally 2 years and after the expiry of these batteries, it is presumed that non of them will buy new batteries to operate radio cassette or TVs in the future since they can adjust their television viewing and radio listening times to the hours power is available from the generator. Cost saved under different assumptions is illustrated in table A5 of appendix.

iii. Cost saving by reducing torch battery utilization

Torch batteries are other energy source to operate radio and the average consumption is 5 batteries per month (Survey data 1995). The total battery consumption is 138 batteries per month among 28 people. It costs Rs.27,720 (US$513) to the community (Rs.16.50 [US$0.30] per battery). Assuming that battery consumption will be reduced by 75 after getting electricity the cost saving is Rs.20,790 (US$385).

External Benefits

i. Tea yield improvement due to soil conservation practices.

Due to improved conservation practices, the tea is expected to improve by 6% in 46 ha small holdings. The average annual green leaf yield is 8892 kg per ha in the area (SCOR survey). The annual yield increment for 46 ha is 24541 kg and the incremental income of this is Rs.269,960 (US$5,000) (Average green leaf price is Rs.11/kg)

ii. Value of the trees planted

Since the environmental value of trees cannot be measured accurately, only the timber value is considered, which is lower than the environmental value.

Returns to reforestation

3500 plants will be established under reforestation programme and value of timber after 20 years (at current prices). Assuming only 50% will be harvested, is estimated to be Rs.11,750,000 (US$21,760).

Returns to the enrichment planting of degraded forest (0.5 ha)

If 50% harvested the value after 20 years is Rs.1,189,000 (US$22,018).

These computations include only the value of timber and excludes the value of harvest from fruit trees and other minor export crops included in both

reforestation and enrichment planting programs. eg: Durian, Arecanut, Rambutan, Mango, Kithul (Trickle products and kithul flour, etc), coffee, etc.

Returns from stream reservation conservation

The estimated timber value alone amounted to Rs.1,275,000 (US$23,610).

Financial Analysis

Financial analysis is of the project was carried out taking into consideration only direct costs and benefits of the project. In the process of discounting a discount rate 6% was used. I was assumed that beneficiaries will not use batteries after receiving the electricity.

The B/C ratio and Internal (Financial) Rate of Return were estimated to be 1.08 and 7% respectively.

Economic analysis

Economic analysis considered all direct and secondary (including conservation benefits) and true economic price of kerosene and labor etc. The economic analysis is carried out under 6 assumptions

Assumption 1

* The opportunity cost of the labour for de-silting channel bed is 0.
* The opportunity cost of the labour spent during Sundays and holidays to build and establish micro hydropower plant is 0.
* Car battery users continue to use car batteries after receiving electricity during day time.
* Conservation benefits are not included.

Assumption 2

* The opportunity cost of the labour for de-silting channel bed is 0.
* The opportunity cost of the labour spent during Sundays and holidays to build and establish micro hydropower plant is 0.
* Car battery users will not use car batteries after receiving electricity during the day time.
* Conservation benefits are not included.

Assumption 3

* The opportunity cost of the labour for de-silting channel bed is 0.
* The opportunity cost of the labour spent during Sundays and holidays to build and establish micro hydropower plant is 0.
* The potential battery use beneficiaries will not use car batteries after receiving electricity during day time.

* Conservation benefits are not included.

Assumption 4
* The opportunity cost of the labour is not zero for any operation.
* The actual battery use beneficiaries will not continue to use car batteries after receiving electricity during day time.
* Conservation benefits are included.

Assumption 5
* The opportunity cost of the labour is not zero for any operation.
* The actual battery use beneficiaries will not use car batteries after receiving electricity during day time.
* Conservation benefits are included

Assumption 6

* The opportunity cost of the labour is not zero for any operation.
* The actual battery use beneficiaries will not use car batteries after receiving electricity during day time.
* Conservation benefits are included

The result of the economic analysis is given in the table 2.

Table 2. Economic analysis.

Assumption	NPV(at 6%)	B/C Ratio (at 6%)	IERR%
Assumption 1	-280955	0.74	1%
Assumption 2	26527	1.02	6%
Assumption 3	311733	1.28	10%
Assumption 4	6028185	2.40	19%
Assumption 5	6335707	2.47	20%
Assumption 6	6620913*	2.54*	21%*

* 8% Discount rate.

Table A2. Cost of labor & material.

a. Labor

Item	Cost (Rs.)
Installation and transmission	64,750
House Wiring	38,933
Connection from the main line	1,472
Total	1,05,155

b. Material

Item	Cost (Rs.)
Civil construction	74,551
Electromechanical Equipment	2,95,850
Transmission Wires	1,43,586
House wires	2,04,690
Connection wire from the main	32,050
Contingencies	30,000
Total	7,80,727

(Survey data 1995)

Table A3. Cost of battery charging center.

Item	Cost
Labor	5000
Civil construction	10,000
Battery charger and accessories	15,000
Total	30,000

Table A4. Cost of tea land conservation in the first year.

Item	Cost Year 1	Cost Year 2
Rehabilitation Grass	8000	
Labor cost	15000	30000
Dolomite	3000	
Fertilizer	2800	2800
Tea plants		30000
Total	28800	62800

Table A5. Cost saving through reduced battery utilization.

(1) No of Batteries	(2) Frequency of recharging (Weeks)	(3) Frequency of rechargin g battery/Ye ar (Weeks)	(4) Rechargin g cost per battery	(5) Total annual recharging cost (Rs)	(6) Annual cost for battery replacemen t	(7) (5)+(6)	(8) Cost saving
Actual 20							
Before project	3.5	15	34	10200	25000*	35200	
After project							
Assump 1	4.5	11	20	4400	25000*	29400	5800
Assump 2	4.5	11	20	4400**	0	4400	30800
Potential 48							
Before project	3.5	15	34	24480	60000*	84480	
After project							
Assump 1	4.5	11	20	10560	60000*	70560	13920
Assump 2	4.5	11	20	10560**	0	10560	73920

Assumption 1. Beneficiaries keep existing batteries to utilize during the day time and buy new batteries after expiry of their batteries.
Assumption 2. Beneficiaries existing keep batteries to utilize during the day time after expiry of available batteries the do not buy new batteries.
*Assuming a battery life of the and hat half of the batteries replace each year
** This cost is reduced by 50% in the second year and it is 0.00 in third year onwards
(Since people do not replace their batteries under assumption 2)