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Economic Analysis of Consumptive Applications of Water

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1. Introduction

Drinking, Domestic, Industrial and Irrigation water are the four main consumptive applications of water in Sri Lanka. World Health Organization [WHO] of United Nations reports thousand cubic metre of water per annum is the minimum water requirement of each human. As far as water resources are concerned, Sri Lanka is identified a rich country in the world with an average annual rainfall exceeding 1700 mm and annual run off of some sixty thousand million cubic metre [MCM] of water into the sea. Sri Lanka needs only 20,000 MCM of water to meet the water requirement of entire population. Water has an economic value depending on the quality, availability, storage facility and the requirements. On the other hand excess water also causes some harmful effects to the human life resulting negative economic impact.

Sri Lanka has a well developed reservoir system with a storage capacity over 5,000 MCM, especially in the dry zone. Those reservoir systems are capable of absorbing part of the flash floods and gradually release the water as per the human requirements. However, Sri Lanka faces severe scarcity of water particularly during the dry season. This can be attributed to the ineffective water management practices taking place everywhere in the country. Most of the people in the country are unaware of the fact that water has an economic price subjected to drastic changes. Proper economic analysis of different applications of water may also reveal shortcomings in the present water management system.

2. Methodology

This research was carried out by interviewing 100 persons representing more than 500 people belonging to different economic classes living in various part of the island. This paper is based on the information given by them.

3. Calculation of per capita water Requirement

3.1 Drinking water [potable water]

Only a little quantity of potable water is required for drinking. National Water Supply & Drainage Board [NWS&DB] and other related organizations had worked out that per capita drinking water requirement is five liters per day. However, recent research carried out by using 100 office workers revealed that average person drinks 2.5 to 3.5 liters of water per day. Under the hot and dry weather conditions this may be increased to 3.5 to 4.5 liters per day. According to this annual per capita drinking water requirement is 1.0-1.5 Cubic meters.

3.2 Domestic water requirement

NWS&DB has already worked out the per capita domestic water requirement per day [pcdwrpd] as follows.

Table 1-Domestic water requirement as per NWS&DB regulations

Activity	Requirement Litres per day
Drinking	5
Cooking	10
Washing face, hands etc	15
Bathing	40
Washing clothes	30
Washing pots dishes etc	15
Toilets flushing	45
Watering flower beds	10
Other unclassified applications	10
Total	180

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If there is a scarcity of water, domestic requirement can be restricted as shown in column no 2 of table no 2 especially in rural areas.

Use of washing machines and frequent toilet flushing has resulted twenty percent increase in domestic water requirement especially in the urban areas. [Column no 3]

Table 2- Domestic water requirement under different conditions.

Activity	If there is a scarcity of water	Water is readily available Excess consumption
Drinking	4	5
Cooking	6	15
Washing face, hands etc	10	20
Bathing	-	40-250
Washing clothes	10	50
Washing pots dishes etc	10	25
Toilets flushing	15	50
Watering flower beds	-	50
Other unclassified applications	-	20
Total	55	275-485

Table 02

By considering positive and negative variations it can be shown that annual domestic water requirement is about 75 m3 per annumn.

3.3 Industrial water requirement

Sri Lanka is an agricultural country and therefore Industrial water requirement is comparatively small. Rubber manufacturing and paddy processing are the main industries in the rural areas which consume a fairly large quantity of water. However, there are large numbers of water consuming industries in the urban areas. Twenty five cubic meters of water per person per anumn is assumed to be the industrial water requirement. Domestic water and industrial water satisfy same quality standards and therefore they have a same price structure.

3.4 Irrigation water requirement

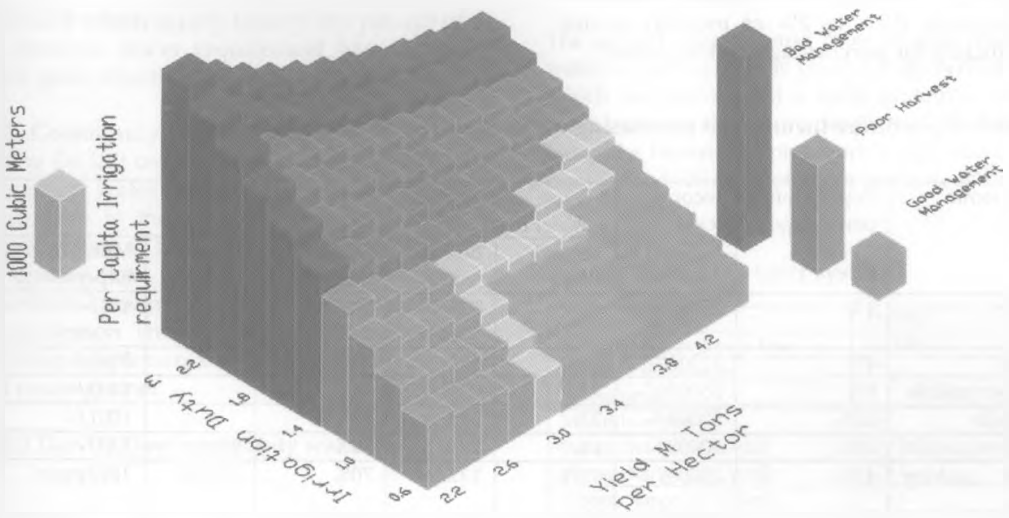
Domestic and industrial annual per capita water requirement is less than 100 m3. Therefore the balance 900 m volume is required 3for food production. Highly populated urban areas mainly depend on the imported or transported food items require less water while the food production zones require huge volume of irrigation water. As far as Sri Lanka is concerned nearly ninety five percent of the irrigation water is used for paddy cultivation. Other field crops such as sugar cane, banana and maize need less water compared to paddy. Therefore per capita irrigation requirement can be measured in terms of paddy cultivation. Per capita Irrigation requirement is directly proportional to the irrigation duty and inversely proportional to the harvest per unit area. Following specimen calculation shows the Irrigation requirement under the normal circumstances. The three dimensional bar chart describes the variation of per capita irrigation water requirement with irrigation duty and harvest per unit area.

Table 3-Calculation of per capita irrigation water requirement

Description	Quantity with units
* Assumed irrigation duty	1200mm
* Paddy production per Ha	4200 kg
* Per person rice consumption	0.4 kg
* Other field crops (Equivalent of rice)	0.1 kg
Annual rice consumption	183 kg
* Milling Factor	0.6
Rice production per Ha	2520 kg
Water requirement per Ha	12000 m^3
Water requirement for 1 kg of rice	4.76 m^3
Rice : Water Ratio	1:4760
Per capita Irrigation water requirement	876 Units
Per capita Irrigation water requirement (Duty 1500mm)	1095 Units

* Based on my personal experience

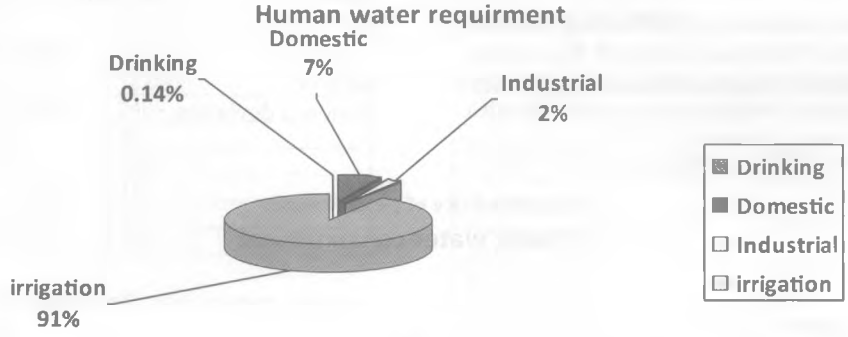
Graph 1-Shows the variation of irrigation demand with the irrigation duty and harvest



Summary of water requirement

Drinking water	=1-1.5 m^3	Irrigation	=1000 m^3
Domestic	=75 m^3	Industrial	=25 m^3

Graph 2-Human water requirement



4. Price fixing of water

4.1 Drinking water

Potable water may be priced at twenty Rupees per liter to five cents per litre .Market prices or actual prices of drinking water are given in the following table No4.

Table 4- shows price of drinking water

Type of potable water	Price per liter
#Bottled water (one liter)	20.00
#Bottled water(large)	10.00
* Boiled water	4.00
Treated Water	.03-0.06
* Unsafe water	.10-.50
* Needs head carrying	

Market survey reveals this result

Expenditure incurred on drinking water by different economic classes is given in table no 5. Normally 0.5% to 2% of monthly income is sufficient for purchasing drinking water.

Table 5-Expenditure incurred on purchasing water by different economic classes

Economic class	Population percentage	Income level	Type of Drinking water used				
			Bottled water	Boiled water	Natural or treated	Unsafe water	Monthly Expenditure
Elite	1%	250000/-	85%	10%	5%	-	4141-
Rich	4%	125000/-	30%	45%	25%	-	2165/-
Upper middle	8%	750000/-	7%	60%	33%	-	1402/-
Middle	12%	50000/-	2%	50%	48%		1001/-
Lower middle	20%	30000/-	1%	20%	70%	9%	335/-
Just making life	45%	20000/-	0.5%	10%	70%	19.5%	182/-
Poor	10%	10000/-	-	5%	55%	40%	98/-

According to the survey 3.33% of the people use bottled water while another 21.65% of the population uses boiled water. Out of the rest 60.45 % find the safe water at minimum price and nearly 14.5 percent lack safe drinking water.

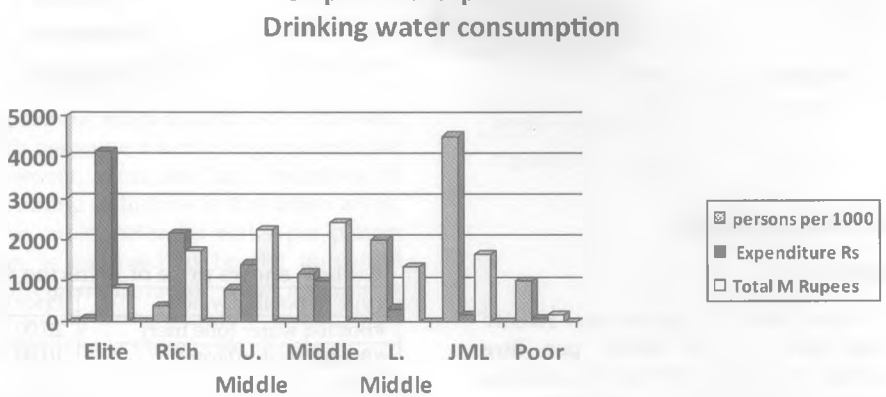
Expenditure incurred in purchasing drinking water shows the cross section of the income level of the different people in the country. There are rich people in the country who can expend more than five thousand Rupees on drinking water while some other people enjoy the same benefits at negligible cost. ,

Average price of drinking water=0.0333*10+.02165*4+0.6045*.05+0.145*.10

=1.25 Rupees per liter

Standard deviation =2.25

Graph 4-Price of potable water



4.2 Domestic water supply

NWS&DB which supply twenty five percent of the domestic water requirement has already fixeda price structure for domestic water.

4.2.1 Community water Supply

During the last two decades a large number of community water supply schemes were developed. This is the cheapest domestic water supply system in Sri Lanka. However, most of the gravity flow type water supply schemes experienced severe shortage of water during the dry season. This problem may be overcome by using supplementary ground water source and pump system.

4.2.1.1 Gravity flow community water supply

Cost analysis pertaining to a typical gravity flow type community water supply project is given below. Government contribution is not counted.

Table 6-Cost estimate for gravity flow type Community supply scheme

Initial labour cost	5,000/-
Material cost	1,000/-
Storage tank	10,000/-
Internal pipe laying	2,000/-
Total Investment	18,000/-
Monthly interest	240/-
O&M charges	60/-
Price of water	300/-
Unit price [25 units]	12/-
Unit price[10 units]	30/-
Unit price[5 units]	60/-

4.2.1.2Community well and pump storage system

Two meter diameter 6 m deep well serving twenty houses are consid ered for the analysis.

Table 7-price of water Community well

Excavation of well	25,000/-
Civil works	75,000/-
Storage Tank	200,000/-
Pipe laying	100,000/-
5 HP water pump	100,000/-
Domestic tanks	200,000/-
Internal pipe laying	100,000/-
Capital cost	800,000/-
Monthly interest	10,000/-
Monthly yield m^3	500
Pumping cost per unit	6/-
Total cost per unit	26/-

4.2.2 National Water supply and Drainage Board Supply

The second cheapest and most reliable treated water supply service is provided by NWS&DB which has introduced a tariff system to save more water so that more people will be able to enjoy the benefits of pipe born water. Average family needs 25 units of water and cost estimate is given below

Table 8-NWS&DB tariff system

Connection fee	15,000/-
Storage tank and pipe line	15,000/-
Monthly interest on investment	375/-
Monthly rental	50/-
Water charge [20 Units]	67/50
Water charge [25 Units]	325/-
Water charge [30 Units]	775/-
Unit Price [20 Units]	24/63
Unit price [25 units]	30/-
Unit price [30 units]	40/00

4.2.3 Shallow well and pump system

Shallow wells can not be constructed in the urban areas mainly due to the ground water contamination. It can be shown that NWS&DB supply is cheaper than this system. Typial estimate is given below.

Table 9-Shallow well and pump system

Excavation cost	12,000/-
Cylinder placing/Civil construction cost	20,000/-
Pump installation 0.75 hp single phase water pump	12,000/-
Storage tank Pipe laying	10.000/- 2,000/-
Total cost	56,000/-
Monthly interest	700/-
Pumping charge	6/-
Capital cost 25 units	28/00
Capital cost 50 units	14/00
Unit price 25 units	34/00
Unit price 50 units	20/00

4.2.4 Deep well and pump system

Actual work cost incurred for the construction of a deep well is given below. In both applications it can be shown that unit price of the water may be cut down by nearly fifty percent, if two houses can share one well.

Depth of the well = 12m
Diameter of well = 1.2 m
Pumping head = 20 m

Table 10-Deep well supply

Excavation cost	25,000/-
Cylinder placing/Civil construction works	35,000/-
Pump installation 1.0 hp single phase water pump	18,000/-
Storage tank Pipe laying	10,000/- 4,000/-
Total cost	92,000
Monthly interest	1,150/-
Pumping charge	12/-
Capital cost 25 units	46/-
Capital cost 50 units	23/-
Unit price 25 units	58/-
Unit price 50 units	35/-

4.2.5 Bowser water supply

The bowser supply is the easiest method of short term domestic supply if there is a road network available to serve the people. The bowser supply is very popular in the Middle East countries. [Water is extracted from deep aquifers and transported by consumer owned large bowsers] The long term bowser supply is 5-10 times expensive than pipe supply. The rich people or the, government has to bear up the cost.

Table 11-Bowser supply

Hourly charge of 6 m^3 bowser	1,200/-
First km loading and unloading	1 hr
Any subsequent km	6 minuts
Water charge	65/-
Unit price 1 km	265/-
Unit price 2 km	285/-
Unit price 3 km	305/-
Unit price 5 km	345/-
Unit price 10 km	445/-
Unit price 20 km	645/-

4.2.6 Rain water harvesting [RWH]

Rain water satisfy best quality standard water if it is collected in the pure form. Nearly thirty percent of the domestic requirements can be met with collected rain water. There for RWH ease pressure on NWS&DB supply in urban areas and economic unrest in the rural areas. A primitive RWH system may be constructed at negligible cost and 20-50 units of rain water may be collected annually.

As far as urban areas are concerned ground water infiltration is very low and surface run off is very high.On the other hand ground water pollution is also high. Therefore necessary legislations have now passed byparliament by making provisions for theessential RWH.

Table 12- Tentative estimate for large scale RWH project

Consider roof area of 200 m^2	
Annual rainfall	3000 mm
Tank capacity	20 m^3
Specific yield	50%
Annual yield	300 m^3
Capital investments	100,000
Monthly interest	1500/-
Unit price	60/-

Table 13-Estimate for medium scale RWH project

Consider roof area of 150 m^2	
Annual rainfall	3000 mm
Tank capacity	10 m^3
Specific yield	40%
Annual yield	180 m^3
Capital investments	60,000
Monthly interest	900/-
Unit price	60/-

Table 14-Estimate for small scale RWH project

Consider roof area of 100 m^2	
Annual rainfall	3000 mm
Tank capacity	5 m^3
Specific yield	35%
Annual yield	105 m^3
Capital investments	24,000
Monthly interest	300/-
Unit price	35/-

4.2.7 Fetching water

Table No 15 describe price of domestic water with hauling distance and lifting height in the case of manual transport. This is very common in rural areas without pipe born water. Under extremely difficult situation price of water might be increased up to 1500 Rupees per unit.

Table 15 – Estimate for Fetching water

Lifting height/Hauling distance(m)	10	20	50	100	200	500	1000	2000
5	71	76	92	118	139	295	556	1076
10	106	111	127	153	174	330	590	1111
15	141	146	161	188	208	365	625	1146
20	175	181	196	222	243	399	660	1181
25	210	215	231	257	278	434	694	1215
30	245	250	266	292	313	469	729	1250
35	280	285	300	326	347	503	764	1285
40	314	319	335	361	382	538	799	1319
45	349	354	370	396	417	573	833	1354
50	384	389	405	431	451	608	868	1389

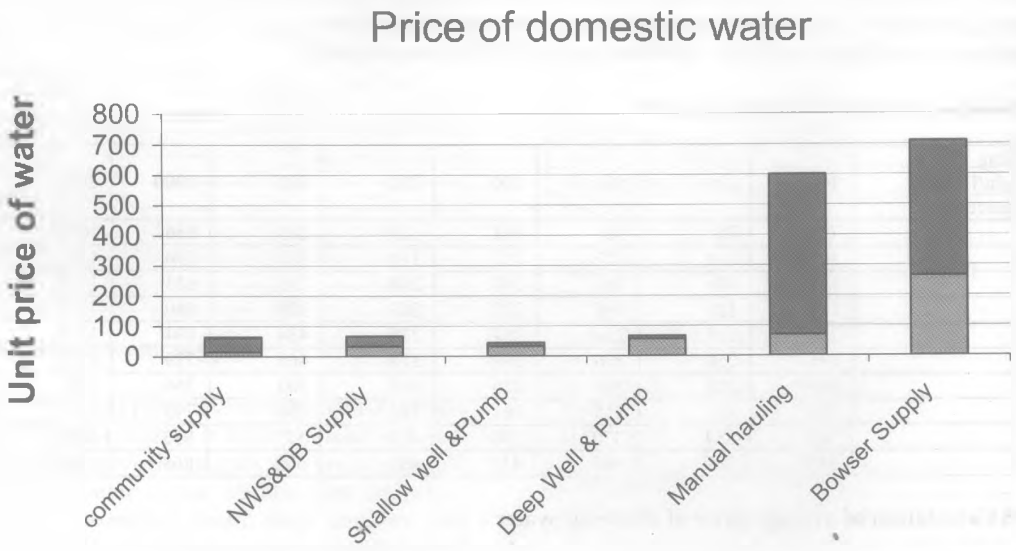
4.2.8 Calculation of average price of domestic water

Table 16 - summary of domestic water consumption estimate.

Main Group	Sub Group	Population percentage	Price of water Rupees per Lit	Weighted factor
Community	Group No 1	8%	6.00	48
	Group No 2	9%	12.00	108
	Group No 3	4%	30.00	120
	Group No 4	2%	60.00	120
NWS&DB	Group No 1	8%	25.00	200
	Group No 2	8%	30.00	240
	Group No 3	7%	40.00	280
	Group No 4	2%	50.00	100
Shallow well & Pump	Group No 1	5%	34.00	170
	Group No 2	5%	27.00	135
	Group No 3	5%	20.00	100
Deep well & pump	Group No 1	3%	58.00	174
	Group No 2	3%	47.00	141
	Group No 3	4%	35.00	140
Manual Hauling	Group No 1	4%	80.00	320
	Group No 2	4%	125.00	500
	Group No 3	4%	250.00	1000
	Group No 4	4%	400.00	1600
	Group No 5	1%	500.00	500
Bowser Supply	Group No 1	1%	280.00	280
	Group No 2	1%	345.00	345
	Group No 3	1%	445.00	445
Free & Subsidized		3%	30.00	90
Rain Water harvesting		2%	40.00	80
Unclassified		2%	30.00	60
				7296

Average price of domestic water=72.96 Rupees Standard deviation =109 rupees

Graph No 5



4.3.1 Fixing a price for Irrigation water

Most of the large scale irrigation schemes may be treated as multipurpose projects. Irrigation as well as hydropower, water supply, flood control, navigation recreation and aquatic resources are the main benefits that could be derived from a large scale reservoir project. Negative economic impacts such as environmental degradation and desturbing the ecological are also caused balance by the large multipurpose water resources development projects.

4.3.1.1 Mahaweli Multipurpose project

As far as Mahaweli multipurpose water resources development project is concerned, cost benefit analysis can't be carried out by isolating irrigation component. Mahaweli hydropower system has so far been able to generate massive energy of some 37,500 GWh worth 600 billion rupees. Accelerated Mahaweli project mainly focused on hydropower development and nearly two third of the benefits should be in the form of hydropower while the balance one third may be in the form of irrigation benefits. Based on this simple assumption unit price of irrigation water can be calculated as follows.

Official web site of the Mahaweli Authority reveals that present worth of the total project cost in 2006 is 89.9 billion rupees. However, present worth of the project is more than Rs 750 billion Sri Lankan rupees mainly due to the high inflation rates prevailed in the country.

Table 17- Mahaweli project cost benefit analysis

* Mahaweli Project cost in year 1984	50 billion Rupees
Internal rate of return	12%
Present worth of project (2008)	759 billion Rupees
Present worth of Hydropower benefits (2008)	600 billion
Present worth of Irrigation benefits(2008)	300 billion
Value of surplus benefits	900 billion
Surplus return	141 Billion
** Newly cultivated area under the Mahaweli project	100,000 Ha
Assumed Irrigation Duty	1500 mm
Volume of water issued	75 BCM
Price of water	4.00 Rs per Unit

4.3.1.2 Uda Walawe Project

Uda Walawe Multipurpose reservoir was built in 1969 mainly for irrigation. Uda Walawe reservoir has 3 Numbers of 2 MW hydroelectric turbines in order to harness the available energy in the irrigation water. Under the most unfavorable circumstances Uda Walawe power station had been able to generate 585 GWh worth 9360 Million Rupees. Project cost benefit analysis is given below.

Table 18-Uda Walawe project cost benefits analysis

Project cost in Year 1969	165 Million Rupees
Rehabilitation cost in year 1987	1200 Million Rupees
Internal rate of return	12%
Present worth of the project	26.8 billion
Present worth of the left Bank Extension project 2005	10.0 Billion
Hydropower benefits	9.36 billion
Irrigation benefits	27.44 Billion
Water issued	17.55 BCM
Price of water without O&M	1.57 Rupeees per unit
Price of water with operation and maintenance charges	2.00 Rupees per unit

4.3.1.3 Alternative price structure based on potential energy of water

Comparatively low prices of water have been resulted mainly due to the very low oil prices prevailed in the world during the last few decades. During the last eight years oil prices increased nearly by six hundred percent. Electricity prices have increased by approximately 300% Largest non consumptive application of water is hydropower and therefore economic analysis may be carried out by considering a unit of water stored in medium level Victoria and Samanalawewa reservoirs.

Table 19-Economic value of water based on potential energy

Reservoir Description	Victoria	Samanalawewa
Elevation	430 m MSL	440 m MSL
Effective head	264 m	340 m
Energy Stored in one unit of water	0.66 kWh	0.85 kWh
Oil based price of electricity	10.56	13.60
Economic price of water	More than 12.50	More than 14.00

As far as water resources planning is concerned, market price of irrigation water may be taken as six rupees per unit.

Farmers estimate on paddy cultivation is given below.

Table 20- Farmers estimate on irrigation

Harvest per Ha	4200 kg Paddy 2500 kg of rice
Price of rice	56 Rs per kg
Income	140,000 Rupees per ha
Irrigation duty	1200 mm
Affordable water charge	6% of income 8400/-
Water used	12000 Units
Affordable price	70 cents per unit
	Say 1 Rupees per unit

5.0 Table 21-Summary of all consumptive applications of water

Following table summarized the water requirement estimate at national level.

Application of water	Unit price (Rupees)	Standard deviation (Rupees)	Quantity[MCM]	Amount Billion Rupees
Drinking	1,250/-	2,250/-	25	31.25
Domestic(Average)	72/75	109/-	1,500	109.125
Domestic(Favorable) With RWH	40/00	20/-	1,200	80.00
Industrial	72/75	-	100	7.275
Irrigation (Actual)	5/00	-	18,000	90.00
Irrigation(Subsidized)	1/00	-	18,000	18.00
Total				165-200

6. Conclusion

Ground water contamination has become a serious problem in urban areas. Direct waste water disposal is not permitted indeveloped countries like the United Kingdom. Clean water act should be passed without further delay so that poor people of the country will enjoy the benefits of quality drinking water at cheap prices.

Drinking water that confirms with WHO standard may be priced at 5 cents per litre to 25 Rupees per litre. This variation has to be minimized, [The standard deviation of prices of drinking and domestic water is higher than the average prices and this has resulted a negative skewness in the price distribution.]

People living in Anuradhapura, Polonnaruwaand few other districts have experienced chronic renal failure mainly due to the bad quality of drinking water. Bottled water industry may be developed so that low income people in the affected areas will be able to buy potable water at a reasonable price.

Many man months are lost due to the short term water born diseases suchas cholera. Disinfection methods like Ultra violet radiation and Ozonization may be used for purifying potable water.

Price of domestic water also varies from 6 to 600 rupees per unit. Most of the privileged rich people can enjoy reliable domestic supply at a reasonable price mainly due to the water service provided by NWS&DB. Therefore, additional cost incurred on domestic water has to be born by the poor people in the village.

During severe droughts, which is common natural disaster in Sri Lanka, government normally supply free water for the affected people. Short term bowser supply is an expensive method and this situation may be controlled by having large number of decentralized medium scale water supply projects comprising of large storage tanks. Rain water harvesting may be popularized among the high income groups.

Most of Sri Lankan dislike the term "Irrigation water taxation". Economic decline in the country can be partly attributed to this myopic notion of the people. All the same, the government had already made a massive investment on irrigation projects. It can be shown that irrigation water may be priced at 2 Rupees per unit to 12 Rupees depending on the availability of water and various other factors.

However, agricultural crop cultivation is not a profitable industry in Sri Lanka. Therefore poor farming community cannot bear up the actual cost incurred on irrigation water. Equitable distribution of water among the farmers has become a serious problem and this has resulted active discrimination among the farming communities. This problem may be overcome by introducing a reasonable tax system on irrigation water so that excess consumer may bear up the additional cost incurred while starving people may also enjoy the benefits of irrigation water.

As far as the Mahaweli project is concerned project cost has already been recovered in terms of hydropower and returns during the next twenty years will definitely contribute to boost the economy. Effective watershed management as well as effective watermanagement is also a sine qua non for sustainable development.

Reference

1. Mahaweli Authority official web site
2. Water supply and sanitation- prof. Dunkan Mara paper presented at Jubilee congress -2002
3. NWS&DB price list-2005
4. Hydropower development in Sri Lanka by Eng H.B. Jayasekara-Kulasinghe felicitation volume
5. Annual Report Energy conservation fund-2004

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