# Poverty, Soil Erosion and Water Quality A Case Study in Kurundu Oya Sub Catchment of Upper Mahaweli Catchment, Sri Lanka

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## 1. Introduction

Land degradation caused by soil erosion due to agriculture is a serious environmental and economic issue in Upper Mahaweli Catchment Area (UMCA) of Sri Lanka. UMCA covers approximately 3118 $km^2$ of the hill country of Sri Lanka and feeds four major reservoirs, viz. Kothmale, Victoria, Randenigala, Rantambe and a diversion pond at Polgolla. These reservoirs generate over 54% of the country's power requirement and irrigate about 300,000 ha of agricultural lands (Gamage and Aheeyar, 1998). Soil erosion has been severe in the UMCA, particularly on cropping lands due to combination of various factors. Wallingford (1995) reported that 0.5 million tonnes of sediment are carried down by Mahaweli River annually. Sediments affect water quality of rivers and accelerate the siltation of reservoirs. Studies show that 46% of the Polgolla diversion pond and 36% of the Rantambe reservoir were silted within the first 10 years of the impoundment. Victoria and Randenigala reservoirs are getting silted at a rate of 0.5 and 7.25MCM per annum respectively (Wallingford, 1995). The process of soil erosion in the upper Mahaweli catchments in Sri Lanka has accelerated in the early $19^{th}$ century with the introduction of plantation crops, such as coffee and tea, by the colonial administration. Even after independence, land clearing has been continued for establishment of human settlements and for agricultural purposes (Madduma Bandara, 1996).

### *1.1 Soil erosion and Water Quality*

Surface and groundwater quality is generally linked to the land use and management practices in a catchment. Many researchers have concluded that soil erosion in agricultural land uses strongly contribute to the nitrogen (Johnson *et al.*, 1997) phosphorus (Hill, 1981) and sediment load (Ahearn *et al.*, 2005) in stream and reservoirs. It was found that concentrations of $SO_4$, $NO_3$, $PO_4$ and K were apparently increased by

agricultural activities in Himalayan mountain streams due to lack of soil conservation measures and over application of chemical fertilizers (Jenkins *et al.*,1995). Kothyari *et al* (2004) reported that per unit loss of organic matter and nutrient was maximum in rain-fed farming systems in Bhetagad watershed of Central Himalaya, India. Up country vegetable growing soils in Sri Lanka show high nutrient levels compared to the virgin forest soils (Rajakaruna, *et al.*, 2005). In addition, the nutrient levels in shallow groundwater in cropped lands are significantly higher than that of forest lands. These situations have partly occurred due to prevailing high rate of soil erosion. Soil erosion is closely associated with the existing land use system coupled with socio-economic factors related to demographic pressure and rural poverty.

## *1.2 Poverty and land degradation*

The rural community in many parts of the UMCA is generally poor and often is struggling to meet their basic living requirements. This situation has compelled the farmers to practice primitive and non-sustainable management practices. The existing soil and water conservation measures introduced by the Department of Agriculture require substantial investment in money, labour, material that many farmers are not in a position to afford. At the same time, access to low cost credit facilities is limited.

However, the impacts of poverty on soil erosion are hard to predict. On one hand, poverty reduces farmers' ability to invest on soil conservation and limit their interest in making long-term investments in soil and water conservation. On the other hand, poor people may have more incentive to conserve their land because they own little else than the land they occupy (Siddhisena and Jayathilaka, 2004).

## *1.3 Population pressure on lands*

The limited employment opportunities in the industrial sector and the lack of any other alternative income sources in UMCA have aggravated the pressure on land causing over exploitation of natural resources. Gamage and Aheeyar (1998) reported that most of the small-holder farmers cultivate their lands with about 250% cropping intensity leaving no time for natural improvement of soil fertility in Nuwara Eliya district. Landlessness has affected adversely on the development of rural economy of the UMCA for many decades. According to Land Commission Report (1987), Nuwara Eliya district where Kurundu Oya catchment is situated, had the highest proportion of landless population of 42.8%. The 1986 census revealed that about 75.4% of paddy farmers in Nuwara Eliya

district owned less than one acre (0.4 ha) of cultivable paddy lands. Stirrat (1997) observed that nearly 50% of the population in the UMCA is landless or operates no more than home garden plots which have less than one acre in extent.

Therefore, this study was undertaken to assess the relationship between poverty and soil erosion in farmlands which is directly related to the surface water quality of the Kurundu Oya sub catchment of the UMCA. It specifically includes following:

i) An investigation of the household characteristics of the study area
ii) An assessment of physical condition of different farming systems using selected soil parameters
iii) The impact of socio-economic factors on severity of soil erosion.

## 2. Methodology

### *2.1 Characteristics of the Kurundu Oya catchment*

The study was conducted in Kurundu Oya catchment (a sub catchment of the UMCA) which consists of a considerable heterogeneity in geomorphology and the farming systems (Figure.01). Paddy farming is the dominant land use system in the lower part of the catchment located below 750 m from Mean Sea Level (MSL). Most of the arable lands in 750 – 1500m elevation range of the catchment are kept under rotational farming system which is consisted of paddy in the wet season and vegetable in the dry season. The elevation of the upper catchment is above 1500m from MSL. Major land uses in the upper catchment area includes tea and intensive vegetable cultivation. Apart from that, home gardening and rain-fed farming are being practiced as subsistence farming all over the catchment.

### *2.2. Household survey*

A household survey was carried out during a six month period from May to October 2008 to collect poverty and other socio-economic data required for the analysis. Three villages, namely Batagolla, Kalaganwaththa and Binganthalawa situated

respectively in lower, middle and upper parts of the catchment were selected for the household survey. Because of high heterogeneity of the population in terms of their land use, stratified sampling was carried out to obtain a sample of 150 households representing all farming systems available in the catchment to administer a pre-tested questionnaire. Interviews were also conducted during the visits to each selected household to confirm the clarity of information collected by questionnaire survey. Collected data includes information on household characteristics and farming variables.

### *2.3 Soil sampling and testing*

Soil sampling and testing were carried out to determine soil physical and chemical properties. Soil samples were collected from each farm allotment of the surveyed households before land preparation for cultivation. A gouge auger was used to draw samples from the surface (0-30 cm depth) and two samples were obtained from each allotment. Samples were then air dried and passed through 2mm sieve prior to analysis. Soil testing was done to determine the gravel percentage, the levels of organic matter, total nitrogen, available phosphorus and exchangeable potassium. The gravel content was measured using dry sieving technique. Available K was extracted using 1M ammonium acetate solution and estimated by flame photometry. Available soil P was determined by the Olsen's method (Olser and Sommers, 1982). Organic matter content was determined by the Walkey and Black method (Nelson and Sommers, 1982). Total N of the soil samples were determined by distillation of $NH_3$ after Kjeldahl digestion (Bremner and Mulvaney, 1982).

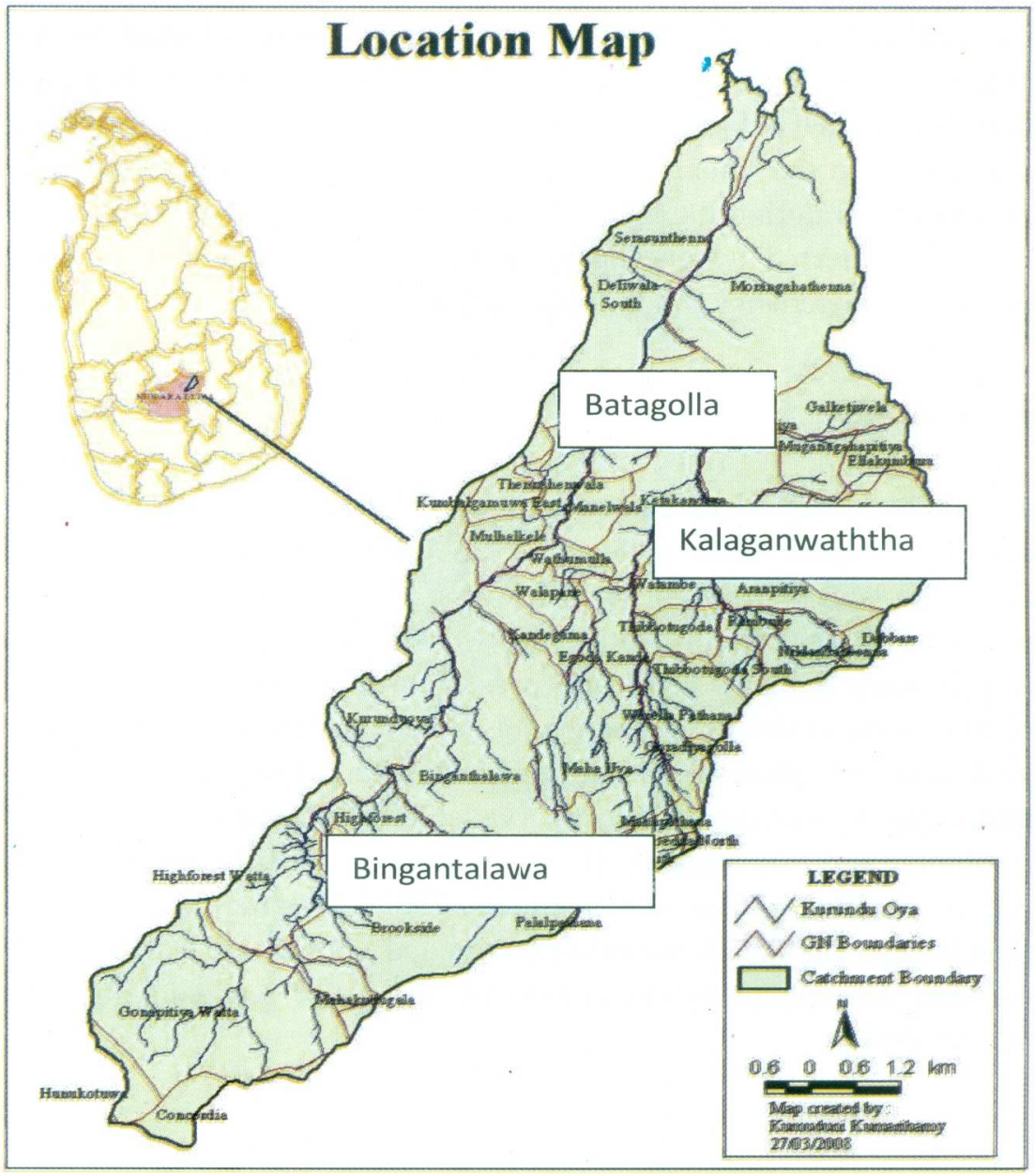


***Figure 01: Kurundu Oya sub catchment***

## *2.4 Analysis of soil and household survey data*

Complete Randomized Design (CRD) was used to analyze soil parameters. The mean comparison was done using Analysis of Variance (ANOVA) test and mean separation was done by Duncan's Multiple Range Test (DMRT) using Statistical Analysis Software (SAS). Descriptive statistics were used to analyze household variables using Statistical Package for Social Sciences (SPSS).

## 3. Results and Discussion

### *3.1 Land availability*

It was found that nearly 18% of the sampled households live in the study area were landless. A greater majority of farm households among surveyed community is operated on small uneconomic holdings (Table 01). Expanding population has exerted pressure on land in the catchment, limiting its per capita availability to 0.22 ha which is low in comparison to the national figure of 0.29 ha.

***Table 1- Size of farm holdings of the sampled households***

| Land size (ha) | Percentage |
|---|---|
| Landless | 18 |
| Less than 0.2 | 39 |
| 0.25 – 01 | 25 |
| Above 01 | 18 |
| Total | 100 |

Land scarcity in the catchment has resulted in increasing land prices rendering land out of the hands of the poor. This situation enhances further sub-division of the existing arable lands and encroachment of ecologically vulnerable lands, such as forest and stream reservations. There are several factors that affect the pressure on land in Kurundu Oya catchment. First, high population growth in the area has been recorded during the past century due to natural growth and immigration of people from South India for working in tea estates. Second, nearly 80% of the lands available in the catchment are under government control and these lands cannot be accessed by people. Third, alternative income sources are highly limited due to slow growth of the industrial sector (Gamage and Aheeyar, 1998). As a result, the household economy is mainly dependent on agriculture and the incidence of poverty in the study area is highly associated with the lack of access to arable lands. Therefore, low availability of lands has become a serious issue causing adverse impacts on social and economic development of the catchment. Brink (2003) pointed out that countries like Kenya and Zimbabwe have obtained better results in rural poverty alleviation through implementation of land alienation programs.

### *3.2. Household income and the poverty level*

The results of the household survey indicated that average total monthly income among the sampled households was Rs.8500. However, 19% of the sample households had a total monthly income less than Rs. 2500 with an average of Rs.2100 per family. More than 60% of the sample households obtained less than Rs. 10000 per month (Table 02). Only 2% of the total sample households had a monthly income above Rs.30000. Agriculture is the main income source of the surveyed community. Gamage and Aheeyar

(1998) reported that low income from agriculture is more likely to be associated with smaller size of the land holding operated by the farmers. The results of the household survey clearly confirmed this finding that low monthly income was associated with small farm allotments (Figure 02). The lowest monthly income of Rs. 2300 was reported by landless households. Though they had no any land with legally accepted ownership, most of them operated on encroached or leased lands.

***Table 02: Distribution of households among different income categories***

| Income category (Rs) | No of households | Percentage |
|---|---|---|
| 0 – 2500 | 28 | 19 |
| 2500 – 5000 | 36 | 24 |
| 5000 – 10000 | 31 | 21 |
| 10000-15000 | 25 | 17 |
| 15000-20000 | 11 | 7 |
| 20000-25000 | 6 | 4 |
| 25000-30000 | 10 | 6 |
| >30000 | 3 | 2 |
| Total | 150 | 100 |

However, the average size of the landholding of the sample household was 0.2 ha. The fragmentation of lands into small sizes is a major problem because cultivation on very small pieces of lands has become uneconomical. At the same time, it may lead to land disputes. It is very clear that only households having above 0.4 ha of farm allotments could obtain income above Rs. 20000 per month (Figure 02).

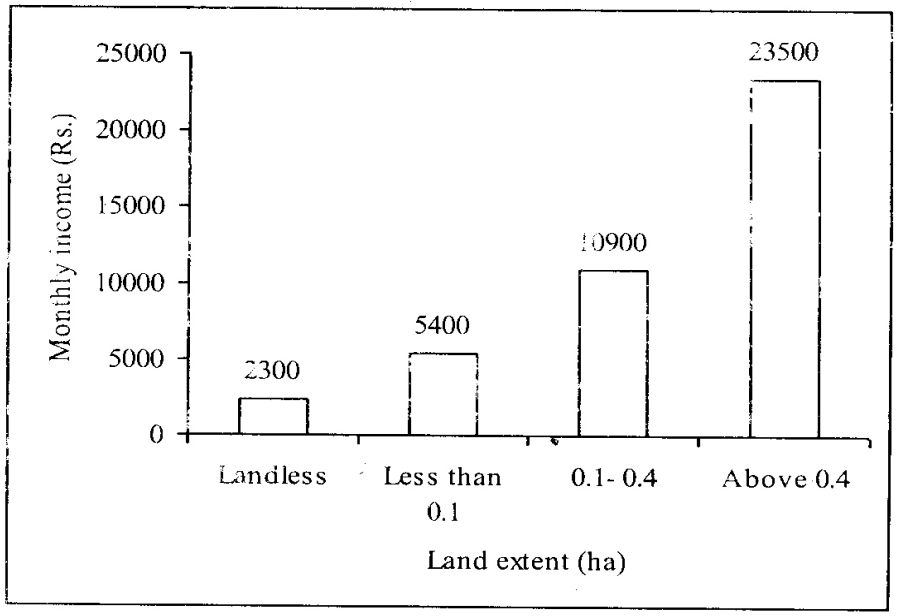


***Figure 02: Mean monthly income by the extent of the farm allotments***

The definition of poverty is highly complicated because it has different dimensions. Poverty is not just an inadequacy of household income to meet basic needs, but it is linked with many other factors like landlessness, unemployment, illiteracy, malnutrition, poor infrastructure, high infant mortality, etc. (Siddhisena and Jayathilaka, 2004). However, in this study three factors, viz. income level of the households, size of operational holdings and the education level of the households were considered to determine the poverty line. When considering the monthly household income, 28 families (19%) of the total sample had less than Rs.2500 per month. Further, it was found that 18% of the sample households were landless and their average monthly income was Rs. 2300. In addition, the average monthly income of very low education level (no schooling) category was Rs.4200 (Figure 03). Therefore, it is very much clear that most of the households belong to Rs. 0-2500 income category have low education and often landless. Therefore, monthly income of Rs.2500 was considered as the poverty line. Accordingly, nearly 20% of the sampled households live below the poverty line.

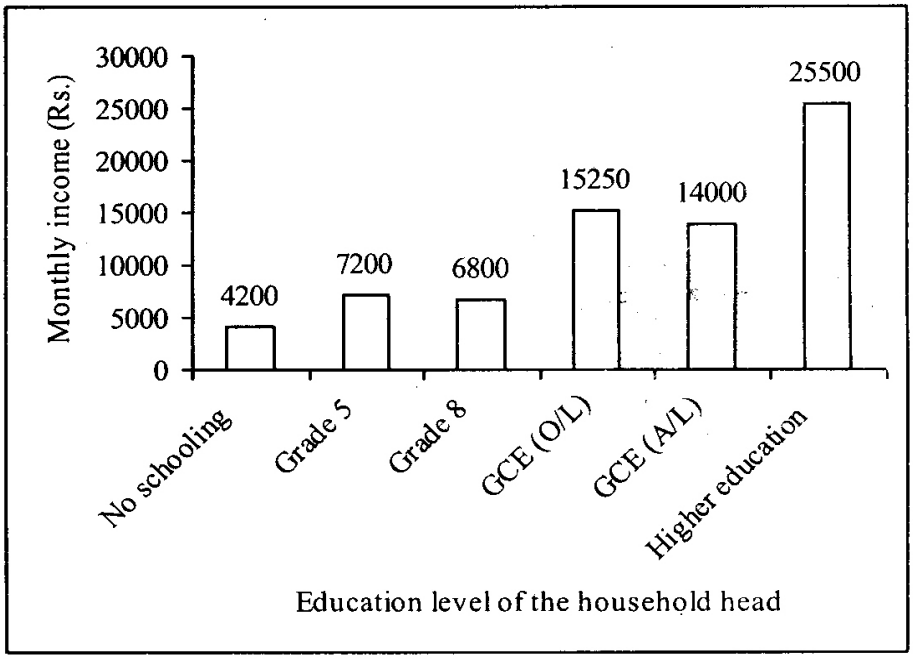


***Figure 03: Average monthly income by the education level of the household head***

### *3. 3 Farming systems available in the catchment*

Six different farming systems could be identified in the catchment. Paddy cultivation is confined to the lowlands where soil depth is high. Paddy fields are located on bench terraces and surrounded by earthen bunds in order to impound water. Farmers in the lower catchment practice paddy farming in both dry and wet seasons because of the high availability of water and ill-drain conditions of the soil. However, in the middle reach of the catchment, a rotational farming system consists of paddy and vegetable is dominant. Paddy is confined to the wet season and vegetable is grown in the same field

during dry season. Since the upper catchment is located above 1500m from MSL, the climatic condition is more favorable for exotic vegetables. Therefore, year-round intensive vegetable farming system is continued, and maximum use of land and water resources can be observed. Rain-fed farming systems and home gardening are two subsistence farming systems available all over the catchment. Cereals and coarse grains are the major crop types cultivated under rain-fed farming, and perennials such as fruits and spices are mainly grown in home gardens. Although, tea is the main agricultural land use in the catchment, it is not much common as a household farming system. However, tea smallholdings are now becoming popular, especially in the middle part of the catchment.

The mean monthly income obtained from different farming systems ranges from Rs. 2600 to 13000 per ha. Intensive vegetable farming recorded the highest income of Rs.13000 per month where rain-fed farming system produces the lowest monthly income of Rs.2600 (Figure 04). Most of the households involve in rain-fed farming falls into low income category (Rs.0-2500), because in general, the input cost of the rain-fed farming is low. However, low input cost always attributed to low productivity. Very often, demand for the crops cultivated under rain-fed farming is low compared to the crops grown under other farming systems.

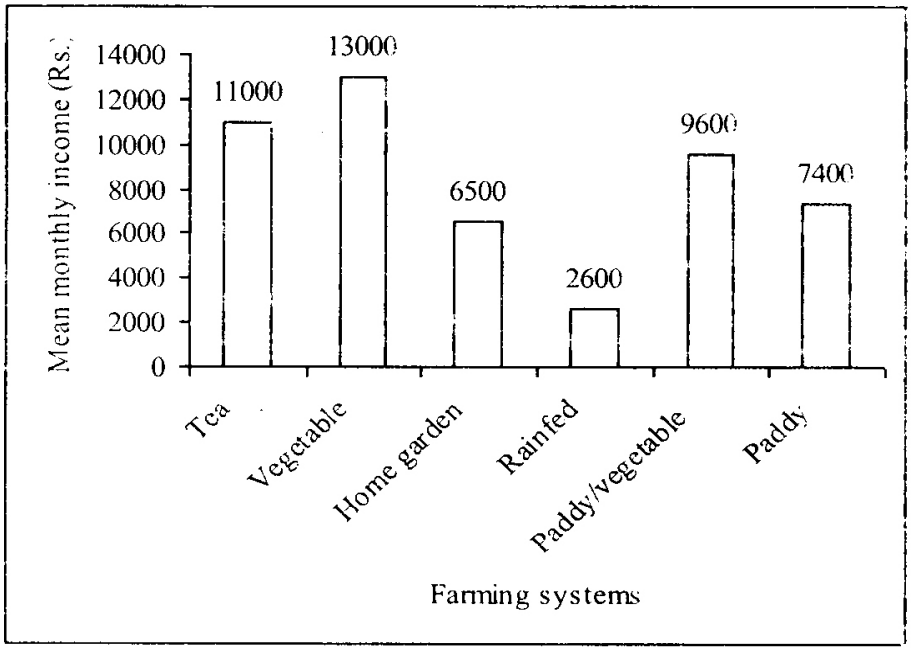


***Figure 04: Mean monthly income obtained from different farming systems***

Most of the rain-fed farmlands are encroached lands which are located next to the dense forest. Therefore, a considerable amount of yield loss is often recorded due to the damage done by the predators. As usual, the success of rain-fed farming mainly depends on the amount of rainfall received which cannot be predicted easily. Therefore, all these factors affect more or less equally to reduce the final income of rain-fed farming system.

### *3.4 Severity of soil erosion and its impact on soil fertility of different farming systems*

Land degradation due to soil erosion by bad agricultural practices results in loss of fertility, silting of reservoirs and increasing incidences of landslides. The process of soil erosion is overruled by several factors, including land management. A number of indicators have been developed to measure the severity of soil erosion. The gravel content (particles > 2mm in diameter) of the top soil (0-30 cm depth) is one of the indicators widely used by researchers (Botschek *et al.*, 1998). Table 03 shows the average percentage of gravel content of the top soil in different farming systems available in the study area. Rain-fed farming system has recorded the highest gravel percentage of 29.2 which is significantly greater than the other farming systems. On the other hand, paddy fields which are surrounded by earthen bunds are less vulnerable to soil erosion, and gave the lowest gravel percentage of 12%. Stocking (1992) reported that there are about 48450 ha of lands under rain-fed farming in the UMCA, and the estimated annual soil loss from these lands is around 75 tons/ha/year. He further mentioned that rain-fed farming contributes to around 62% of the total soil loss and 53% of the nutrient replacement cost of the UMCA. Therefore, it is very clear that rain-fed farming is highly vulnerable to soil erosion and contributes significantly to increase sediment and nutrient load passing through the streams.

***Table 03: Mean value of particles greater than 2mm in diameter in different land use categories***

| Farming systems | Particles >2mm % |
|---|---|
| Paddy | 12.0 de* |
| Paddy/Vegetable | 14.3 d |
| Home gardens | 19.1 bc |
| Rainfed | 29.2 a |
| Tea | 19.0 bc |
| Vegetable | 21.8 b |

Note: *Means followed by same letter are not significantly different at 5% probability level

The levels of available plant nutrients and organic matter contents were considered as accurate indicators of the existing soil fertility of any farming system (Nayakakorale, 1998). The results of the soil analysis indicated that the lowest levels of N, P and K and soil organic matter content were recorded for the rain-fed farming system (Table 04). Inadequate application of chemical fertilizers and removal of nutrients and organic matter with eroded soil may eventually lead to low nutrient level of the soil. Since the cost of synthetic fertilizer is remarkably high, farmers in low income categories are reluctant to apply recommended doses. In addition, soil conservation methods adopted in many rain-fed farming systems are not very successful compared to other farming systems (Dharmasena, 1998).

***Table 04: Chemical properties of soils collected from different land uses***

| Land Use | Mean value | | | | |
|---|---|---|---|---|---|
| | Soil pH (1:2.5 soil: water ) | Soil OM % | Available P ppm | Exchangeable K ppm | Total N ppm |
| Paddy | 5.2 | 2.4 b* | 136.3 a* | 128.3 b* | 934.1 a* |
| Paddy/vegetable | 4.7 | 1.7 c | 61.0 c | 143.7 a | 925.7 a |
| Home gardens | 4.8 | 2.1 b | 20.4 de | 68.3 c | 451.2 c |
| Rainfed | 4.8 | 1.1 d | 18.9 e | 48.3cd | 411.2 c |
| Tea | 5.1 | 1.9b c | 28.7 d | 61.4 c | 697.3 b |
| Vegetable | 5.5 | 3.0 a | 103.5a b | 125.5 b | 861.6 a |

Note: *Means followed by same letter in each column are not significantly different at 5% probability level

### *3. 5. Land tenure and soil conservation*

Five different land tenure systems were identified during the household survey (Table 05). Of the total land holdings in the study area, 13% were encroached lands. Out of 20 encroached farm allotments, 13 were under rain-fed farming. Most of the encroachers try to exploit lands resource in maximum intensity due to the uncertainty of continued ownership. It was observed that farmers living adjacent to forest and stream reservations always tend to encroach lands. Since tea estate workers live in line rooms, they have limited access to lands. Therefore, most of the lands allocated for stream reservations have been encroached by them. Apart from that, tea estate management companies have leased out stream reservations in the estate, to the workers and out side growers in order to get extra income. The results of the household survey indicated that more than 50% of the riparian zones in the upper catchment have been encroached. As long as farmers have no legally accepted ownership for their farm lands, it is unrealistic to expect them to invest on soil conservation measures.

***Table 05: Farming systems adopted by the households according to the type of land tenure***

| Status of the allotment | Farming system | | | | | | Total | % |
|---|---|---|---|---|---|---|---|---|
| | Paddy | Paddy/ Vegetable | Vegetable | Rainfed | Tea | Home garden | | |
| Sole owner | 23 | 20 | 09 | 05 | 05 | 14 | 76 | 51 |
| License obtained from government | - | 03 | 07 | 06 | 01 | 07 | 24 | 16 |
| Leased | 08 | 12 | 09 | 01 | - | - | 30 | 20 |
| Encroached | - | 02 | 02 | 13 | - | 03 | 20 | 13 |
| Total | 31 | 37 | 27 | 25 | 06 | 24 | 150 | 100 |

Bench and forward slope terraces are the widely-used methods in the study area (Table 06). Bench terraces are mostly confined to the valley bottoms where soil depth is high. In general, paddy fields are found in the bench terraces, and forward slope terraces are adopted in rain-fed farming systems which are mainly confined to steep slopes with shallow soils. In addition more than 50% of rainfed farmlands are encroached lands where farmers have no legal rights. It was found that farmers belong to low income category prefer to select forward terraces due to couple of reasons. One is the simplicity and low cost associated with forward terraces. Secondly, they reluctant to invest on other high cost methods because of the uncertainty of the land owners hip. However, forward terraces are not very successful in soil conservation as compared to other available methods.

***Table 06: Farming systems according to the soil conservation methods adopted***

| Soil conservation method | Farming system | | | | | | Total | % |
|---|---|---|---|---|---|---|---|---|
| | Paddy | Paddy/ Vegetable | Rainfed | Home garden | Vegetable | Tea | | |
| Forward slope terraces | 06 | 04 | 20 | 07 | 07 | - | 44 | 30 |
| Bench terraces | 26 | 31 | - | - | - | - | 57 | 38 |
| Reversed slope terraces | - | - | - | - | 05 | - | 05 | 3 |
| Stone bunds | - | - | 04 | 09 | 11 | 6 | 30 | 20 |
| Contour trenches | - | - | | 04 | 01 | - | 05 | 3 |
| Hedgerows | - | 01 | 02 | 04 | 02 | - | 09 | 6 |

### *3. 6 Factors affecting investment on soil conservation*

Monthly income and the investment on soil conservation showed positive correlation. According to the results, as farm income increases the investment on soil conservation increases (Figure.05). According to farmers' perception low farm income is the major constrain to invest in soil conservation measures. The initial cost to establish soil conservation measures are fairly high due to lack of skilled labour. At present one Labour Day is cost about Rs. 500.00 and nearly 30 labour days are needed to construct earth bunds in one acre of land.

Figure 06 illustrates that higher the education level of household head, higher the investment in soil conservation. At the same time investment in soil conservation increases with the increases of awareness on soil conservation (Figure 07). When considering the type of land ownership, it was found that investment in soil conservation was low in encroached lands compare to the other land tenure types existing in the study area (Figure 08).

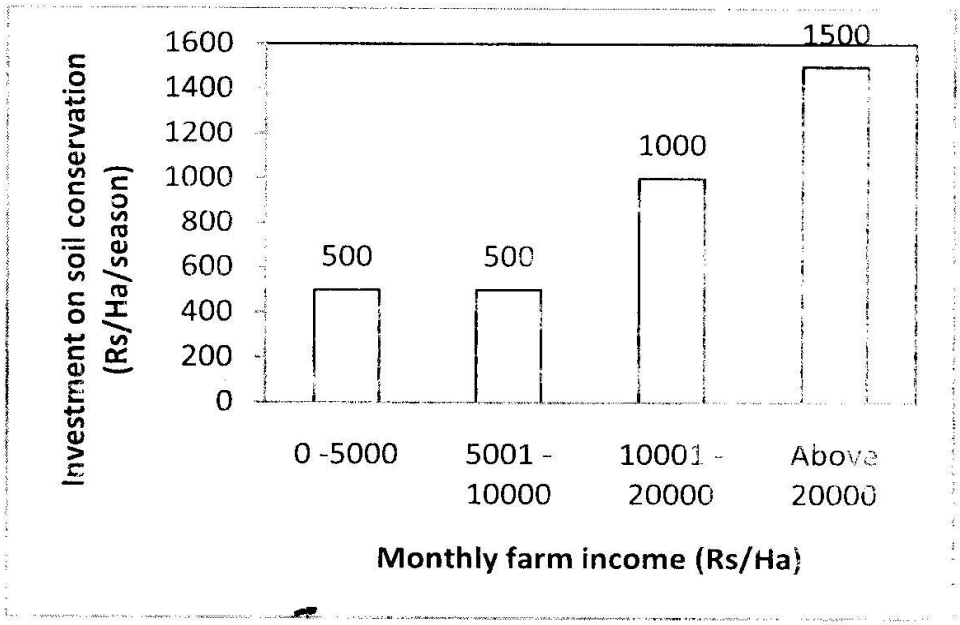


***Figure 05: Investment in soil conservation by the farm income***

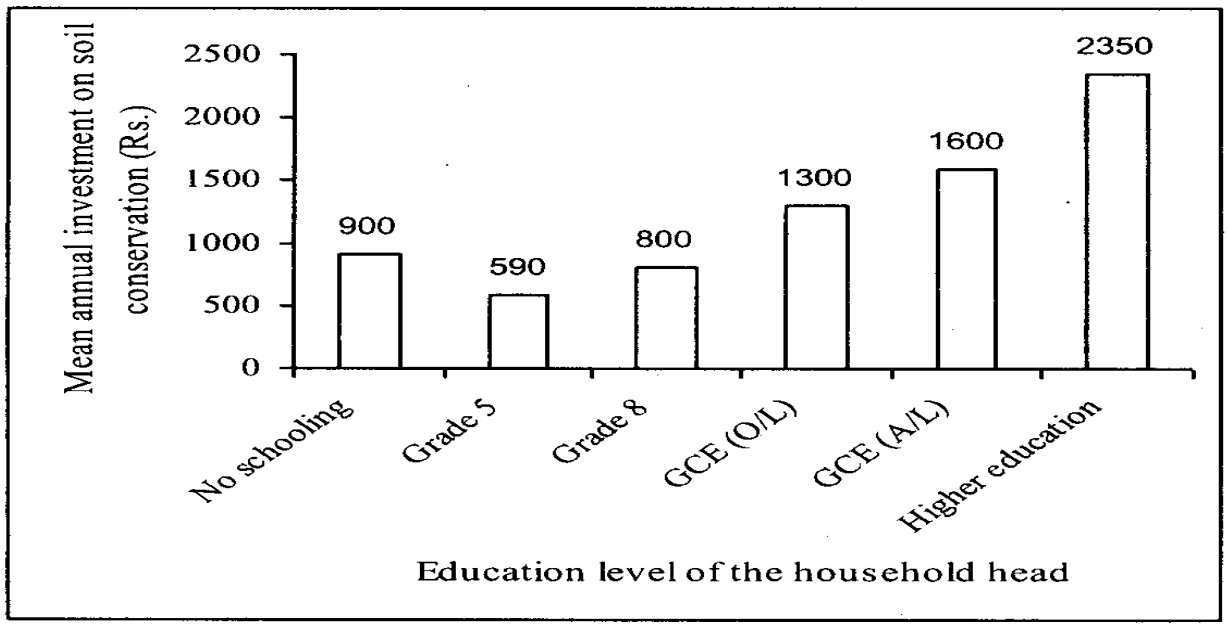


***Figure 06: Investment in soil conservation by the education level***

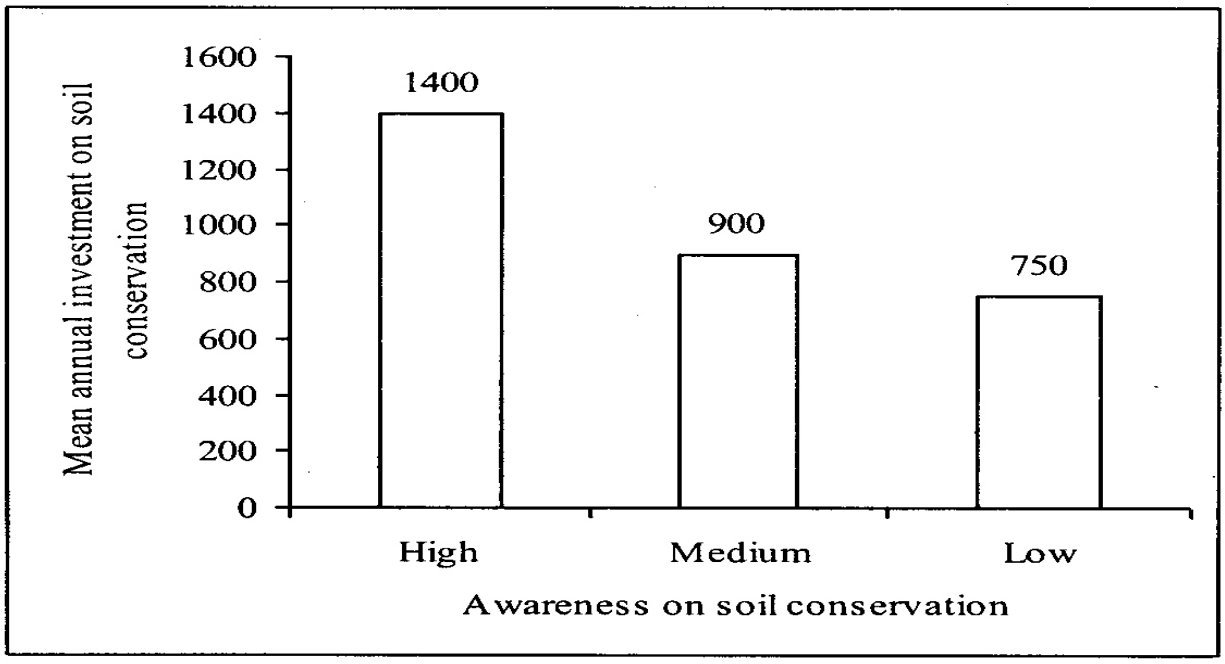


***Figure 07: Investment in soil conservation by the awareness***

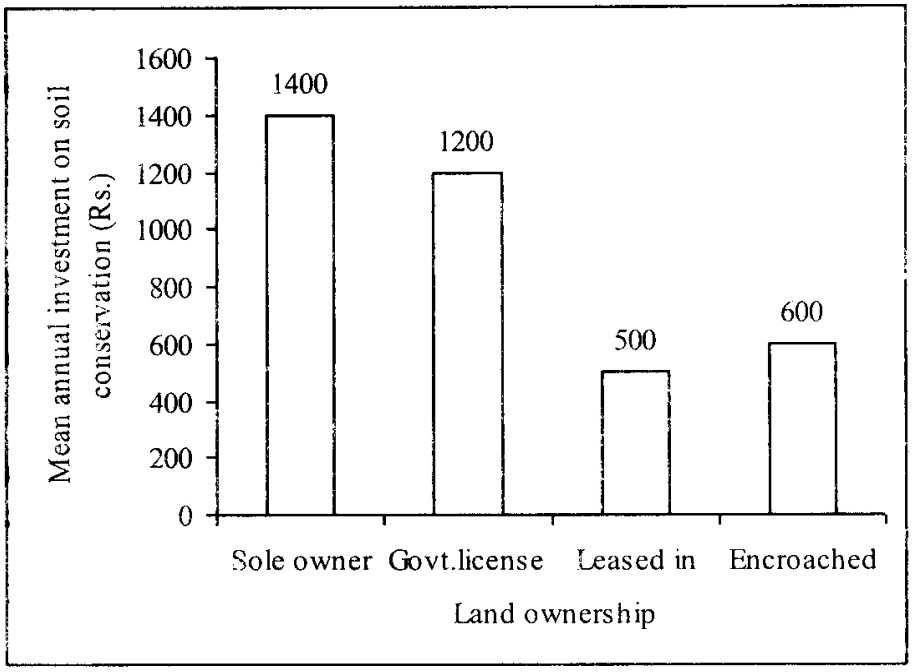


*Figure 08: Investment in soil conservation by the type of land ownership*

## 4. Conclussions and Recommendations

Most of the households belong to low income category involve rainfed farming which is associated with low productivity and high soil erosion. Nearly 20% of the sample households live below the poverty line (i.e., Rs. 2500) which was defined based on household income, education level of the household head and the extent of land allotment operated by the households. Household income was identified as the major factor that affect on the investment on soil conservation. Apart from that, low education level, lack of awareness and insecurity of ownership of land negatively affect on the investment on soil conservation. All these factors contribute to the poverty in the rural economy of Kurundu Oya catchment area.

There is an urgent need to address these issues with a better understanding of the root causes. Since the economy is mainly based on agriculture, the existing marketing channel of the farm products has to be improved to the favor of the producer. Appropriate policies at micro and macro level need to be introduced, with legal and institutional reforms to enhance the productivity of lands.