59

*Engineer*
*Vol. XXXVIII, No. 01, pp. 59-67, 2005*
*© Institution of Engineers, Sri Lanka*

# Economic Benefits of Water by Assessing the Comparative Advantage of Water used Activities. A Case Study at Kaltota Irrigation Scheme Associated with Geoinformatics Techniques.

**K. M. P. S. Bandara**
Department of Irrigation

***Abstract—*** *The term water use can be classified into consumptive use and non-consumptive use. In Sri Lanka, the highest volume of water is used for irrigated agriculture for paddy cultivation and hydropower generation. In hydropower generation the total amount of water does not undergo a state change i.e. non-consumptive use, whereas in irrigated agriculture only a portion of the released water undergoes a state change i.e. consumptive use. By nature, the balance portion is used for the sustainability of the environment including social life. There was no reliable technique to quantify the consumptive use of water in irrigated agriculture. Therefore ,as a common practice the total amount of water released has been accounted for the event of crop production. If irrigation water is not released for a season, the affected outcome is the immediate loss of crop production. If this is continued for consecutive seasons, several unfavorable situations related to the social life and the environment could be experienced. Hence, one has to identify the different water use activities related to irrigated agriculture and apportion the released amount of water among such activities. Techniques of Satellite Remote Sensing can now be used to estimate the consumptive use of water irrespective of the type of vegetation cover over the land surface. This paper describes the author's work of estimation of the amount of water consumed by the paddy crop at the Kaltota Irrigation Scheme using Geoinformatics techniques. The economic benefit of water for paddy production is compared with the same for hydropower generation at Samanalawewa Hydropower Station which is situated on the same water course at the upstream of the Kaltota Irrigation Scheme.*

***Key words:*** *Consumptive use, non-consumptive use, evapotranspiration, ground water, water reuse*

## 1. Introduction

Assessing the economic benefits of water by comparing the market prices of "water used products" for which water is used as the main component during the production process or computing "amount of rupees generated by a drop of water" has now become a common practice. In this context, water, as a commodity will receive a relative value than an absolute value because, unlike gold, there is no way to assess the absolute value of water. On the other hand, nature can survive without gold, but not without water. The total amount of fresh water available does not vanish in the global context. But the pattern of receiving water has been hampered by man made activities. And, also, with the increasing population, water is treated as a scarce resource.

In irrigated agriculture, water is used for several activities such as evaporation, transpiration, percolation, surface drainage etc.

Manuscript received: 30.09.2004
Revised manuscript received: 05.10.2004
Manuscript accepted: 10.10.2004

Once the water is released, it is distributed over a large area and physically disappears throughout the season. The amount of water used for the crop growth (*actual evapotranspiration* or ET_act) i.e. the amount of water transpired from the crop canopies including the amount of water evaporated from the land surface, will undergo a state change and added to the atmosphere, which is a *consumptive use*. The portion which is discharged as surface drainage will be (re)used by the downstream users and the environment in the vicinity. By measuring the drainage discharges, this amount could be estimated. But the quantification of the balance portion, which infiltrated as deep percolation to recharge the ground water table, is rather difficult. In order to compute the water productivity over irrigated agriculture, the amounts of water used for said activities have to be estimated.

When water is used for hydropower generation, the amount of water used will usually be discharged to the same watercourse at a further downstream location. The amount of water does not undergo a state change. In other words, it is a *non-consumptive use*. The amount of water used and the units of hydropower produced could be easily quantified. During the last decade, scientists have shown increasing interest in using data from earth observation satellites to obtain information on land surface parameters which undergo spatial and temporal changes. Information on such parameters related to soil, water and vegetation is of prime importance for managing natural resources. Remote Sensing produces the spectral measurements that provide the biophysical input data needed to determine evapotranspiration, crop water stress, soil moisture at root zone depth, and biomass growth, etc. Area representative measurements instead of point measurements and time series analysis of data acquired in shorter intervals will improve the quality and the accuracy of the results. High frequency satellite measurements can fulfill both requirements. This research study estimates the actual evapotranspiration of crop growth using satellite remote sensing and computes the water productivity over said activities. And it also computes the water productivity over hydropower generation to assess the comparative advantage of water. The following objectives have been established in this study.

- To carry out a *water use study* on a selected irrigation scheme to identify the actual processes of water use during a cultivation season.
- To estimate the actual portion of water consumed by the crop from the total amount released for the irrigated agriculture. A remote sensing and GIS approach is applied.
- To assess the water productivity on irrigated agriculture and the water productivity on hydropower generation, using a common water source.

## 2. Study area and its water use

Kaltota Iirrigation Scheme and Samanalawewa Hydropower Project on Walawe Ganga were selected as the study area. Samanalawewa Reservoir was constructed at the confluence of Walawe Ganga and Belihul Oya at a location called Kumbalgama and was commissioned in 1992. Water is diverted to the 120 MW power station at Kapugala through an under ground tunnel. After power generation, the water is released to Katupath Oya, which falls into Walawe Ganga downstream of the Kaltota Irrigation Scheme. The Kaltota Irrigation Scheme, one of the oldest irrigation schemes in Sri Lanka, is located between Samanalawewa reservoir and the Katupath Oya and provides irrigation facilities for cultivating 910 ha of paddy and about 2000 farmer families are benefitted. In addition to this, about 150 ha is cultivated using drainage water. A diversion weir (Anicut) is constructed across the Walawe Ganga (at Kaltota) and water is delivered through two irrigation canals at right and left banks of the weir. The location map of the system is shown in Fig 1.

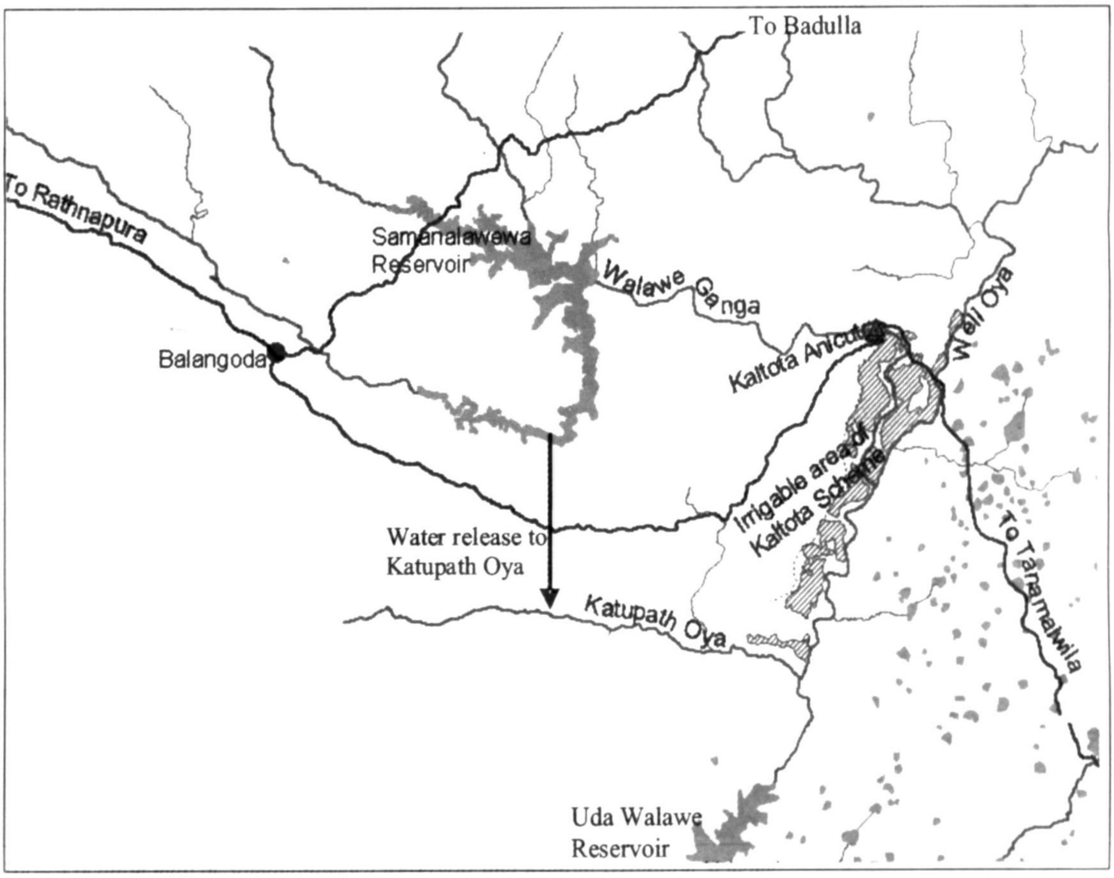

*Fig. 1 Location map of Samanalawewa Reservoir and Kaltota Irrigation Scheme*

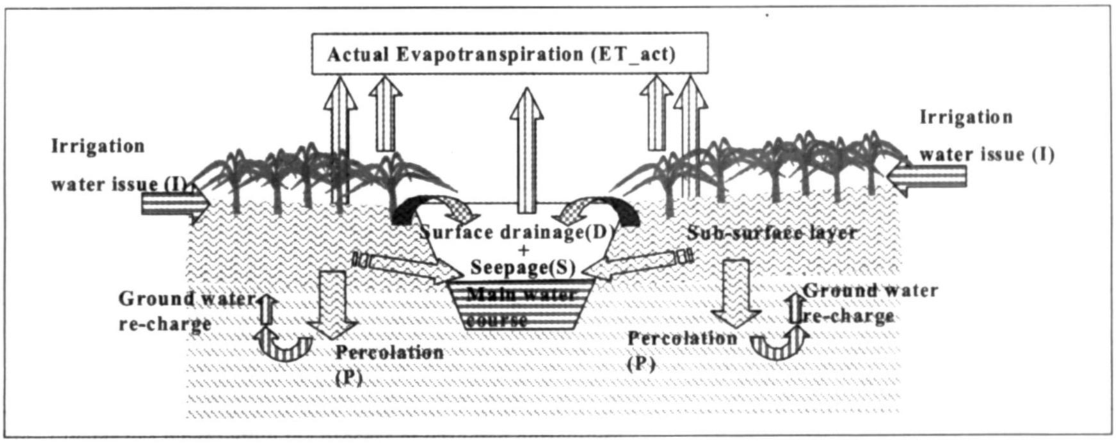

*Fig. 2 Water use types within the process of irrigated agriculture*

Irrigation water is released to the Walawe Ganga from the Samanalawewa reservoir through its bottom outlets. There exists a permanent water leak from the reservoir, which also accumulates to the irrigation release. The amount of water leaking is also accounted for while releasing the irrigation demand.

## 3. Water use study for the Kaltota Irrigation Scheme

It is required to identify the water use types before estimating the quantities. In this study the amount of water received from rainfall is not considered. The water use types within the process of irrigated agriculture are shown in Fig.2 and thereby the water use equation can be expressed as;

$$I = ET\_act + D + S + P \quad \text{Eq. (1)}$$

Where ET_act is the amount of water consumed by the crop and D+S+P is the amount of water not consumed by the crop.A simple water use study can be carried out for the Kaltota Irrigation Scheme for a single cultivation season. The total amount of water used by the crop, i.e. the actual evapotranspiration (ET_act), has to be computed. The author uses the technology of satellite remote sensing associated with GIS (Geographical Information System) techniques to estimate the actual evapotranspiration over the land cover.

## 4. Remote sensing and GIS approach to compute actual ET of crop

Several approaches were developed for estimating spatio-temporal parameters related to soil, water and vegetation over the land surface. Compositing typical spectral bands of satellites within the visible and near infrared region of the electromagnetic spectrum are commonly used. The thermal energy available is used to perform the process of water vaporization and transpiration over the vegetative areas. Hence, temperature sensitive thermal infrared bands are used in the approach to estimate the surface temperature. The SEBAL (Surface Energy Balance Algorithm for Land) approach (Bastiaanssen, 1995) is used for the estimation of ET_act. This method requires spectral radiances in the visible, near infrared, and thermal infrared regions of the spectrum to determine its constitutive parameters: surface albedo, normalized difference vegetative index (NDVI), and surface temperature. The remote sensing input used in the study was AVHRR data from day-time (early afternoon) ascending

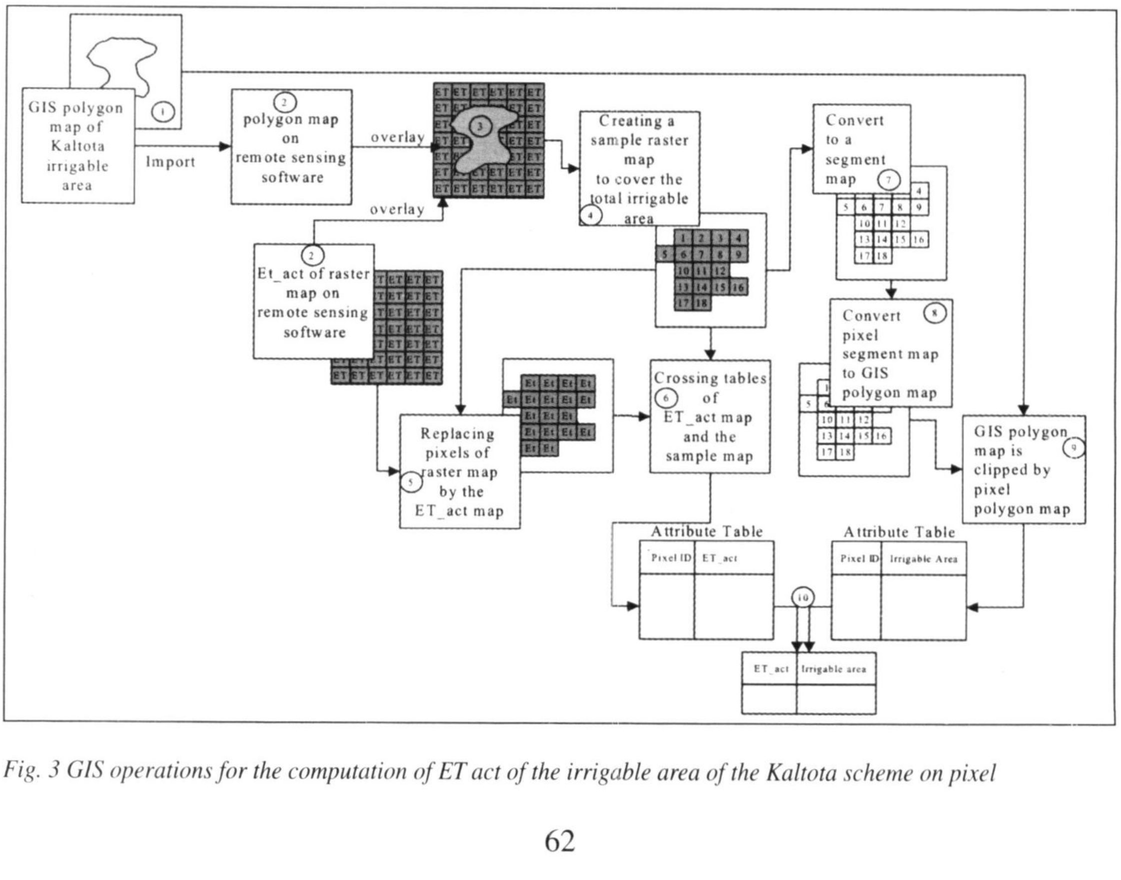

*Fig. 3 GIS operations for the computation of ET act of the irrigable area of the Kaltota scheme on pixel*

mode pass of NOAA 14 meteorological satellite, having a spatial resolution of 1.1 km (1.1 km. Ancillary data such as air temperature, wind speed, relative humidity, sun shine hours were obtained from the Department of Meteorology. The land surface energy balance, ignoring energy required for photosynthesis and the heat storage in vegetation, in its most simplified form reads as:

$$Q^* = G_0 + H + \lambda E \qquad \text{Eq. (2)}$$

Where $Q^*$ (W/m$^2$) is the net radiation absorbed at the land surface, $G_0$ (W/m$^2$) the soil heat flux to warm or cool the soil, H (W/m$^2$) the sensible heat flux to warm or cool the atmosphere and the latent heat flux associated with soil, water and vegetation. SEBAL solves the Eq.(2) resulting (E(W/m$^2$) as the residual of the energy budget on pixel by pixel basis over the NOAA raster image of the Kaltota irrigated area. GIS techniques were used to incorporate the actual shape of the irrigable area with the corresponding pixel values of the raster map of ET_act, computed by SEBAL (Fig.3).

Daily NOAA satellite images, acquired during the Yala season of 1999 for another study were used for this study also. (Daily MODIS satellite images are now available and can be down loaded from the internet.) The daily Output maps of SEBAL were converted into 10 day composites for easy computation and results are shown in Table 1.

*Table 1. Estimation of ET_act using remote sensing approach*

| 10 day intervals of Yala season, 1999 | Actual Evapotranspiration of irrigated paddy at Kaltota Scheme during Yala 1999 | | |
|---|---|---|---|
| | LB Area only (MCM) | Both LB & RB Areas (MCM) | RB Area only (MCM) |
| Apr. 01-10 | 0.117 | | |
| Apr. 11-20 | 0.146 | | |
| Apr. 21-30 | | 0.472 | |
| May. 01-10 | | 0.474 | |
| May. 11-20 | | 0.488 | |
| May. 21-31 | | 0.492 | |
| Jun. 01-10 | | 0.384 | |
| Jun. 11-20 | | 0.360 | |
| Jun. 21-30 | | 0.427 | |
| Jul. 01-10 | | 0.410 | |
| Jul. 11-20 | | 0.347 | |
| Jul. 21-31 | | 0.288 | |
| Aug. 01-10 | | 0.394 | |
| Aug. 11-20 | | 0.332 | |
| Aug. 21-31 | | 0.319 | |
| Sep. 01-10 | | 0.317 | |
| Sep. 11-20 | | | 0.188 |
| Sep. 21-30 | | | 0.096 |
| Total ET_act = (6.05 MCM) | 0.263 | 5.503 | 0.284 |

Discharge measurements of main irrigation canals (Right Bank & Left bank) are available from the year 2000 onwards. The available water statistics indicate that the seasonal discharges during the Yala season are 33 MCM along RB main canal and 15 MCM along LB main canal. Hence the total amount of water delivered to the Irrigation system can be taken as 48 MCM. Water releases from the Samanalawewa Reservoir during the Yala sesaon 1999 are shown in Table 2.

***Table 2. Water releases from the Samanalawewa Reservoir during the Yala sesaon 1999***

| **Month of 1999** | **Hydropower Generation (GWH)** | **Water leak to the upstream of Kaltota (MCM)** | **Water relases from the bottom outlet to Kaltota (MCM)** |
|---|---|---|---|
| April | 17.141 | 5.77 | 0.00 |
| May | 14.911 | 5.63 | 2.99 |
| June | 37.998 | 5.41 | 3.66 |
| July | 47.053 | 5.52 | 3.73 |
| August | 32.124 | 5.19 | 4.92 |
| September | 28.624 | 4.83 | 0.00 |
| TOTAL | 177.851 | 32.35 | 15.3 |

Source: CEB office Samanalawewa

Based on the above data, a simple water balance can be carried out at the Kaltota Anicut for the Yala season of year 1999.

1. Amount of water discharged to the Anicut from the bottom outlet = 15.3 MCM
2. Amount of water discharged to the Anicut from the water leak = 32.35 MCM
3. Total amount of water discharged to the Anicut = 47.65 MCM
3. Amount of water delivered to the Irrigation Scheme (I) = 48.0 MCM
4. Hence, the amount of water received to the Anicut from the local catchment = (48.0-47.65) MCM = 0.35 MCM

Substituting the computed values to the Eq(1);

$$\begin{aligned} 48.0 &= 6.05 + D + S + P \\ D + S + P &= 48.0 - 6.05 \\ D + S + P &= 41.95 \text{ MCM} \end{aligned}$$

The above water use study determines that 41.95 MCM out of the total irrigation issue is used as surface drainage flows, sub surface seepage flows and percolation. Surface drainage flows and seepage flows are accumulated at the main watercourse, i.e. the Walawe Ganga, and will be an inflow to the downstream users which is not a consumptive use at the Kaltota Scheme. Two major irrigation schemes, namely Uda-walawe and Liyangastota are located at the downstream of Kaltota scheme in addition to the small and medium scale users.

The crop uses only 6.05 MCM, which is the consumptive use of water during the 1999 Yala season to produce 4200 Metric Tons of paddy. Though the crop has not consumed the balance amount of 41.95 MCM, it is not wasted. Bos and Wolters (1989) have pointed out that the portion of water diverted to an irrigation project that is not consumed is not necessarily lost from a river basin, because much of it is reused within the basin.

The amount of water which infiltrates as deep percolation, recharges the ground water table. Lowering of ground water table may cause salinity development and change the environment by affecting the ecosystem[1]. Groundwater has been the fundamental resource which allows economical and more reliable supply of water with improved quality, for a large proportion of the rural population of Asia (Clarke et al, 1996). The use of ground water has led to the significant development in human health and quality of life in innumerable village communities. Ground

---

[1] consists of a dynamic set of living organisms (plants, animals, and microorganisms) all interacting among themselves and with the environment in which they live (soil, climate, water and light)

water has also provided security against droughts, especially in areas where irrigation is provided with surface water resources, as in dry years like year 2000 in Sri Lanka.

All the said benefits have a direct impact on the social life and health security of the rural population and the sustainability of the ecosystem. But it is rather impossible to make an assessment of all the benefits in monetary terms, other than the crop yield which has a regular market price. One can think of carrying out a survey by withholding the release of irrigation water to the Kaltota Scheme for a few years continuously. On humane grounds such an exercise would be highly undesirable.

However, in one cultivation season, farmers in the Kaltota Scheme received financial compensation equivalent to the 100% risk free value of their seasonal harvest assuming that a harvest is the only benefit gained by irrigation water. The amount of water to be released for irrigation was used to produce hydropower. But, this cause of action compelled the farmers to face grave consequences. Traditional farmers couldn't change their life style from farming activities to any other activity. Easy money began to corrupt their life style. The social and cultural system started to collapse by threatening human health, social life and peace. The new system was not repeated and therefore the ecosystem was protected without any permanent damage taking place.

## 5. Assessment of water productivity over hydropower and agriculture

For the economic development of the country, industrial development is also necessary and as important as the agricultural development. In this context, energy, in the form of electric power, is one of the major factors of production. Hydropower and Diesel-power plants are used to produce electric power. On the other hand, rice is the staple food of the country where water and land become major factors of production. The following two scenarios were considered for the computation.

1. In the 1999 Yala season, if irrigation water (47.65 MCM) was not released to the Kaltota anicut from the Samanalawewa Reservoir (assuming the leak was repaired) what will be the possible losses and amount of water accountable for such losses and at what cost?
2. In the 1999 Yala season, if the same amount of water (47.65 MCM) was not used for producing hydropower at the Samanalawewa power station what will be the possible losses and the amount of water accountable for such losses and at what cost?

Table 3 shows the computations.

Following statistics were used for the computation of water productivity.

| | | |
|---|---|---|
| Selling price of paddy in 1999 | = | Rs. 12.00 per kg |
| Paddy production of Kaltota scheme during the Yala season of 1999 | = | 4200 Metric Tons |
| * Avg. Selling price of Electricity in 1999 | = | Rs. 4.43 per kWh |
| * Water Productivity in terms of producing hydropower (by considering average reservoir heights for the year 1999 and average CEB rates) | = | 0.764 kWh per $m^3$ |

* Source of data -Weerasinghe et al. 2002

*Table 3. Estimation of possible losses due to non availability of water*

| Possible losses as a result of non irrigation | | Accountable amount of water | Losses as a result of non-producing hydropower using accountable amount of water |
|---|---|---|---|
| **Type of direct losses** | **Amount (Rs in million)** | **MCM** | **(Rs in million)** |
| 4200 MT of paddy | 4.2 x 1.2<br>= 50.4 | 6.05 | 0.764 x 6.05 x 4.43<br>= 20.5 |
| Non availability of drainage discharges to the downstream users | Such losses cannot be determined in monetary terms. And also such losses cannot be regained. | 41.95 | 0.764 x 41.95 x 4.43<br>= 142.0 |
| Lowering ground water table and salinity development | | | |
| Permanent damages to the ecosystem | | | |
| Social system failure | | | |

From the above computation productivity of water can be assessed on the basis of irrigated agriculture for paddy crop and producing hydropower.

Productivity of water on irrigated agriculture for paddy crop

$$= \frac{50.4 \times 10^6}{6.05 \times 10^6}$$

$$= 8.33 \text{ Rs. per m}^3$$

Productivity of water on generating hydropower

$$= \frac{20.5 \times 10^6}{6.05 \times 10^6}$$

$$= 3.39 \text{ Rs. per m}^3$$

## 6. Remarks

- Water used activities provide direct benefits as well as indirect benefits to the society. The direct benefits are the immediate outcome which could be estimated easily. The indirect benefits are the long run survival of the system which are difficult to estimate. Due consideration has to be given on the assessment of indirect benefits.
- Comparative advantages of the water used activities could be fairly assessed by estimating the effects due to the non-availability of water i.e. by assessing the opportunity loss.
- It is not fair to assess the comparative advantage of water used activities by computing the next best alternative. i.e. the opportunity cost. Because, finding alternatives for indirect benefits of the social life, environment sustainability, ecosystem, etc. could be rather impossible. On the other hand, the selected alternative may be the next available one than the best alternative.

- In order to assess the overall productivity of water released for irrigated agriculture, the economic benefits of water, which have not been consumed by the crop, have to be estimated.
- Unlike other Hydropower Projects in Sri Lanka, the Samanalawewa Project discharges the used water further downstream, bypassing the Kaltota Irrigation Scheme. Therefore, the effects are much more significant.

## 7. Conclusion

According to this case study, the economic benefits of water can be assessed in terms of water productivity under two alternative scenarios; irrigated agriculture for paddy and hydropower. The remote sensing approach has opened an avenue to estimate one major component of the water use study i.e. the actual amount of water consumed by the food crop during any particular time period. The common practice of accounting the total amount of irrigation water only to paddy production is not acceptable. Performance indicators have to be developed to assess the economic benefits of the portion of water not consumed by the crop i.e. the indirect benefits. Most of such benefits are directly related to the social life, culture and the ecosystem. Irrigated agriculture protects the sustainability of both the social system and the physical environment and is the very core of rural life. The age-old concept "Wewai, Dagebai, Gamai, Pansali (Reservoir, Degaba, Village, Temple)" reveals that the social system of the village life is based on the irrigation system. Therefore, irrigated agriculture is not merely a food producing exercise. The indirect benefits are much more valuable than the direct pricing of the seasonal harvest. However, available water resources have to be carefully managed because water is not a *free commodity.*

## References

1. Bastiaanssen, W.G.M., 1995. *Regionalization of surface flux densities and moisture indicators in complex terrain. A remote sensing approach. PhD thesis submitted to the Wageningen University, The Netherlands.*
2. Bos, M.G., and Wolters W. 1989. *Project overall efficiency in irrigation theory and practice. Proceedings of the international conference held at the University of Southampton.*
3. Clerke, J.J., Lawrance A.R., and Foster S.S.D. 1996. *"Ground water - A Threatened Resource." UNDP Environment Library Series 15.*
4. Weerasinghe, M.L., and Somathilaka, H.S. 2002. *Proposal to optimize the benefits of Samanalawewa waters. "Engineer" Journal of the Institution of Engineers, Sri Lanka, Vol xxxv No.1, Jan. 2002.*

## Biographical Sketch

**K.M.P.S.BANDARA,** B.Sc. Civil Eng., M.Sc (Geoinformatics/ Netherlands), MBA, C.Eng, MICE(London), MIE(Sri Lanka), Graduated from the University of Peradeniya, Sri Lanka in 1981. Worked at State Development & Construction Corporation between 1981 and 1983. Joined the Irrigation Department in 1983. Presently, Deputy Director (Geoinformatics), the Department of Irrigation, Sri Lanka.