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Availability, Use and Productivity of Water In Walawe River Basin

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Abstract - An improved understanding of the water availability and its present use in a river basin will benefit those who are involved in planning new water resources development schemes or expanding existing schemes in the basin. How such an understanding is obtained is shown in this paper by carrying out a water accounting to a Sri Lankan water basin. In particular, this study estimates the Walawe Basin's water availability, use, depletion and productivity both at present and after the ongoing expansion activities are completed. The water accounting is based on a water balance approach. The results indicate that a considerable amount of water available for utilization within the basin flows out to the sea without being used at present and will do so even after the ongoing expansion activities are completed. We hereby establish how a water accounting may be systematically applied to gain a valuable understanding of how to design and operate river basins scientifically so as to have the best use of water.

Key words: water accounting, water balance, productivity

1 Introduction

An account of water in a region can be very useful in estimating its present use and future availability. Such estimates are often necessary for strategic planning and efficient management of water. Besides, it helps in the design and operation of various development activities in a basin, specifically bringing out the on-site and off-site impacts of water resources development.

The concepts and definitions to account for water use, depletion and productivity in a basin presented by Molden and Sakthivadivel [1] could be very useful in the assessment and efficient management of water resources in a basin. They explained these definitions through their application to a cascade of tanks in the Anuradhapura District in Sri Lanka. Molden *et al,* [2] applied to water accounting procedure to four basins in South Asia: Bhakra in India, Chistian in Pakistan, and Huruluwewa and Kirindi Oya in Sri Lanka.

This Paper presents a study carried out to gain an improved understanding of the water availability, use, depletion and productivity in the Walawe River basin in Sri Lanka. The procedure involves the calculation of water balance for the area. Presently, there are two major reservoirs, power plants, a diversion structure and many water conveyance structures in the Walawe River basin to meet the water supply needs of farmers, industries and hydropower generation. Despite these water management systems, water supply adequacy and its spatial and temporal distribution remain a concern in the Basin because of the vagaries of rainfall and increased demand for water due to the envisaged further expansion to the existing water resources development schemes.

2 Walawe River Basin

The Walawe River basin, located in southern Sri Lanka, has 2442 km^2 of drainage area. The average rainfall over the catchment is about 1750 mm in a year. The Walawe river flows from north to south with the total river length being 105 km. Major tributaries of the river are

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Mau Ara, Hulanda Oya, Timbolketiya Oya and Weli Oya.

In the Study, the River Basin is divided into three catchments based on the development activities in the Basin. The uppermost drainage area termed the Samanalawewa catchment is the area upstream of the Samanalawewa dam and the area is about 338 km^2. The drainage area of about 771 km^2 between the Samanalawewa and Udawalawe dams is called the Udawalawe catchment while the drainage area of 1333 km^2 below the Udawalawe dam is called the catchment downstream of the Udawalawe dam. Figure 1 shows the Walawe river basin and the three catchments.

Samanalawewa reservoir has been built mainly for hydropower generation. It supplies irrigation water to Kaltota Irrigation Scheme located just downstream of it. The Udawalawe Reservoir built next along the Walawe River is meant for supplying irrigation water from the Reservoir through two main canals. The total land area on the left bank canal that is supplied with irrigation water is about 6110 ha while that on the right bank canal is about 11400 ha. Development of about 5340 ha more on the left bank has commenced. The Liyangastota diversion weir is the most downstream water resources development scheme on the Walawe River. It diverts water for irrigation.

3 Water Accounting Definitions

The water accounting procedure is based on the water balance of a domain selected within a basin. The domain selected may be a farmer's field or an irrigation system or a whole basin. Molden and Sakthivadivel [1] classified the components of the water balance into the following water-use categories.

Gross inflow is the total amount of water flowing into the water balance domain from precipitation and surface and subsurface sources. *Net inflow* is the gross inflow plus any changes in storage (both surface and subsurface). *Net inflow* is either depleted or flows out of the water balance domain.

Water depletion is a use or removal of water from a water basin that renders it unavailable or unsuitable for further use. Water is depleted by four generic processes: i) *Evaporation*, where water is vaporized from surfaces or transpired by plants; ii) *flows to sinks*, when water flows into a sea, saline groundwater or other location where it cannot be economically recovered for reuse; iii) *pollution*, when water quality is degraded to an extent that it is not suitable for certain uses; and iv) *incorporation into a product* by a process such as incorporation of irrigation water into plant tissues.

Beneficial depletion occurs when water is depleted in providing an input to produce a good result such as an agricultural output, or providing a need such as drinking or bathing water, or in any other manner deemed beneficial such as supplying water for environmental uses. Beneficial depletion can be further classified as *process* or *non-process* depletion. *Process depletion* is that amount of water diverted and depleted to produce an intended good result. *Non-process depletion* occurs when water is depleted by a natural use such as evaporation from forest cover or when diverted water is depleted, but not by the intended process.

Non-beneficial depletion occurs when no benefit or a negative benefit is derived from the depletion of water. Examples are evaporation from fallow land, discharge into sinks in excess of environmental requirements, deep percolation into saline aquifers, or evaporation from water logged areas.

Committed water is that part of outflow that is allocated to other uses. For example, downstream water rights or needs may require that a certain amount of outflow be realized from an irrigated area. Or water may be allocated to environmental uses such as minimum stream flows, etc..

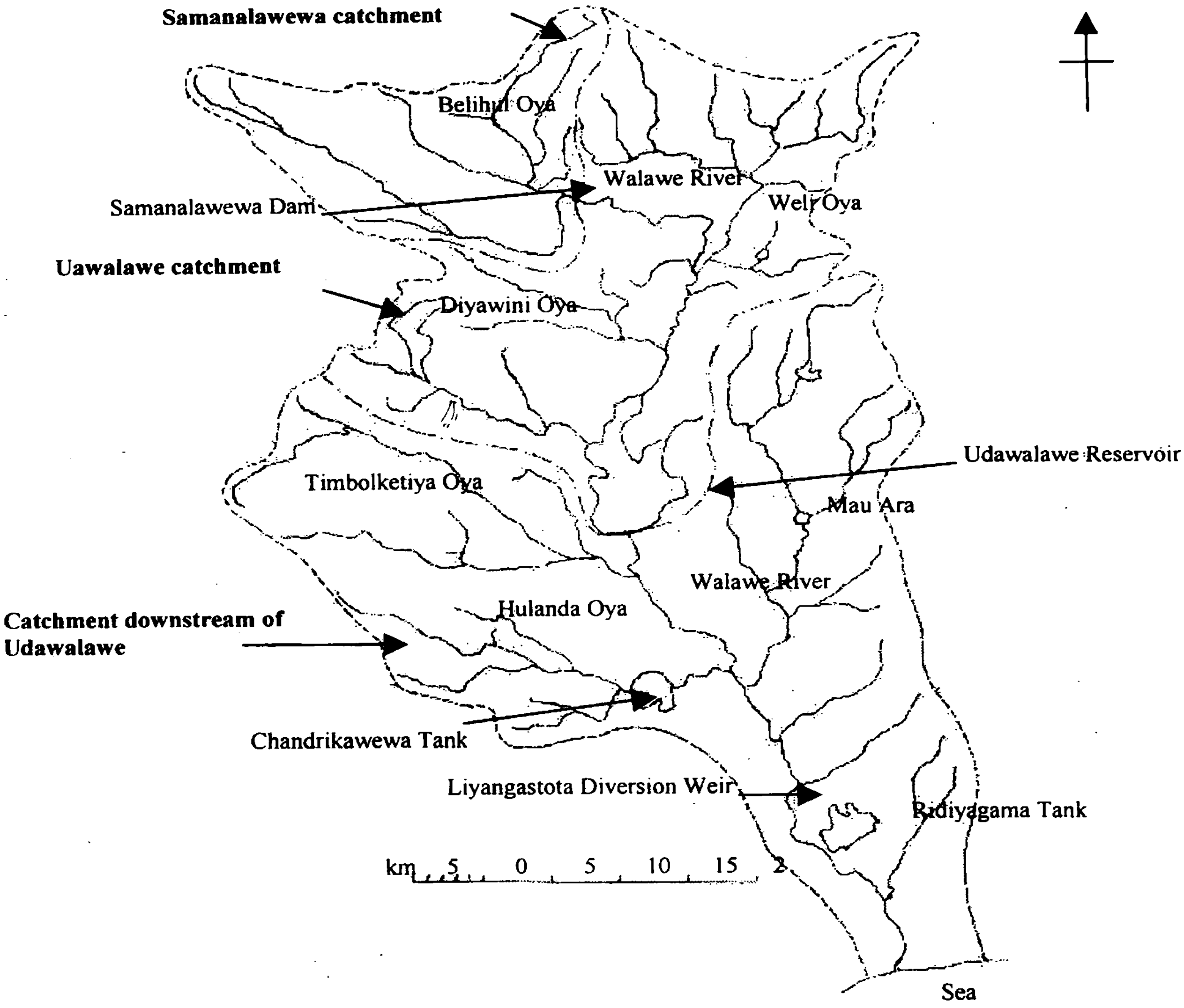

Figure 1: *Walawe river basin*

Uncommitted outflow is water that is neither depleted nor committed, is available for use within a basin or for export to other basins, but flows out due to lack of storage or operational measures. For example, waters flowing to a sea in excess of requirements for fisheries, environmental or other beneficial uses are uncommitted outflows. Uncommitted outflow can be classified as *utilizable* or *non-utilizable*. Outflow is utilizable if, by improved management of existing facilities or through construction of additional facilities, the water could be beneficially used. *Non-utilizable* outflow exists when extreme flood flow occurs which cannot be captured or the outflow is so polluted that it is of no use.

Available water is the net inflow less the amount of water set aside for committed uses and less non-utilizable uncommitted outflow. It represents the amount of water available for use at the basin.

Water Accounting Indicators

Molden and Sakthivadivel [1] present three types of indicators that can be used in a water accounting study. This study uses only one type of indicator called physically based indicators. These indicators provide information about the flow paths of water, how much water is being depleted and which use is depleting the water. Two physically based indicators that characterize the system, which are in the form of depleted and process fractions as defined by Molden and Sakthivadivel [1] are given below.

Depleted fraction (DF) is that part of the inflow that is depleted by all process uses. Defined in terms of gross inflow, depleted fraction is:

$$DF_{gross} = \frac{Depleted\,Water}{Gross\,Inflow}$$

DF indicates the amount of gross inflow that is depleted at the basin level. Depleted fraction can be defined in terms of net inflow (DF_{net}) and available water ($DF_{available}$).

Similarly, a process fraction (PF) is defined as the ratio of process depletion to gross inflow (PF_{gross}), net inflow (PF_{net}), available water ($PF_{available}$) or depleted water ($PF_{depleted}$). PF is useful to distinguish the percentage of water depleted by intended uses.

4 Computation of Water Balance Components

Annual water balance over the Walawe river basin covers the period from 1994 to 1999. The Theissen polygon method [3] was employed to estimate the average rainfall over the catchments. Table 1 presents the annual areal rainfall over the three catchments during the period 1994 – 1999, so estimated by us.

Water budgets of the major reservoirs in the basin are needed to account for water in the basin. Table 2 presents the yearly basis water balance for the Samanalawewa reservoir during the analysis period. It is based on the historical (observed) records [4] of the reservoir inflow, releases for power and irrigation, water leak from the reservoir and reservoir water levels during the period.

Table 3 shows the annual water balance of the Udawalawe reservoir. Lands on the left bank and the right bank are supplied with irrigation water from the Udawalawe reservoir by the left bank canal and the right bank canal. Water releases through the two canals, reservoir spills and reservoir water levels are observed values [4] while inflows to the reservoir were estimated based on a reservoir operation simulation carried out based on water balance. The water balance of the Chandrikawewa tank, which is situated in the area downstream of the Udawalawe reservoir was not considered explicitly since it is not located along the main Walawe river.

Table 1: *Annual rainfall over the catchment during the period 1994 - 1999*

Year	Samanalawewa catchment		Udawalawe Catchment		Area Downstream of Udawalawe reservoir	
	Mm	10^6m^3	mm	10^6m^3	mm	10^6m^3
1994	2740	926	1880	1449	1217	1622
1995	2663	900	1946	1500	1342	1789
1996	2331	788	1760	1357	1358	1810
1997	3098	1047	2813	2169	1988	2650
1998	2506	847	1713	1321	1227	1636
1999	2675	904	1764	1360	1280	1706
Average	2669	902	1979	1526	1402	1869

Table 2: *Annual water balance of the Samanalawewa reservoir*

Year	Inflow 10^6m^3	Releases			Rainfall 10^6m^3	Evaporation 10^6m^3
		Power 10^6m^3	Irrigation 10^6m^3	Leak 10^6m^3		
1994	495	402	41	68	3	4
1995	567	403	92	68	2	4
1996	338	208	16	68	2	4
1997	628	358	57	75	4	5
1998	434	426	11	67	3	6
1999	448	399	29	62	4	7
Average	485	366	41	68	3	5

Table 3: *Annual water balance of the Udawalawe reservoir*

Year	Inflow 10^6m^3	Releases		Spill 10^6m^3	Rainfall 10^6m^3	Evaporation 10^6m^3
		Left Bank 10^6m^3	Right Bank 10^6m^3			
1994	966	254	429	287	43	46
1995	1150	262	492	538	39	50
1996	518	146	282	0	27	30
1997	1597	255	448	826	55	40
1998	1036	231	557	310	36	54
1999	830	251	465	127	38	51
Average	1016	233	446	348	40	45

A major portion of the rainfall returns to the atmosphere from the basin through evapotranspiration. Reference crop evapotranspiration (ETo) was estimated using the Penman Method given in [5]. Meteorological observations at the observatory at the Sugar Research Institute at Udawalawe were used to estimate ETo values for the Udawalawe catchment. Since meteorological data was not available for the Samanalawewa catchment, the estimated ETo values for Udawalawe were changed according to the same ratio of the ETo values used in a JICA report [6] for these two catchments. The ratio of ETo of the Samanalawewa catchment to that of the Udawalawe catchment varied between 0.89 and 1.0 depending on the month. The estimation of ETo for the area downstream of the Udawalawe reservoir is based on data at the Angunakolapelessa and Hambantota meteorological stations.

The areas of different land cover in the three catchments along with the respective crop factors were used to estimate total evapotranspirations (ET) by multiplying ETo by crop factors. Table 4 presents the areas of different land covers in the Samanalawewa and Udawalawe catchments as obtained from digitized 1:10,000 maps of the Survey Department. The Table includes the estimated evapotranspiration losses. Table 5 shows the different land covers in the area downstream of the Udawalawe reservoir existing at present, as given in [6]. The irrigated area is divided into several irrigation blocks. The estimated total evapotranspirations from these different land covers are also given. The evapotranspirations were estimated on a monthly basis.

Table 4: *Different land covers and evapotranspirations - Samanalawewa and Udawalawe catchments*

Catchment			Rice	Tea	Rubber	Coconut	Forest	Pasture	Bare Soil
Samanalawewa	Area	km^2	47	55	0	0	89	103	44
	ET	10^6m^3	63	96	0	0	137	18	100
Udawalawe	Area	km^2	47	46	8	15	154	376	125
	ET	10^6m^3	65	87	9	18	261	87	403

Table 5: *Different land covers and evapotranspirations – Area downstream of Udawalawe reservoir*

	Irrigation Block		Rice	Banana	Sugar	Other	Forest	Grass	Bare soil
			ha	ha	ha	ha	ha	ha	ha
	Embilipitiya	Yala	1570	40	17	42	707	5528	1843
		Maha	1608	45	19	30	707	5503	1834
Right	Chandrikawewa	Yala	2208	41	0	45	707	5861	1954
Bank		Maha	2293	50	0	68	707	5773	1924
Canal	Binkama	Yala	1938	36	2	36	0	2363	788
		Maha	1964	41	0	77	0	2311	770
	Angunakolapelessa	Yala	1241	83	19	61	1061	2971	990
		Maha	1304	93	7	84	1061	2908	969
	Murawesihena	Yala	821	175	0	60	0	2667	889
		Maha	850	197	0	87	0	2609	870
	Sevenagala	Yala	970	0	2630	0	170	1053	351
Left		Maha	970	0	2630	0	170	1053	351
Bank	Kiriibbanara	Yala	1137	25	1	26	1415	6146	2049
Canal		Maha	1172	37	1	17	1415	6117	2039
	Suriyawewa	Yala	1738	29	0	75	4244	6001	2000
		Maha	1711	19	0	26	4244	6065	2022
Liyangastota		Yala	6100	0	0	0	0	639	213
Scheme		Maha	6100	0	0	0	0	639	213
Undeveloped		Yala	0	0	0	0	23400	40950	13560
Area		Maha	0	0	0	0	23400	40950	13560
Total Evapotranspiration (10^6m^3)			259	8	49	3	543	181	830

5 Water Accounting for the Walawe Catchments

The water accounting based on the estimated water balance components for the Samanalawewa and Udawalawe catchments and the area downstream of the Udawalawe reservoir is presented in Table 6. It compares the situations in the area downstream of the Udawalawe reservoir at present and after ongoing development activities on the left bank are completed.

For the Samanalawewa catchment the depleted fraction of the available water is 0.47. This means that only 53% of the water is available for the downstream use. This 53% is also equal to the runoff coefficient since no inflow except rainfall occurs in this catchment. The process fraction of depleted water in the catchment is 0.38, which means that only about 38% of water is consumed by crop ET and the remaining 62% is evaporated from free water surfaces and non-crop vegetation including forest.

Table 6: *Water accounting for the three catchments of the Walawe basin*

	Samanala-wewa Catchment	Udawalawe Catchment	Area downstream of Udawalawe Dam	
			Present	Developed
Total area (ha)	33800	77100	133300	133300
Inflow ($10^6 m^3$)				
Surface inflow	-	475	1026	1026
Rain on tank and area	902	1526	1869	1869
Gross inflow	902	2001	2895	2895
Tank storage change	-8	0	-	
Net inflow	894	2001	2895	2895
Depletion ($10^6 m^3$)				
Process (Crop ET)	159	179	319	417
Process (Industry)	-	-	75	75
Process (Drinking)	-	-	11	11
Non process depletion (Trees)	137	261	543	543
Evaporation from tank	5	45	10	10
Evap from soils, vegetation	118	490	1011	936
Total depleted	419	975	1969	1992
Outflow ($10^6 m^3$)				
Committed water	--	--	--	--
Utilizable water	475	1026	926	903
Total outflow	475	1026	926	903
Available water ($10^6 m^3$)	894	2001	2895	2895
Indicators				
Depleted fraction (dimensionless)				
-of gross inflow	0.46	0.49	0.68	0.69
-of available water	0.47	0.49	0.68	0.69
Process fraction (dimensionless)				
-of gross inflow	0.18	0.09	0.14	0.17
-of available water	0.18	0.09	0.14	0.17
-of depleted water	0.38	0.18	0.21	0.25

For the Udawalawe catchment, the depleted amount of water is about 49% of the available water. In this catchment, the process fraction is only about 18% of the depleted water. That is, a considerably large amount, 82% is evaporated from free water surfaces and non-crop vegetation.

The depleted fraction of available water in the area downstream of the Udawalawe Reservoir is 0.68, which means that 68% of available water is depleted. However, the process fraction of this depleted water is about 21% only. After the extension of the irrigation area on the left bank the depleted fraction increases to 69% of the available water only. That is, about 31% of the water available in the catchment leaves it without being used. Further the process fraction of the depleted water rises to 25% only after the development activities are completed.

The average annual amount of utilizable water that leaves the Walawe river basin without being used is estimated to be about 926×10^6 m^3. An estimation carried out based on the data collected at the Liyangastota diversion weir indicates that the Walawe River discharges approximately about 450×10^6 m^3 to the sea annually at Ambalantota. Several drainage paths originating from the irrigation area carry the balance directly to the sea or lagoons at the downstream end of the Basin. Kachchigalara drainage is a major drainage that carries a considerable amount of diverted irrigation water out of the Basin to the sea via the Kalametiya lagoon. Observation of flows in the Kachchigalara drainage over a period of six months (February to July) in the year 2001 showed that a flow of about 140×10^6 m^3 passed to the sea during that period. As Table 6 shows, even after the extension of the irrigation area on the Left Bank is completed, the water flowing out of the basin without being used is considerably high. The results further show that the changes in the land cover, after the completion of the Left Bank extension works do not affect the depleted amount of water much.

The crop evapotranspiration (process depletion) is about 319×10^6 m^3 compared to the average total diversion of 679×10^6 m^3 from the Udawalawe Reservoir in an year. That is about 50% of the water diverted for irrigation drains without being used and therefore, by better water management practices within the area, more water could be saved and put to beneficial uses.
There are several tanks (small reservoirs) downstream of the Udawalawe reservoir within the Walawe Basin, which are not functioning properly at present. By rehabilitating these tanks a significant amount of utilizable water, which is leaving the Walawe Basin at present, could be saved and put to productive use. The small tanks will improve the temporal distribution of water in the basin enabling reliable water supply to the existing irrigated areas and inducing development of more agricultural lands.

6 Summary and Conclusions

Water accounting for the Walawe river basin was carried out by dividing the basin into three catchments: (a) the watershed of the Samanalawewa reservoir, (b) the watershed between the Samanalawewa reservoir and the Udawalawe reservoir, and (c) the area downstream of the Udawalawe reservoir. The water accounting methodology used in the study indicates the present and future use, depletion and productivity of water as well as water available for further use in the Walawe Basin. This information would be very valuable to those who are involved in planning and managing water resources in the basin.

The Study indicates that a considerable amount of water available for utilization within the Walawe River Basin is flowing out to sea at present. The planned increases in the cultivation areas on the Left Bank, downstream of the Udawalawe Reservoir will not fully utilize the water available in the Basin. The utilization of some of this excess water can be effected possibly by storing it in the numerous existing tanks in the Basin that need rehabilitation. Though the expansion activities will increase the process depletion, the total depletion in the basin will not change appreciably compared to the water available in it. This is because developmental activities will change only the land use pattern, which will increase the depleted fraction only marginally.

This work shows how a systematic application of water accounting for a river basin can enhance the water resources development and management activities in the Basin to have the best use of water. A water accounting is a must to know the flow paths of water within a basin, where and how water is utilized, where we can save water, and put the saved water to productive use.

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