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Water Resources Management Under Competing Demands in the Walawe River Basin, Sri Lanka

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ABSTRACT

Many developing countries depend on their agricultural production to ensure food security. However, along with agriculture, there are many other sectors that impose demands on basin water resources. Declining water supplies and growing demands require better management decisions in water allocation. This paper describes the current water demand and supply situation in a rural river basin of a developing country and analyzes several solutions to overcome the water allocation issues.

1. INTRODUCTION

Food security is an ongoing problem faced by the governments of both developed and developing countries. This problem is aggravated by the increasing population and the limited increase in food production. Between 1980 and 2000, global population rose from 4.4 billion to 6.1 billion (World Population Prospects 2000), while the per capita cereal production has been declining since 1984(FAO 2005; Dyson 1999). Projections show that an 80% demand increase for cereal and 90% demand increase for meat will arise from developing countries by 2025 (Rosegrant and Cai, 2000). It is evident that population growth alone can pose a threat to food security in developing countries in the coming years.

Grain production plays an important role in achieving food security. The majority of global population still primarily consumes food made from grain. Animal products provide 27% of food calories in developed countries and 13% in developing countries (FAOSTAT, 2001). However, urbanization, rising incomes, and globalization of trade amounts to a considerable change of diets in developing countries, which has placed an additional demand for grain in these countries (Pinstrup-Andersen et al., 1997). For the poorest countries with limited economic capabilities, increases of domestic agricultural production remain the key option for achieving food security.

Along with suitable land, availability of fresh water plays an equally important role in crop production. Agriculture accounts for about 70% of all water withdrawals globally, and as much as 80% in many developing countries (UNDP, 2006). Limitations in the availability of fresh water due climate change have exerted pressure on water supply for agriculture worldwide. The situation is further exacerbated by the growing demands for water from energy, industry, urban, recreation, and environmental sectors.

Industrialization of developing countries produces an increasing demand for energy. Hydropower provides a renewable energy source with high capital costs but with low operational costs. More than 90% of the economically viable hydropower potential is located in the developing world. Therefore hydropower provides a cheap natural energy resource affordable to these countries. In 2004, the share of hydropower in total renewable energy supply was 3.1%, 21.0% and 6.8% in Africa, Latin America, and non OECD (Organization for economic Cooperation and Development) Asia, respectively (IEA, 2007).

In the face of dire economic stresses faced by these countries, the related environmental issues are often overlooked. However the supply of fresh water for these services is inherently related to the environmental well being of water resources. Therefore the role of environmental flow is now receiving more attention in the developing world as well.

The above discussion highlights the role of developing world's freshwater resources in food production, power generation, human consumption, industry, recreation and environment protection. The increasing uncertainty in supply and the growing demand produces competition among water users in a river basin. This conflict calls for supply augmentation, demand control, and water conservation and reallocation (Molle, 2004). If the river basin supply and demands are not managed in a sustainable manner, it could lead to the over exploitation of water resources and system degradation.

Unfortunately, most river basins in developing countries are poorly managed, causing social and economic losses to the basin water users. Examples of such situations are abundant throughout the developing world. It has been shown that solutions adopted by developed countries cannot be readily applied to developing countries due to differences in hydrologic, demographic, socio-economic regimes (Shah et al., 2001). Therefore, it is important to undertake studies that explore the water management issues in river basins of developing countries. As a test case, the water management issues of the Walawe River basin located in southern Sri Lanka are studied in this work.

2. WALAWE RIVER BASIN

2.1 Physical Description

The Walawe river basin extends from the southern ridge of central mountains of Sri Lanka at an altitude of over 2000 m and extends to the sea (Figure 1) and the driange area is about 2440 Km^2. The basin contains high mountainous regions as well as intermediate mountainous regions of ridges and valleys and a lowland plain, which accounts about 70% of the area.

An important characteristic of climate in Sri Lanka is the well defined distribution of annual rainfall between two monsoon periods (Dharmasena and Keerthisena, 1988). The major wet season, referred to as *Maha* is from October to January. The shorter rainfall period called *Yala* is from May to June. The rainfall that occurs between these two periods is due to the mountain effects and is less significant (Zubair et al. 2008).

About half of the average annual rainfall reaches the Walawe river network as runoff while the rest is used by plants or evaporated (Molle and Renwick, 2005). Shallow ground water in the basin is recharged by the natural rivers, irrigation canals, reservoirs, and rice fields located throughout the basin. Groundwater recharge in the basin is about 7-12% of the average annual rainfall and shows a high spatial variability (Seneviratne, 2007). On average, the Walawe basin discharges about 1.1 billion m^3 of water to the sea annually.

2.2 Water Users

Over the years, agricultural practices of the Walawe basin have transformed from an individual plot based farming to large-scale crop production under public funded irrigation systems (systems K, U, and L). At present, Walawe river basin is one of the major crop production areas of Sri Lanka. Another important relatively new water user of Walawe is the hydropower sector in system S and competes for water from the Walawe irrigation systems. Due to the expansion of the agricultural sector and increasing population growth, new water users have emerged in the basin. At present, a small fraction of more than 200,000 receives pipe borne water from the Walawe basin. However it is expected that the municipal water demand will increase to include a large share of Walawe water. Other water users such as industry and environment are also gaining importance in the basin.

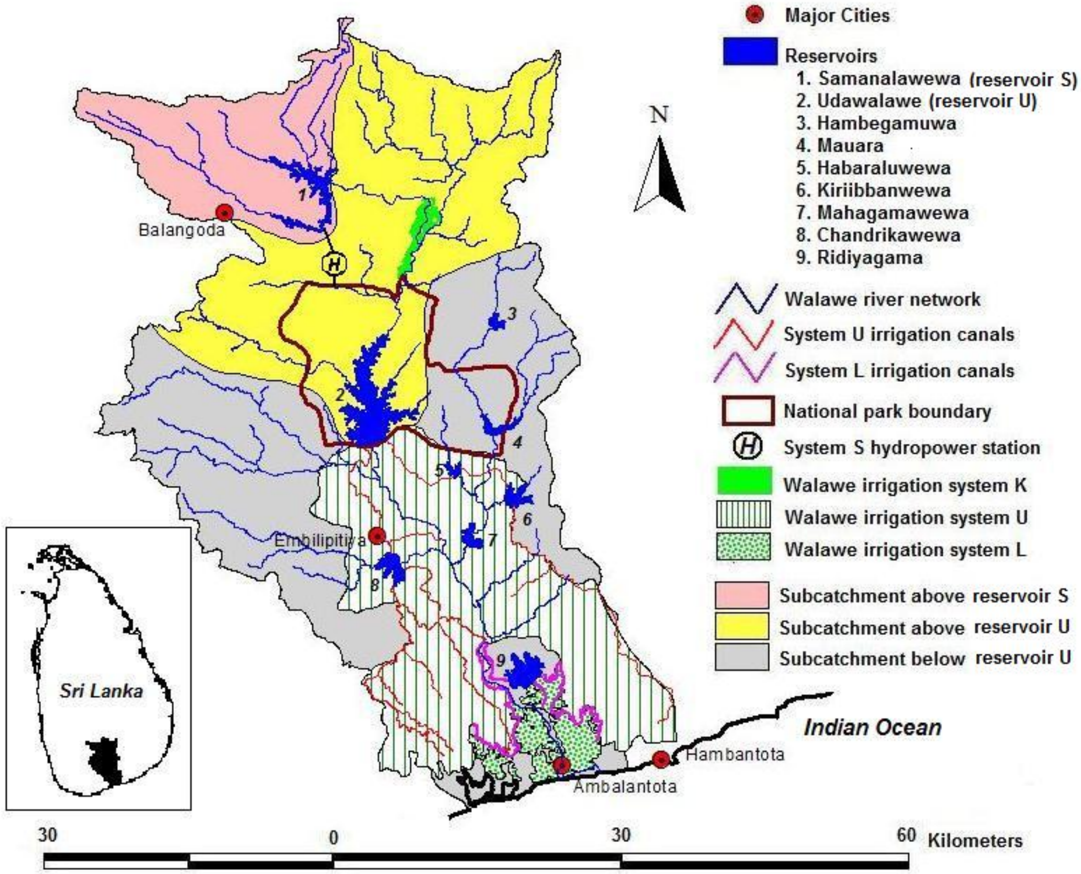

FIGURE 1. Physical layout of the Walawe river basin, its water resources and users

3. WATER RESOURCES MANAGEMENT RELATED ISSUES

The water users of the Walawe river basin experience water shortages during certain periods of the year. These water shortages occur at different scales and in various water use systems. A multitude of factors contribute to these shortages and discussed below.

3.1 Non-availability of water or higher priority use

The available inflow and the storage capacity of the Walawe river basin are inadequate to supply the demand. A typical example is the Walawe systems S and K. The combined demand for hydropower and irrigation exceed the supply available at the reservoir. This leads to prioritization of allocation and leave some water users with shortages. During the past decade, a consistent reduction of crop area has been observed at system K due to this shortfall (Kumara and Wijeratna, 2004). Similar competition and resulting water shortages are prevalent among other water users of the basin.

3.2 Increased crop areas and cropping intensity

The commissioning of new crop areas that rely on already committed water resources also produces shortage issues. Due to phase wise development of Walawe irrigation systems the crop areas are expanded gradually. This process occurs in a number of years, during which the water supply as well as the demand patterns change. During the initial years only croplands on the right bank of the river were irrigated with no allocation to the left bank. This allowed the first water users to exceed their estimated legal allocation for a number of years. New crop areas on the left bank were commissioned in 2005, demanding the full allocation for the left bank. This has challenged the right bank farmers to cultivate strictly with their legal water allocation. It has been estimated that with the current water use efficiencies, the water demand of crop areas in both banks cannot be sustainably fulfilled (IWMI, 2000).

3.3 Infrastructure issues

As typical to irrigation systems in many developing countries, the Walawe systems also experience water shortages caused by infrastructural deficiencies. Lapses in the planning stages have caused a limited storage capacity of reservoirs and the limited carrying capacities of main canals. The decisions made at the implementation stage (selection of single banked earth canals for the main distributaries, low excavation depths of canals, lack of cross regulators in main distributaries, etc.) have caused seepage and spillage losses. The degradation of irrigation infrastructure due to poor operation and maintenance has also contributed to these shortages.

3.4 Poor management and institutional framework

The establishment of suitable water allocation practices and their implementation is entrusted to the water management institutions. As the water uses in the basin evolve, proper institutional changes should accommodate the required changes to management. Management institutes of the Walawe irrigation systems have not adequately adapted to these changes (WIIP, 1998; IWMI, 2000) over the years when the demand is increasing and the supply is limited.

4.4 Emergence of new water users

The rapid development processes in the southern part of the basin have produced new water users in the Walawe basin. The ongoing construction of an international sea port, oil refinery and distribution facility, an international airport, industrial zone, and the expansion of existing urban water supply invariably exert more demands for water (Table 1). The rapid development of rural basins also entails increased concerns on environmental degradation. Therefore the environment flow requirements in the Walawe basin have also gained priority in the recent times.

4. WATER MANAGEMENT RELATED ISSUES AND POSSIBLE SOLUTIONS

The situation described above calls for urgent solutions to water shortages faced by the Walawe water users. Changes to the current water resources and demand management are required to achieve a resolution. In this section, the reasons for the above water shortages are analyzed and some possible solutions are discussed.

4.1 Water availability

The water availability estimate was conducted on an annual basis from 1994 to 1999. For the analysis, the Walawe river basin is divided in to three sub-basins: sub catchment above system S, and sub catchments above and below system U, as shown in Figure 1. To estimate the water availability for future developments, the calculated net inflows and demands were compared and the results are shown in Table 1. The results indicate that on an average annual basis, 26% to 42% of surface water from the Walawe basin is discharged to the sea.

TABLE 1. Water balance of the Walawe river basin (average annual values from 1994 to 1999)

Description	Sub catchment above reservoir S	Sub catchment above reservoir U	Sub catchment below reservoir S
Catchment Area (km^2)	290	730	1420
Inflows			
From upstream catchment (MCM)	NA	485	1016
From Rainfall (MCM)	663	1469	2071
Total Inflow	**663**	**1954**	**3087**
Reservoir storage change (MCM)	- 8	0	NA
Water Use			
Crop evapotranspiration (MCM)	159	179	319
Used by industry (MCM)	< 1	< 1	75
Public & Municipal use (MCM)	< 1	< 1	11
Forest evapotranspiration (MCM)	137	261	543
Evaporation from surface water bodies (MCM)	5	45	10
Bare soil & grassland evaporation (MCM)	118	490	1011
Percolation to subsurface (MCM)	66	147	207
Total Depletion	**485**	**1122**	**2176**
Available Water			
Water available for use (MCM)	178	832	911
As a percentage of net inflow	26 %	42 %	29 %

4.2 Seasonality of inflows and demands

Despite having surplus water on an annual basis, the basin water users experience water shortages periodically due to the seasonal changes in supply and demand. The irrigated croplands of Walawe use rainwater as well as irrigation water during the cropping season. Therefore, the irrigation demand is related to the seasonal rainfall pattern. Of the two cropping seasons that coincide with the monsoon rainfall, the shorter rainfall season is highly dependant on supplemental irrigation.

4.3 Low water use efficiency

The Walawe irrigation system K has recorded the highest water use in the country during a dry cropping season (WWDP, 2006). The high water use in this system has been attributed to several reasons.

The irrigation system K is located in the boundary where the mountainous part of the basin turns to flat terrain (Figure 1). It is therefore largely located in lands with high slopes. The majority of the lands consist of sandy soils where the seepage and percolation rates are about 7-10 mm/day (Molle, 2005). The only crop cultivated in this system is rice. Compared to other crops, rice has a high water requirement and rice requires prior preparation of land. This process consists of initial land soaking (3-7 days) and two rotations of plowing, bund repair, puddling, and leveling. However the conventional land preparation method requires longer supply durations and consumes about 1/3 of the total water requirement in the cropping season (IIMI, 1990). Molle et al. (2005) estimated a water use of 800 mm/day during the land preparation period. This amount is almost twice of that due to the sum of seepage, percolation and evaporation. Therefore it is evident that a significant amount of water is lost due to poor efficiency, and the lack of farmer education and oversight.

4.4 Hydropower and Irrigation

Hydropower is generated in the Walawe system S throughout the year (CECB, 1985). At present, this power station is operated under a “variable power generation mode” supplying national demand deficit while providing negotiated irrigation releases to the Walawe system K.

The priority of the reservoir in system S is power generation. However the water rights of the 2000 year old Walawe system K are acknowledged by the controlling agency of the reservoir (Molle, 2005). Therefore attempts are made to provide optimal allocations to both users utilizing a dam leak, which covers a significant portion of the current irrigation demand.

A comparison of economic gain to the national economy from water use for irrigation and hydropower was conducted for the years 1999 and 2003. For one cubic meter of water used, the net economic value of hydropower is five times greater than the net value of irrigation. When compared to import prices in 1999, the cost of replacement is twice for foregone electricity compared to the forgone paddy production. The overall implication is that production of hydropower is much beneficial to the national economy compared to paddy cultivation.

The discussion so far highlights the opportunity of water saving from irrigation and the corresponding economic gains from hydropower production. However, one cubic meter of water reallocated from irrigation does not simply translate to an equivalent one cubic meter of water in power generation. The reservoir for hydropower generation can only be used if the water elevation is above the minimum operational level (MOL) of the turbines. Therefore, it is important to estimate the actual increase in power production that could be achieved due to such reallocation. A daily water balance of the reservoir in system S was conducted for five years from 1999 to 2003. The results of this water balance analysis are shown in Figure 2.

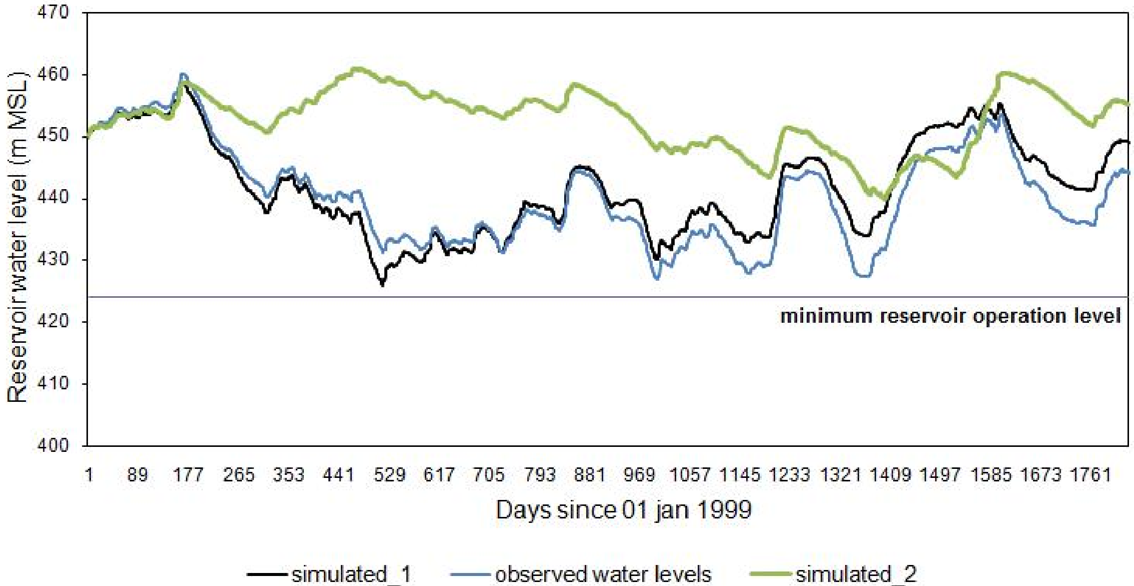

FIGURE 2. Water level of reservoir S under three scenarios: Current operation (observed), Variable power generation mode (simulated_1) and Firm power generation mode (simulated_2)

The *observed* reservoir water levels in Figure 2 show the actual operation of reservoir (with irrigation water issues) during the five year period. The results indicate that a major increase in the power generation is not possible under the present power station operation mode. The *simulated_1* reservoir water levels show the proposed omission of water allocation for irrigation. However the omission of irrigation releases to system K, allows only for 10% increase in flows to power generation. This is the maximum possible power production flow increase achievable under the “variable power generation” operation mode. The operation of reservoir S under a “firm power generation” mode (which also enables to release supplemental irrigation flows to downstream reservoir U) is discussed below.

4.6 Conjunctive use of reservoirs

The reservoir in system U experiences water shortages at certain times of the year. Therefore it is logical to explore the possibility of releasing supplemental flows from the upstream reservoir to enhance its storage. A possible change to the mode of operation of the power station could provide the water required for irrigation. This possibility was verified by conducting the simulation under a "firm power generation" mode. An annual firm power generation target of 285 GWh was considered with no releases for irrigation.

The reservoir water levels were significantly higher when compared with the variable power output scenario. The *simulated_2* data series in Figure 2 show the reservoir water levels under this operation mode. It is estimated that during the months of July, August, and September, the water levels are increased between 2 - 20 m in each of the five years considered. In addition, the increased water levels in the reservoir have enhanced the leak flows by 10% providing more water for irrigation in the Walawe system K.

The elevated water levels in the firm power scenario, indicates the possibility of flow augmentation to the downstream reservoir in the months of July, August, and September. The increased power generation outflows under this scenario are able to cover 3%, 6% and 29% of system U irrigation demands during these months. Further flow enhancements could be expected due to increased return flows from irrigation system K.

5. SUMMARY AND CONCLUSIONS

The findings and conclusions from the study are summarized as follows. (1) On an annual basis, more than one fourth of water available in the basin is not used. The water shortages experienced by the users are due to the seasonality of inflows. It is not possible to increase the irrigated areas under the current water use efficiencies and management practices. (2) Significant water saving can be achieved by switching to less water intensive crops and efficient management practices. (3) The reallocation of water from irrigation to hydropower generation at system K is beneficial. (4) A change in the operational mode of hydropower generation can increase the annual power output while enabling supplemental flows to the downstream irrigation system.

Overall the current study highlights that the changes to the current management practices could yield positive impacts. Knowledge gained through such studies is useful to initiate the much needed changes to the river basins management in developing countries.

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7. REFERENCES

Central Engineering Consultancy Bureau (CECB). 1985. Samanalawewa Power Project: Technical Report. Colombo, Sri Lanka.

Dharmasena, P. B. and G. B. Keerthiratna. 1988. Agro-climatic analysis of selected locations in the dry zone of Sri Lanka. ICRISAT (informal publication).Andhra Pradesh, India.

Dyson, T. 1999. World food trends and prospects to 2025. Proceedings of the National Academy of Sciences, USA. 96:5929-5936.

Food and Agricultural Organization Statistics Database (FAOSTAT). 2001. http://www.fao.org

(accessed May 5,2007).
Food and Agricultural Organization(FAO). 2005. Statistical Year book. http://www.fao.org (accessed May 5,2007).
International Energy Agency, 2007. Renewables in Global Energy Supply: An IEA Fact Sheet http://www.iea.org (accessed May 5,2007).
International Irrigation Management Institute (IIMI). 1990. Irrigation Management and Crop Diversification in Sri Lanka, Final Report.
International Water Management Institute (IWMI). 2000. Special Assistance For Project Implementation :Walawe Left bank Upgrading and Extension Project. Colombo. Sri Lanka.
Kumara, U.E. and A.W.Wijeratne. 2004. Estimation of Economic Loss Due to Reduction of Paddy Land Areas: Construction of Samanalawewa Reservoir.Paper presented at Water Professionals' Day 2004. Geo Informatics Society of Sri Lanka (GISSL).
Molle, F. 2004. Technical and Institutional Responses to Basin Closure in the Chao Phraya River Basin, Thailand.Water International, 29(1):70–80.
Molle, F., M. Renwick. 2005. Economics and politics and of water resources development: Uda Walawe Irrigation Project, Sri Lanka. Research Report 87. Colombo, Sri Lanka: International Water Management Institute (IWMI).
Pinstrup-Andersen, P., R. Pandya_Lorch and M. W. Rosegrant.1997 The World Food Situation: Recent Developments,Emerging Issues, and Long_Term Prospects. IFPRI Food Policy Report 2020 Vision. Washington, DC: IFPRI.
Rosegrant, M. W and X. Cai, 2000. Modeling Water Availability and Food Security: A Global Perspective: The IMPACT-WATER Model, working paper, Washington, DC: IFPRI.
Seneviratne, K. 2007. Development of Steady State Groundwater Flow Model in Lower Walawe Basin-Sri Lanka, Proceedings of The Water Professionals' Day 2007. Geo-Informatics Society of Sri Lanka
Shah, T., I. Makin and R. Sakthivadivel, 2001. Limits to Leapfrogging: Issues in Transposing Succesful River Basin Management Institutes in The Developing World. In Intersectoral management of river basins. Proceedings of international workshop on Integrated Water Management in Water-Stressed River Basins in Developing Countries: Strategies for Poverty Alleviation and Agricultural Growth, Loskop Dam, South Africa.
United Nations Development Programme (UNDP). 2006. Human Development Report 2006 United Nations Development Programme. NewYork.
Walawe Irrigation Improvement Project Report. 1998 Effects of Samanalawewa on the Walawe Irrigation Project Sir M.MacDonald & Partners Limited, Consulting Engineers, WIIP
Wester, P., M. Burton, and E. Mestre-Rodriguez, 2001. Managing the Water Transition in the Lerma –Chapala Basin, Mexico, In Intersectoral management of river basins: Proceedings of international workshop on Integrated Water Management in Water-Stressed River Basins in Developing Countries: Strategies for Poverty Alleviation and Agricultural Growth, Loskop Dam, South Africa.
World Population Prospects. 2000 revision. Population Division Department of Economic and Social Affairs United Nations. New York. NY 10017
Zubair, L., M. Siriwardhana, J. Chandimala and Z. Yahiya. 2008 Predictability of Sri Lankan rainfall based on ENSO. Int. J. Climatol. 28: 91–101

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