

Assessment of performance and water demand and supply deficit of Hakwatuna Oya irrigation system, Sri Lanka

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Abstract

The Hakwatuna Oya is one of the major irrigation systems in Kurunagela district. Frequent crop failure, abandoning of cultivation and reduced crop yields are the common issues in this system, mainly due to climate variability and inappropriate irrigation water management decisions. Therefore, appropriate management interventions are necessary for effective, efficient and sustainable use of scarce water resource. Reliable and adequate data collection and analysis are necessary to find out the current water resource status of a system, required to make sound decisions in advance to ensure the sustainable management of an irrigation system. Further, estimation of water demand and supply deficit is a prerequisite for project planning, designing and management of an irrigation system. Performance assessment of irrigation systems using suitable indicators plays a vital role in identifying the shortcomings and in finding out solutions for increasing the productivity of the systems. In this study, performance of Hakwatuna Oya irrigation system was assessed and compared with other two major irrigation systems based on estimated values of selected indicators for 2014/15 Maha and 2015 Yala seasons. Water demand and supply deficit for the period from 2004-2014 were estimated using collected data. The results revealed that the average cultivation extent of Hakwatuna Oya system is nearly 46% in Yala and 87% in Maha seasons. Average cropping intensity of Hakwatuna Oya is 1.47 whilst it is 1.81 for Bathalagoda and 1.86 for Kimbulwana Oya. Although the Hakwatuna Oya irrigation system recorded the lowest seasonal irrigation water supply of 0.22 m³/m² and 0.44 m³/m², the highest water productivity of 2.36 kg/m³ and 1.04 kg/m³ were recorded in 2014/15 Maha and 2015 Yala seasons, respectively. When compared to other two major irrigation systems, the Hakwatuna Oya is a water scarce system with relative water supply of 1.32 in 2014/15 Maha and 0.87 in 2015 Yala seasons. Demand and supply analysis showed that there is high fluctuation in annual demand and unmet demand from year to year due to variations in extent of cultivation, type of crop and water supply from reservoir and rainfall. Under long term average flow condition, cultivation of paddy in the entire command area in both Maha and Yala seasons demands nearly 30 MCM additional water supply.

Keywords: Cropping intensity, Performance assessment, Relative water supply, Water productivity, Water scarcity.

Introduction

The world is entering a period of water scarcity. Rapid population growth and changes in climate, land use and technology have placed a large burden on quantity and quality of water in both engineered and natural systems. Since the last century, the population of the world has increased three times whilst use of non-renewable energy and industrial production have increased by 30 and 50 times, respectively¹. This means demand for water is increasing over time and resources with suitable quality are depleting because of urban, agriculture and industrial uses.

In many river basins, increasing water demand leads to over exploitation of finite water resources and more frequent and more pronounced periods of extreme water scarcity². In addition, there is an anticipation that climate change is going to increase the water demand and supply gap in the future. The projected gap is 40% in 2030s³.

Sri Lanka is mainly an agricultural country. The primary form of agriculture is rice production. Nearly 800,000 farmers and their families depend on paddy, cultivated on 30% of the land area⁴. Approximately 44% of the paddy is irrigated under major irrigation schemes and 24% is irrigated under minor irrigation schemes⁵. Sri Lanka's rice demand is projected to increase by about 35% in 2020⁵ and much of this increase will rely on irrigated agriculture. In many parts of the country, productivity is below optimal levels due to its dependence on insufficient irrigation water supplies and inappropriate management decisions. Appropriate management of land, water, and agricultural inputs, and efficient operation and maintenance of irrigation systems are fundamentals to achieve optimum crop yield⁶. Reliable and adequate data collection and analysis are necessary to find out the current water resource status of a system, required to make sound decisions in advance to ensure the sustainable management of an irrigation system. Further, performance assessment of an irrigation system using suitable indicators is vital to identify the shortcomings in the current

management and to form appropriate management strategies so as to increase the productivity of the system⁶. Performance of an irrigation system is the outcome of a number of activities such as planning, design, construction, operation of facilities, maintenance and application of water⁷. Performance assessment facilitates an efficient and effective use of available water resources⁸. In addition, proper assessment of the water resources in time and space is essential to develop management strategies to use water rationally and on a sustainable basis in future⁹.

The Hakwatuna Oya is one of the major irrigation systems in Kurunagela district. Farmers cultivate paddy as the main crop in both *Maha* (September– February) and *Yala* (March – August) seasons. Farmers hardly cultivate twice a year due to inadequate water supply. Frequent crop failure, abandoning of cultivation seasons and reduced crop yields are the common issues in this system. Abandoning of cultivation seasons and crop failures lead to high economic loss to the farming families, particularly those who depend entirely on agriculture. Variability or uncertainty in income has great impacts on livelihoods of nearly 3500 farming families in this system. The above issues are mainly due to climate variability and inappropriate irrigation water management decisions. Hence, appropriate management interventions are vital to cope with climate variability and water scarcity. With this background, this study was carried out to assess the performance of Hakwatuna Oya irrigation system and to estimate the demand and supply deficit.

Materials and methods

Study area: The Hakwatuna Oya irrigation system located in the North Western Province of Sri Lanka is one of the major irrigation systems in Kurunagela district (Figure-1). The Hakwatuna Oya reservoir supplies water to Right Bank (RB) and Left Bank (LB) canals in order to supply water to an extent of 2,578 ha of command area. This reservoir collects runoff water from Hakwatuna Oya catchment. The latitude and longitude of this catchment are 7.77°N and 80.46°E, respectively. This Irrigation system is in the IL3 agro ecological region and receives an expected annual rainfall of more than 1,100 mm. The main rice growing soils in this region are

Reddish Brown Earth, Low Humic Clay and Non Calcic Brown soils situated in an undulating terrain¹⁰. Monthly mean maximum temperature ranges from 29.9°C-33.4°C while monthly mean minimum temperature varies from 21.8°C-25.0°C. The annual pan evaporation is about 1243 mm.

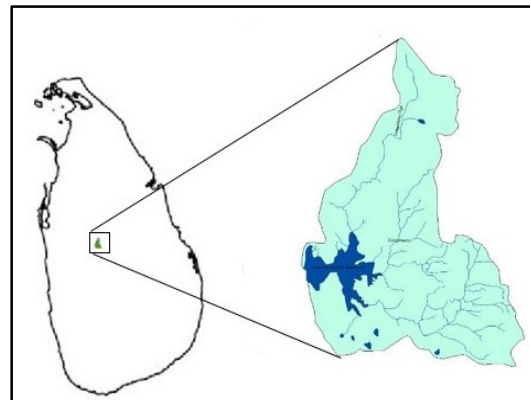


Figure-1: Location of Hakwatuna Oya irrigation system.

Performance assessment: Criteria used in performance studies are important for detailed assessment of an irrigation system, while facilitating the operation through better monitoring and controlling¹¹. Water delivery and supply indicators are useful to identify the efficiency of the services provided by an irrigation system. Three indicators such as irrigation contribution (%), seasonal irrigation supply per unit irrigation area and relative water supply have been used in the irrigation and drainage sector to assess irrigation service delivery regarding system operations¹². Agricultural productivity is the expected output of an irrigation system by utilizing irrigation water. There are several indicators which have been used to assess the agricultural productivity of a system. In this study, cropping intensity, average yield, relative yield and water productivity were used as agricultural productivity indicators to assess the system performance. Data collected from Hiriyala Irrigation Department for 2014/15 *Maha* and 2015 *Yala* seasons were used for the computation of performance indicators. Details of the selected performance indicators are given in Table-1.

Table-1: Selected performance indicators used in this study.

Indicators		Description
Water delivery and supply indicators	Irrigation contribution (%)	Amount of irrigation water diverted x 100/ Total water requirement for paddy including land preparation
	Seasonal irrigation supply per unit irrigation area	Seasonal volume of irrigation supply/Seasonal irrigated crop area of the system
	Relative water supply	Total water supply (IR+RF)/Crop demand (ET+Seepage)
Agricultural productivity indicators	Average paddy yield	Total paddy yield/Total cultivated extent
	Cropping intensity	Total area cultivated / Total Command area
	Relative yield	Actual crop yield/ Expected crop yield from major irrigation systems (5 Mt/ha)
	Water productivity	Total yield per season/ Diverted seasonal irrigation supply

Estimation of water demand: At present, agriculture is the main water use sector in this system. Paddy cultivation has been practiced in both *Maha* and *Yala* seasons. Farmers cultivate OFCs occasionally when water is limited. In this system, farmers cultivate beans, beet, and radish as OFCs. At present, there is no any non-agricultural water use sector. Therefore, current water demand is only from agricultural sector. In this study, crop water requirement (CWR) of 3½ months paddy variety was taken as 1282 mm for *Maha* season and 1381mm for *Yala* season¹³. Irrigation water requirement of beans (IWR_{OFC}) which is the popular OFC crop in this region was estimated using Equation-1.

$$IWR_{OFC} = (ET_{crop} - P_e) \times I_{eff} \quad (1)$$

Where; IWR_{OFC} is the IWR of beans, ET_{crop} is the crop evapo transpiration, P_e is the effective rainfall and I_{eff} is the irrigation efficiency. Here, current irrigation efficiency was assumed as 50%.

Demand and supply deficit: In this study, annual water demand and supply deficit (unmet demand) were estimated from 2004-2014 using available data. For each year, total water demand was estimated based on CWR and effective rainfall. Supply deficit is the difference between annual water demand and annual water supply. Overall supply deficit of this irrigation system under current management scenario (cultivation of paddy in the entire command area in both *Maha* and *Yala* seasons) was estimated under long term average flow condition.

Results and discussion

Performance of the irrigation system: Figure-2 shows extent of crop cultivation in both *Yala* and *Maha* seasons over the past three decades in the Hakwatuna Oya irrigation system. OFC cultivation is rarely practiced in *Yala* season. In most cases, cultivation of entire command area is not possible due to water scarcity, particularly in *Yala* season. Due to variations in rainfall in terms of quantity and time of distribution the extent of cultivation was limited even in *Maha* season in the past decades.

Abandoning of cultivation seasons and frequent crop failures were experienced due to inadequate water supply. For instance, within last 15 years some seasons were abandoned particularly 1996 and 1997 *Yala* seasons and 2000/01 *Maha* season. Crop failure were experienced in 2000 and 2002 *Yala*, and 2008/09 *Maha* seasons.

Figure-3 shows last five years average extent of cultivation of major irrigation systems in Kurunagela district. Cultivation extent was limited in all major irrigation systems in *Yala* season due to water scarcity. The second lowest extent of cultivation in *Yala* season was recorded in Hakwatuna Oya irrigation system. The highest cultivation extent in both *Maha* and *Yala* seasons was recorded in Batalagoda irrigation system. For instance, the last 5 years average cultivation extent of Hakwatuna Oya irrigation system are 46% and 87% in *Yala* and *Maha* seasons, respectively. The corresponding values for Batalagoda system are 92% and 100%. It means that this system suffers due to extreme water scarcity, particularly in *Yala* season. Water scarcity has resulted in lower crop productivity in this system. The Second Inter Monsoonal (SIM) and North East Monsoonal (NEM) rainfalls adequately support crop cultivation in *Maha* season. At present, rainfall contributes nearly 34% and 22% of CWR in *Maha* and *Yala* seasons respectively¹³. Efficient use of monsoonal rainfall would reduce IWR of paddy. It was reported that most of the CWR could be met by rainfall during *Maha* season by adhering to proper planting dates and preventing any possible moisture stress by supplementary irrigation¹⁴.

Cropping intensity is the primary and essential criteria to measure irrigation service performance¹⁵. Figure-4 shows cropping intensity of Hakwatuna Oya, Bathalagoda and Kimbulwana irrigation systems over the past two decades. Accordingly, cropping intensity of this irrigation system is below 2 except the years 2003, 2006, 2008, 2012, 2013 and 2015. Further, average cropping intensity of Hakwatuna Oya, Bathalagoda and Kimbulwana Oya irrigation systems are 1.47, 1.81 and 1.86, respectively.

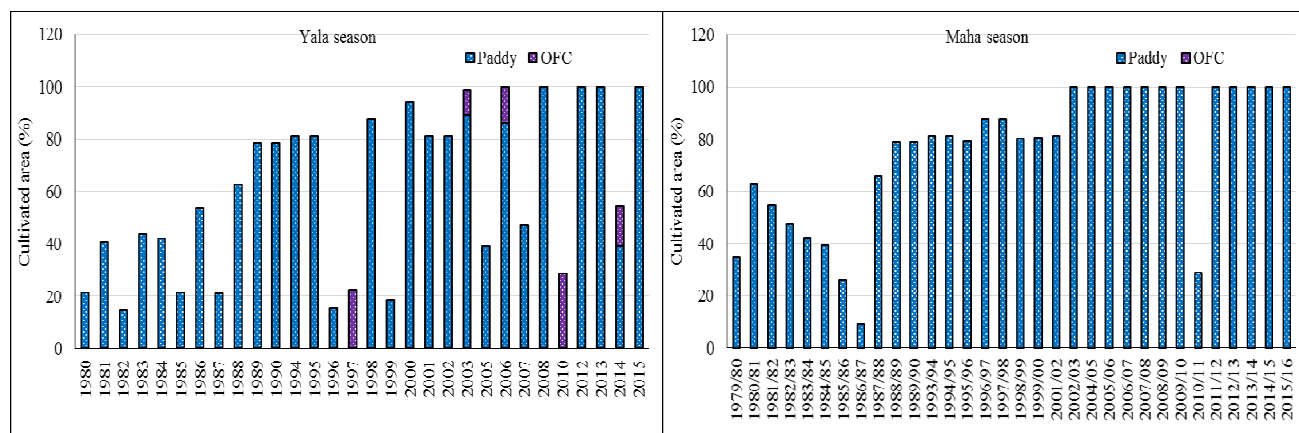


Figure-2: Extent of cultivation in Hakwatuna Oya irrigation system over the recent past decades in *Yala* and *Maha* seasons.

The values of water duty at the end of the cultivation season give the overall water adequate details about the adequacy, reliability and timeliness of operations⁶. Figure-5 shows irrigation duty of major irrigation systems in Kurunegala district for 2012/13 *Maha* and 2013 *Yala* seasons. In the recent past, farmers cultivated entire command area in the Hakwatuna Oya irrigation system (Figure-2). However, irrigation issue is restricted due to water shortage. For instance, farmers cultivated entire command area in 2012/13 *Maha* and 2013 *Yala* seasons. Though, irrigation duty for both *Maha* and *Yala* seasons were

only 1.46 Acft/Ac and 1.68 Acft/Ac (Figure-5). This is the lowest water duty recorded in *Yala* season among major irrigation systems in Kurunegala district. For instance, irrigation duty in 2012/13 *Maha* and 2013 *Yala* seasons were 3.8 Acft/Ac and 5.5 Acft/Ac in Usagala Siyambulagamawe which is one of the major irrigation systems in Kurunegala district. Due to water shortage, dead storage was pumped in 2012/13 *Maha* season in the Hakwatuna Oya irrigation system in order to supply water for crop cultivation.

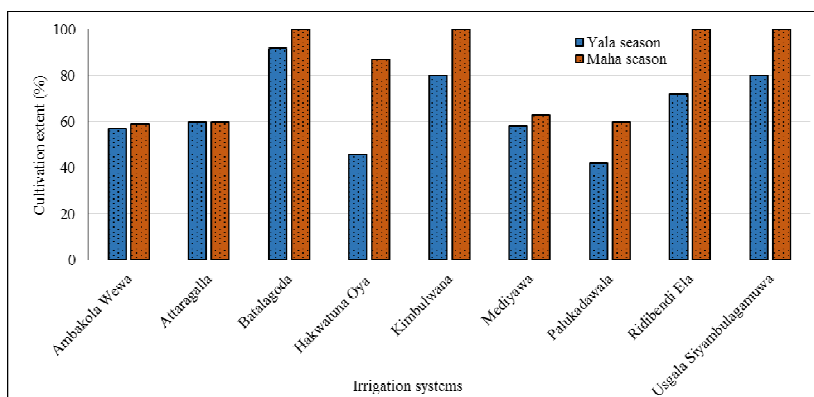


Figure-3: Average last five years cultivation extent (%) of major irrigation systems in Kurunegala district.

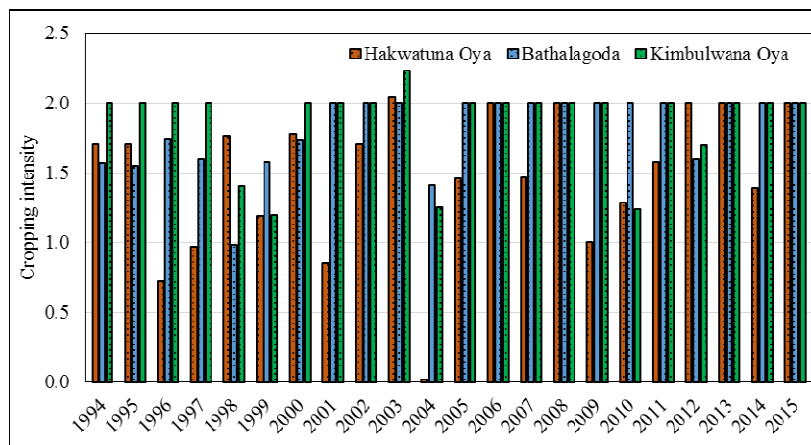


Figure-4: Cropping intensity of major irrigation systems in Hiriyala division in Kurunegala district.

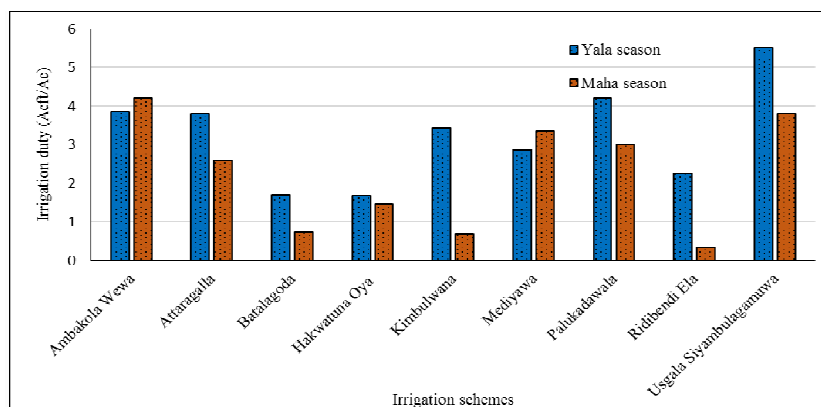


Figure-5: Irrigation duty of major irrigation systems in Kurunegalla district for 2012/13 *Maha* and 2013 *Yala* seasons.

Table-2 summarizes the estimated values of selected indicators for three major irrigation systems for 2014/15 *Maha* and 2015 *Yala* seasons. Accordingly, the lowest irrigation duty and seasonal irrigation water supply per unit irrigated area in both *Maha* and *Yala* seasons were recorded in Hakwatuna Oya irrigation system. Relative water supply as an indicator gives the condition of water abundance or scarcity of a system¹⁶. The lowest relative water supply of 1.32 in 2014/15 *Maha* and 0.87 in 2015 *Yala* seasons were recorded in Hakwatuna Oya irrigation system. Corresponding values are 1.50 and 0.96 for Bathalagoda and 1.41 and 1.20 for Kimbulwana Oya in both *Maha* and *Yala* seasons, respectively. Accordingly, Hakwatuna Oya is a water scarce system whereas Kimbulwana Oya is a water abundant system. Further, Bathalagoda system could be considered as moderately water abundant system.

The highest paddy yield of 5.16Mt/ha was recorded in Hakwatuna Oya system in 2014/15 *Maha* season whilst Kimbulwana Oya system recorded highest paddy yield of 4.9 Mt/ha in 2015 *Yala* season. Average paddy yield reflects the productivity of land and this indicator depends on the scarcity of land resource¹⁷. However, the highest water productivity of 2.36 kg/m³ in 2014/15 *Maha* and 1.04 kg/m³ in 2015 *Yala* seasons were recorded in Hakwatuna Oya system. It means the Hakwatuna Oya has higher production per unit use of irrigation water. The relative yield as an indicator gives the ability of an irrigation system to produce over the expected yield at optimum conditions. The highest relative yield of 1.03 was recorded in Hakwatuna Oya system in 2014/15 *Maha* season. Although irrigation duty was low in 2014/15 *Maha* season in Hakwatuna Oya system, higher effective rainfall along with soil type might have attributed for highest relative yield. The Kimbulwana Oya

recorded highest relative yield of 0.98 in 2015 *Yala* season. It might be due to higher water duty in 2015 *Yala* season.

Current water demand and supply deficit: Figure-6 shows past annual demand and unmet demand (supply deficit) from 2004 to 2014. There was a high fluctuation in both demand and unmet demand from year to year due to variation in extent of cultivation and water availability. Water deficit was observed in all the years except 2004 and 2011. It is because farmers avoided paddy cultivation in *Yala* season in 2004 and 2011 and the stored water along with rainfall satisfied water demand in *Maha* season. Further, under long term average flow condition, cultivation of paddy in the entire command area in both *Yala* and *Maha* seasons requires nearly 30 MCM additional water supply.

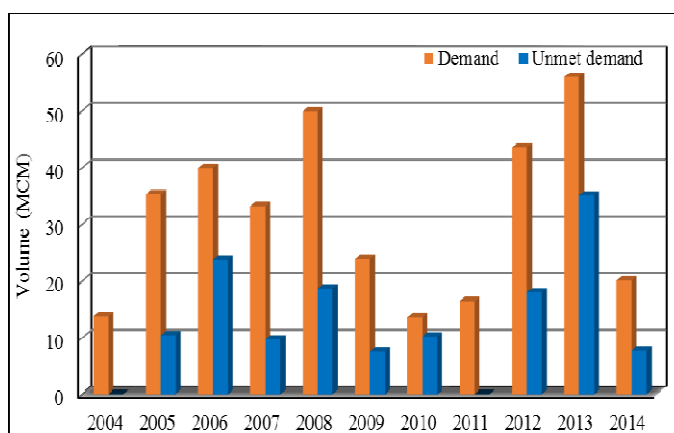


Figure-6: Annual variations in demand and unmet demand in Hakwatuna Oya irrigation system.

Table-2: Estimated values of performance indicators of three major irrigation systems for 2014/15 *Maha* and 2015 *Yala* seasons.

Indicators	Bathalagoda		Hakwatuna Oya		Kimbulwana Oya	
	<i>Maha</i>	<i>Yala</i>	<i>Maha</i>	<i>Yala</i>	<i>Maha</i>	<i>Yala</i>
Irrigation duty (Acft/Ac)	1.67	2.04	0.73	1.48	2.77	3.35
Estimated eff.rainfall (ft)	4.74	2.38	4.89	2.52	3.27	2.17
Water duty (Acft/Ac)	6.41	4.42	5.62	4.0	6.04	5.52
Irrigation contribution (%)	39	44	17	32	65	73
Seasonal irrigation supply per unit irrigated area (m ³ /m ²)	0.50	0.61	0.22	0.44	0.83	1.01
Relative water supply*	1.50	0.96	1.32	0.87	1.41	1.20
Average paddy yield (Mt/ha)	3.87	3.87	5.16	4.64	4.12	4.90
Water productivity (Kg/m ³)**	0.77	0.63	2.36	1.04	0.50	0.49
Relative yield***	0.77	0.77	1.03	0.93	0.82	0.98

Conclusion

The Hakwatuna Oya irrigation system is a water short system. Average cultivation extent is nearly 46% in *Yala* and 87% in *Maha* seasons. The average cropping intensity is 1.47. In addition, water duty in this system is less than 2 Aft/Ac. According to comparative performance analysis, this system has lowest seasonal irrigation water supply. However, it produces higher yield per unit use of irrigation water compared to Bathalagoda and Kimbulwana Oya irrigation systems. Annual water demand and unmet demand vary from year to year due to variations in water availability, crop type and extent of cultivation. Under long term average flow condition, cultivation of paddy in the entire command area in both seasons demands nearly 30 MCM additional water supply.

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