

Trade-off between Ecosystem Services: Change in Economic Values of Veeranam Ecosystem Services due to Water Reallocation

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ABSTRACT

Increasing water demand forces the decision makers to reallocate water from one sector to another sector for efficient utilisation of available water. Water reallocation creates potential trade-off between the services generated by water resources thereby affecting Pareto optimality. Economic valuation of ecosystem services helps to understand the net economic benefits and costs associated with trade-offs. This paper analyses the change in economic values of ecosystem services, especially irrigation water and drinking water services due to water reallocation from Veeranam lake located at Cuddalore district of Tamil Nadu to Chennai city for domestic use. Production function method and opportunity cost method were used to estimate the marginal value of irrigation water and drinking water respectively. The economic value of irrigation water is estimated to be Rs. 36,83,87,041/year (1,52,858/ha/year) and the opportunity cost of drinking water is estimated to be Rs. 103,97,95,200/year (Rs. 4,31,450/ha/year). Although water reallocation generates the net economic benefit of Rs. 97.52 crores/year, the economic welfare of farmers has been declined. The paper suggests that the additional net economic benefit could be utilised by establishing market based instruments such as Payment for Ecosystem Services scheme in order to create win-win situation for all stakeholders.

Keywords: Water Reallocation, Trade-off, Ecosystem Services, Economic Valuation, PES scheme

Journal of Economic Literature (JEL) Classification Number: Q510, Q560, Q570

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1. INTRODUCTION

Ecosystems generate a number of goods and services to the beneficiaries thereby contributing to human wellbeing (Costanza, et al., 1997; MEA, 2005; Barbier, et al., 2008; TEEB, 2010; Everard and Waters, 2013) either directly or indirectly at local, regional and global scale. Decision making on protection and management of ecosystems become difficult when allocating the ecosystem services involve trade-offs (Adeyemi, et al., 2013). Certain characteristics of ecosystem services such as absence of market, tangibility, visibility, subjectivity and reach (local, regional and global) make it difficult to identify and quantify the economic cost due to trade-off between ecosystem services (Venkatachalam and Balooni, 2017).

Veeranam lake, located at Cuddalore district of Tamil Nadu, India, irrigates 18,152 hectares of wet lands in Kattumannarkoil Taluk and Chidambaram Taluk of Cuddalore District. 128 villages including 54 villages of Chidambaram Taluk and 74 villages of Kattumannarkoil Taluk in Cuddalore district are benefited by the irrigation system of Veeranam lake covering 8,625 hectares and 9,497 hectares respectively. The implementation of Chennai city Water Augmentation Project in 2004 to meet the drinking water requirement in Chennai city has affected the economic welfare of farmers in Veeranam lake irrigated area since water supplied for irrigation from Veeranam lake has been reduced. DEFRA (2007) suggests that it is important to analyse the changes in economic values of ecosystem services due to introduction of or change in policy. Water valuation in particular helps in efficient and equitable allocation which is vital in water resource management (Ghosh and Bandyopadhyay, 2009). Economic valuation helps to understand the economic importance of ecosystems and provide guidance on understanding the preferences of beneficiaries on various alternative utilisation of ecosystem services (de Groot, et al., 2012). Also, it helps to generate economic incentives for effective management of ecosystems (Farley and Costanza, 2010) and paves way for implementing market based instruments especially Payment for Ecosystem Services (PES) scheme for sustainable and efficient management of ecosystems (Landell-Mills and Porras, 2002; Wunder, 2005; Pagiola and Platais, 2007; Engel, et al., 2008; Pagiola, 2008; Gomez-Baggethun, et al., 2010). Economic valuation of water supports the design of efficient water allocation system, and estimation of opportunity costs of water across different uses (Al-Karablieh, et al., 2012). It is also helpful for rational decision making on water resource management (Hellegers and Perry, 2006), investment decisions on water resource development, policy decisions on sustainable water use and socio-economic impacts of such decisions (Hussain, et al., 2007).

2. MATERIALS AND METHODS

Environmental economists have developed a set of valuation methods to estimate the economic values of ecosystem services that are not sold in market. These valuation methods are broadly categorised into revealed preference methods and stated preference methods (Kramer, 2005). A detailed review of valuation methods to estimate economic value of water is presented in literature (Agudelo, 2001; Turner, et al., 2004; Young, 2005; Lange and Hassan, 2006). This paper adopts quadratic form of production function method and opportunity cost method to estimate the economic value of irrigation water and drinking water respectively.

Production function method estimates the marginal value of input as change in output due to one-unit change in input. Being a factor of production, marginal change in irrigation water influences the marginal change in agricultural production assuming other factors of production remain constant (Moore, 1999; Shatanawi and Naber, 2011). Although paddy is the main crop cultivated in Veeranam irrigated area, farmers also cultivate sugarcane and betel leaf at significant level. Each crop requires different amount of irrigation water during cultivation process. Hence the value of water depends on marginal productivity and market price of each crop. For the analysis, economic value of irrigation water is estimated by analysing marginal productivity of irrigation water with respect to paddy cultivation.

The general form of production function is,

$$Y = f(IW, \{Xs\}) \dots\dots\dots (1)$$

Where, Y = Total production (kg),

IW = Irrigation water (m³),

{Xs} = Vector of input variables such as land (ha), labour (man-days), fertiliser (kg)

Since the marginal productivity of irrigation water is found to be in diminishing return to scale in study area, quadratic production function is adopted to capture the curvilinear effect. It is assumed that other factors of production except irrigation water remain constant.

Following Karthikeyan (2010), the quadratic form of production function is:

$$Y = a + b_1IW + b_2IW^2 \dots\dots\dots (2)$$

Where, Y = Total output (kg/ha),

IW = Total quantity of irrigation water (m³/ha)

IW² = Total quantity of irrigation water (m³/ha)²

a = constant

b₁ = coefficient of IW

b₂ = coefficient of IW²

To estimate the economic value of marginal product of water:

$$VMP_w = (\delta Y / \delta W) * P_y = MP_w * P_y \dots\dots\dots (3)$$

Where, VMP_w = Value of marginal product of water

MP_w = (δY/δW) = Marginal product of water (m³)

P_y = Price of output (kg)

Opportunity cost method is the measure of the value of non-market good by estimating the cost to access alternative good sold in market to gain same level of benefit. Since drinking water supplied for urban use from Veeranam lake is non-market in nature, opportunity cost method has been adopted to estimate economic value. The method measures the cost incurred by urban consumers to purchase additional unit of drinking water from alternative source. Both government and private sources sell drinking water to urban consumers where demand for water is higher than actual supply by Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB).

To estimate the opportunity cost of drinking water:

$$OC_w = Q_w * (AP_w - C_w) \dots\dots\dots (4)$$

Where, OC_w = Opportunity cost of drinking water

Q_w = Quantity of water (m³)

AP_w = Price of alternative water (m³)

C_w = Cost of supplying alternative water (m³)

3. RESULTS

Based on field investigation, nine ecosystem services were identified to be generated by Veeranam lake (Table 1). The identified goods and services were classified based on Millennium Ecosystem Assessment (MEA, 2005) framework. Intermediary services are omitted from the list to avoid double counting and only final goods and services that benefit the people are incorporated.

Table 1. Ecosystem Services of Veeranam Lake

Sl. No	Ecosystem Services	Spatial Scale	Benefit Level	Impact due to Water Reallocation
Provisioning services				
1	Irrigation water	Local	Very high	Direct and Highly negative
2	Drinking water	Regional	Very high	Direct and Highly positive
3	Fisheries production	Local	High	No Impact
4	Fodder for livestock	Local	Medium to high	Indirect
5	Silt/Sediment as fertiliser	Local	Low	No Impact
Regulating Services				
6	Flood regulation	Local	Medium to high	No Impact
7	Climate regulation	Global	Low to medium	No Impact
Cultural services				
8	Recreation	Local	Low	No Impact
9	Spiritual service	Local	Medium	No Impact

Source: Observed from Field Investigation in the year 2017

Among the nine Veeranam ecosystem services, irrigation water service and drinking water service are directly involved in the trade-off. The impact of water reallocation on fodder benefit is indirect since the reduction in irrigation water supply leads to reduction in fodder availability. The change in fodder benefit due to water reallocation and associated economic value is difficult to estimate as the farmers purchasing irrigation water from nearby bore well owners during irrigation water shortage indirectly aids in accessing fodder for livestock. Hence, the changes in economic values of irrigation water and drinking water services alone are estimated to find the net economic benefit due to water reallocation.

To estimate the economic values of irrigation water service and drinking water service by Veeranam lake, the recent available data on the quantity of water supplied to both services (for the year 2013-14) are taken into account. Water supplied from Veeranam lake in 2013-14 for both irrigation purpose and drinking purpose are listed in the table below.

Table 2. Water Allocation from Veeranam Lake (2013-14)

Sl. No.	Month	Water Level in Ft (average)	Storage in Mcft (average)	Inflow in Cusecs	Outflow to Chennai Metro in Cusecs	Outflow to Channels in Cusecs
1	April	40.50	137	-	851	-
2	May	37.86	-	-	-	-
3	June	-	-	-	-	-
4	July	-	-	-	-	-
5	August	44.97	975	23275	920	230
6	September	45.15	920	10135	2136	6605
7	October	44.30	744	18515	2269	9025

8	November	45.06	892	12170	1448	3064
9	December	45.65	1020	8140	2270	3850
10	January	44.76	846	13000	2289	1905
11	February	46.30	1190	720	2127	-
12	March	45.00	901	-	2360	-
Total Cusecs (year)				85955	16670	24679
Total Mcft (year)				7427	1440	2132

3.1 Economic Valuation of Irrigation Water

Following equation (2),

$$Y = 1420.1 + (0.339) IW^{***} - (0.000006) IW^2 **$$

*** = 1% significant level

** = 5% significant level

Following equation (3), the economic value of marginal product of irrigation water is estimated to be Rs. 6.102/m³. Converting this value to total irrigation water supplied from Veeranam lake i.e. 2132 Mcft (assuming there is no water wastage), the economic value of irrigation water is estimated to be Rs. 36,83,87,041/year and 1,52,858/ha/year.

3.2 Economic Valuation of Drinking Water

Chennai Metro Water and Sewerage Board charges different water tariffs based on quantity of water purchased by different user groups. The water tariffs for domestic supply through tanker lorries ranges from Rs. 475/6m³ to Rs. 1200/12m³ (source: <https://chennaietrowater.tn.gov.in/>). To estimate the economic value of water, operation and maintenance cost and cost incurred to hire lorries have to be deducted. Since the cost on hiring lorries is not available, the charge levied by Chennai metro for domestic water supply at metro water filling points itself (Rs. 40/m³), is taken for analysis. The operation and maintenance cost including water purification is estimated at Rs. 29 lakhs for 200 million litres (source: <https://chennai.citizenmatters.in/chennai-cost-of-desalination-vs-surface-water-treatment-plants-8405>) equal to Rs. 14.5/m³. Hence, the substitute cost of drinking water is estimated at Rs. 25.5/m³. Converting the estimated substitute cost to the total water supplied for drinking purpose from Veeranam lake (1440 Mcft), the total value of drinking water is estimate to be Rs. 103,97,95,200/year (Rs. 4,31,450/ha/year).

4. DISCUSSION AND CONCLUSION

Economic valuation of ecosystem services helps to understand the net economic benefits and costs associated with trade-offs. Site specific economic valuation to determine changes in economic values due to trade-off was conducted for irrigation water and drinking water. While irrigation water benefits local community i.e. farmers, drinking water benefits at regional scale i.e. urban water consumers. The results suggest that the economic value of irrigation water estimated using quadratic form of production function method was Rs. 1,52,858/ha/year (Rs. 6.102/m³). The economic value of drinking water is estimated at Rs. 4,31,450/ha/year (Rs. 25.5/m³). If water from Veeranam lake was not reallocated for drinking purpose and total 3572 Mcft of water supplied for irrigation purpose alone, the total value of

irrigation water would be Rs. 61.72 crores/year. Since water is reallocated for urban use, the same quantity of water value is estimated to be Rs. 113.54 crores/year thus generating net economic benefit of Rs. 51.82 crores/year. Although water reallocation brings in high net economic benefit, the economic welfare of farmers has been declined.

International expert forums such as Dublin Principles (1992), World Summit on Sustainable Development in Johannesburg (2002), Third World Water Forum 2003) and World Water Development Report (2006) stressed that water has to be treated as an economic good. Several studies have found that households in rural (Manikandan and Boopathi, 2020) and urban (Venkatachalam, 2015) areas of Tamil Nadu are willing to pay for improved water supply. Monetisation of drinking water supply based on opportunity cost principle will increase water use efficiency from the demand side and generate economic incentives for sustainable management of the lake from the supply side. Suitable policy decisions on creating market based instruments such as Payment for Ecosystem Services (PES) scheme will be helpful to incorporate farmers of Veeranam lake in terms of generating economic incentives for sharing their irrigation water with urban consumers.

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