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ECONOMIC VALUATION OF ECOSYSTEM SERVICES IN THE MICRO-WATERSHED AREA OF TUTICORIN DISTRICT, TAMIL NADU

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ABSTRACT
Integrated Watershed management is initiated to minimise drought-prone areas and promote development in rural areas. The watershed Programme was implemented to improve and regulate ecosystem services in rural areas and to enhance the livelihoods of rural communities. This research focuses on the economic valuation of ecosystem services and the impact of micro-watershed development interventions in the Tuticorin district. The study is conducted by collecting data using purposive random sampling. The watershed impact was measured by comparing pre- and post-watershed market prices, and incremental changes in ecosystem service values were estimated using the market price method. The interventions in the study area include check dams, farm ponds, crop diversification, crop intensification, and soil moisture conservation, with impacts on employment and milk yield. The results indicate that milk production has increased, and crop diversification and land area cultivation in the study region have also increased. The check dam and the farm pond have improved the groundwater table in the watershed and enabled timely crop irrigation. Employment has been provided to more than 150 village farmers in each micro watershed region. The results also indicate that interventions significantly increased agricultural productivity and increased the average net income of around Rs. 19750 per hectare per year from crop production. This valuation of ecosystem services highlights the role of integrated watershed management in increasing food security and improving the livelihoods of rural communities in arid regions.

KEYWORDS: Watershed, Ecosystem services, Valuation, impact assessment.

1. INTRODUCTION
Environmentalists and policymakers depend mostly on natural resource economics. In recent years, the number of studies representing ecosystem services has been evaluated and discussed. The concepts have been globally accepted by various organisations. To improve ecosystem-based services globally, maintain ecology and natural resource management. Economic valuation of ecosystem services in a region or a particular ecosystem helps us better understand the services nature provides. This shows trade-offs between production and environmental conservation, quantifying the benefits of natural ecosystems and their direct use value. These estimates help policymakers to prioritise environmental sustainability. Since 1970, watershed development has been integral to improving India's agricultural background. Most regions in India depend on a rainfed cropping pattern.

Globally, water resources are under increasing stress, and only 3 per cent of freshwater is accessible[1]. Groundwater is primarily depleted by the agricultural sector globally, and it is the main source of irrigation and drinking water for more than 2 billion people [2, 3]. Over the past decades, water scarcity has increased from affecting 0.24 billion people to affecting 3.8 billion people as water consumption has quadrupled [4, 5]. Climate change is also a key driver of global water stress, particularly in India and eastern China[6]. Satellite and model-based assessments indicate that water storage trends are not uniform. Climate change is intensifying droughts, floods, cryosphere loss, and hydrological imbalance, with projections indicating that about 56 per cent of the global population will be affected by water scarcity in the future [2].

The degradation of land and water resources poses a severe threat to global food security and environmental sustainability[7], particularly in the arid and semi-arid regions of the developing world. In India, rainfed agriculture accounts for nearly 51% of the net sown area, making it highly vulnerable to climate variability and erratic monsoon patterns[8]. To combat desertification, soil erosion, and groundwater depletion, the Government of India, along with state agencies, has heavily invested in watershed development programs. These programs operate on the fundamental principle that a watershed is a geo-hydrological unit that drains runoff to a common point, enabling the targeted implementation of ridge-to-valley conservation techniques.

In India, rainfed agriculture occupies about 60% of the net sown area and helps half a billion livelihoods. Integrated watershed management serves as the primary policy instrument for drought-proofing and land degradation neutrality [9]. State-led interventions, such as the watershed development component of Pradhan Mantri Krishi Sinchayee Yojana[10], focus on micro-watersheds to implement in situ soil moisture conservation, surface storage creation, and ecosystem restoration. In recent decades, policymakers and environmentalists have focused on estimating the valuation of ecosystem services due to severe drought and climate change. This assessment of ecosystem services helps the government make economic decisions to improve ecosystems nationwide[11]. These may improve environmental sustainability and highlight the value of ecosystem services through market-based valuation methods, provided there are no market distortions[12]. Watershed development has been integral to India’s efforts to improve agricultural productivity and alleviate poverty in rainfed regions. Watersheds to enhance rainwater harvesting, prevent soil erosion and increase soil nutrients and carbon content, improving crop productivity and rural livelihoods[13]. Improved agricultural yields enhance both human welfare and national food security. There are numerous studies estimating watershed regions in India, but they are limited to wetland and provisioning ecosystem services. Ecosystems in arid regions remain unnoticed; none of them has attempted to evaluate the economic valuation studies. Therefore, this research seeks to examine the ecosystem services of a particular watershed in Tuticorin, evaluating its ecological, economic, and social significance. This study aims to quantify improvements in ecosystem services by watershed in an arid region affected by drought. Due to low rainfall, degraded areas were rehabilitated through micro-watersheds in various regions of Tuticorin district, thereby improving ecological, economic, and rural livelihood conditions. This research enhances the existing ecosystem services valuation and provides valuable enrichment of ecosystem services by watershed development activities. Ecosystem services are broadly categorised into provisioning (e.g., food, timber, freshwater), regulating (e.g., climate regulation, water purification), supporting (e.g., nutrient cycling), and cultural (e.g., recreation, spiritual values). Hence, the valuation of these services has gained traction to justify conservation budgets and natural resource management. a critical assessment of the value of recreational ecosystem services in India, highlighting that non-use and cultural values often constitute a massive yet overlooked economic surplus [14]. Utilising methodologies such as the Travel Cost Method and the Contingent Valuation Method, such studies demonstrate that the Total Economic Value of managed ecosystems far exceeds their direct agricultural output. In the context of Tuticorin's watersheds, valuing regulating services such as groundwater recharge and soil erosion prevention is critical to understanding the true return on investment of government watershed programs. This study was designed to address the following questions: What changes have occurred in agricultural and livestock and groundwater levels after the initiation of watershed development practices? What are the ecosystem services that are enhanced by watershed management interventions?

Fig 1. Impact of watershed interventions- crop production activities

Fig 2. Surface water storage interventions in the study area

2. REVIEW OF LITERATURE

Zhao et al. (2021) analysed the value assessment model for the complex ecological environment in Gansu Province, China [15]. They created a model for regional contrast and adjustment indices for 11 types of ecosystem services. It highlighted how local climate and biodiversity maintenance functions contribute to the total Ecosystem Service Value (ESV). Their results suggest that valuation without regional calibration can dramatically distort the real economic value of local ecosystem services. Wang et al. (2014) studied ecosystem services in Ningxia, China, and the fluctuations in values over the past decade of ecological restoration [6]. The results showed that the total ESV increased significantly with increases in forest land area and water bodies, and that the area of land cover in a watershed has measurable economic benefits. Chan et al. (2011) measured the difference in the economic value of ecosystem service provision between two land-use scenarios: conservation and timber harvesting[16]. They value services such as carbon storage, timber production, and recreation to illustrate the trade-offs among different management decisions. The work emphasises the need for conservation planning that goes beyond the direct benefits of watershed protection to carefully consider the co-benefits and economic costs to local stakeholders. Vicente et al. (2023) evaluated the advantages of the Balatin River Sub-Watershed in the Philippines using the Total Economic Value (TEV) approach[17]. They showed how the economic benefits of regulating services and irrigation were shared among different stakeholders in the community, using different valuation approaches (market price approaches for direct household water supply and benefit transfer for non-use values).

3. MATERIALS AND METHODS

The study focuses on the Tuticorin district in Tamil Nadu, located between latitudes 8°19' and 9°22' N and longitudes 77°40' and 78°23' E. The district covers an area of approximately 4,621 square kilometres. Geomorphologically, the region transitions from the eastern coastal plains to the western undulating terrain. The major river basins draining the district include the Thamirabarani, Korampallam, and Vembar rivers. However, outside the Thamirabarani command area, agriculture is strictly rainfed, relying heavily on the northeast monsoon (October to December). Vaippar River is the major connecting tributary across the districts. This study covers nearly five micro-watershed blocks, namely Kovilpatti, Kayathar, Vilathikulam, V.Pudur, and Poosanur. An area of more than 35000 ha has been proposed for the watershed intervention program. Several conservation works were carried out in arid regions to improve water harvesting structures, such as major and minor check dams, farm ponds, and orchard plantations. These measures were employed either individually or in combination, depending on the problem to be addressed in the region and crop demonstrations of improved practices were introduced. The soils vary from deep red loam in the western blocks (like Vilathikulam and Pudur) to black cotton soils and coastal alluvium. The heavy reliance on groundwater for agricultural use in the study area has led to severe localised seawater intrusion, making inland watershed recharge structures critical for maintaining the freshwater-saltwater interface.

Data collection and sample design

The study is based on a primary data survey. To assess the impacts of watershed management activities, data were collected during 2024-25, through face-to-face interviews with individual respondents using a pretested structured questionnaire. The questionnaire was structured into 14 sections for the impact assessment and economic valuation of ecosystem services. A total of 200 respondents were interviewed from five blocks in five villages. About eight respondents were interviewed from each selected village. A purposive random sampling method was used to select the watershed villages based on the area of the implemented watershed program. The questionnaire was prepared in English, and the farmer's interview was held at their field in the local language. This study was conducted by before and after watershed approach. Data on specific ecosystem services were collected from field observations and secondary sources, such as case studies, reports, and government records, for the year 2025. The impact of integrated watershed management and soil water conservation was measured using Pande et al. (2023) [18] approach.

ESWM= IWM1-IWM0

Where, ESWM = Ecosystem services due to Watershed management: IWM_1 = ES after integrated watershed management; IWM_0= ES before integrated watershed management.

Table 1. Number of samples selected from the study area Name of the BlockWatershed Villages

S. No.	Block / Area	Sample Villages / Locations	Sample Size
1	Thirumangalakurichi	Chettikurichi	—
2	Kayathar	—	—
3	Kovilpatti	—	—
4	Ottapidaram	—	—
5	Vilathikulam	—	—
6	V. Pudur	Periyasamipuram	**40**
7	—	Vellalankottai, Vadakkuilandikulam, Pechithailavanpatti, Vadakkupatti	—
8	—	Melapatti	**40**
9	—	Ilayarasanendal, Pillayarnatham, Keelamudiman, Cyclone Colony	—

S. No.	Block / Area	Sample Villages / Locations	Sample Size
10	—	Vellarai	**40**
11	—	S. Kumarapuram, Thalavaipuram, V. Vedapatti, Marthandapatti	—
12	—	Jagaveerapuram	**40**
13	—	Poosanur, Kalaignanapuram, Muthulapuram, Veerapatti	—
14	—	Mellakarandhai	**40**
15	—	Keelakarandhai, Masarpatti	—

Ecosystem service classification

According to the Millennium Ecosystem Assessment, ecosystem services have been broadly classified into four main categories: Provisioning, Supporting, Regulating and Cultural services. Based on available data, some of the ecosystem services managed by watershed interventions were identified and valued at 2025 market prices.

Table 2. Ecosystem services and methods used for valuation

Ecosystem Services	Indicator	Methodology	Data Used
Provisioning Services – Food	Crop production	Assess changes in crop production before and after watershed intervention	Area sown, yield changes, and market price
Provisioning Services – Fodder	Fodder production	Assess changes in fodder production due to watershed management intervention	Area under fodder crops and production due to watershed management intervention
Provisioning Services – Livestock	Livestock production	Assess change in milk production due to IWM intervention	Number of cattle, milk production, and local market price of milk
Provisioning Services – Water	Fresh water for household use	Assess change in surface water storage due to IWM intervention	Surface water storage and wells
Provisioning Services – Livelihood Support	Employment generation	Assess change in employment generated in the watershed due to IWM intervention	Number of days employed in different activities
Regulating Services – Water Flow	Groundwater recharge	Assess change in annual groundwater recharge due to IWM intervention	Watershed area, annual water levels in wells and borewells
Cultural Services – Awareness Creation / Demonstration	Awareness creation / knowledge acquisition	Assess the value of acquiring knowledge about natural resource management due to IWM intervention	Number of people acquiring knowledge and average expenditure on watershed visits by trainees or visitors

4. Results and discussion Provisioning Services

Watershed interventions include provisioning and regulating ecosystem services, which directly enhance the availability of commodities and resources within watershed areas for human activities. It plays a major role in the welfare of rural communities in watershed areas.

Crop production

For food security, farm output was analysed by area under cultivation before and after watershed interventions. Depending on the commodity's yield and market price, values are estimated. It was found that the watershed interventions from crop production major crops such as Maize, Cotton, and black gram have increased yield due to the construction of check dams and farm ponds, which help ensure the timely irrigation of crops in the watershed. It is also supported by farming additional seasonal crops and maintaining soil moisture conservation in the region. Improved irrigation in the arid region has increased yields and added a cropping season by allowing sowing more than once a year.

Table 3. Changes in provisioning ecosystem (crop production) with watershed intervention in Tuticorin district

Major crops	Total production Before watershed (qtl/ha)	After watershed (qtl/ha)	Market value /Quintal)	price	(Rs.
Black gram	3.19	6.61	6700		
Groundnut	1.63	2.02	1800		
Cotton	12.03	12.42	2200		
Maize	41.43	53.01	2100		
Sorghum	17.34	18.92	1800		

Livestock Production

It is a fundamental financial part of the rural livelihood community, as it helps them by providing nutritious food and valuable products in their day-to-day lives, interacting with ecosystems through the intake of grass into milk, and increasing the value of livestock. Additionally, livestock mobility allows them to respond to resources and climate fluctuations. Results indicate that additional income post-intervention was estimated.

Table 4. Valuation of ecosystem services of animal husbandry in the watershed area

Particulars	Before watershed	After watershed	Net Changes
Total Number of livestocks	208	506	298
Total Milk Production (lit/yr)	2080	2912	832
Gross income (Rs. /year)	56160	93184	37024
Net income (Rs. /year)	24876	44751	19875
Value of Milk (Rs. /litre)	27	32	5

Employment generation

The watershed development program positively impacted employment opportunities during the program, generating man-days of crop and livestock production employment compared to before the project. Additionally, they were created during the project's implementation phase. The major factor behind the increase in employment is improved irrigation facilities. In addition, the construction of check dams and farm ponds in the watershed region created employment.

Table 5. Valuation of Employment created by the watershed interventions Before watershed After watershed

Particulars	Employment generated	Gross value (in lakh)	Value (per respondent)	Employment generated	Gross value (in lakh)	Value (per respondent)
Crop production	9270	37.08	0.18	12772	41.08	0.19
Livestock production	208	0.56	0.03	506	0.93	0.07
Off-farm activities	12620	50.48	0.24	16568	69.40	0.33
Non-farm	7699	18.49	0.18	10224	30.67	0.14

Regulating ecosystem services

The regulation of ecosystem services from watershed growth focuses on the benefits that ecosystems provide by regulating environmental processes. The following regulating ecosystem services are identified and evaluated. Soil and water conservation are major components in enhancing groundwater recharge and water storage by reducing runoff and improving soil moisture content. The study estimated that the construction of check dams improved water levels in nearby wells and borewells, resulting in an additional crop area due to reduced runoff. The borewell levels also increased by 10 to 20 meters, increasing the amount of available water.

Table 6. Valuation of groundwater recharge and water harvesting

Particulars	Before Watershed	After Watershed
Addition in surface water storage	0	21.86
Duration of water availability in wells – 12 months	12	16
Duration of water availability in wells – 9 months	30	52
Duration of water availability in wells – 6 months	45	66
Duration of water availability in wells – 3 months	48	68
Average groundwater level	0.92	1.76
Average annual pumping hours	584	651
Average time required for recharge (hrs)	6	4
Surface water storage (ha)	0	452

Cultural ecosystem services

Cultural ecosystem services resulting from watershed development are the intangible benefits individuals derive from the watershed's ecosystems. These services foster human well-being by providing education or skill-development opportunities, offering recreational activities, and facilitating aesthetic experiences. The valuation of the watershed training program or demonstration by the watershed committee members to farmers through a capacity-building and training program. One can assess the monetary value of a watershed training ecosystem service, which does not produce a market product, through expenditures or stated preferences associated with the services. Unlike other ecosystem services, the distinctive feature of training services is that their financial costs are relatively well-defined and can be expressed as a specific amount of money. In our case, the sponsoring agency or training institution finances the trips for trainees visiting watersheds for educational purposes, eliminating individual expenses. The valuation of training services was based on the total expenditure for training trips to the watershed, valued at sixty-nine lakhs.

Table 7. Valuation of training created by the watershed interventions Particulars

Particulars	**Value**
Average transport cost (Rs.)	**5,000**
Average rental duration (hours)	**6**
Typical trainee group size	**107**
Average travel cost for one trainee (Rs.)	**280.37**
Additional value / cost (Rs.)	**1,210**
Watershed training ecosystem service value (Rs.)	**6,900,000**
Watershed training ecosystem service value per trainee (Rs.)	**194.75**

CONCLUSIONS

The study of the micro-watersheds in the Arid region of Tuticorin district indicates that watershed development interventions significantly improved agricultural productivity, livestock production, groundwater recharge, water availability, and soil moisture content. These interventions uplifted the rural livelihoods of farmers in the watershed region and highlighted the uplift in ecosystem services amid climate change fluctuations. Hence, due to data limitations, the accurate valuation of ecosystem services could not be estimated in this research to fully understand the watershed's importance. Furthermore, integrating watershed management with agroforestry and livestock rearing can increase the resilience and multifunctionality of these ecosystems, highlighting the essential role of policy in promoting comprehensive and sustainable resource management.

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Data availability: The research dataset is available as supplementary material. Primary data available on reasonable request

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