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r-RAPFISH analysis of fisheries and its management in Mettur (Stanley) Reservoir, India

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Abstract

Mettur reservoir, located in Salem district, Tamil Nadu, is the largest dam in the state with an average Water Spread Area of 9324 hectares. The reservoir has been a vital resource for fisheries, supporting the livelihoods of local communities. However, the impact of illegal fishing and poaching has led to a significant decline in the fish catch per unit of the reservoir from an average of 1177 kg/ha/year (1961) to an average of 157 kg/ha/year (2015), raising concerns about its sustainability. Understanding the overall sustainability will help in identifying the dimension in which the fishery has to be strengthened through necessary interventions. To address these concerns and gain a comprehensive understanding of the fisheries and their management, a detailed analysis was conducted using both primary and secondary sources of data. The study focused on the five dimensions essential for sustainable fisheries management: Ecology, Economic, Social, Technology, and Governance. However, r-RAPFISH analysis revealed that the overall sustainability of Mettur reservoir fisheries is in "Quite" status (Sustainability score – 74.51%), which is obtained by taking an average of sustainability value obtained by the reservoir in each of the five dimensions [Ecology - 83.86%; Economic-90.40%; Social - 44.93%; Technology - 85.59%; Governance -67.76%]. It has also been observed that the social and governance aspects of the fisheries management in Mettur reservoir have to be improved to get an overall 'good' sustainable development status.

Keywords:
Fisheries, Reservoir, r-RAFISH, Mettur

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Introduction

The origin of the Mettur (Stanley) reservoir dates back to the period of the famous 18th-century famine in the Madras State of British India. Despite the existence of Upper Anicut, discontinuous water inflow due to prolonged drought urged the British Government to construct a larger dam across Cauvery at Mettur for strengthening the legendary Cauvery delta irrigation system. Though the plan for construction of the dam was ready soon after the construction of Upper Anicut, differences of opinion in dam construction and water sharing between the then Mysore and Madras Governments hindered the progress. After decade-long arbitrations, the agreement entered into between the two Governments in 1924 paved the way for the completion of dam in 1934 (Ramya, 2014). Thus, Mettur dam with 15346 hectares of water spread area, came into existence as the largest dam in Tamil Nadu. General information about the Mettur reservoir is given in Table 1. Sharing Cauvery water still remains a major inter-state dispute between Karnataka and Tamil Nadu. The maximum water level of the reservoir is 120 feet, and is irrigating approximately 1.1 lakh hectares of land in the Cauvery Delta region of the State. The overarching problem is the detrimental impact of illegal fishing on the Mettur reservoir's

fishery resources. This unchecked exploitation has not only diminished the economic returns for local communities but has also raised concerns about the overall sustainability of the reservoir. A comprehensive sustainability assessment is imperative to address the multifaceted challenges faced by the Mettur reservoir. Understanding the ecological, economic, social, technological, and governance dimensions is essential for devising targeted interventions. Since its existence, this multipurpose large reservoir has been studied by researchers owing to its significant role in fisheries biodiversity and fishers' livelihood of the region. However, a comprehensive fisheries sustainability assessment was not done till date, which the present study attempted.

Materials and methods

r- RAPFISH - a customised tool developed by Lloyd *et al*. (2022) to assess the sustainability of Asian reservoir fisheries is used in the study. r-RAPFISH has five (*ecology, technology, economy, social, governance*) evaluation fields with each field having five indicators to comprehensively understand the factors attributing to the sustainability of fisheries in a reservoir. Information provided by 50 respondents, which includes the fishers (reservoir user), staff of Tamil Nadu Fisheries and Fishermen Welfare Department [TNFFWD] (reservoir manager) and domain (ICAR Scientists, Academicians working in Indian reservoirs) experts were collected using a five-point Likert scale-based schedule which served as the primary data for the study. Grey literature of TNFFWD, technical and non-technical publications about the Mettur reservoir were used as secondary data for the study. Scores were assigned to the aforesaid r-RAPFISH indicators based on the collected primary and secondary data. r-RAPFISH analysis was done using the RAPFISH version 3.1 for Windows. The normalization required to fit to the RAPFISH scores between '0' and '10' was also done. The final RAPFISH score for each evaluation field ranges from 0% (bad/worst) to 100% (good/best). The sustainable development index is the value of each evaluation field that describes the state of health. A typology of sustainability status [Very Poor (0-25), Poor (25.1 - 50), Good (50.1 - 75) and Very good (75.1 - 100)] used by Lloyd *et al*. (2022) was used to categorize the status of Mettur reservoir using the final RAPFISH scores (in %).

Results and discussion

Fisheries and its management in the Mettur (Stanley) reservoir were analyzed using the r-RAPFISH methodology. The scores obtained by Mettur reservoir fisheries for each indicator of the five evaluation fields are illustrated in Figure 1.

Inference of the obtained scores is discussed under each evaluation field for more insight as follows:

Ecological evaluation field:

In the ecological evaluation of Mettur reservoir fisheries management, five crucial indicators were employed: Trophic status, Species composition, Fish production, Recruitment variability, and Environmental degradation. Starting with the first indicator, 'Trophic status,' it involves assessing the overall status of the reservoir's trophic system through three different methods. These methods include the Trophic State Index, which examines plankton

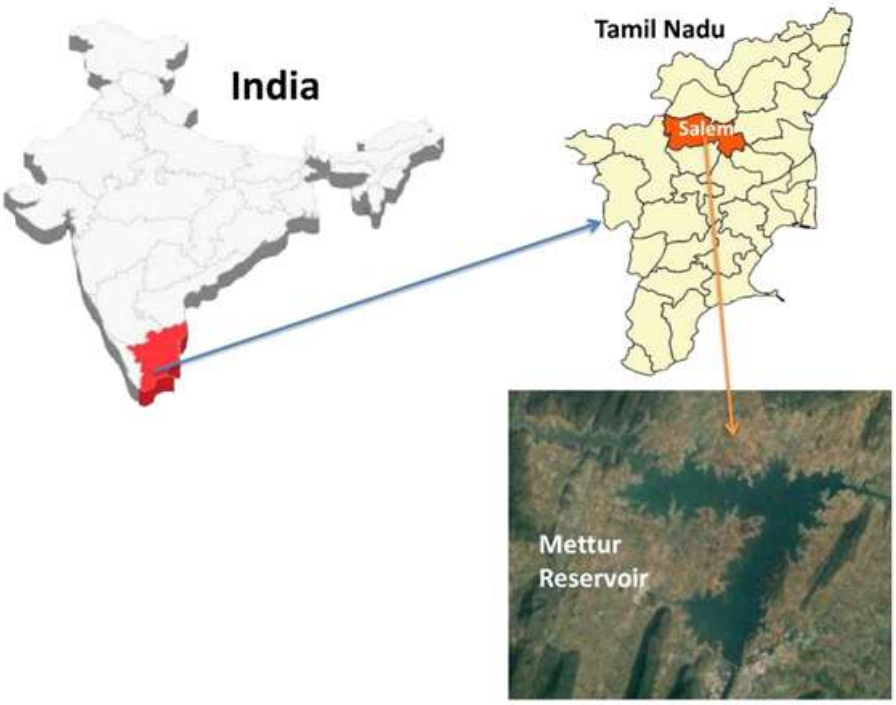
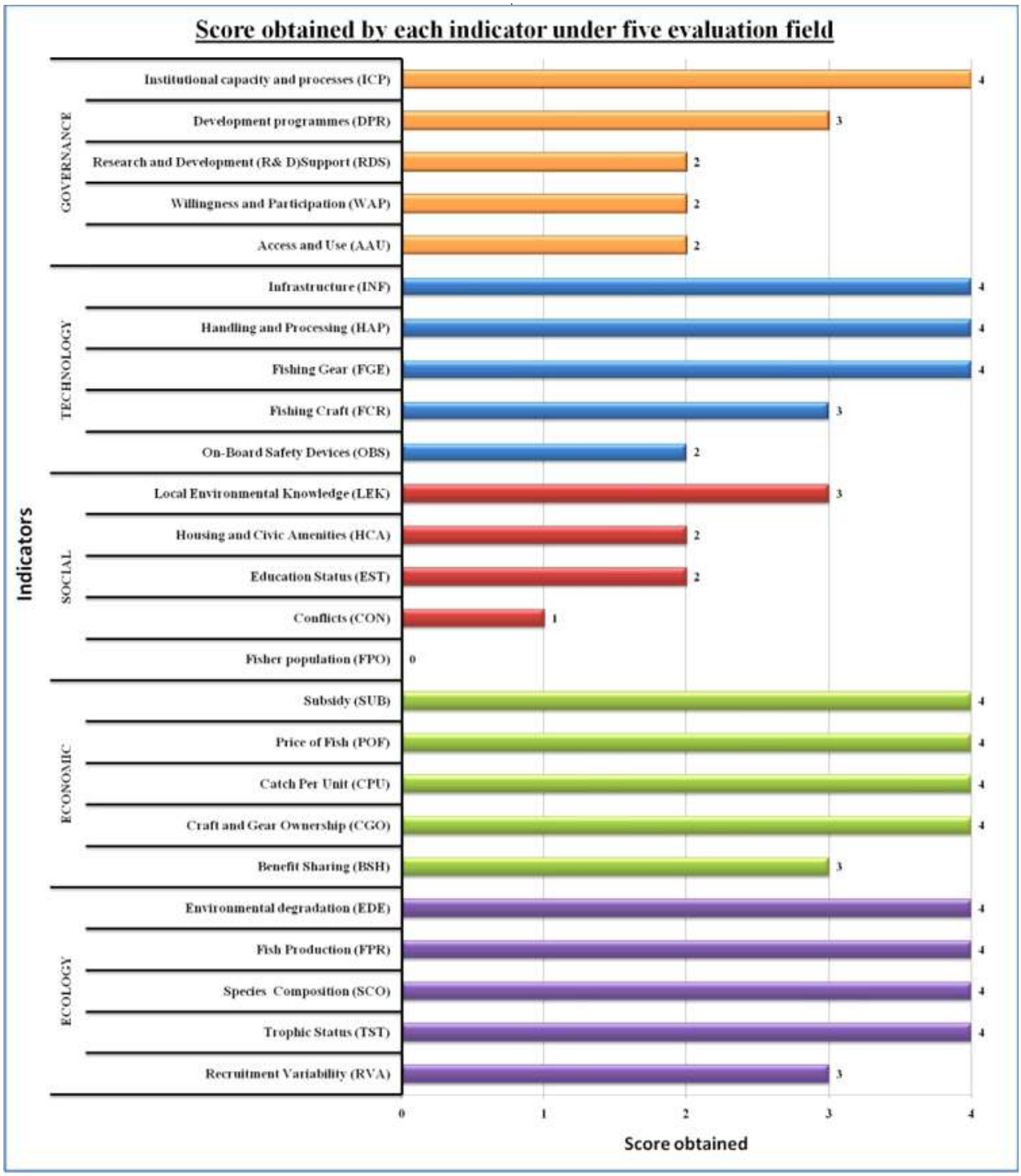


Fig.*1 Study locale*



abundance and distribution, the measurement of phosphorus levels within the reservoir, and the evaluation of the pH range in the reservoir. The Mettur reservoir scored '4,' suggesting a high to very high level of productivity. Moving on to the second indicator, 'Species composition,' it focuses on the diversity of fish species within the reservoir, as evidenced bycatch records and literature. It also considers the trophic position of these identified fish species and their contribution to the overall fish catch in the reservoir. Ideally, a pyramidal trophic level structure is preferred. In the case of the Mettur reservoir, it scored '4,' indicating that the fish trophic levels are well-balanced and resemble a pyramidal structure, with the presence of omnivores, herbivores, detritivores, mid-level carnivores, and high-level carnivores. In the case of the first two indicators, Chacko *et al.* (1955) acknowledged rich fish diversity in the Cauvery River system and listed 80 species of fishes belonging to 23 families in the system. There is no argument that the dam is highly beneficial for irrigation purposes, but it is disastrous, when it comes to the immediate effect of the dam over fisheries of the Cauvery River below. Dam made the anadromous *Tenualosa ilisha* (Raj, 1939),

Indigenous barb and carp varieties like *Puntius dubius*, *Cirrhinus cirrhosa* (Sreenivasan, 1976) and *Labeokontius* (Sugunan, 1995), as well as many deep pool breeding fishes, decline initially in numbers over the years and now has become almost extinct in the waters. Despite regular seed stocking, an increase in naturally recruiting riverine catfish (*Mystus aor* and *Mystus seenghala*) population had seriously challenged the existence of indigenous carps like *Cirrhinuscirrhosa* in the reservoir over the years (Sugunan, 1995). However, the coexistence of self-repopulating major carps with catfish fishery (form 10-15% of the total fishery) showed a predator-prey balance has been struck between these piscivorous catfishes and transplanted major carps in the reservoir (SankaraSubbaiyan and RamachandraMenon, 1984).

The third indicator, 'Fish production,' assesses the level of exploitation within a specific fishery or the changes in the total catch of a targeted fishery within the reservoir over the past twenty-five years. The Mettur reservoir scored '4,' indicating an increasing fish production rate. The fourth indicator, 'Recruitment variability,' examines the annual fluctuations in the percentage of new fish entering the fishery, known as "recruits." This is measured by analyzing year-to-year landing variations based on the total catch data from the past 20-25 years. Mettur reservoir received a score of '3,' signifying a medium level of recruitment variability. The fish production and catch per fishing unit in the reservoir is given in Table 2. Lastly, the fifth indicator, 'Environmental degradation,' considers the extent of environmental harm resulting from various activities such as industrial pollution, urban sewage discharge, agricultural runoff, and unregulated fishing practices, all of which affect the reservoir's fishery. The Mettur reservoir scored '4,' indicating a high level of environmental degradation in the area. Industrialisation began in Mettur with the setup of Mettur Chemicals and Industrial Corporation (India's first caustic-chlorine factory) above the reservoir in 1936. This event can also be considered as the origin of pollution in the reservoir and its downstream area. Divya (2014) reported that this industry (currently known as ChemplastSanmar Pvt Ltd), along with Mettur Thermal Power Station and Malco Industries (Vedanta Group) have heavily contaminated air, water and land-threatening drinking water installations, consumers of fish and agricultural produce in the area. Ganapati and Alikunhi (1949) were the first to study the impact of factory effluents in downstream of the reservoir and reported that the effluents caused pollution in the deep pools of the river, especially during the dry season. Jeyachandran and Raj (1975) reported bioaccumulation (mercury) in fishes caught from the reservoir. Even in recent times, it is continuing as Ghosh (2008) reported that several industries (dyestuff units, leather tanneries, distilleries, solvent extraction units, plastics, textile mills, cement, aluminium, Dairy and allied products) are located in and around the Cauvery basin which all are capable of releasing highly toxic effluents and pollute the river. He further stated that especially in the case of Mettur Dam, the Mettur Chemicals and Industries Pvt Ltd, which is located in the dam's vicinity discharges mercury and mercaptans, which are bioaccumulated (mercury-2 ppm) into the fishes of the area. Lobo *et.al.* (2016) acknowledged diatom communities (due to its sensitivity) as indicators of environmental conditions, especially water quality and habitat conditions in river systems and streams. Venkatachalapathy and Karthikeyan (2012, 2013a) recorded 60 diatoms of 21 genera from the Cauvery River in parts of Tamil Nadu. In connection to the aforesaid studies, Venkatachalapathy and Karthikeyan (2013b) investigated the extent of pollution in the dam and its immediate downstream area by keeping diatoms as the pollution indicators and revealed that the Cauvery water in Mettur is highly polluted by direct contamination of sewage and other industrial effluents. Similarly, Pazhaniraja *et. al.* (2014) also reported that the Cauvery River is naturally favourable for the discharge of effluent from chemical industries in and around Mettur dam during rainy seasons. He also stated that these effluents have completely polluted the groundwater on the banks of the river Cauvery to an extent that cannot be used for domestic and also for drinking purposes. Kumaresan and Nagarajann (2013) conducted a study on the water quality of river Cauvery at four sampling locations over a distance of 10 Km in the stretch between Hogenakkal to Mettur reservoir with reference to physicochemical characteristics and compared it with water quality standards. Their study revealed that the pollution caused by urban wastes and sewage entering from both the banks of Cauvery upstream has not only affected the reservoir's fish diversity but also made the water unsuitable for drinking purposes as certain water quality parameters are exceeding the prescribed limits set by Central Public Health and Environmental Engineering Organisation (CPHEEO) and Bureau of Indian Standards (BIS). Tamil Nadu Pollution Control Board (TNPCB) investigated water samples near the dam area (Pannavadi) after local fishers found dead fish washed out on the banks and alleged water contamination in the river as the major reason for it (Times of India, 2015). Water quality parameter Nambirajan *et al.* (2015) pH- 6.5 to 8.8 Dissolved Oxygen - 4.2-6.1 ppm.

Table 2: Fish production, yield, and species group wise landings in Mettur reservoir (1961-2015)

Year	Total Fish Catch (tons/year)	Speciesgroup-wise Fish Catch (tons / year)				Unit Fish Catch	
		Indian Major Carps	High-Value non-IMC Fish	Low-Value non-IMC Fish	Tilapia	Yield (kg / ha)	Catch (kg / fishing unit)
TE 1963	388.54	170.91	211.90	5.73	2.88	42	1,295
TE 1966	265.74	68.00	189.32	5.54	2.61	29	795
TE 1969	340.79	110.50	223.08	4.60	10.10	36	917
TE 1972	247.83	30.09	189.83	17.82	8.90	27	760
TE 1975	384.00	178.17	181.23	15.70	19.86	41	1665
TE 1978	424.00	77.55	290.56	36.04	15.48	46	2150
TE 1981	516.05	139.33	330.27	30.96	13.81	55	948
TE 1984	376.90	112.61	224.82	25.66	11.99	40	603
TE 1987	280.45	91.19	156.09	21.17	7.63	30	413
TE 1990	153.10	55.32	76.67	13.48	8.19	16	207
TE 1993	153.67	58.26	72.75	14.47	17.38	17	189
TE 1996	244.60	61.52	139.87	25.84	18.48	26	293
TE 1999	272.06	82.35	135.98	35.25	6.43	29	324
TE 2002	220.64	122.78	78.71	12.72	8.19	24	293
TE 2005	210.23	92.59	94.05	15.41	16.26	22	250
TE 2008	305.25	115.73	144.52	28.74	12.79	33	212
TE 2011	240.13	91.04	113.69	22.61	13.05	26	193
TE 2014	245.03	92.89	116.01	23.07	9.50	26	182
TE 2015	178.36	67.62	84.44	16.80	2.88	19	157

Note:

(a) Data Source: TNFFWD records namely General Information Register (GIR), master register and monthly report termed as periodical (PDL) of the reservoir

(b) Non-IMC high value= Eels, pearl spot, *Pangasiussp*, common carp, mirror carp, silver carp, fringed lipped carp, Calbasu and other *Labeosp, Cirrhinasp*, murrel, eel, mullet, freshwater shark, *Mystussp*, Notopterussp,; Non-IMC-Low value= *Puntius/Barbussp, Siloniasp, Glassogobiussp*, other catfishes, miscellaneous fishes.

(c) Fish production data source: 1961-65= Rani Palanisamy (2015); 1966-77= Sreenivasan (1976);1978-81= Sreenivasan (1998); 1982-2015= Mettur fishermen co-operative society

(d) Species-wise breakup data source: 1978-2015 = % average of each fisheries from Sreenivasan (1976) and Rani Palanisamy (2010)

(e) 1 Fishing Unit consists of 2 fishers fishing in a traditional fishing craft - 'parisal' (coracle)

Economic evaluation field:

In the economic evaluation of Mettur reservoir fisheries management, Craft and gear ownership, Catch per fisher, Price of fish, Benefit-sharing, and Subsidy are the five indicators used. The first indicator, 'Craft and gear ownership,' it assesses the extent of ownership of fishing gear and tools among actively engaged fishers in the reservoir. In the case of the Mettur reservoir, it scored '4,' indicating that nearly everyone (about 95%) owns their own craft and gear. Moving on to the second indicator, 'Catch per fisher,' it quantifies the average amount of fish captured by fishers (fishing units) at a specific time and how it has altered over the past 25 years (Kg/unit/year) in a particular reservoir. A fishing unit consists of 20 nets, 50m length each, employing a coracle as the craft (Ranganathan and Venkataswamy (1967), whereas in terms of persons, a fishing unit means two persons, a person who has the fishing license (default member of

the society) and any of his/her family member who function as a helper to license holder in fishing. The help usually is done in terms of rowing the craft, and releasing and hauling the fishing gear. Thus, at least 2400 people are directly as well as legally involved in reservoir fishing. The Mettur reservoir scored '4,' suggesting an increasing trend in per capita fish catch as it is more or less connected with the 'fish production' indicator in the ecological evaluation field. The third indicator, 'Price of fish,' focuses on the individual price at which fish is sold by fishermen or lessees at the initial point of sale. It evaluates changes over the past two decades (1995-2015) and the proximity of this price to the market price (the price at the final point of sale). The Mettur reservoir received a score of '4,' indicating significant fluctuations in fish prices between 1995 and 2015. Table 4 shows the different groups of fishes landed from the reservoir and their difference in minimum price/kg over the years. The fourth indicator, 'Benefit-sharing,' examines alterations in the income or earnings of fishing units over the past two decades (1995-2015). It also includes an evaluation of the fairness of the established benefit-sharing arrangement between the fishing rights holder and the fishers, as well as its practical implementation at the field level. In the case of the Mettur reservoir, it scored '3,' suggesting that there has been little to no change in the benefit-sharing system observed. On average, a fisher could catch 1260 kg of fish per annum, earning an income of Rs.14706 (per kg price of Rs.11.60).

Table 4: Group of fishes and their difference in minimum price/kg

Type of nets	Origin	Features	Mesh size (in mm)	Current specifications
Rangoon nets	This entangling gear was brought from the Godavari Delta fishers (who obtained the concept of gear from Burma) by the State TNFFWD and introduced it for fishing experiments in deep waters of the reservoir.	Length of 50 metres and a hung depth of 3.9 metres.	50	100 metres in length with 100 mm mesh size
Thoppavalai	Rangoon nets exclusively used for Catla		100-130	500 metre in length with 200-210 mm mesh size targeting IMC
Kendavalai	Modified version of Rangoon net targeting *Cirrhinus cirrhosa*		40	
Uduvalai	Entangling gear with reduced fishing height and usually operated in shallow marginal areas for small varieties of fish.	Length of 40 metres and a hung depth of 2 metres (6 meshes of 35 mm)	35	100 metres in length with 75-80 mm mesh size (if it is 50 m long with 30-35 mm mesh size, its known as Sidavalai/Kunjuvalai) and usually of 2 metres (25 mesh) hung depth targeting small barb varieties (10-15 gms in weight) which are used as baits in hooks
Sarattuvalai (seine)/Veechuvalai (cast net)			100 metre in length 80 mm size targeting IMC varieties	
Hooks		Peak season of Wallago is June and July		500 in number targeting unstocked fishes mainly Wallago and catfishes

Winter prices are higher (Rs.34/kg) than summer prices (Rs.27/kg) for both the grades due to low demand in summer. There is only one marketing channel, viz, Fisherman- Cooperative Society- Fisheries Department- Commission agent- Retailer- Consumer. Lastly, the fifth indicator, 'Subsidy,' assesses whether subsidies, including those not openly declared, effectively support the fishery and the fishermen. The Mettur reservoir scored '4,' indicating a substantial number of subsidies available to the fishing community. Once in four years under the NADP scheme, active fishers (cooperative society members) are provided 50% subsidy (maximum purchase limit is Rs.15, 000) for buying fishing nets. The society members were also found to be benefitted under NFDB schemes for inland fisheries development especially mobile inland fish marketing. Under these schemes, the society members paid Rs.5627 to the TAFCOFED to ensure the 25% subsidy (Rs.8700) from NFDB to own a Moped (usually TVS Excel super) with an ice box. In addition to it, the society also has purchased a modified Bolero with the help of a 40% subsidy from NFDB, which is now used to bring fish from the landing centres to the society's fish sales centre.

Social evaluation field:

In the social evaluation of Mettur reservoir fisheries management, five crucial indicators were utilized: Fishers population, Local environmental knowledge, Education system, Housing and civic amenities, and social cohesion and conflicts. The first indicator, 'Fishers population,' it pertains to the total count of active fishers in proportion to the size of the resource area accessible for their livelihood. This indicator reflects the level of fishing pressure within the selected reservoir. The Mettur reservoir scored '0,' indicating that it is overpopulated, with a high density of active fishers. Moving on to the second indicator, 'Local environmental knowledge,' it evaluates how well fishermen in the Mettur reservoir understand the local fishery resources, the ecosystem, weather patterns, and fishing equipment, including boats and gear. It received a score of '3,' suggesting a good level of local environmental knowledge among fishers. Mettur reservoir's vast shoreline borders Dharmapuri district in the North and Salem district in the South. A total of 40 villages from both these districts are located near to the reservoir. Despite agriculture being the predominant primary occupation in the villages/habitations located near the reservoir, it is roughly estimated that around 5000 people from the aforesaid locales depend on the reservoir for their livelihood. Among the fishing-dependent habitations, Keeraikaranur in the Koonandiyur village has the maximum number (300) of fishers. Apart from the regular fishers, there are also occasional fishers (1000) who fish only when they need money or target certain fishery and fish only during its peak season. The remaining people (1000) are involved in various facets of fish marketing, starting from bulk purchases to retail selling. Fishers of Kullaveerampatti in the Kaveripuram village are considered to be the only one who strictly adheres to the moral policy of non-destructive fishing in the reservoir. This morality towards fishing can be attributed to their tradition, as the majority of the fishers in the village belong to the traditional fishing community named Sembadavar. Apart from this village, Sembadvars are predominantly seen in Madhaiyan Kuttai habitation of Navapatti. Currently, Sembadavars are the second (23%) largest community involved in the reservoir fishing falling only next to the Hindu Vanniyars. In general, Hindu Vanniyars are the most dominant and largest community in the reservoir area, even majority (70%) of the fishers of the reservoir too belong to this community, and the rest of the fishers are Christians (5%) and Scheduled Castes (2%) mainly comprising of Paraiyar and Chakkiliyar (arundhathiyar). The third indicator, 'Education system,' involves assessing the educational and literacy rate among fishers within the reservoir. This is determined by the total number of years of formal schooling completed. In the case of the Mettur reservoir, it scored '2,' indicating that approximately half of the fishers have completed 6-8 years of schooling, reflecting a middle-level education status.

The fourth indicator, 'Housing and civic amenities,' evaluates the living conditions of fishers residing near the reservoir. It combines housing type with access to sanitation facilities, clean drinking water, electricity, and cooking fuel. The Mettur reservoir scored '2,' signifying average housing and civic amenities for the fishing community. Finally, the fifth indicator, 'Social cohesion and conflicts,' examines the working patterns of fishermen, whether they operate as individuals, within family structures, or as part of community collectives. It also investigates how these modes of operation may lead to conflicts, such as those between licensed fishermen and poachers. Additionally, it assesses the existence of divisions within fishing communities based on political affiliations, caste, or occupation. The Mettur reservoir scored '1,' indicating less social cohesion and a notable presence of conflicts within the fishing community. Mettur fishers face many problems/constraints in relation to their fishing and fish marketing activities, as reported by Ramya (2014), Josephine (2015) and Angela *et al.* (2015), largely relating to illegal fishing /poaching in the reservoir. One who fishes in the reservoir without TNFFWD granted licence is said to be involved in illegal fishing in the reservoir.

In connection to the illegal fishing and as a measure to check it, the State Government allowed (G.O. No. 132 dated 09.08.2005) the Director of Fisheries to increase the number of fishing licences from 1300 to 2000 in the year 2005. Even after increasing the number of fishing licences, it was found that every year only an average of 66% of the licence was renewed, and the non-renewal was predicted to make a considerable amount of revenue loss to the State Government.

The reason for non-renewal is

(a) Licensee (fishers) becoming old/health problems

(b) Lack of subsidy/financial power to carry on fishing activity

(c) After the death of a licensee, his/her next generation doesn't like to indulge in fishing activity (or) sometimes they feel like they don't want anybody's permission to exploit their nature gifted resource

(d) Licensee feel department is not so effective in controlling poaching in the reservoir. So, they don't feel there is no difference between a licensee and a non-licensee

In connection to the above, in the year 2014, the Joint Director of Fisheries (Regional- Dharmapuri) requested the Government not to increase the number of licences from 2000 to 2500, as it will not bring any changes in the existing problems. Several local and National newspapers have already reported the illegal fishing and its negative impact on the livelihood of the licenced fishers of the reservoir. The lack of adequate TNFFWD staff is seriously questioning the capability of the department's role in stopping illegal fishing in the reservoir. This condition has prevailed for many years, which is reflected in the increase in number of illegal fishers in the reservoir. Mosquito nets 250 feet in length and 50 feet in height are being used in the reservoir by illegal fishers. Many times, licenced fishers chase these illegal fishers and burn their highly destructive fishing nets. Even they cite some incidents in which the captured illegal fishers escaped later due to caste-based political intervention. Licenced fishers allege that the inactiveness of TNFFWD officials in controlling the illegal fishers makes such illegal fishing a cakewalk to anyone. On the other side, TNFFWD officials allege that such illegal, destructive fishing happens with prior knowledge and aid of the licenced fishers (if not all, at least to considerable numbers), and they (licenced fishers) criticise TNFFWD as irresponsible only for the sake of criticising. Moreover, anybody in the reservoir area can easily identify unlicensed fishers' coracles in the water as it will not have the licence number painted over it, and even then no one bothers about it. Despite this, they rarely report it to the department out of unknown personal reasons and project it as occupational competitiveness. Local newspapers (The Hindu, 2023) have also reported bomb fishing (using hand grenades) in the Palar River catchment area of the dam.

Technology evaluation field:

Fishing craft, Fishing gear, Handling and processing, On-board safety devices, and Infrastructure are the five indicators used in the technology evaluation field. The first indicator, 'Fishing craft,' it assesses whether fishermen in the Mettur reservoir have made any modifications to their fishing craft over the last 25 years, aiming to improve fishing efficiency and safety. Additionally, it considers changes in the fishing capacity, specifically the number of fishing units, during the same period. The Mettur reservoir received a score of '3,' indicating that fishermen have made significant alterations to their fishing craft, resulting in a 50% increase in catching power and safety over the past 25 years. Coracle is the major and only fishing craft used in the reservoir. Initially, these country crafts are made of split bamboo mats covered with buffalo hide, but due to its lack of durability, the animal hide was replaced with plastic sheets coated with tar. Despite such periodic upgrades, over time, it has been realised that due to heavy wind action in the rocky catchment area of the reservoir, these coracles lose their fishing efficiency within 2 months and require periodical repair, maintenance and replacement of broken bamboo sticks, polythene sheet patchwork, and additional tar coating. Nowadays, even the cost of indigenous coracle is also high due to the non-availability of bamboo trees in the forest. To overcome the situation, Fibre-reinforced plastic (FRP) coracle (comparatively highly durable) has been recommended by the TNFFWD for fishing in the reservoir. At present, almost all the licensed fishers of the reservoir have switched over to FRP coracles. In addition to the fact of being a boost to uplift the socio-economic status of the poor fisher folk, the FRP coracles even proved much more beneficial by providing a platform for the TNFFWD to mark (with paint) the licensed fishing unit's coracles with their respective license numbers as a front step to check illegal fishing in the reservoir. It also shows that comparatively disadvantageous indigenous coracles are used either by regular illegal fishers or occasional fishers.

Moving on to the second indicator, 'Fishing gear,' it examines whether fishers have adapted their fishing equipment within the last 25 years to enhance their ability to catch fish more efficiently or selectively. This assessment also differentiates between gear types as active/passive and categorizes them as primitive/modern/specialized. In the case of the Mettur reservoir, it scored '4,' suggesting that fishermen have made substantial changes to their fishing gear, significantly improving catching power and safety over the past 25 years. In the case of fishing gear used in the reservoir, Raj (1941) stated that the newly formed reservoir urged the TNFFWD to introduce and demonstrate deep-water fishing equipment to the fishers who were initially fishing in the shallow river region. Like all the other reservoirs in the State, the gill net is the most commonly used fishing gear in the reservoir. Fishers of Mettur reservoir are considered the pioneers of gill nets (widely used gear in reservoirs all over India) as these nets were the outcome of their trial-and-error methods (Sugunan, 1995). Over the years, they modified these nets according to the targeted fishery and named them accordingly. The vernacular names of different types of nets used in the reservoir are Rangoon valai, Thoppavalai, Uduvalai, Uduvalai, Kunjuvalai,

Sarattuvalai and Thoondi. The TNFFWD records state that the licenced fishers in the reservoir use only a gill net (Kannivalai) of mesh size of above 80 mm. The specific features of each of these nets are discussed by Kuriyan (1973), which are listed in Table 3, along with the current-day specifications of the gear. This comparison is an attempt to know how the fishing gear has evolved in the past three to four decades in the reservoir. Many of these nets are just a modified form of gill nets varying in their "aayam" (vernacular name of mesh) sizes. The mesh size of a net largely depends on the targeted fishery, which again attributes to the particular fishery's peak season. Rangoon nets are used throughout the year, whereas Thoppavalai are used mainly during the entry of new water (due to southwest monsoon rainfall in the catchment area) in the months of June-July, as it is considered as the peak season of the major carp fishery in the reservoir. Nets like Uduvalai, Sidavalai and Kunjuvalai are carried along with the hooks, as these nets are mainly used for catching small fishes which are used as baits in the hooks. However, TNFFWD has instructed fishers not to use these (bait fishes targeting) smaller mesh size nets during the period of fish seed stocking and ensure its non-usage at least for the following three months. Depending on the fishery season, fishers carry 5- 15 kg nets. The cost of a net depends on the quality of the material it is made up of. Generally, the net is made up of nylon monofilament.

Table 3: Types of fishing gears (nets) used in Mettur reservoir

The third indicator, 'Handling and processing,' evaluates whether fishermen utilize specific handling methods while on board their vessels to preserve fish or conduct pre-sale processing activities such as sorting, grading, gutting, and filleting. The Mettur reservoir scored '4,' indicating that fishermen consistently use handling methods, particularly icing after fishing, as well as other preservation and processing techniques. The fourth indicator, 'On-board safety devices,' assesses whether fishermen employ safety devices and additional equipment while on their vessels, such as mobile phones and life jackets. In the case of the Mettur reservoir, it received a score of '4,' implying reliance on onboard safety devices among fishermen. Lastly, the fifth indicator, 'Infrastructure,' examines the presence of centralized or minimal landing sites in the area. These sites should have concrete structures or halls with facilities for tasks like washing, icing, and loading/transportation. The Mettur reservoir scored '2,' indicating the presence of infrastructure with centralized facilities in the region.

Governance evaluation field:

Access and use, Stakeholder participation, Development programmes, Institutional capacity and processes, and Research and development (R&D) support are the five indicators used in the governance evaluation field. The first indicator, 'Access and use' (AAU), it assesses the existence of a comprehensive and functional leasing and licensing policy and regulatory framework. This framework aims to support the sustainable growth of fisheries and the well-being of fishermen within reservoirs. In the case of the Mettur reservoir, it received a score of '2,' suggesting a predominant focus on welfare-oriented policies. Sreenivasan (1998) reported that the relaxation of the "limited entry" policy (a policy to regulate the number of fishing units in the reservoir through the issue of fishing licences to them) in the year 1959 increased the fishing units, i.e., from 244 (1958) to 1000 (1992). There are fifteen conditions over which the TNFFWD issues fishing licences to fishers of the reservoir. The fishing licence is issued under the provisions of the Indian Fisheries Act, 1897 (Act IV of 1897) and the Indian Fisheries (Madras) Amended Act, 1927 (Madras Act II of 1927) and the rules framed there under to control and regulate fishing in the waters specified below and subject to the conditions prescribed there under

(a) Mettur Dam

(b) The Cauvery River above the Mettur reservoir from Alambadi upto Salem-Coimbatore-tri-junction in the North

(c) The Cauvery River below the Mettur reservoir from Nattamangalam to Perumpallam in Tiruchengode taluk in the South

(d) The Cauvery River from its junction with the supply channel Mettur to its continuance with the surplus channel at Nattamangalam

Initially a sum of Rs.120/annum collected as licence fee to use coracle and nets to fish in the reservoir. Apart from this, royalty for the quantity of fish catches is also collected from the fishers. The licence fees have been enhanced to Rs.750/annum with effect from April 1997 onwards, and the collection of royalty has been discontinued. Until the year 2015, Rs.1250 was collected for a single fishing licence. Moving on to the second indicator, 'Stakeholder participation,' it examines the extent to which key stakeholders, primarily fishermen, actively engage in the planning process and adopt resource management measures, including regulations related to access and utilization. It also considers the level of illegal, unreported, and unregulated (IUU) fishing as a proportion of the total catch. Mettur reservoir scored '2,' indicating that only half (50%) of stakeholders are willing to participate actively. Though a licence for fishing in the reservoir was expected to be an effective conservancy measure, the Assistant Director of Fisheries (ADF) of Mettur Dam reported the occurrence of a huge number (around 3000) of fishing without a licence (illegal) in the reservoir. Even though only the society members (2016) are eligible for fishing licences, around 3000 people fish in the reservoir. This shows illegal fishers (1700) are more than legal fishers (1300). As discussed earlier and alleged by TNFFWD officials, the licensed fishers rarely bother or complain about the

illegal fishers, as they are either their relatives or near and dear to them. The State TNFFWD has given the fishing rights of the reservoir on lease to the K.K.98 Mettur Dam Fishermen Co-operative Marketing Society Limited, Mettur Dam. Every year sealed tenders are invited by the Special Officer/President of the Society from Bonafede fish merchants with sound financial standing in the format prescribed by the society for purchasing fish caught in Mettur reservoir and procured by the society. The successful tenderer will be authorised to purchase the quantity and kinds of fish of all sizes of the group from the society. The society makes sure that the rates offered by the tenderer are not less than that of the price referred against each group of fish.

The third indicator, 'Development programmes'(DRP), assesses the presence and successful execution of fisheries development initiatives. These include stock enhancement programs, the operation of fish hatcheries and seed farms, and cage/pen culture practices. The Mettur reservoir received a score of '3,' suggesting a good level of development programs.

The fourth indicator, 'Institutional capacity and processes (ICP),' evaluates the general capability and efficiency of the Fisheries Department and institutional structures in ensuring good governance. It takes into account factors such as the availability of human resources, transparency, fairness in implementation, collaboration with relevant agencies, the operational status of fishermen's cooperatives, and conflict resolution measures, among others. The Mettur reservoir scored '4,' indicating a very good level of institutional capacity and processes. Sensing the potential of fisheries as well as an effort to equate the fishery loss, the British Government, in addition to the conservancy measures, started to concentrate on fisheries development in the reservoir waters by stocking major carps since 1922 (Mammen *et al.,* 1962).The State TNFFWD transplanted Catla in 1928, followed by other major carp (Rohu, Mrigal, Calbasu) from 1948 onwards in the reservoir. Tamil Nadu Fisheries and Fisherman Welfare Department (TNFFWD) transplanted Catla in 1928, followed by other major carps (Rohu, Mrigal, Calbasu) from 1948 onwards in the reservoir (Sreenivasan, 1988). Though the Government sanctioned a fish farm with hatchery and technical staff to maintain the farm in 1936, hatchery establishment on the farm took place only in 1960. After the establishment of necessary hatchery facilities, the farm, which was earlier functioning as a rearing centre, was upgraded as a breeding centre of major carp. Immediate fishery conservancy measures after dam formation were the formation of fish sanctuaries and the complete prohibition of fishing in the reservoir. Region (up to four miles) immediately below the famous Hogenkkal Falls and outlet channels, especially Ellis's surplus, were selected as fish sanctuaries. The above conservancy measures, coupled with the optimum food fish (major carps) seed stocking, have improved the fishery condition of the reservoir. Hence, after a five-year (1934-39) hiatus, fishing in the reservoir resumed fishing in the reservoir targeting the stocked variety, Catla (Raj, 1941). Another important and interesting factor is that, even in large reservoirs like Mettur where natural breeding of major carps takes place, regular seed stocking is required to ensure fish catch in the reservoir. The TNFFWD decides the number of fish seeds to be stocked on the basis of the average water spread area (which is usually 50% of the full storage level) of the reservoir due to heavy water level fluctuations caused by the frequent release of water for irrigation in most of the reservoirs of the State. Keeping this in view, the stocking norm adopted by the department in the reservoir was 500 standard fingerlings per ha (SankaraSubbaiyan and Ramachandra, 1984). According to Sreenivasan (1984), 10,000 Catla seeds stocked got established in the reservoir that sustained a capture fishery for many years.

Fisheries in the reservoir has seen its up and down; fish landing records show that during certain years the landings were more than a ton/day, and in some years very less catch. Less catch is attributed to continuous drought conditions in the reservoir area and the discharge of maximum water from the reservoir for agricultural purposes. Hence, to avoid certain uncertainties, the department is mainly involved in the intensive fish seed stocking and conservancy measures in the reservoir. Mettur Fish Farm was started by TNFFWD in 1936 with six breeder ponds. These ponds were utilised for the rearing of Catla, Common carp and Gourami seeds and stocked the same in the reservoir. As the years passed by, the farm improved its activities. In 1960, the farm successfully turned itself into an induced carp spawning centre by achieving induced breeding of major carp in its ponds. In 1960, TNFFWD started an ice plant (5-ton capacity) to ensure fish quality for marketing (Sugunan, 1995). In 1981, a jar hatchery unit was introduced in the centre, and a high production of 177 lakhs of early fry was attained. This unit helped in achieving the target seed production set by the department and the seeds produced were stocked in the reservoir and other reservoirs under the control of TNFFWD. Natural breeding of Catla, Rohu and Mrigal in the reservoir is observed in the upper reaches of Hogenakkal area, which is being carefully protected and conserved by the department. Apart from seed production, TNFFWD collects naturally available fish seeds from three collection centres viz. Mettur dam, Cauvery cross and Jedarpalayam areas and stocked (5 cm size) in the reservoir. The Mettur Reservoir fishery is well protected by stocking fish seeds produced at the farm. At present, the centre is functioning as a fish seed farm and research station with a total farm area of 15.84 acres which includes rearing (7178 m^2 and brood stock (20300 m^2) area. Under the National Fisheries

Development Board (NFDB) reservoir fisheries management scheme, more than 50 lakhs of quality advanced fingerlings of IMC have been stocked during the years 2008-09 and 2009-10 in the reservoir and now are being reflected in the daily catches from the reservoir.

Finally, the fifth indicator, 'Research and development (R&D) support (RDS),' examines the scope and quality of research-derived information used for the sustainable management of resources. It also considers the extent to which planning relies on concrete evidence, including the accessibility of dependable fisheries data. In the Mettur reservoir, it scored '2,' implying an average level of R&D support.

Conclusion

r-RAPFISH has proven its efficiency as an interdisciplinary fishery sustainability tool. The present study reassures it by showing significant differences in showing the sustainability status of the water body under each evaluation field. The ecological evaluation of fisheries management in the Mettur reservoir, showcased its high productivity, diverse species composition, increasing fish production, moderate recruitment variability, and significant environmental degradation challenges. The economic evaluation of fisheries management in the Mettur reservoir, highlighted high ownership of craft and gear, an increasing trend in per capita fish catch, price fluctuations, stable benefit sharing, and significant subsidy support. The social aspects of fisheries management in the Mettur reservoir, indicated overpopulation, good local environmental knowledge, a middle-level education system, average housing and civic amenities, and a relatively lower level of social cohesion with conflicts prevalent among the fishing community. The technological evaluation showed improvements in fishing craft, gear, handling methods, safety equipment, and the presence of specific infrastructure for fishing activities. The governance evaluation of fisheries management in the Mettur reservoir, highlighted the areas of focus on welfare-oriented policies, stakeholder participation, development programs, institutional capacity and processes, and the need for improved research and development support., r-RAPFISH analysis revealed that overall sustainability (Figure 2) of Mettur reservoir fisheries is in "Quite" status (Sustainability score – 74.51%) which is obtained by taking average of sustainability value obtained by the reservoir in each of the five dimensions [Ecology - 83.86%; Economic-90.40%; Social - 44.93%; Technology - 85.59%; Governance - 67.76%]. It has also been observed that the social and governance aspects of the fisheries management in Mettur reservoir have to be improved to get an overall 'good' sustainable development status.

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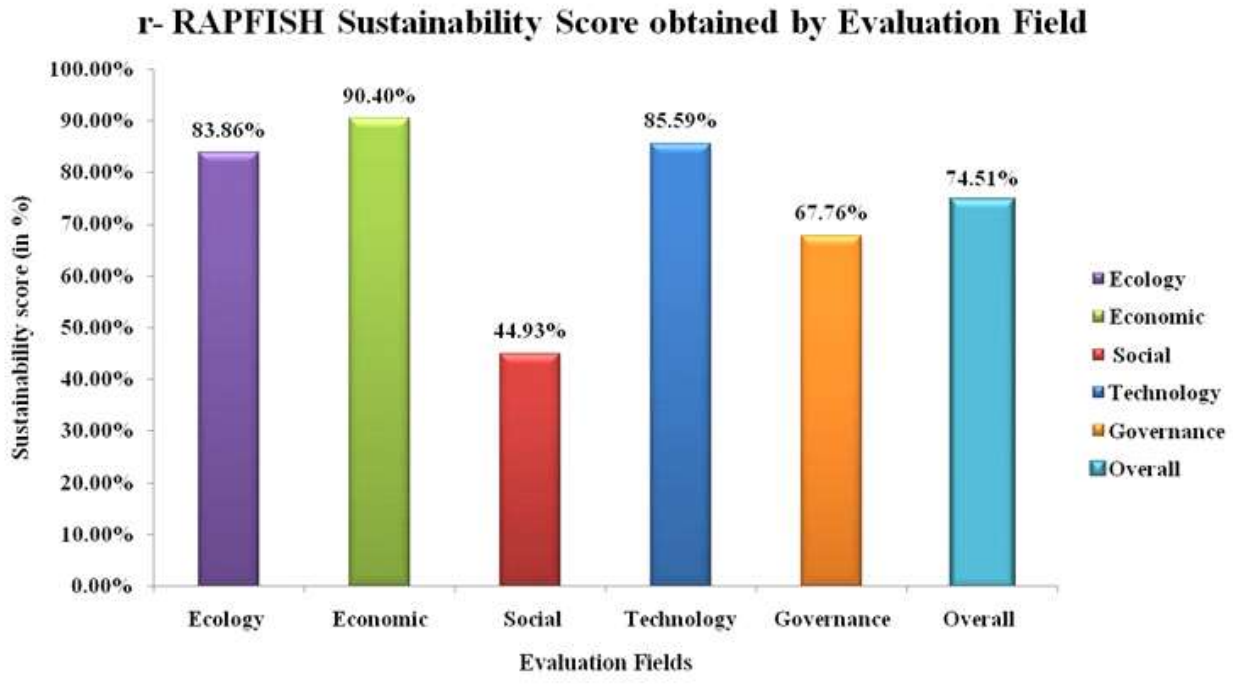

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