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Carbon emissions in Indian marine fisheries sector: Cradle to Grave Analysis

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ABSTRACT
Climate change impacts the oceans globally, its resources, resource users and environment; since 1960 there has been a paradigm shift in Indian marine fisheries from subsistence to mechanisation and consequent commercialisation. Though yielding high landings, the shift catapulted consumption of soaring levels of fossil-fuel and resultant carbon emissions. The study employed the "Cradle to Grave" approach in assessing emissions between fishing sectors across the value chain. The results indicate highest

emissions from mechanized sector, however minimal when compared with developed countries. The study suggests incentive based approaches for minimal carbon emissions in fishing leading to a blue carbon economy.

Key Words: Marine Fisheries, Climate change, Emissions, Carbon Budgeting, Incentives

1. INDIAN MARINE FISHERIES- A STATUS OVERVIEW

The Indian subcontinent has one of the longest coastlines of 8129 km, of the many services that the oceans provide to this country; the marine fisheries sector is one of the most vital in terms of food security as well as economy. The Indian marine fisheries sector is one of the fastest growing food sectors in the world, with an average landing of 3.58 million tonnes, with a gross value at landing centre of US$ 5.29 billion and a retail centre value of US$ 8.73 billion. Bringing in export earnings of US$ 5.5 billion, the sector contributes to 0.8% of country's GDP and 5.4% in agricultural GDP share.

The marine fisheries sector is grappling with numerous constraints like over- exploitation of fishery resources, targeted fishing, juvenile fish capture, lack of enforceable property rights regime, degradation of habitats and open access to the fishery. In addition to the existing problems, Climate change also exacerbates the status of fisheries with reduced landings and distributional and range shifts of fish species[1, 2, 3].

Climate change is not just impacting the resources, but also the resource users. Proven research reveals that climate change is modifying the distribution and productivity of marine and freshwater species and is impacting the sustainability of fisheries and aquaculture, eventually having a profound effect on the livelihoods of the communities that depend on fisheries [4]. The effect of sea level change reveals that the coastal fishing communities are vulnerable and are in the front line of the detrimental effects of sea level rise.

Marine fisheries profile of India

Marine fisheries sector in India provides livelihood to around three and a half million fisher folk, across 3288 fishing villages. Nearly 37.8 percentage of the marine fisher folk are engaged in active fishing with 83.4 per cent of them engaged in full time fishing. The marine fisheries sector has 1,94,490 crafts, of which 26 percentage of the crafts are non-motorised, 36.7 percentage motorised and 37.3 percentage mechanised. The current values project disparity in the contribution in terms of landings to dependent population. The mechanised sector contributes the maximum in terms of landings, thereby monopolising the scenario, leading to a wide divergence between number of people involved in fishing and the catch.

Table 1 Fishery profile of India

Sector	No. of people involved (Million)	Landings (Lakh Tons)	Catch/Craft (Tons)	Catch/ Fishermen (Tons)
Mechanised	0.58	26.79	36.93	4.62
Motorised	1.43	8.38	11.74	1.17
Non-Motorised	0.25	0.75	1.48	0.30

Though regulatory measures for livelihood sustenance of non-mechanised sector is present, such as closed fishing ban for mechanised sector, there still exists significant income disparity among the sectors.

Two ways of approach is possible to achieve this desirable situation,

(i) Develop adaptation and mitigation measures.

(ii) Enforce policies in the sector of fisheries, so that carbon emission is controlled, as carbon emission is considered a direct driver for climate change.

Fishing activities are a source of GHG emission. Fishing is considered the most energy intensive food production method in the world. Use of large amounts of fuel in activities such as catching fish, on-board processing, refrigeration and freezing of fishes results in considerable emissions of GHGs. The studies also revealed that the maximum energy requirement and highest CO_2 emission (90.2%) occurred in the harvest phase [5]

The objectives of the study includes identification of different constituent operations across the value chain, estimation of carbon emissions across the value chain and assessing carbon emission across sector and to suggest policy measures by which emission reduction can be carried out, such as highlighting carbon emission as a major driver in fish trade for the future.

2. DATA & METHODOLOGY

The data employed in the study was obtained from selected primary sources and secondary sources. Sufficient check was done on secondary data through ground testing validation. Data mining was carried out for arriving at standardised emission factors. Case study approach was employed involving key informants to estimate the harvest operations such as fuel and ice requirement, apart from which survey schedules were used. Focus group discussions were held in selected coastal villages of Southern India to understand the changing scenario of fisheries sector in terms of mechanised and non-mechanised vessels. In places of missing data, realistic proxies were computed. The primary data was collected during the period between June 2014 and May 2015.

3. RESULTS AND DISCUSSION

The results and discussions are presented objective wise

(I) Identification of different constituent operations across value chain

In general, while considering "fishing", the harvesting of fish resources is the only process taken into account. In order to get a holistic picture, the entire process of the operation has to be considered. Majorly there are four vital operations across the marine fisheries value chain; they are pre-harvest, harvest, and post-harvest and utilisation- consumption.

Pre-harvest

The pre-harvest operations include all operations/ process leading to the manufacture of fishing crafts and gears. In Indian context, there are a range of crafts and gears, based on the need, such as duration of operation, depth of fishing, the fishing ground and targeted resources.

In the mechanised sector, the major crafts include Trawlers, Gillnetters, Purse seiners, Dol-netters, Ring seiners and liners. The major constituents used in manufacturing such crafts are wood, steel, aluminium, nylon and paints. These crafts usually range from 10 m to 20 m in length and are made of wood, with a life of 20 to 30 years (with annual maintenance after five years).

The major crafts in the motorised sector, which mostly include outboard engine are catamaran, dugout canoe, plank built boat, plywood boat, fibre glass boat, ferro cement boat, carrier boat and theppas. These crafts range between two to fifteen metres and are made up of majorly wood, steel, concrete or glass or mix of two or more constituent materials. These crafts have a life up to ten to fifteen years, with annual maintenance after five years.

The traditional sector constitutes crafts such as catamaran, dugout canoe, plank built boat, ferro-cement boat, thermocol boats, out rigger and masula. Their major raw materials are wood and thermocol. They are sized between five and ten metres. The traditional crafts have a maximum of ten year life.

The major gears used in combination with the above mentioned crafts were taken into account for the study. These include, trawl nets, gillnets, driftnets, ring seines, purse seines, boat seines, bag nets, shore seines, cast nets, troll lines, fixed nets, traps, scoop nets and hooks and line. Most of the nets are made from nylon, with steel or alloy rings (aluminium, titanium, copper, brass). In some cases, such as troll lines, PVC is used. The gears vary extensively in dimensions, ranging from metres to sometimes kilo meters. The gears are chosen based on species targeted and operational complexities.

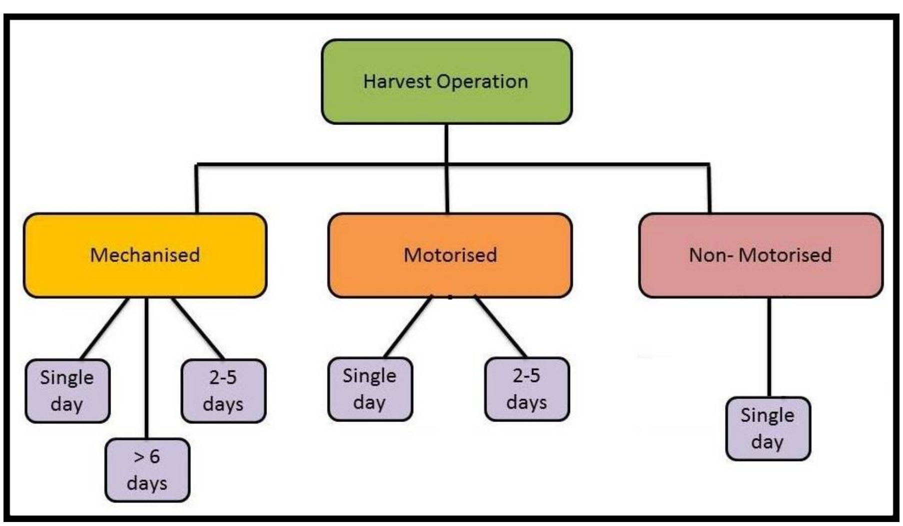
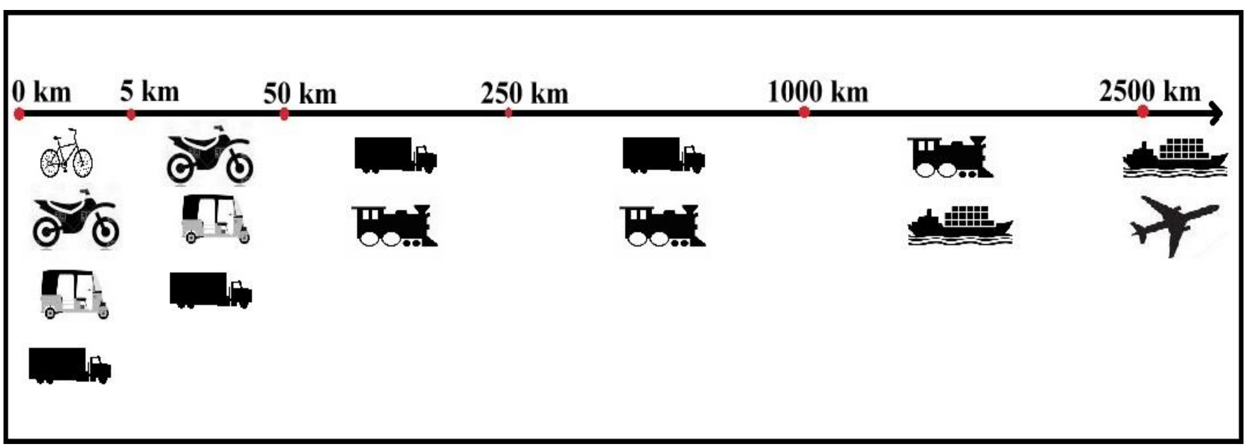


Figure 1 Harvest operation in Indian marine fisheries sector

Harvest

The harvest operation in marine fishery sector refers to the venturing of the crafts into the sea for fishing. The harvest operation is based on sector wise harvesting, where there are mechanised, motorised and non-motorised crafts. These vessels go to the sea as shown in the figure 1and 2 for either a single day, or between two to five days, or more than six days (Voyage). These are recent changes noticed in the sector on account of dwindling catches, decreasing catch per unit effort, high cost of input, and increased fish hold capacity of the vessels.

Figure 2 Traditional fishers after single-day harvest operation during field study at Ernakulam district, Kerala



**Distance not to scale*

Figure 3 Post-harvest and mode of transport

Post-Harvest

Post-harvest operations are very important and include trading as well as the utilisation considering the form, time, place and possession. Since there exist a difference between the production centre and the consumption centre to which the commodity is traded; Fish needs to traverse a sizeable distance and undergo \ grading and sorting in order to reach its users in the right form.

Transportation is a complex and vital process, as the distance between point of first sales and last sales may vary between few kilometres to across continents. On an average, five percent of the total catch goes for export, the rest 95% is for domestic use. As the consumption centres are located far from the production centres, the fish move sufficiently long distances prior to consumption with the usage of inputs like ice which enhances the shelf life.

The major modes of transport are cycles, two wheelers, auto rickshaws, trucks, trains, ships and air craft's. The figure 3 shows the mode of transport in accordance with distance travelled.

Consumption

Consumption indicates using up of the wide variety of fishes, according to the consumer's preferences, after purchasing from the point of last sales. Consumers usually prefer to either eat it in the "Fried" form or "Curry" form, which also contributes to carbon emission as fuel in multiple forms are spent in the process of cooking these products. Based on the type of fish, the fuel and the time required for cooking varies.

(II) Assessing carbon emissions in the value chain across sectors.

Estimation of carbon emission across the value chain is based on the data collected. The four stages identified were analysed individually and the emissions in each stage across the different sectors are computed below.

Pre-harvest

Boat building industry is a highly energy-intensive industry, with most of the energy consumption covered by electricity, the production of which has its own environmental and climate change impacts**.** Shipbuilding is basically a metal industry and depends heavily on the use and forming of steel with respect to the construction of larger ships, whereas smaller ships and boats can be constructed of aluminium, wood or composite materials such as fibreglass. Base materials include iron-containing steel (i.e. carbon steel) and non-iron containing metals. The raw material production yields emissions, majorly that of carbon. In Indian context, wood is used more in comparison to steel.

The carbon emission from manufacturing and assembling the crafts was analysed by taking into account the emission during manufacture of unit mass of the raw material and the dimensions of the vessel.

The carbon emission from the manufacturing of gears was done similar to that of the crafts, by taking the product of average carbon emission per unit mass of the raw material and the dimensions of the gear.

Table 2 Raw materials and average carbon emissions during production

Material	Emission (CO_2 kg/ kg production of material)
Nylon	5.43
Steel	1.8
Aluminium	1.5
Brass	6.7
Poly vinyl carbon (PVC)	1.8
Copper	3
Glass	8.39
Concrete	11.3
Plastic	6
Thermocol	3.46

Wood is the most commonly used raw material in boat building. For the purpose of calculation, Mahogany (*Swietenia macrophylla*) is taken as the material used[6]. The carbon emission from wood is the proxy of the actual amount the tree can sequester in its lifetime. By cutting down plantations for timber, carbon dioxide is released into the atmosphere, which would have otherwise been sequestered. A typical mahogany plantation of one hectare area would accommodate about four hundred trees and can sequester 90.53 tons CO_2/ ha. The sequestration potential was found based on the lifespan of the tree, its growth rate, cropping density and the spacing in plantation apart from the physical parameters such as height and girth.

The weight determination of a tree was done based on volumetric computation and was found to be around seven tons. The entire inventory of different crafts available in the country was drawn and the corresponding raw materials with quantity required were listed. Since most of the crafts in every sector had similar raw materials, the inputs were generalised sector-wise.

For the construction of one mechanised vessel, Steel (0.2 tons), Aluminium (0.2 tons), Nylon (0.25 ton) and plastic (0.1 ton) is required, their corresponding emission factors are 1.8, 1.5, 4.43 and 6. Apart from which wood of 5 ton weight is used all leading to emission of 154.17 ton of CO_2. Similarly to build one motorised vessel glass (0.1 ton), steel (0.15 ton), plastic (0.05 ton), aluminium (0.1 ton) is used with a corresponding emission factor of 8.38, 1.8, 6 and 1.5, while the wood requirement is 0.7 tons, leading to a total carbon emission of tons of 77.46 ton of CO_2. The traditional sector has boats made of varying raw material; the wooden boat has an emission of 75.9 tons of CO_2, while that made of thermocol has an emission value of 3.12 tons of CO_2

The Indian marine fisheries sector employs an array of fishing gears, sometimes used in varied combination with crafts. In some cases the gears used in mechanised and motorised sector are the same, with just a difference in operational capacity. Though previous studies have reported that fishing gear typically makes a smaller contribution to the overall energy profile of a fishery when compared with inputs to craft construction,[7] we have still considered it for the present study to arrive at a detailed picture. Details of the raw materials required in manufacturing the gears were collected by visiting boat building yards and through secondary sources.

Gears in mechanised sector are Trawl net, Gillnet, Driftnet, Ring seine, Purseine, Boat seine, Bagnet, shore seine, hooks and lines and troll nets. The major raw materials include Nylon (0.5 ton), Steel (0.05 ton), Brass (0.05 ton), and PVC (0.05 ton), with corresponding emission factors of 5.43, 1.8, 6.7 and 1.8 respectively. The average emission from gear making in mechanised sector is 3.23 tons CO_2. Similarly the emission due to manufacture of gears in motorised sector and traditional sector was estimated to be 2.69 tons and2.17 tons of CO_2per gear respectively. In order to get a holistic picture across the value chain, the emission in terms of one ton of fish caught were estimated. It was estimated that 0.09 boat of Motorised and 0.03 boat of mechanised is required to catch 1 ton of fish, assuming the average life of boats in both these sectors is twenty years the values were off setted, and the yearly emission in tons of CO_2 was found to be 0.33 and 0.21 respectively.

The traditional sector possesses a diverse nature, owing to the varied nature of raw materials employed in construction of the boats. Primarily boats are either built using wood, ferrocement, thermocol or fibre. By taking an inventory of number of boats in each category, with corresponding quantity of raw material used and emission factors, the emission per sector (i.e. based on raw material) was deduced. The commonly used traditional boats in India are Dugout, catamaran, plank, ferrocement, thermocol, outrigger and Masula. The emission factor for wood was found to be about 30.83 kg CO_2/kg produced. While that of ferrocement, thermocol and fibre were found from secondary sources as 3.39, 3.46 and 6 respectively. Considering the lifetime of the boats in this sector the emission per boat per year was estimated, and the average was found to be 0.09 ton CO_2.

Thus, the emissions in the pre-harvest sector were calculated based on number of boats required to catch one ton of fish, the emission from manufacture of craft and gear as well as the life time of the fishing vessel. Considering the actual number of crafts in Indian marine fisheries sector, 72,545 in mechanised sector, 71378 in motorised sector and 50,567 in traditional sector; the corresponding emissions were calculated and projected in terms of ton CO_2 per ton of fish caught per year (Table 3, Figure 4).

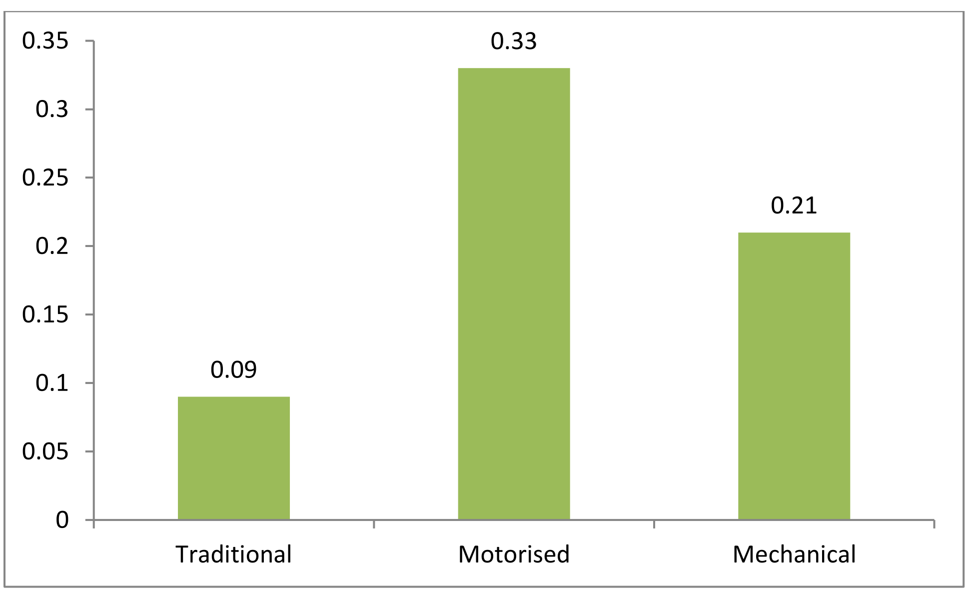


Figure 4 Emissions from per ton per year in the pre-harvest sector

Table 3 Emission in pre harvest

Sector	CO_2 Emission per year per ton of fish caught (tons)
Traditional	0.09
Motorised	0.33
Mechanical	0.21

Harvest

The harvest operation includes two sub-operations, navigation and trolling. Navigation is the process by which the craft moves from the shore to the off shore, while trolling is the process in which the gears are discharged and the catch is loaded. Depending on the method of trolling (manually or mechanically towed) and navigation, the sectors are divided into four types (Figure 5). In order to facilitate these two processes, fuel as well as ice for catch storage is required. The fuel requirement for the harvest process was collected partly using primary data and secondary data. Data of landings over the ten years, i.e.; from 2003 and 2014 was sourced from National Marine Fishery Resources Data Centre (NMFDC) of Central Marine Fisheries Research Institute, Kochi. Questionnaires and focus group discussions were employed to assess the fuel and ice consumption of various crafts and gears during the operation.

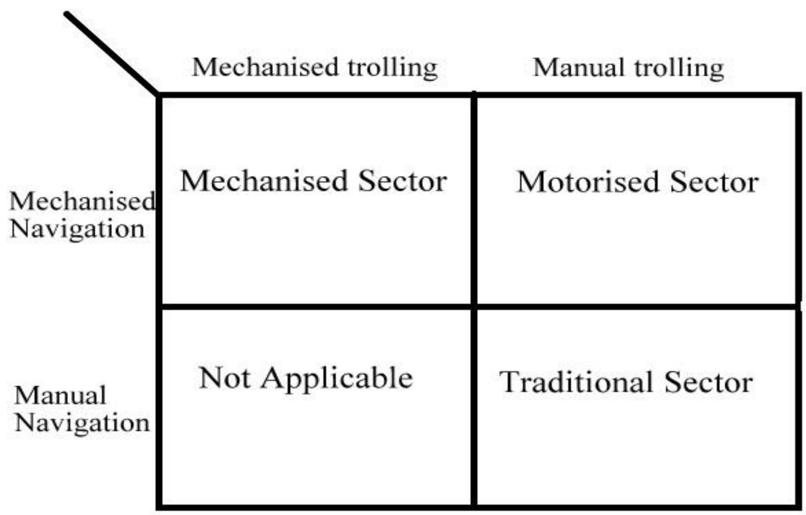


Figure 5 Vessels based on navigation and trolling systems

The fuel consumption pattern for the various sectors was assessed by taking into account the engine horse power, the navigation and trolling speed and the distance travelled. The emission from fuel consumed was found based on the fuel consumed and the carbon emission factor of the fuel; this was cross checked with data collected during field visit. The emissions from ice were tabulated using a proxy, where the units of electricity required for manufacturing unit mass of ice was collected and thereby the emission was found using emissions from unit electricity and mass of ice consumed. Table 4 shows the sector wise emission, the catch per sector [8] and the corresponding emissions. The skewed nature of the emissions based on sector is clearly evident as shown in table 4.

Table 4 Emissions from harvest operations.

Sector	Emission (Ton CO2/ ton)	Percentage contribution (Landings)	Percentage contribution (Emission)
Mechanised	1.43	79.51	85.78
Motorised	1.02	18.55	14.22
Traditional	0	1.93	0.00

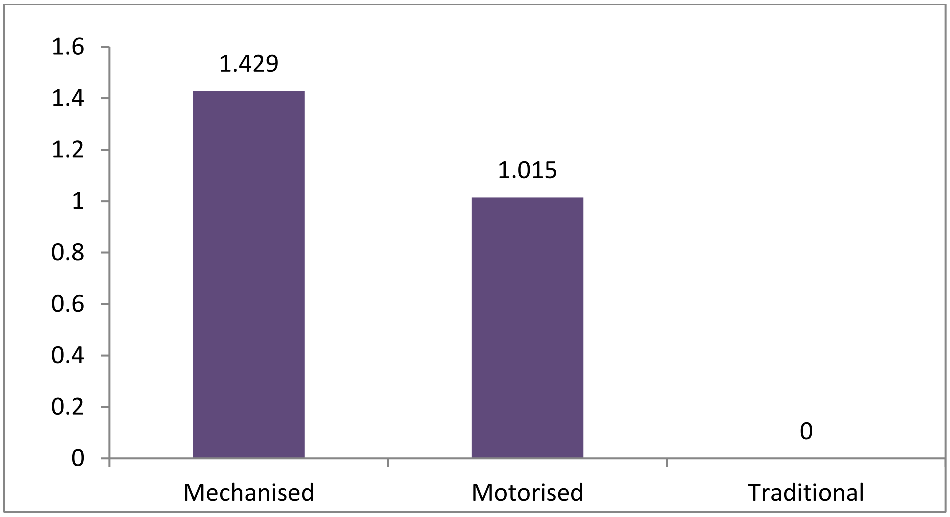


Figure 6 Emissions across sectors per ton of fish caught in harvest operation

Post-Harvest

Post-harvest operations primarily encompass trade of fish from point of first sales to point of last sales. Depending on the distance travelled by the fish, the mode of transport used and the ice required, the emissions were calculated for every ton of fish caught. This study considers distance as one of the critical factors in determining emissions, thus the ice requirements were taken in ratios. The carbon emission from ice used in post-harvest was calculated based on the electricity consumption in producing unit mass of ice. For the purpose of analysis, the emission from post-harvest operations was calculated for one ton of fish caught (Table 5). In order to compute the emission in the process, the fuel used (such as diesel, petrol, aviation fuel), its corresponding emission factors, average mileage, average speed and distance covered were found. Apart from local transport of fish, for the purpose of exports, ships and air craft's have been included[9].

Table 5 Emissions from 1 ton fish traded in post-harvest operation.

Vehicle	Catch (%)	Average distance travel (km)	C emitted (kg)
Cycle	2	2.5	
Bike	4.5	20	1.15
Auto	11.0	50	3.945
Truck	11.5	100	15.78
Truck with cooler	27.0	200	13.15
Train	35.0	500	105.2
Ship	7.0	1000	487037.04
Flight	2.0	2500	384000

Table 6 Emissions during postharvest operations across sectors

Vehicle	Traditional (kg CO_2 emitted)	Motorised (kg CO_2 emitted)	Mechanised (kg CO_2 emitted)
Cycle	0.00	0.00	0.00
Bike	0.07	0.34	0.32
Auto	0.09	0.37	0.59
Truck		0.31	0.59
Truck with cooler		0.31	0.98

Train		0.49	3.13
Ship			0.01
Flight			497.04

Table 6 indicates the emission from traditional, motorised and mechanised sector while trading one ton of fish. The distances travelled by each kind of craft were found based on interactions with fishermen as well as fish traders in and around the southern coast of India.

The carbon emission from traditional sector is a meagre value of 0.0002 tons/ year, while that of motorised sector is 0.002 tons/year and that of mechanised is 0.503 tons/year Table 7. Considering the landing per sector and the crafts per sector the mechanised sector emits the largest.

Table 7 Emissions from post-harvest operations

Sector	Emission (Ton CO_2/ ton)	Percentage contribution (Landings)	Percentage contribution (Emission)
Mechanised	0.503	79.51	99.56
Motorised	0.002	18.55	0.39
Traditional	0.0002	1.93	0.03

Consumption

The final step in the value chain is consumption of the catch. Majorly the fish caught in India is used for consumption; a meagre proportion of the catch is used in fish meal industry.

The fish available for consumption is either used for domestic purpose or is exported. The major percentage of catch (95%) is used within the country for both household as well as commercial needs. In Indian context, fish is usually made into traditional curry or fried. Using survey schedules it was found that about 70% is made into curry, while the rest is fried. The emission in this sector is based on the type of dish cooked (curry or fry), type of fuel used for cooking (Primarily LPG), type of oil added to the dishes as well as the time required for cooking (ranging between 30 minutes to an hour).

Based on the above mentioned criteria while cooking one ton of fish, there is an emission of 0.11 ton of CO_2.

Indian marine fisheries: cradle to grave approach

The cradle to grave approach of Indian marine fisheries brings to light some interesting findings. The mechanised sector (2.24 tons) is the largest carbon emission contributing sector, in comparison to the motorised (1.46 tons) and traditional sector (0.2 tons). The highest emission occurs during the harvest operation in mechanised sector with an emission of 1.42 tons of CO_2 (of which sector). The pre-harvest sector contributes 0.63 tons of CO_2, while the harvest sector 2.44 tons of CO_2 and post-harvest sector contributes 0.5 tons of CO_2. The details are given in table 8.

Table 8 Comprehensive table of emissions in Indian marine fisheries sector

			Emissions in ton			
Sector	No. of crafts	No. of people involved (Million)	Preharvest- boat manufacture normalised by life period of the craft	Harvest- while catching 1 ton of fish	Post-Harvest- Trading 1 Ton of fish	Consumption- 1 ton fish as either curry or fry.
Traditional	5050	0.252	0.09	0	0.0002	0.11
Motorised	71378	1.427	0.33	1.02	0.002	0.11
Mechanical	72545	0.58	0.21	1.42	0.5	0.11

Way forward: Policy measures for sustainable marine fisheries in times of climate change

Proven studies reveal that fisheries contribute to global green house gas emissions (GHGs) during fish capture or growth, processing, transportation and storage. The present study reveals that the Indian marine fishing scenario is not at its best in terms of sustainability and coping with climate change. This can be explained by the uncontrolled growth in the mechanised sector. Just like how industrial revolution at the dawn of the 19th century brought unimaginable development within a short span of time, but led to pollution and other anthropogenic issues. The mechanised sector in India is leading the fisheries sector to a plateau of stagnation. The traditional fishermen who have been thriving for centuries have now lost hold in their own regime. Even with policies such as closed fishing seasons, which allows traditional fisherman to fish while the mechanised sector is forbidden to venture into the sea, the situation hasn't bettered. Not only is it a socio-economic crisis, but it is also an environmental deadlock. With the increase in fishing fleets, which venture deeper and deeper into the oceans, unsustainable fishing is but evident. Usage of trawl nets and other high end gears has led to increase in by-catch during fishing and also led to the fishing of spawns.

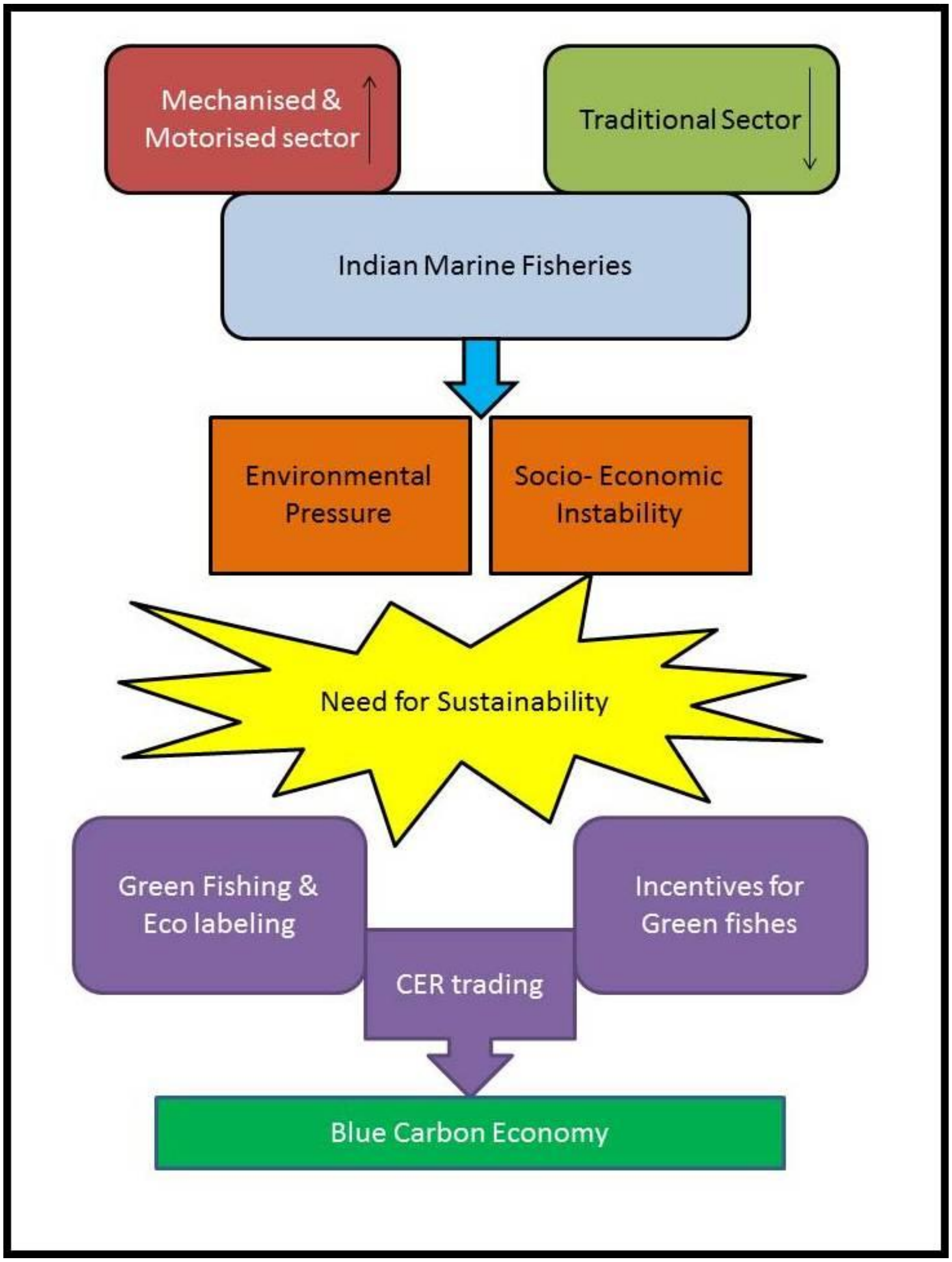


Figure 7 Blue carbon economy through green fishing practices.

However on an international platform, India's position is much brighter. Globally there are many different kinds of fisheries with many different fuel requirements. These range from small low-power single engines to larger vessels to fish factory ships. One of the primary differences between fuel-use in developed and developing-country fisheries is fuel efficiency, where the proportion of revenue spent on fuel, with developing countries spending up to 50 percent of total catch revenue on fuel[10]. Fuel emissions from fishing vessels and product transportation are the main source of emissions in the fisheries sector. Products are typically transported via freight on ships or plane, especially if they are moving from developing countries to developed-country markets.

In addition, fisheries management contributes to some of this inefficiency with policies that create a "race to fish". This refers to policies that inadvertently create incentives for more powerful engines to catch more fish, which can quickly lead to overfishing. Vessels will then have to travel farther or to deeper waters and spend more to catch the same amount of fish as they have in the past.

In order to better the situation in terms of social up liftment of the traditional fishers as well as bringing environmental tranquillity, the concept of green fishing needs to be popularised, and supported with incentive based policies. Pricing the marine fish caught based on the method of fishing, and selling them with a green tag, which suggests the emission they have contributed, can be a precursor for a large movement in the fisheries sector. Once this idea gains popularity, it can be scaled up at a global level and can work on the basis of Kyoto Protocol, where Annex I parties can pay in terms of CER (Certified Emission Reduction) to Annex II parties. This will lead to traditional fishers benefitting, as well as will reduce emissions in the fisheries sector at large and achieving a fishery induced blue carbon economy Figure 7.

4. CONCLUSION

Climate change is no unidirectional issue, it brings along with its effects on both the resources and resource users, thus the adaptation to it should ensure that the multifarious impacts it brings along can be tackled. Development cannot be ceased, nor can exploitation be hailed, the key to successful climate change adaptation is implementing sustainable development through incentive based polices and empowering the economically weaker sections of the society with environmentally friendly livelihoods.

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