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Roadmap for Mariculture Advisory Service in India : A Geospatial Modelling Approach

by

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Abstract (100 words)

This is an effort to underline the potential of mariculture industry in the Indian EEZ. It also demonstrates possibility of a new service and roadmap to make it a success. A developed mariculture industry can help India mitigate malnutrition and land-use conflicts while effectively implement coastal zone regulations. Food resources farmed under controlled environment can help effectively control quality. Marine environment offers untapped resources for bio-fuel, drugs and other bio-active compounds. Mariculture can ensure accessing such resources without putting natural stock under the threat of overexploitation.

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ABSTRACT

Global capture fishery is either stagnant or depleting. Stock often tumble or collapse due to exploitation pressure. Further, changing climate pose uncertainty over archaic practice of hunting the marine resources. Despite having favorable conditions within Indian EEZ, entrepreneurs have not embraced mariculture yet. On the other hand, INCOIS boasts to make PFZ (Potential Fishing Zone) advisories operational and popular among fisherfolk across the India. While global output from culture fishery is on the verge of surpassing capture fishery, this can be right time for India to take first step toward blue revolution.

A developed mariculture industry can help India mitigate malnutrition and land-use conflicts while effectively implement coastal zone regulations. Food resources farmed under controlled environment can help effectively to control quality. Marine environment offer untapped resources for bio-fuel, drugs and other bio-active compounds. Mariculture can ensure accessing such resources without putting natural stock under the risk of overexploitation.

In this regard, we showcase an effort to underline the potential of mariculture industry in Indian EEZ. It also demonstrates possibility of a new service and roadmap to make it a success.

1. Introduction

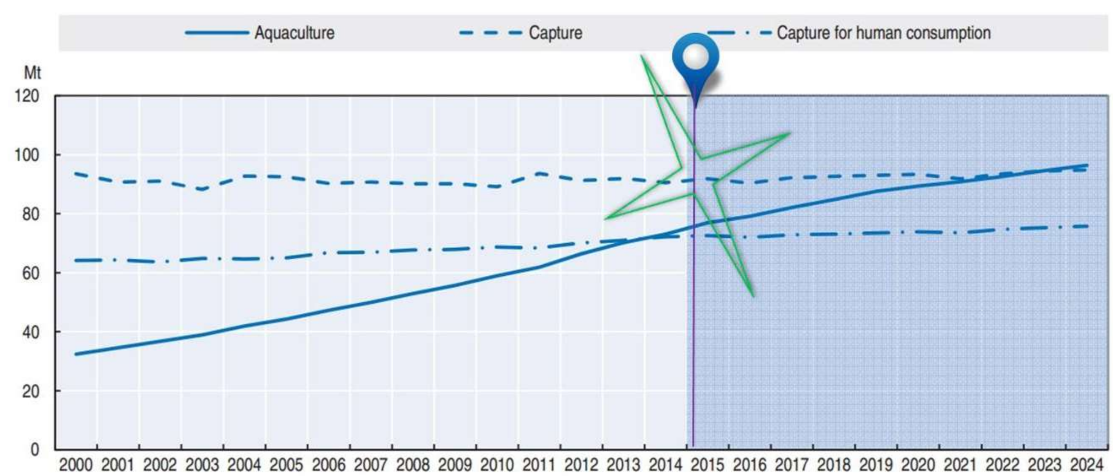
1.1 Marine Fishery: Indian Scenario

Mechanized or motorized fleet that operates chiefly in near shore waters drives Indian marine fishery. The focus of this fleet is typical tropical fishery where multiple species are being targeted (Pillai N.G.K., 2004). While global marine capture fishery is mostly stagnant or in depleted stage, India witnessed first major rise in annual marine fish production in 1960s with introduction to mechanization of fleet however, to witness afterwards only moderate increase or stagnancy (Pauly et al., 1998; Ramakrishnan Korakandy, 1994). Till date fishery has remained mostly an individual affair and has not taken any significant corporate shape. This had inhibited the fleet from venturing away from the shore in many parts of the country. In early 1990s, Indian Space Research Organization (ISRO) laboratories took up primary studies with the help of fishery research organizations, on scouting marine resources by employing satellite data and these efforts met with encouraging results (Solanki et al. 2001a, 2001b, 2003, 2005 and 2008; Nayak et al., 2003; Dwivedi et al. 2005). Today the Indian Marine Fishery Advisory Services (MFAS) – popular as Potential Fishing Zones (PFZ) – is a unique program with decade-plus long experience and data-archive, reaching to an estimated 100,000+ fishermen (≈10% of active marine fisher-folk as latest population estimation of year 2011 by CMFRI) on daily basis. Validation experiments has shown many positive and encouraging results (Choudhury et al., 2007; Tummala et al., 2008; Das et al, 2010; Pillai and Nair, 2010; Deshpande et al., 2011; Nammalwar et.al., 2013; Subramanian et al., 2014). Similarly from fishermen feedback, PFZ advisories are found to be beneficial in obtaining more profit, by reduction in searching time (and fuel consumption) for fishes. This in turn helps improving India's footprint by cutting carbon emissions per unit mass of fishes caught (NAIP Annual Report 2011-12; Vivekanandan et al., 2013; Ghosh et al. 2014; Ravi et al., 2014).

1.2 Capture and Culture

Despite such success of PFZ program it should be noted that it supports primitive method of food gathering – hunting. This can be compared with food gathering efforts of pre-historic men on land, who had primarily two methods for obtaining food – gather some type of food (fruits etc) or hunt (animals). With time, such land resources were obtained more and more in proportion of nutritional requirement, from farmed source in compare to the hunting. In case of aquatic resources, freshwater resources are also following the same trend; however in marine sector globally the industry has followed hunting as major mode till recent time, with exception of some countries.

Interestingly, data and projections for marine fish production as estimated by FAO (Food and Agriculture Organization) and OECD (Organization of Economic Cooperation and Development) show that only a portion of the capture fishery goes to human consumption (Fig.1)(OECD, 2015). In this regard, it is significant that 2015 might be the year that witnessed the culture production surpassing the production for the human consumption from its capture counterpart, for the very first time in the human history.



Note: "Capture for human consumption refers" to the Capture production excluding ornamental fish, fish destined to the production of fishmeal, fish oil and other non-food uses. All aquaculture production is assumed to be destined to human consumption.
Source: OECD/FAO (2015), *"OECD-FAO Agricultural Outlook"*, *OECD Agriculture Statistics* (database), *http://dx.doi.org/10.1787/agr-outl-data-en.*
StatLink http://dx.doi.org/10.1787/888933229221

Figure1. World capture and culture production trends and projections.

1.3 Indian Requirements and Initiatives

While marine farming is considered the key mode of next blue revolution in the southeast Asian and in the Mediterranean countries, India practically has no marine farming – other than minor exceptions in Gulf of Kachchh and in Gulf of Mannar. Revised population projections show that India will become world's most populated country six years earlier than the previous estimates, by 2022. As most of this increase will be at the base or lower half of the population pyramid, fulfilling nutritional requirements will be a challenging task for the managers. Presently, India is having a third of the land area than the USA while having more than three times of the population. Even in 21st century, most of our agriculture is monsoon dependant, which is projected to follow erratic patterns owing to climate change. As uncertainty over availability of freshwater reservoirs for culture rise, reliability on the same for freshwater aquaculture also has limited scope to fulfill country's needs. As noted, marine resources are either offshore or the fisheries are stagnant or at decline. Setting up coastal aquaculture farms require land, much of which falls under coastal regulations or in eco-sensitive zones. Salinity intrusion in the coastal aquifers due to seepage from culture ponds is also a prevalent issue.

In such situation, mariculture has scope to offer a smart solution. The same does not limit to the farming of only food resources, but also that of bio-active compounds and bio-fuel (Apryshko et al., 2005; Mata et al., 2010)). Despite efforts by CMFRI (Central Marine Fishery Research Institute) and NIOT (National Institute of Ocean Technology) to demonstrate this technology with model farms, Indian entrepreneurs are not yet investing (Gopakumar et al., 2007). Their reluctance or inability is due to lack of information on site-selection and technology. In this era of globalization, technology acquisition is not a hurdle. Thus, timely and reliable site-selection information and subsequent service as Decision Support System (DSS) is essential. In this report, we propose a roadmap to address the same.

2. Data and Methods

We studied the literature (Table 1) and derived the important parameters and their optimum ranges that support the mariculture of tropical species. Prevalence of environmental conditions within these values were chosen as a suitability criteria at any respective location within Indian EEZ for a particular month.

Table 1. Optimum range of various parameters used for mariculture site selection

Sr#	**Parameter**	**Suitable Criteria**	**Reference**
1	Sea Surface Temperature	27-31 °C	Imelda *et al.,* 2010; Vijayakumaran *et al.,* 2010; Philliphose *et al.,* 2012; Suresh kumar *et al.,* 2012;Ritesh *et al.*, 2014; Gulshad *et al.,* 2010; Syda *et al.,* 2010; Philliphose *et al.,* 2013; Windupranata & Mayerle;, 2009, FAO, 2013; Brian &Hatim, 2010; Jon *et al,* FA0 458, 2007.
2	Bathymetry	5-30 m	
3	Salinity	25-37	
4	Surface chlorophyll	>0.5 mg m^{-3}	Madhu *et al.,* 2015; Padmakumar *et al.,* 2012
5	Secchi depth	>3 m	Joaquín . *et al*., 2005; Halmar *et al.,* 2009; Morel *et al.,* 2007
6	Significant wave height	<0.5 m	Halmar *et al*., 2009; Brian &Hatim, 2010; Falconer *et al.,* 2003; JOAQUI΄N *et al.,* 2005; Windupranata & Mayerle;, 2009
7	Surface current	<50 cm s^{-1}	

The Indian seas witness high degree of intraseasonal variability due to distinct monsoons twice a year. On the other hand, based on a species being cultivated, duration of crops to be undertaken may vary from weeks to many months. Hence, in order to facilitate site selection, it is important to determine that for how many months of the year a site is suitable for mariculture. To address this, we used monthly data of these parameters (Table 2).

Table 2. Data source of various parameters used for mariculture site selection

Sr#	**Dataset**	**Source**	**Resolution**	**Period**
1.	Chlorophyll	MODIS-Aqua	4 km	2002-2015
2.	SST	MODIS-Aqua	4 km	2002-2015
3.	Water Clarity	MODIS-Aqua	4 km	2002-2015
4.	Significant wave height	INCOIS-ROMS model	10 km	2014
5.	Surface Current	NOAA-OSCAR portal	≈33 km	2014
6.	Surface salinity	HYCOM model portal	9 km	2014
7.	Bathymetry	GEBCO portal	≈1 km	N.A.

The ocean color sensor onboard MODIS-Aqua (Moderate Resolution Imaging Spectroradiometer) is operational since year 2002. We used monthly climatology data that is generated since then. In case of model or observation products, we used monthly data for the most recent year (2014). Bathymetry data was obtained from GEBCO (General Bathymetric Chart of the Ocean) portal. This is being derived by combining quality-controlled ship depth soundings with interpolation between sounding points guided by satellite-derived gravity data, and is not a dataset that vary year by year. However latest version of the product (year 2014) with highest resolution was used.

These datasets were brought in to ArcGIS and analyzed at 4 km spatial resolution. Monthly layers of various parameters were overlaid and areas falling under suitability thresholds were identified with the help of multi-criteria suitability analysis.

3. Mapping of suitable sites for Mariculture

A recent FAO technical paper has attempted global assessment of mariculture site suitability, indicating India as one of the countries with the most favorable outlook for maricuture industry development potential (Kapetsky et al., 2013). However, the study being on global scale, had the parameterization schema that is needed to be modified to a schema that is feasible for Indian conditions e.g. bathymetry range 5-30 m taken here – instead of 25-100 m proposed – deriving areas closer to the shore for the cost effectiveness (Fig.2).

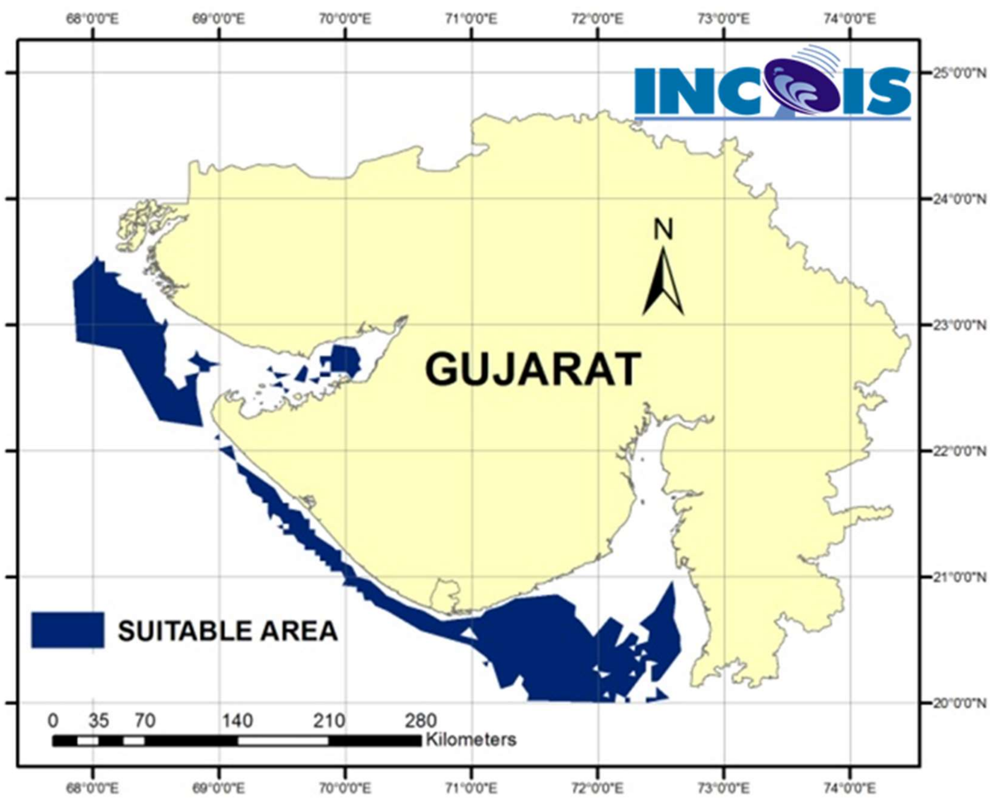


Figure2. An example output map of mariculture site suitability for one month

Based on our parameterization schema, we derived the total area available for mariculture along the west and the east coast of India (Fig.3 and Fig. 4). As it can be observed, suitable areas reduce drastically along the west coast during summer monsoon (July). The same at lesser magnitude was observed for the east coast in June. A window of at least ten months yields an encouraging total of more than 100,000 km^2 for the development of industry.

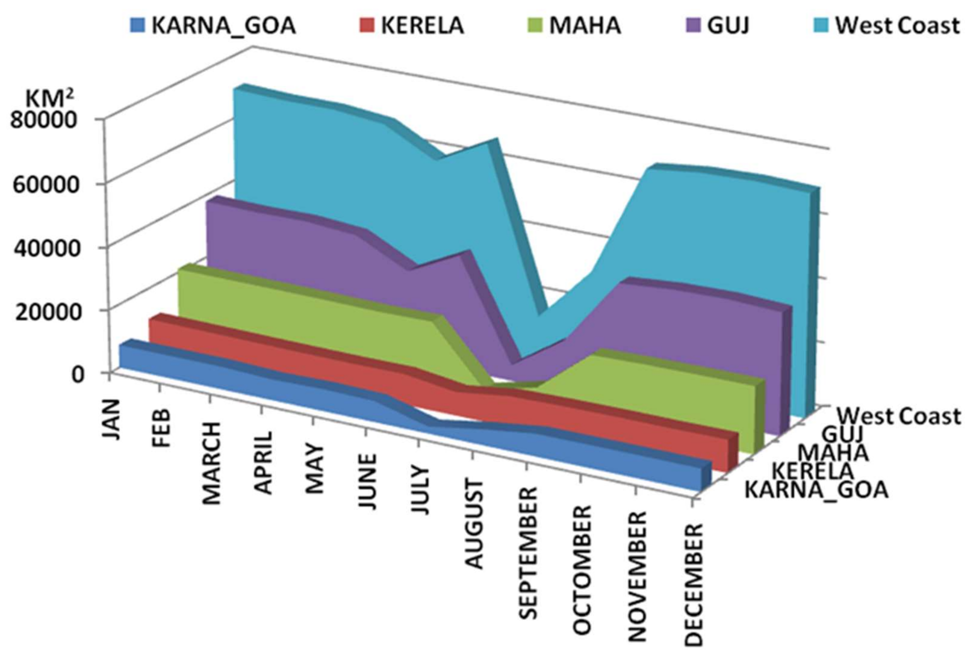


Figure3. Month-wise available area for mariculture along the west coast of India

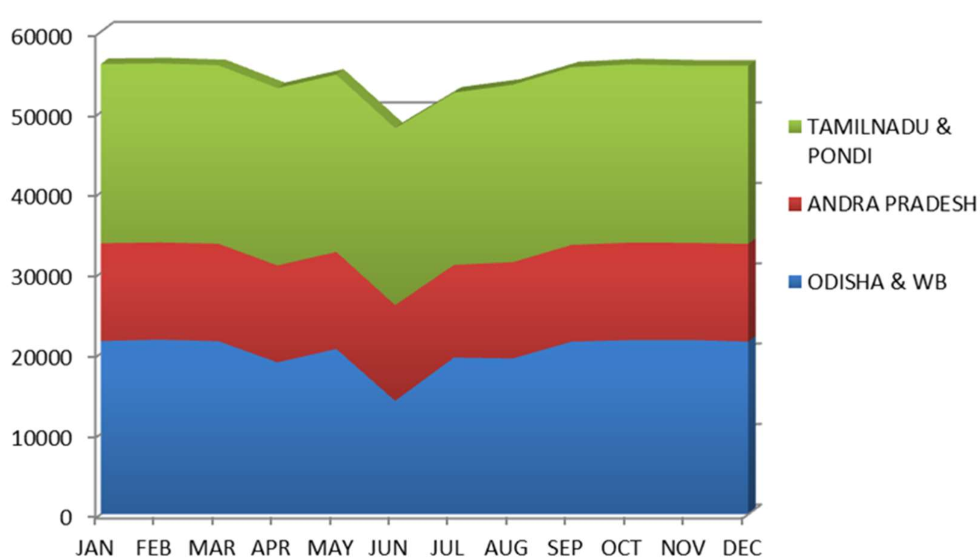


Figure4. Month-wise available area for mariculture along the east coast of India

4. Mariculture Atlas and Advisory Service

Due on such findings, it is thus necessary to provide a handy catalogue to the users, for making decision on the site selection . An atlas of mariculture site suitability is envisaged to be prepared by INCOIS in the year 2016. Once month-wise suitable areas are documented, fisherfolk will have decision support system akin to the land farmers who have access to soil type and groundwater maps etc data.

As demonstrated in the template example, the atlas will have a primary map per month for each of the coastal states, provided along with six sub-maps (Fig.5). The primary map indicates the classes that were determined considering bathymetry as the base parameter (constraint) and checking suitability of other (total 6) oceanographic parameters. This provides positive combination of only two variables leading to least suitability. In ascending manner (two to six), maximum possible suitability of all the six parameters derives highest site suitability. Further, parameter-wise suitability is also included as sub-maps. This allows a user to check if parameter due to which the lesser suitability arises (e.g. SST in this example) is critical for his/her needs (species and site). This ensures freedom for case-based choices.

While the first version of the atlas is generalized, future versions may address the species-specific requirements. Similar customized atlas or advisories can be prepared for different cage designs addressing the structural stability and resilience aspects. Based on these areas derived, an advisory service on the same lines of PFZ advisories is envisaged to be made beta-operational. Presently, reliable model forecast products are available for up to two weeks in advance. The same can be employed for providing outlook on weekly or biweekly basis. Such outlook can allow determining onset and closure of the culture season. This can also support critical decisions such as if the cages should be kept deployed or the stock should be harvested in case of adverse sea-state is imminent. As the feedbacks from the industry are received, such advisories can be further refined.

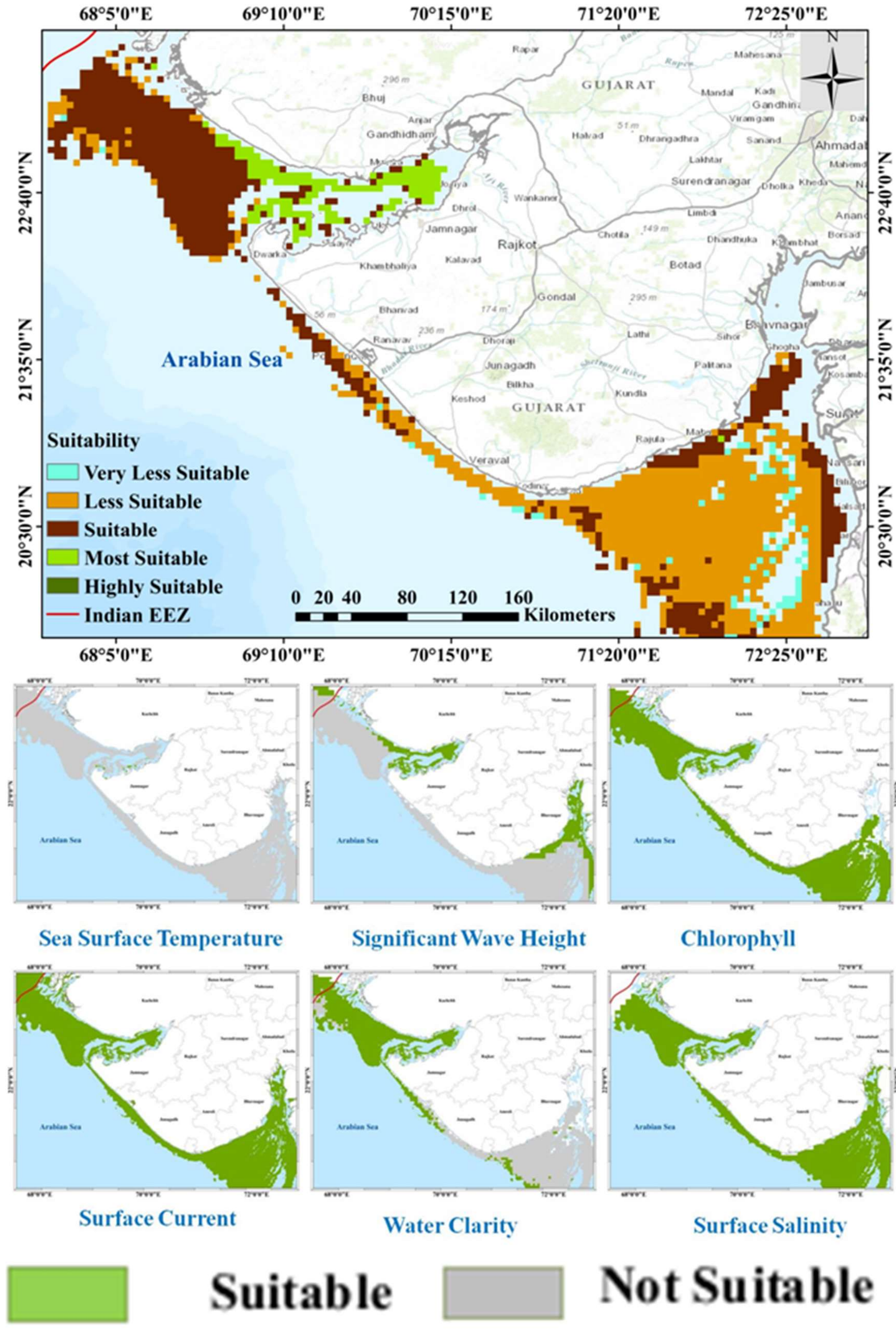


Figure5. A template example of mariculture atlas under preparation

5. Future Roadmap

Refined versions of atlas can be prepared with higher spatio-temporal resolution and includes more parameters. An important aspect could be to derive growth rates from *in-situ* data from culture experiments. This will allow determining seasonal optimum ranges of the parameters for a given species. Another useful factor to parameterize is structural stability for various cage designs. GIS layers of logistic and socio-economic aspects will make the outputs (atlas, advisories, WebGIS etc) further case-specific and user friendly. Future outputs may address avoiding conflict of interests with other marine usages such as marine protected areas, navigational channels and off-shore oil rigs etc. This will help in better Marine Spatial Planning (MSP) to realize Blue Economy potential. Scenario of culture-potential and maximum sustainable yield can be derived. Collaborations for awareness and acceptance are needed.

6. Summary & Conclusion

Present effort underlines the potential of mariculture industry in India. We also demonstrate possibility of a service and the direction that India can take to make it a success. A developed mariculture industry can help India mitigate malnutrition and land-use conflict while effectively implement coastal zone regulations. Food resources farmed under controlled environment can help achieve effective quality control. Marine biome offer untapped resources for bio-fuel, drugs and other bio-active compounds. Mariculture can ensure accessing such resources without putting natural stock under the threat of overexploitation.

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