ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24SEP1401

A Data Driven Approach to Dynamic Geofencing for Sustainable and Profitable Fisheries

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Abstract:- Geofencing is a technology that uses a virtual perimeter around real world areas. This concept is discussed widely in multiple past publications, in the context of fishery. The most common application is for marking international coastal boundaries and preventing their violation by fishermen. Here, geofencing is taken into application for sustainable fishing practices along with helping the individuals working in this industry guarantee their safety by maximizing fish yield. The dynamic nature of the geofences is proposed in this research, where the virtually marked areas are susceptible to change based on the real time and past generated data, thus safeguarding the breeding patterns of multiple fish species. The approach's implementation is further explained with the example of the coastline of Maharashtra state in India. This technique is possible to be implemented at different levels of authority, namely the district, state, and the country, for varied scales of fishermen which is further discussed. This approach is advantageous as it helps in balancing the fish population, and guiding fishermen to find the most prone fishing spots, also protecting them from accidental violation of the country's borders. The implementation accuracy of this model depends on the data sources provided, including the Orbital Thermal Imaging and other weather-related data.

Keywords:- *Fishery, Geospatial Data Analysis, Sustainability, Predictive Modeling, Geofencing, Big Data, Marine Protected Areas, Remote Sensing, Random Forest Algorithm.*

I. INTRODUCTION

Fishery is a source of livelihood for a large amount of individuals on the coasts of India. Around 2.8 crore people are directly or indirectly employed in this sector. India is blessed with a large coastline on both the east and west sides, making India the Second largest producer of fish in the world. In the F.Y. 2021-22 India's annual fish production was 162.48 lakh tonnes. (source: PIB, Ministry of Fisheries, Animal Husbandry & Dairying).

➢ *Indian Coast is the Home for a Diverse Range of Fish Species, out of which the Species with High Commercial value Include:*

- Indian Mackerel (Rastrelliger kanagurta)
- Sardines (Sardinella longiceps)
- Tuna (Thunnus spp.)
- Pomfret (Pampus argenteus)
- Seer Fish (Scomberomorus guttatus)
- Bombay Duck (Harpadon nehereus)
- Threadfin Bream (Nemipterus japonicus)
- Prawns and Shrimps
- Lobsters

If the coast of Maharashtra State is taken into consideration, the most found and demanding species are Indian Mackerel, locally known as Bangda, King Mackerel (Surmai), Pomfret and the Bombay Duck (Bombil).

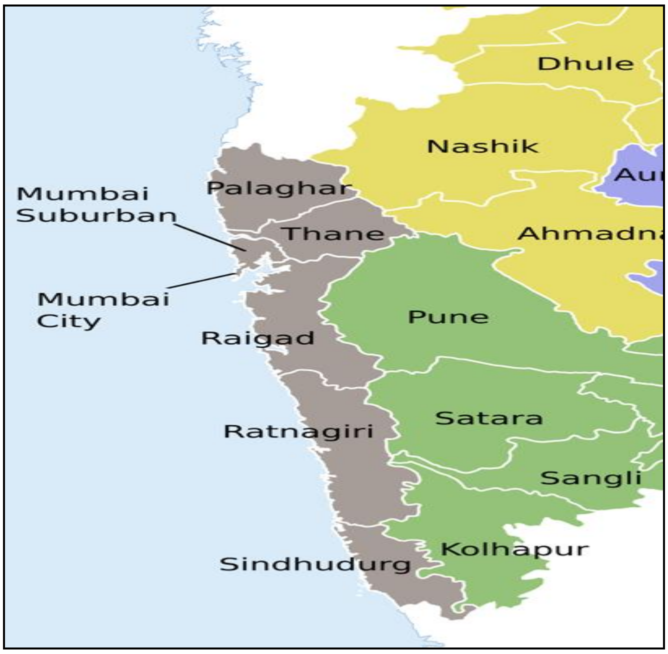

Fig 1 Coastline of Maharashtra. Marked in Gray are Coastal Districts.
(Source. Wikipedia)

The species like surmai being migratory in nature, there lies an entire sea to move, depending on multiple environmental factors such as Climate change, water temperature, ocean currents, salinity level, food availability and even more.

This uncertainty makes it quite difficult for the fishermen to find the right spot for catching.

Also, the fish species have specific conditions to breed in, including season and other factors mentioned above. The fish breeding zones are always vulnerable to be affected from fish catching activities, as the young fish being caught cause a population imbalance in species, also they lack the commercial market value that a fully grown fish gets.

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The objective of this research is to help fishermen to find the right fishing spot and safeguarding the natural habitat of the fish species.

Dynamic geofencing, a technology that utilizes real-time data and advanced analytics to create virtual boundaries, offers a promising solution to these problems. By establishing dynamic geofences based on factors such as fish stock distribution, environmental conditions, and legal boundaries, it is possible to guide fishermen towards sustainable fishing grounds while preventing them from entering protected areas.

This research aims to develop a data-driven approach to dynamic geofencing for the Indian fisheries industry. By leveraging satellite imagery, historical data, and machine learning techniques, we will create a system that can accurately predict fish distribution, identify potential fishing hotspots, and enforce marine regulations. This will not only contribute to the conservation of marine ecosystems but also enhance the profitability of the fishing industry by ensuring sustainable and efficient resource management.

➢ *Significance:*

By leveraging technology, data analytics, and machine learning, this approach can create virtual boundaries that guide fishermen towards sustainable fishing grounds while protecting marine ecosystems. Through real-time monitoring and adaptive updates, dynamic geofencing can help to reduce overfishing, prevent illegal fishing, and promote the long-term sustainability of marine resources. This innovative solution has the potential to enhance the profitability of the fishing industry, protect jobs and livelihoods, and contribute to the overall health of our oceans.

➢ *Problem Statement:*

The Indian fishing industry faces significant challenges due to unsustainable practices, including overfishing, illegal fishing, and habitat destruction. These factors have led to declining fish stocks, environmental degradation, and adverse economic impacts on coastal communities.

Traditional fisheries management approaches have limitations in adapting to rapidly changing environmental conditions and the complex behaviors of various fish species. Static geofencing, while helpful, may not be sufficient to address these challenges effectively.

➢ *Therefore, there is a Pressing need for a Dynamic Geofencing System that can:*

- Accurately predict fish distribution based on real-time data and environmental factors.
- Create and update geofences in response to changing conditions and species behaviors.
- Guide fishermen towards sustainable fishing grounds while preventing them from entering protected areas.
- Support effective enforcement of fishing regulations and reduce illegal activities.
- Contribute to the long-term sustainability of the Indian fisheries industry and protect marine ecosystems

II. LITERATURE SURVEY

The concept of geofencing is widely discussed in multiple past publications, one such example is “Fisherman Navigation and Safety System” by M.B. Mukesh Krishnan, D. Saveetha, A. Arokiaraj Jovith, P. Rajasekar. This research elaborates the implementation of Geofences for the safety of Fishermen, by using positioning systems to avoid their violation of international boundaries. An example of the Sea Border between India and Sri Lanka, where fishermen from India are frequently caught by the Naval Forces of Sri Lanka. Although the paper suggests using the Mobile devices for tracking the fishermen, the devices usually do not get internet signal deep into the sea, so the actual implementation results are dependant to the proximity of the devices from the Indian Coast.

The Fish production and its improvement is further studied in “Estimating fishing effort from highly resolved geospatial data: Focusing on passive gears” by T. Mendo a, *, G. Glemarec b, J. Mendo c, E. Hjorleifsson d, S. Smout e, S. Northridge e, J. Rodriguez f, A. Mujal-Colilles g, M. James. The paper discusses the rate of output with respect to the effort taken for it.

Fishing Effort Estimation Methods: Previous studies on fishing effort, particularly in large-scale fisheries using active gears, have predominantly focused on time spent at sea as a metric of effort. Works like Jennings and Lee (2012) have demonstrated the effectiveness of using vessel monitoring systems (VMS) to estimate fishing effort in large-scale trawling operations. However, such indicators do not perform well for passive gears, prompting researchers to seek better alternatives. The paper focuses on improving the representation of fishing activities in marine spatial planning, especially for passive gears used in small-scale fisheries, which are often overlooked. By using highly detailed vessel tracking data, the authors present a new method for mapping fishing effort, emphasizing that traditional methods based on time spent at sea are less effective for passive gears. Instead, they propose using the length of the vessel's track as a more accurate indicator of effort. The study introduces and validates a method to estimate "soak time" (the time gear is left in the water) from tracking data and shows that maps based on this approach differ significantly from those based on fishing time alone. This new method enhances the ability to manage fisheries sustainably by providing better spatial insights into the distribution of passive gear efforts, which account for a significant portion of global fish catches.

The research titled "Passive Georeferencing: A Promising Approach for Finding Probable Fishing Grounds" by Eldho Varghese, J. Jayasankar, Pratibha Rohit, Somy Kuriakose, K. G. Mini, Grinson George, Vinay Kumar Vase, Reshma Gills, Shelton Padua and A. Gopalakrishnan discusses the probable locations to find the fishing spots from the known data, Passive georeferencing refers to determining geographic information from indirect sources, such as satellite images, vessel movement patterns, or environmental data, without active input from fishermen or direct tagging of fishing vessels.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24SEP1401

This approach being static in nature, it does not take the change in conditions according to the weather and seasons into account. Although the algorithm proposed here for approximating the location for Fishing spots is well studied, and the difference between the Predicted and Actual Fishing locations is also presented.

III. METHODOLOGY

The model incorporates data from multiple sources and with different parameters. The collected data can be either non-changing (fixed) or real-time which do continuously change.

➢ *Constant Data:*

- Seabed Topography: Study and mapping of the underwater landscape, including the depth, shape, and features of the ocean floor. It is the underwater equivalent of topographic mapping on land. Bathymetry helps scientists understand the physical structure of the ocean, including its valleys, mountains, and plains.
- Species specific preferences: Every fish species have its own preference for the water depth, temperature, salinity level, and type of food.
- Historical Data: This includes past records of fishing activities, environmental conditions, and fish distribution. While this data is collected over time, it is generally considered static for the purposes of the geofencing system. Continuous addition is made to the dataset of Past trends and Behaviors of Fish species and seasonal changes.
- Geographic Information: Data such as coastline boundaries, protected areas are generally constant over time.

➢ *Variable Data:*

- *Satellite Imagery:*

✓ Sea Surface Temperature: Maps of ocean surface temperatures to identify areas with suitable conditions for fish species.
✓ Chlorophyll-a Concentration: Indicates the presence of phytoplankton, which is a primary food source for many fish species.
✓ Ocean Currents: Maps of ocean currents to understand the movement of fish and plankton.
✓ Precipitation related Cloud Imagery: Satellite Images of the Cloud Patterns over a region. For example, the INSAT 3DR is a satellite by ISRO with a capability for Weather related imagery.
✓ Salinity Level: The water salinity can change to a certain levels depending on climatic conditions. For example, the SMOS orbiter by European Space Agency have capabilities to monitor Ocean Salinity.

➢ *Weather Related Real Time Forecasts:*

The Meteorological Department Issued Weather Forecasts and Alerts, and the real-time weather that affects the fish movement and can be a potential threat for fishermen.

- Temperature: Air temperature and water temperature can influence fish behavior and distribution.
- Wind Speed and Direction: Wind can affect ocean currents and wave patterns, which can impact fish migration and habitat suitability.
- Precipitation: Rainfall and snowfall can influence water temperature, salinity, and nutrient levels.
- Atmospheric Pressure: Changes in atmospheric pressure can affect ocean currents and weather patterns.
- Humidity: Humidity levels can influence the evaporation rate of water, affecting salinity and temperature.
- Cloud Cover: Cloud cover can affect water temperature and solar radiation, which can influence fish behavior.

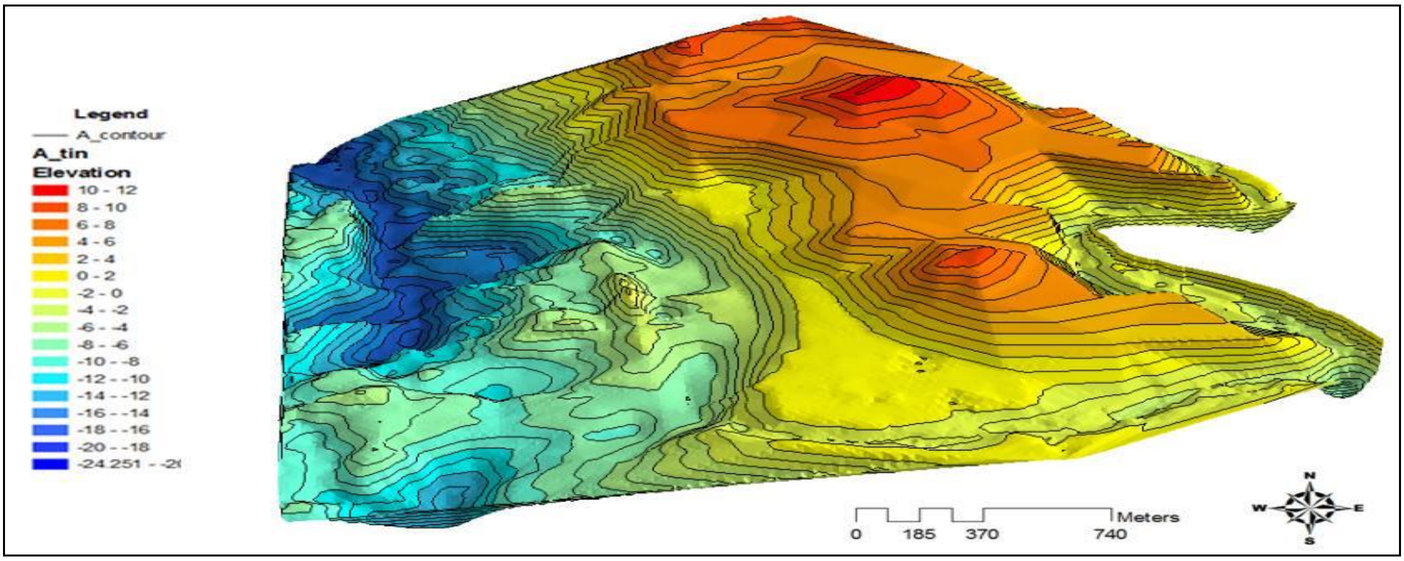

Fig 2 Seabed Topography (Credits: Abdullah Hisam Omar)

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24SEP1401

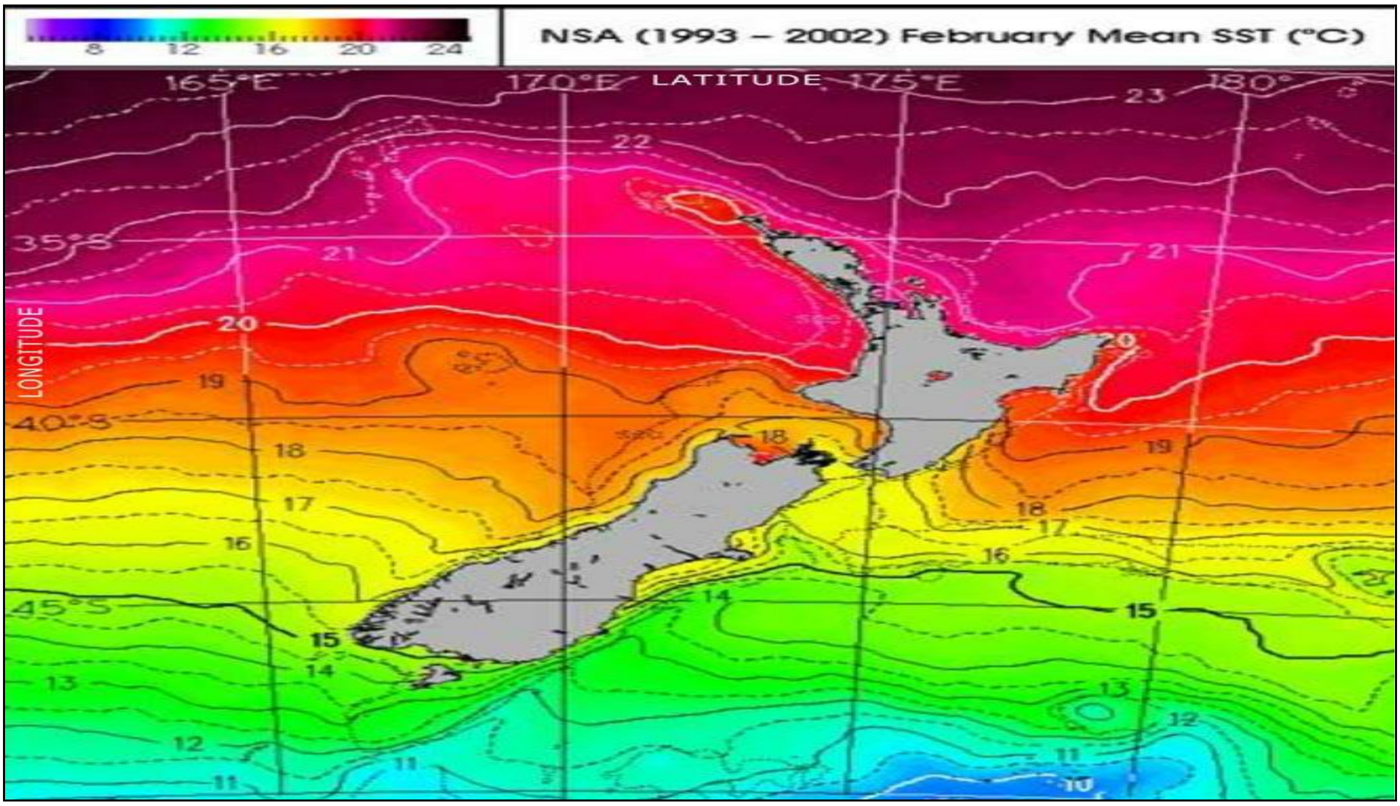

Fig 3 Sea Surface Temperature
(Source: NIWA) (Representational Image)

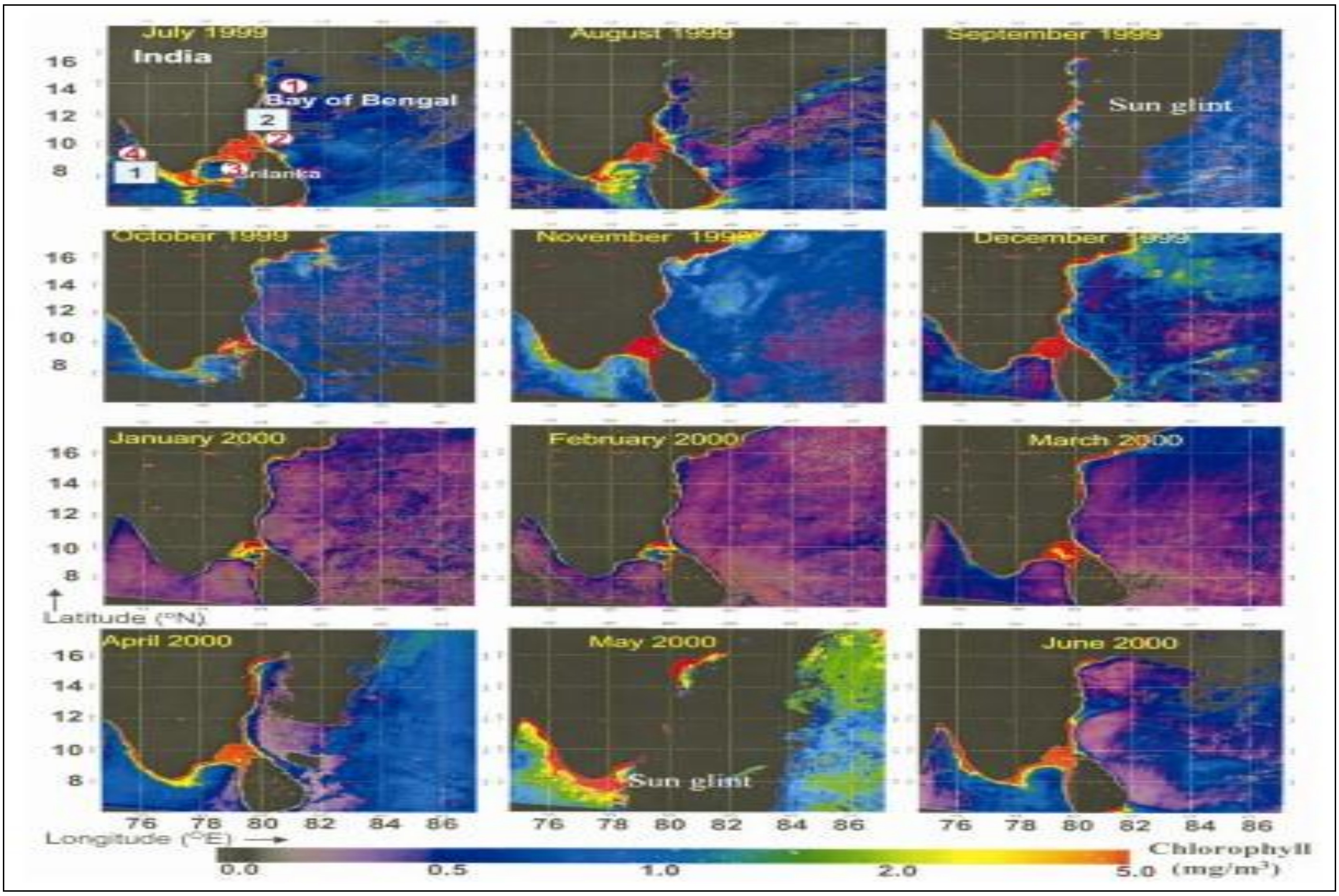

Fig 4 Chlorophyll-a Concentration in Coastal India Observed over Intervals.
(Source: incois.gov.in)

International Journal of Innovative Science and Research Technology
ISSN No:-2456-2165
https://doi.org/10.38124/ijisrt/IJISRT24SEP1401

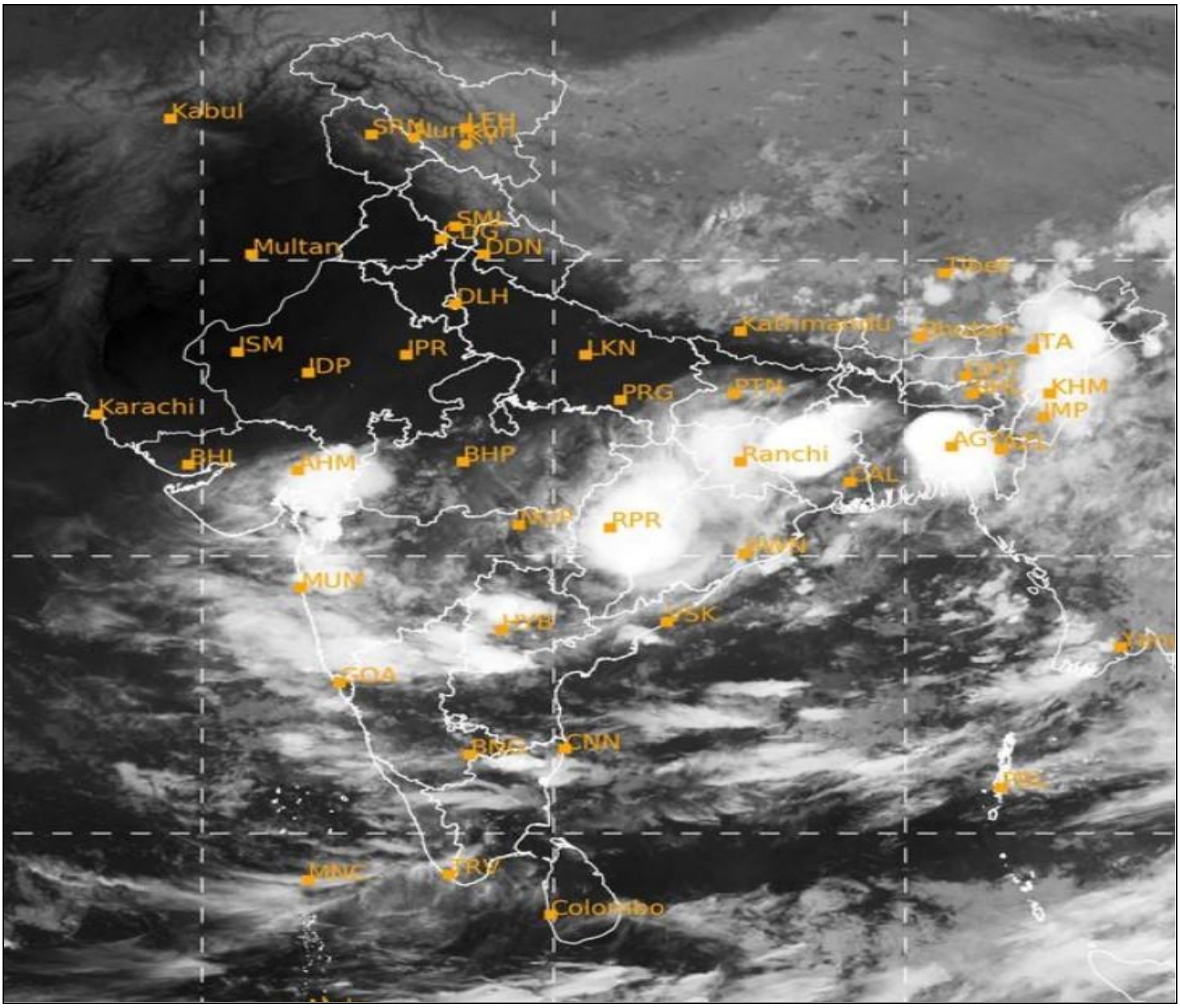

Fig 5 Cloud Pattern by Weather Satellite INSAT 3DR

➢ *Data Collection and Preprocessing:*

The Data from the above mentioned sources is gathered and pre-processing is carried out, which involves handling missing values, outliers, and inconsistencies. This makes the data uniform and suitable for analysis.

The data is normalized and is further utilized for feature extraction.

➢ *The Relevant Features here Include:*

- Distance from coastlines
- Depth
- Sea surface temperature
- Salinity
- Ocean currents
- Historical fishing activity
- Protected areas
- Weather conditions

The proposed model is automated, hence for the real time data the geofences should be created with minimal human intervention.

➢ *Model Training:*

The Random forest algorithm is used for developing the model for dynamic geofencing.

Random Forest is a powerful ensemble learning algorithm that combines multiple decision trees to make predictions. This approach helps to reduce overfitting, a common problem in machine learning where a model becomes too complex and fits the training data too closely, leading to poor performance on new data. Each decision tree in a random forest is trained on a random subset of the features and a random subset of the training data. This helps to prevent the trees from becoming too dependent on any particular feature or set of data points. When making a prediction, the forest combines the predictions from all of its trees using a voting or averaging method.

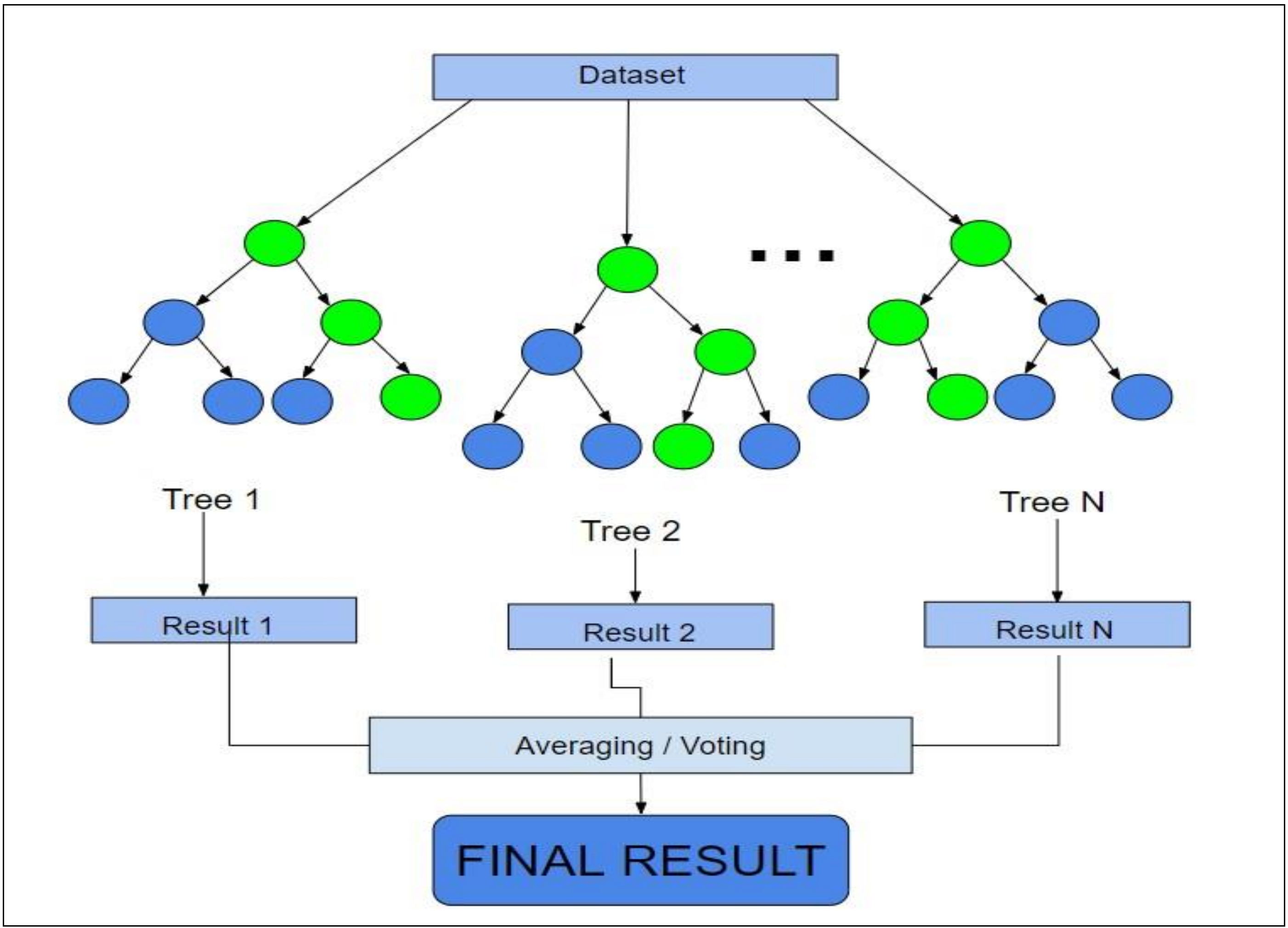

Fig 6 Random Forest Algorithm

The Dataset is partitioned here based on its data source, and the decision trees are formed for each data subset. This allows each tree to specialize in capturing patterns from a specific data source.

Each Decision tree will be trained on the respective subset. The methodology for training an individual tree can be unique, based on the nature of the data. This diverse ensemble of models that can improve overall accuracy and reduce overfitting.

In the next step, the trained trees would be used for making predictions for new data points. The data points would be the sites with the favorable outcome, which can be the probable spot with high fish concentration, or the breeding spot.

The random forest algorithm being based on Ensemble Learning approach, the predictions from individual trees are combined using the voting or averaging method. This helps to reduce the impact of individual tree errors and improve the overall accuracy of the model. The resultant output will be the refined predictions of the data points.

➢ *This Approach has the Following Advantages:*

- Leverages Diverse Data: By using separate decision trees for different data sources, you can capture the unique insights from each type of data.
- Reduces Overfitting: The ensemble nature of random forest can help to mitigate overfitting, which is a common problem when training models on complex datasets.
- Improved Accuracy: Combining predictions from multiple models can often lead to better overall accuracy than using a single model.

➢ *Below are the Summarized Steps for the model Training:*

- Data Partitioning
- Decision Tree Creation
- Feature Extraction
- Training and Prediction
- Ensemble Prediction

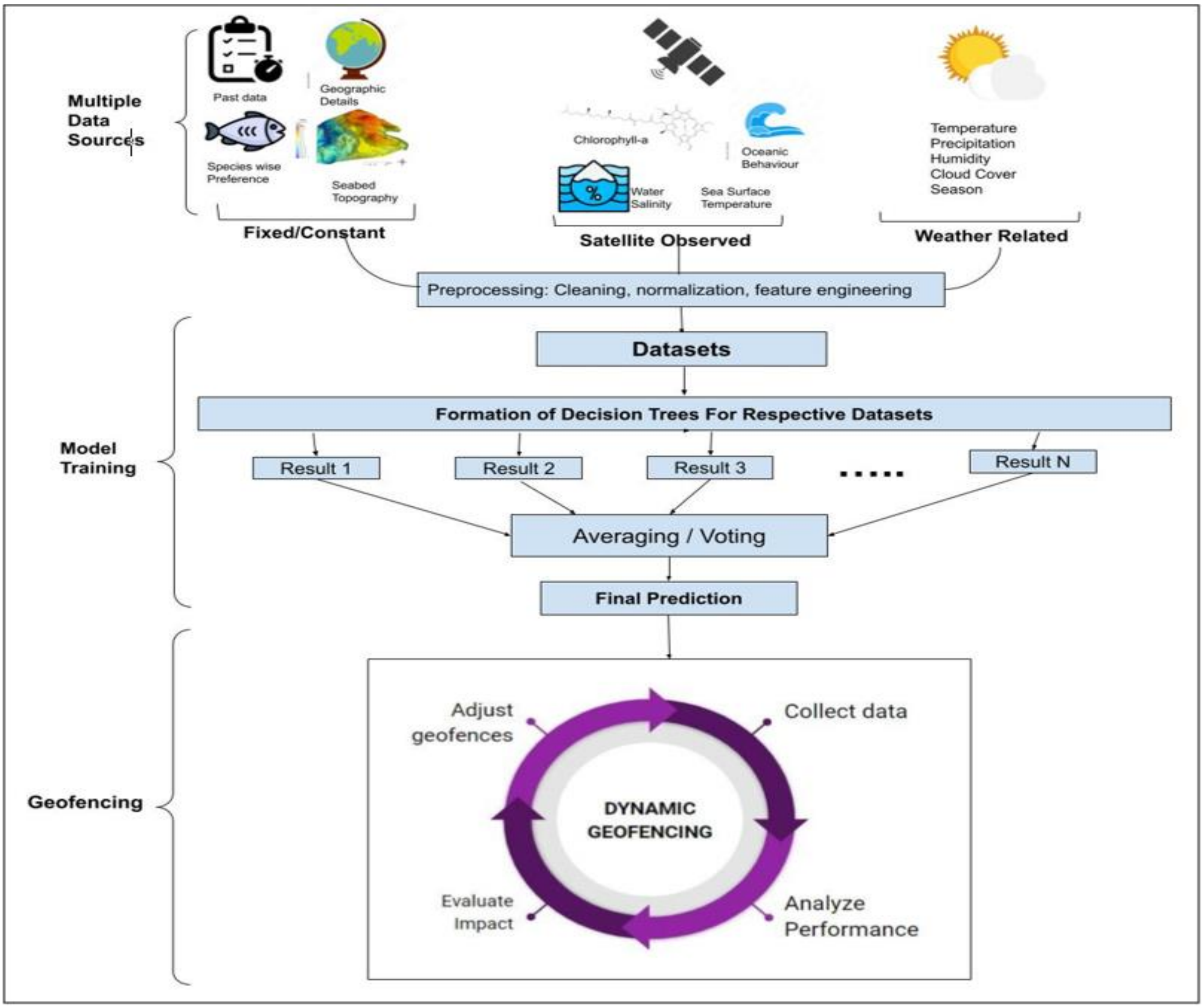

Fig 7 Workflow of The System

Upon training the model based on the Random forest algorithm, the next step would be the generation of the geofences. Thresholds can be set according to the condition, about the concentration of fish. The geofences will be in accordance to the availability of fish and protected zones.

The fishing vessels can be monitored live-time by authorities if needed, in case any unauthorized activity or violation of protected zones is noticed, the necessary action can be taken.

The frequency to update the geofences can be preset, as per the season or depending on the fishing activity observed at a given location.

➢ *Evaluation and Refinement:*

- Monitor performance: Continuously evaluate the performance of the geofencing system to identify areas for improvement.
- Refine model: Make adjustments to the machine learning model as needed based on evaluation results.

The detailed usage and scale of operation is further discussed Into the implementation section.

IV. IMPLEMENTATION

The model can be re-trained at some given intervals, which can be at a week or a month. This has to be done to retain the prediction accuracy of the model. The predictions would be more accurate as the dataset expands, and a strong set of historical records has to be maintained. The process of model training being computationally intensive, since multiple decision trees are formed and the size of dataset would continue to expand.

The scale of Implementation is dependent upon the computational capabilities, the larger the area for geofencing, bigger is the dataset. If the coastline of the state Maharashtra is taken into account, it spans for 720 kilometers, from the

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24SEP1401

Gujarat state at the north to the Goa state at the south. The coastal districts in Maharashtra are Palghar, Thane, Mumbai Suburban, Mumbai City, Raigad, Ratnagiri, Sindhudurg.

The satellite sourced data, such as the Sea Surface temperature, Salinity Level, Weather Related Data, Chlorophyll-a concentration, etc. are measured at different scales, as per the specifications of the satellite. Then it can range from a few kilometers to a few hundred meters. Ideally for the oceanic tides, a medium resolution data would be suitable with a larger scale, whereas for the data such as sea surface temperature, and chlorophyll-a concentration, a high resolution data would be more appropriate. As the fish concentration can be measured at a smaller area.

If the system for geofencing is set up on district level, it would be the most ideal scenario. In a state like Maharashtra, with a long coastline, almost each district has a coastline of 110-130 kilometers, which would a suitable range for observation. Also it would be easier for the personnel managing the system than a centralized system for the entire state's coast.

In the historical data, it can be limited for the past 5 years at max. Maintaining legacy data older than that would be computationally expensive while model training, also due to global changes in the environment, including the global average temperature or the precipitation levels the older data becomes lesser relevant for inference in this scenario. It may affect the accuracy of the model.

The system can be in the form of a website or a smartphone application, where the map with the locations will be made available for the fishermen. For the system to be accessible for a wider section of fishermen, ranging from larger sized trawlers entering in deep sea, to small scale fishermen with smaller boats.

The Large boats are sometimes equipped with onboard systems, for communication and other navigation applications, the geofencing system can be integrated with these systems.

The most useful implementation of this systems would be in the mobile devices; it would be accessible for a wider section of people involved in fishery. The mobile application for this system should have a capability to load an offline version of the geofenced map, before the fishermen begin the journey into the sea. Most internet services continue to work up to a distance of 10 kilometers from the coast. So, till the point the device gets network, the tracking data of the device will be recorded into the system, and after the device loses internet connectivity, the application will locally store the path of the boat, which will be uploaded into the system upon entering into coverage area. This recorded information can be useful for the fishermen to track and maintain the records of the locations they visited.

The geofences being dynamic, would be updated at intervals of days, or hours. So the offline version of map stored on devices would held valid for the given interval. The fish activity varies differently for every species. Some species possess high rate of migration, so their probable location of migration should also be studied by the model, as the fish specific information is also used as a data source.

Another aspect of Implementation would be about the species of fish. For the example of Maharashtra, the demanding fish species are King Mackerel, Pomfret, Bombay Duck, Indian Mackerel, and many others.

The fish species like the Pomfret do not migrate for long distances and is generally found in shallow waters, whereas the King Mackerel are highly migratory species and may travel for long distances and have good tolerances of water temperatures. The Bombay duck has a lesser market value and is easily available in abundant quantities in shallow waters with a sedentary pattern.

As the fish species have different behaviors, the system can provide suggestions and probable locations as per the species of fishes. The predictions must not lead to over exploitation of a certain species of fish, so the scale of predictions must not be much accurate.

If the fishermen try to enter a zone marked with conditions for fish breeding, immediate alerts must be given to the fishermen. Since the positioning system is Satellite based, it would continue to work even in locations farther from the coast. The GPS tracker can be fit to the boat and paired with the smartphone device or would use the available sensor on the device.

The implementation of this system is complex on certain aspects and requires multiple factors to be taken into consideration.

V. CONCLUSION

The approach towards sustainable and profitable fishery presented in this research potents to bring a positive change in the fishing industry. The actual taking into application for this methodology will take a large amount of resources, including the presence of Orbiting Satellites with the necessary capabilities to produce data useful for Training the Machine Learning model. Currently the static Geofencing is being taken into effect into fishery. The adaption of dynamic geofencing would take a significant time ranging into years. This would need a complete overhaul of technologies, on both the authority and fisherman point of views. The actual effectiveness of this approach can be studied in further researches, provided the necessary sources of data and availability of satellites positioned in orbit with necessary instruments for observation of oceanic bodies.

REFERENCES

[1]. Eldho Varghese, J. Jayasankar*, Pratibha Rohit, Somy Kuriakose, K. G. Mini, Grinson George, Vinay Kumar Vase, Reshma Gills, Shelton Padua and A. Gopalakrishnan. Passive georeferencing: A promising approach for finding probable fishing grounds.

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[2]. T. Mendo, G. Glemarec, J. Mendo, E. Hjorleifsson, S. Smout, S. Northridge, J. Rodriguez, A. Mujal-Colilles, M. James. Estimating fishing effort from highly resolved geospatial data: Focusing on passive gears

[3]. C. Hentry* and S. L. Rayar, S. Saravanan, N. Chandrasekar and A. Ponniah Raju, K. Kulathuran. Application of Gps in Fisheries and Marine Studies.

[4]. Technologies for Improving Fisheries Monitoring by Rod Fujita, Christopher Cusack, Rachel Karasik, Helen Takade-Heumacher and Colleen Baker.

[5]. Mahima Gokhe1, N.M. Wagdarikar2, Ishita Sharma3, Atul Kumar4. Embedded systems for Geo fencing and Rescue System for Fisherman (Fisherman Protection System)

[6]. M.B. Mukesh Krishnan, D. Saveetha, A. Arokiaraj Jovith, P. Rajasekar. Fisherman Navigation and Safety System

[7]. Ming Kun Tan, Muzzneena Ahmad Mustapha. Application of the random forest algorithm for mapping potential fishing zones of *Rastrelliger kanagurta* off the east coast of peninsular Malaysia.

[8]. B. Padmaja, K. Mounika, P. Sowjanya, P.V.S. Keerthana, K. Tejaswini. Catching Illegal Fishing Using Random Forest and Linear Regression Models.

[9]. Alessandro Colombelli, Jacopo Pulcinella, Sara Bonanomi, Emilio Notti, Fabrizio Moro, Antonello Sala. Fishing the waves: comparing GAMs and random forest to evaluate the effect of changing marine conditions on the energy performance of vessels.

[10]. Simone Vincenzi a, Matteo Zucchetta B, Piero Franzoi B, Michele Pellizzato C, Fabio Pranovi B, Giulio a. De Leo D, Patrizia Torricelli B. Application of a Random Forest Algorithm to Predict Spatial Distribution of the Potential Yield of Ruditapes Philippinarum in the Venice Lagoon, Italy.