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Review

Big data application in fisheries with special reference to inland fisheries sector in India

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ABSTRACT

The application of big data is seen in every aspect of daily life such as health sector, banking as well as in agriculture and allied sectors. In agriculture and allied sectors, precision farming technique is the most shouted example of big data application. In fisheries, big data analysis has great potential for application in monitoring, control and surveillance of fishing activities; useful for fishery management practices and in conservation of natural resources. The inland fisheries sector finds sparse application of big data, like smart cage aquaculture and in vessel tracking and monitoring. The present paper discusses the potential applications of big data in fisheries with particular reference to inland fisheries sector.

Keyword: Agriculture, Big data, Conservation of resources, Fishery management, Inland Fisheries

Introduction

Bigdata, is an emerging ray in data science and in layman's language, is a self-defined term, representing huge datasets. Technically, the datasets whose size or type is beyond the ability of traditional relational database to capture, manage and process, are known as bigdata and comprises complex datasets with new data sources (https://www.oracle.com/in/big-data/what-is-big-data/#link1). However, Snijders *et al.* (2012) defined big data in terms of capacity, the datasets which exceed the capacity of a typical management and analytical software for analysis. The high analytical power is quite helpful for business related tasks such as point of sale based on customer's buying behaviour, risk assessment and to detect fraud related activities. So, big data analysis can reduce the cost as well as the time taken by the analytics in the traditional software databases.

In big data set, seven 'V's (volume, variety, velocity, variability, veracity, visualisation and value) have huge importance (Fig. 1); (i) Volume: High volume (*viz*, hundreds of petabytes, thousands of terabytes) of low-density unstructured data to be analysed; (ii) Variety: Various types of data *viz,* traditional structured data, unstructured data, semi-structured data such as text, audio and video that require additional preprocessing to extract the meaning to support metadata; (iii) Velocity: operated with high velocity on real-time or near real-time evaluation of data; (iv) Variability: refers to the accurate sentiment analysis, *i.e.* algorithms are needed to find out the proper meaning of the phrase/word in a context, (v) Veracity: refers to the accuracy and reliability of the data, (vi) Visualisation: visual representation of data and information and (vii) Value: offers valuable knowledge (Uddin and Gupta, 2014).

The big data application finds importance in many fields *viz,* health sector, systems applications and products (SAP) in data science, economy, stock market, banking, credit card companies, insurance, big enterprises, data mining, data clustering, consumer goods, marketing, smart phones, telecom sector, agriculture and allied sectors, conservation, as well as in government sector. In agriculture and its allied sectors, big data is mainly applicable to precision agriculture and smart farming. In smart farming, smart machine and sensors-based technology generate huge data and its analyses are being done through artificial intelligence (AI). Big data analysis, helps in identifying issues related to farming and other socio-economic challenges; where a structured approach and the conceptual framework are intended for further analysis to tackle the problems (Wolfert *et al.,* 2017).

In this review we discuss the application of big data in fisheries sector covering major thrust areas, such as production, monitoring, conservation and climate change with emphasis on the scope and prospects of big data application in various sectors of inland fisheries.

Application of big data in fisheries

The fisheries sector has more importance in the global food basket in terms of animal protein intake. In the global scenario, total fish production was 178.5 million t

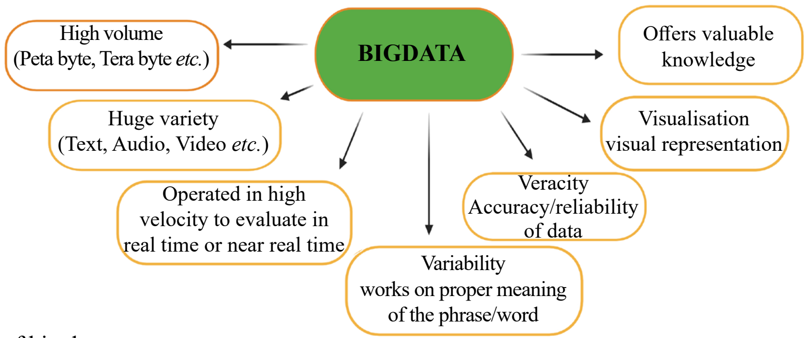

Fig. 1. Seven "V" concept of big data

in 2018, with capture fisheries contributing 96.4 million t and aquaculture sector producing 82.1 million t (FAO, 2020). Although fisheries is a 401 billion USD sector (FAO, 2020), still the use of big data in this sector is at its infant stage. Generally, fish biologists never used huge datasets; rather, they regularly generate dataset on fish biodiversity records, fish growth pattern, water quality parameters and catch data. These datasets can be collated to create a big data over spatial and temporal scales. Big data in the fisheries sector can be helpful for resource users, managers, researchers and other stakeholders to address comprehensive issues like effect of climate change, demarcation of barrier and land use management (Whittier *et al.,* 2016). Fig. 2 depicts some potential areas of big data application in the fisheries sector.

Application of big data in marine fisheries sector

Some sets of examples of big data analysis used by various agencies are orated in this segment. Basically, these are used to manage the global fishery with a prospective of conservation and sustainable use of natural resources.

Global fishing watch (GFW): Global fishing watch (https://globalfishingwatch.org) is a free platform, which delivers online admittance to a mammoth and near instantaneous data streaming from world's large fishing vessels. These data are useful for various ecosystem management prospects. The purpose of GFM is to create and publicly share knowledge about human activity at sea to ensure fair and sustainable use of ocean, which could help lead to fair and effective governance of marine resources in support of biodiversity and sustainable development. With advances in satellite technology, cloud computing and machine learning, an open-access picture of global fishing activity has been made a reality by GFW, which aims to monitor and visualise the impact of ocean-going vessels that are responsible for the majority of global seafood catch. GFM has revolutionised the

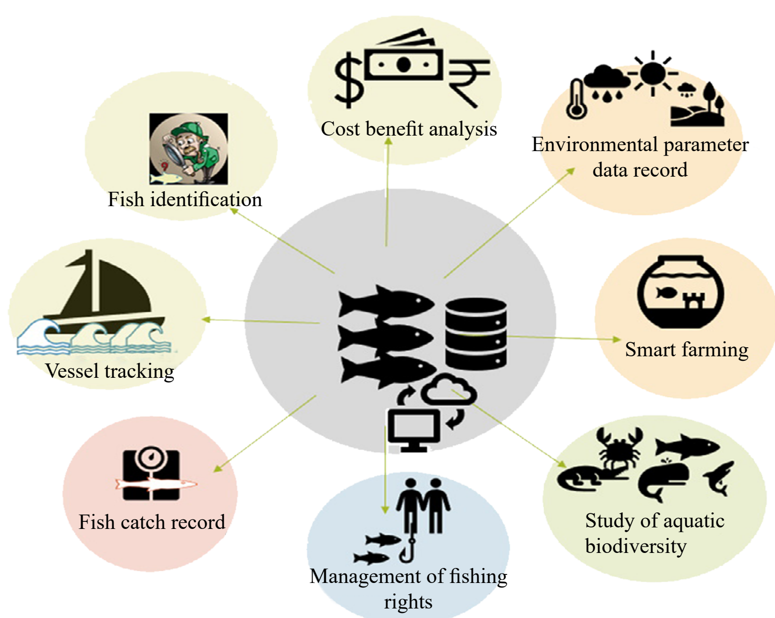

Fig. 2. Potential areas for big data application in fisheries

capacity to monitor commercial fishing, trans-shipment at sea, shipping and even forced labour abuses onboard vessels. The data and technology portals of GFM enables scientific research, support maritime protection and improve the way the ocean is managed.

eCatch: eCatch (https://www.ecatch.co.nz) allows users to catalogue related fisheries data in digital database rapidly, even at sea. Ultimately it reduces the need for expensive fisheries observers and allow the data collection at much finer spatial and temporal scales (Costello and Ovando, 2019).

DOLPHIN: Data for Oceanographic Learning and Fisheries Intelligence Needs (DOLPHIN) is a fisheries support service of CLS (Collecte Localisation Satellites). It comprises 20 years of fisheries data, including the oceanographic parameters which helps in optimising the fleet management, fisheries monitoring and vessel tracking. It uses various vessel monitoring and control techniques, such as fuel and gear sensors, cameras onboard, e-logbooks, traceability systems and VMS (Vessel monitoring system) transponders, for data collection. It also helps the fishers to decide the fishing area before leaving the harbour, helping them in terms of reducing the fuel cost and time meant for searching fishing ground. Also, the administrations monitor catch and effort over an entire region and decide which zone to close. Eventually, it helps in managing the stocks and issue of fishing license (https://fisheries.groupcls.com/big-data-the-future-of-sustainable-fisheries/; https://fisheries.groupcls.com/ fishermen/fisheries-intelligence).

Inspire Challenge Pilot Project by CGIAR (Consultative Group on International Agricultural Research): In this pilot project, 300 small boats were installed with vessel tracking device in Timor-Leste. The device transmits geospatial tracking/geotagged data through cellular networks to an open source. The cloud-based decision dashboard, the analytics and the machine learnings identify the specific fishing activities. The dashboard tracks the fishing activity with the quantity and type of fish caught by individual boats in near real time (https://bigdata.cgiar.org/inspire/inspire-challenge-2018/an-integrated-data-pipeline-for-smallscale-fisheries).

Application of big data in inland fisheries sector

Big data application is not only limited to the marine sector and its footprints are seen in the inland sector too. In the inland sector, big data is used in areas of fisheries management and resources conservation.

MARIS: MARIS is an US based agency that uses big data analysis to study the effect of climate change on the distribution pattern of fish species. It includes records of distribution pattern of more than 1000 fish species and water quality records over 24 states of the United States of America covering more than 1 million sampling sites. The big data in the form of "time series records of temperature of stream and river" are used to relate the fish diversity and distribution pattern. Also, big data analysis is used in fish passage studies to identify prospects for barrier removal, thus creating new habitat for the species, hampered by the habitat fragmentation. These data are also helpful for tracking the historical occurrence of fish species in specific drainages and changes of species distribution over time, occurrence of invasive species and their distribution. All these information are essentially helping to frame managing strategies by solving the queries regarding species reoccurrences, past populations and identifying species locations (Whittier *et al.,* 2016).

NorWeST: It is a collaborative project across the west America in which more than 100 agencies, fisheries biologists and hydrologists are involved. This project works on climate change effect on streams and inland fish resources. It includes different data types *i.e.* habitat surveys, water quality parameters and biological samples. The vulnerability assessment due to climate change is also covered (Isaak *et al.,* 2016; Whittier *et al.,* 2016).

Besides, several data mining tools have been used in the inland sector. Ver Hoef *et al.* (2014) developed a sophisticated spatial-stream network (SSN), an R package for spatial modeling of stream networks. McKenna Jr. *et al.* (2010) utilised the point temperature measurement from more than 3000 streams of New York to classify them according to the summer water temperature. Schlesinger *et al.* (2011) assessed the relative vulnerability of New York's Species of Greatest Conservation Need (SGCN) using NatureServe's Climate Change Vulnerability Index (CCVI), as vulnerability assessments are increasingly becoming an essential tool in climate change adaptation planning. Cold-water organisms are believed to be highly vulnerable to climate change impacts that can cause widespread extinctions of flora/fauna in mountain environments in response to temperature increases, environmental variability and invasions by non-native species. However, most of these predictions are based on small datasets. Employing large stream temperature and biological databases, Isaak *et al.* (2016) showed that habitats in mountain streams are highly resistant to temperature increases and that many populations of cold-water species exist, where they are well-buffered from climate change and there is hope that many native species dependent on cold water can persist this century and mountain landscapes will play an important role in their preservation

Traceability platform for aquatic food products

Yan *et al.* (2013), designed and developed a traceable platform of the aquatic foods supply chain using Tilapia as model, based on Radio Frequency Identification (RFID) and Electronic Product Code (EPC) Internet of Things, with focus on designing Object Name Service (ONS) and EPC Information Service (EPCIS) of this platform. This platform realises all-the-way traceability of aquatic products from breeding, processing, and distribution to sales.

Scope of big data in fisheries sector

Broadly prospective of big data application can be classified under four major aspects of fisheries *viz,* (i) fisheries management, (ii) conservation of resources, (iii) climate change and (iv) smart Farming/ enclosure culture.

Fisheries management

Basically, fisheries management is the major thrust area for big data applications. The AIS (Automatic Identification System) and fishing effort are universal traits for big data analysis. Most of the marine sector agencies like GFW, DOLPHIN and the Inspire Challenge Pilot Project by CGIAR are working in this area. The numerous data of the fishing vessels of different types are analysed and used mainly for the tracking of the fishing vessels and the area in which they operate. The analyses are helpful for different modes of responsible fishing aspects such as monitoring, control and surveillance (MCS), combating Illegal Unreported and Unregulated (IUU) fishing and vigilant on total allowable catch (TAC). Cabral *et al.* (2018) neatly addressed the efficiency of big data analysis to combat IUU fishing and described how Indonesian government used big data analysis to check IUU fishing and also achieved 25% reduction in total fishing efforts. For the quantification of the illegal fishing, they have used different types of data such as the AIS by GFW, the satellite data of night light and the VMS information. Guan and Zhao (2021) have described about big data-based shrimp fishery regulation in East China Sea. The shrimp fishing boats of East China Sea were regulated through firm record of fishing trajectories and behaviour of fishing and with the help of Back Propagation algorithm, these data were used to predict distribution of shrimp farms along East China Sea. Big data analysis has also been used to enforce a right to fishing in EEZs (Exclusive Economic Zones), smaller TURF (Territorial User Rights Fisheries) to monitor their borders by deploying enforcement assets in a beneficial manner (Costello and Ovando, 2019). Mapping of fishing effort in higher resolution in spatial and temporal scales were executed based on AIS data and also through individual AIS data and speed of vessel (Natale *et al.,* 2015). Through the AIS data, a detailed study was carried out by Kroodsma *et al.* (2018); who gave a neat illustration about the spatial fishing operations across the globe with different types of fishing gear, length of fishing vessels, area and depth of fishing operation as well as details on closed holiday/festive period. Along with this, they have differentiated fishing operations with fishing and non-fishing vessels, non-Chinese and Chinese fishing vessels and have also correlated fishing operations with fuel consumption.

The AIS and VMS data analyses are not confined to the classical vessel tracking and real time monitoring of vessels and researchers used them in numerous ways. Sala *et al.* (2018) used them to analyse profitability of fishing vessel in high seas globally. Big data analysis showed that about 54% of high sea fishing vessels are unprofitable and only the subsidised deep-sea fishing vessel operation is profitable.

Conservation of resources

Though the fisheries management aspects are aiming for the sustainable use and conservation of the natural resources, still some authors have opined about the use of big data analysis in conservation aspects such as marine protected areas. McDermott *et al.* (2019) had figured out about the rise in pre-emptive overfishing of up to 65 to 72% in the Phoenix Islands Protected Area (PIPA) marine reserve before the onset of the fishing banning period using the fishing effort and satellite data; also concerned about the existing policies for conservation of natural resources. Runting *et al.* (2020) advocated on use of big data analysis for environmental decision-making process for sustainable uses of natural resources. Now a days, the NRM (Natural Resources Manager) has shifted the focus on environmental DNA (eDNA) studies for conservation types of study. The eDNA atlas databases (Young *et al.* 2018) have shown a new path in comprehensive study of species distribution, assessment and constraints faced by them in their habitat (Elith and Leathwick, 2009; Loftus and Flather, 2012; Isaak *et al.,* 2018). Besides this, the big data analysis approach needs a special acknowledgement for updating and maintaining the databases of different organisms in a timely manner (Graf and Cummings, 2021).

Climate change

Data from various interdisciplinary observations such as remote sensing, huge earth observatory and climate change simulation models are used to predict the impact of climate change (Zhang and Li, 2020a; 2019). Both quantitative numeral data (such as precipitation and temperature) and the qualitative land type or various categories of the qualitative data (Zhang and Li, 2020a, b) have been used for vulnerability assessment by helping in decision making process for the climate change preparedness (Ford *et al.,* 2016).

Smart farming

Food safety and quality of food products is highly concerned towards public health. Quality of food products is one of the bottlenecks in sustainable foreign trade. Farmers particularly in the developing nations lose money and products for not matching with the quality protocols for the consignments in export trade. For maintaining the quality of the aquatic food supply and to trace the origin, different electronic markers such as RFID, EPC, ONS and EPCIS have been developed and the use of these digital markers starts with aquaculture management through process and distribution management systems in smart farming. From the initial breeding stage to storing, the RFID tags are used and later the packaged products are marketed with bar codes (EPC) (Yan *et al.,* 2013).

Prospects of big data application in inland fisheries sector in India

In India, inland sector provides a lion's share in fish production of about 10.43 million t, out of the total fish production of 14.16 million t (https://dof.gov.in/sites/default/files/2021-02/Final_Book.pdf). Inland sector of India is bestowed with vast open water resources like 45000 km of rivers, 0.3 million ha of estuaries, 0.19 million ha of backwaters and lagoons, 3.524 million ha reservoirs, 0.354 million ha of floodplain wetlands and 0.72 million ha of upland lakes (http://www.cifri.res.in/AR/Annual%20Report%202020.pdf), apart from the individual ponds/farms owned by the fish farmers. The open water resources offer a great potential for increasing fish production through community and culture-based fisheries management, including cage aquaculture. Application of big data will help in harnessing the potential fish production from inland open water resources. The bigdata driven precision aquaculture/smart aquaculture practices can be effectively used for inland fish cage culture, where big data can play a pivotal role. It aims to apply controlled engineering principles for fish production and subsequently, to improve the ability of fishers to monitor, control and document biological processes. The surveillance includes biomass monitoring, control of feed delivery, fish disease monitoring and management of crowding in cage culture. Big data application can also be used for vessel tracking in inland rivers, reservoirs and lakes and can also be used to stop illegal fishing in the protected zones of inland waters. In India, the "River Information System (RIS)" has been implemented to track the vessel navigation in rivers for transportation purposes in inland water ways (IWAI, 2021). The same system can be used for tracking the vessels engaged in fishing activity in inland waterbodies. Through the vessel tracking system, vessel position, vessel route and the speed of the vessel can be recorded, which are very much useful to monitor activities of the vessels. Also, like the marine sector, the geo-reference coordinate maps can be installed in the inland fishing boats GPS systems, through which the fishers can identify the no fishing zones and the protected water bodies during fishing related activities (Fig. 3). Besides, big data can be applied to analyse the fishing pressure in different areas/zones, for regulating fishing operations.

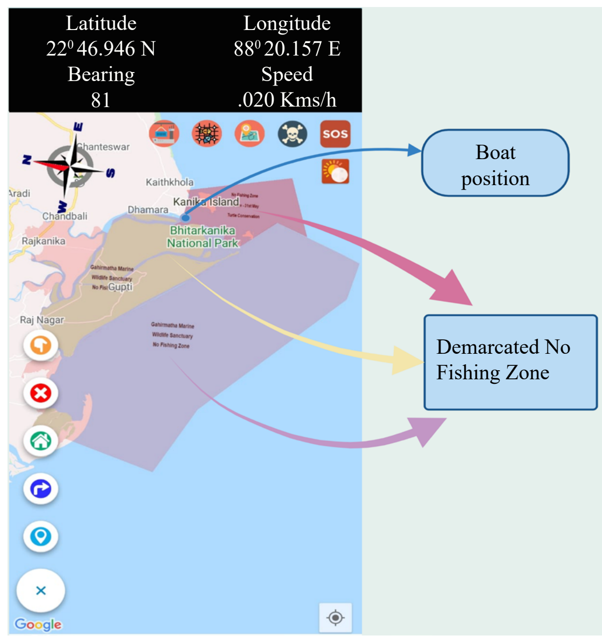

Fig. 3. Areas marked as no fishing zone in different colours for wild life sanctuary, marine sanctuary and for turtle conservation with geo-reference coordinates. Boats having GPS facility can know their position and also can refrain themselves to enter into no fishing zone.

Conclusions

Harnessing big data technology is an important innovation that can play a huge role in fishery sustainability and will be increasingly relevant for real time measures of fish stock health and management interventions. In fisheries, bigdata application suggests an ample scope towards ecosystem-based fisheries management. The outcomes subsequently go towards the fulfilment of Sustainable Development Goal 14 (SDG 14): Life below water by conservation of the habitat, managing the fishery, restricting overfishing as well as IUU fishing to some extent. Also, the big-data enabled smart farming systems could enhance the productivity and production from cage culture in inland waters. The big data application could also help to combat the climate change effect on inland fish production and to take necessary steps for the conservation of fish diversity. The proper and the need-based use of big data is highly required in inland fisheries sector which could serve as a blessing to mankind for management of inland aquatic ecosystem. Therefore, policy frame work for its application in inland fisheries for production enhancement and monitoring of vessels is the need of the hour.

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