Research Article

Construction of Ecological Environment Information System Based on Big Data: A Case Study on Dongting Lake Ecological Area

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With the rapid development of cloud computing, Internet of Things, and other technologies, the information technology trend led by “big data” has an impact on all fields. The application of big data technology in the field of ecological environmental protection enables accurate and comprehensive ecological information collection, data analysis, and mining, accurate ecological problem identification, and effective solution. Taking Dongting Lake Ecological Area as an example, this paper constructs an ecological environment information system based on big data and expounds its specific application in water, atmosphere, soil environment monitoring, and pollution control, aiming to provide a reference for the application of big data technology in the field of ecological environment protection in Dongting Lake Ecological Area and more effectively maintain the ecological environmental quality and safety in the area.

1. Introduction

With the rapid development of cloud computing, Internet of Things, and other technologies, the information technology trend led by “big data” is sweeping in. The emergence of big data technology is closely related to the substantial improvement of the ability of modern information technology in information exchange, storage, processing, and so on. Because of the characteristics of large data scale, complex data categories, and fast data processing speed, big data technology has been widely used in finance, e-commerce, healthcare, public management, and other industries [1] and can provide new thoughts for the monitoring and analysis of ecological environmental problems [2].

In the field of ecological environment, big data technology can quickly collect and obtain massive, multi-category, and multitype data through sensors, satellite remote sensing, Internet, and other technologies [1, 3], while traditional ecological environmental data can only be collected manually, which consumes a lot of manpower, material resources, and time, and the data collected are disorderly, inaccurate, and isolated. In addition, big data

technology can process and analyze the ecological environmental data collected, centralize and upload the data to the database, build a complete ecological environmental big data system, and maximize the application value of ecological environmental data through the integration and sharing of data resources.

Dongting Lake is the second largest freshwater lake in China, and its basin spans Hunan and Hubei provinces, which are known as “land of fish and rice.” As an important wetland, storage lake, and freshwater reserve in the middle and lower reaches of the Yangtze River, Dongting Lake bears the great responsibilities of ecological security, water security, and national food security in the Yangtze River basin [4]. However, due to the huge pressure of economic growth and population growth, ecological problems such as flood disasters, soil erosion, and wetland degradation in the Dongting Lake area have become increasingly serious [5]. In recent years, many scholars have adopted various methods to evaluate the carrying capacity [6, 7], ecological risks [8, 9], ecological compensation [10, 11], and so on, aiming to provide references for the ecological environment protection of the Dongting Lake. However, most of the existing

research adopted traditional research methods, such as qualitative discussion and correlation analysis. The utilization rate of modern information technology, especially big data technology, is very low. Applying big data technology to ecological environment protection not only expands the spatial scope of the research area but also improves the availability, accuracy, and quantity of data, making the analysis results more valuable. Therefore, this paper constructed an ecological environment information system based on big data technology for Dongting Lake, hoping to provide references for the future ecological environment detection and protection of Dongting Lake.

2. Current Situation and Deficiencies of Ecological Environment Information Network Construction in Dongting Lake Ecological Area

2.1. Overview of the Researched Area. Dongting Lake Ecological Area is mainly located in Hunan Province, with a watershed area of about 25.7 km² and a land area of 27260 km², displaying a U-shaped lake. The area is mainly composed of mountains, plains, and hills, with an annual average temperature of 16-17°C and annual precipitation of more than 1200 mm. It has the characteristics of subtropical monsoon climate, such as warm climate, four distinct seasons, sufficient heat, and high temporal concentration of precipitation. Dongting Lake has a very strong storage regulation capacity and accounts for 1/3 of the total annual runoff of the Yangtze River. At the end of the 18th century, due to the comprehensive effects of human activities and natural factors, the evolution trend of the lake was intensified, and the lake basin was gradually raised. At present, the lake basin is divided into three parts: the west, the south, and the east, covering natural and artificial wetlands. In the 1990s, several national nature reserves and provincial nature reserves were built in Dongting Lake in order to protect wetland ecology, rare birds, and so on.

2.2. Current Situation and Deficiencies of Ecological Environment Information Network Construction. With respect to the construction of ecological environment information network, at present, Hunan Province has preliminarily established a real-time data release system for water quality and air quality, which enables real-time release of water quality and air quality information of 14 cities (prefectures), including cities and counties within the Dongting Lake Area, mainly through the official website of the Ecology and Environment Department of Hunan. With respect to water quality, the system mainly publishes real-time data of surface water quality monitoring, including water quality category, pH value, water temperature, dissolved oxygen, and electrical conductivity (as shown in Figure 1). With respect to air quality, it mainly publishes the air quality index (AQI), air quality grade, and primary pollutant of 14 cities (prefectures) on the day and the next day and ranks AQI by city (prefecture) and county (city; district), respectively, in order to compare the air quality of different regions (as shown in Figure 2).

By publishing real-time data of environmental quality in the province, including Dongting Lake Area, the website of the Ecology and Environment Department of Hunan has realized the data sharing of regional water and atmospheric environmental quality and can provide basic data and information for the public and society to know the regional environmental quality in time. However, the construction of information network is not perfect as a whole, which is mainly reflected in two aspects: (1) the capacity of information is low and not comprehensive enough, the data are limited to water quality and air quality, the soil quality information is absent, and the indicators of water quality and air quality are insufficient; (2) deep data analysis and mining are insufficient. The information is simply released, with no comprehensive integrated introduction of regional ecological environmental quality data, nor a display of relevant research results.

The information-sharing platform is the sharing platform and information terminal of the information system. Only with its good construction and mature application can we really break the information silo effect and give full play to the resource value of massive data. Therefore, researchers need to constantly explore and dig omnidirectional, high-precision information data and build a complete and systematic ecological environment information system, which cannot be done without the effective use of big data technology. Although big data technology is only in its infancy in the field of ecological environment, as a technology with massive data and information-based mindset, it has unique advantages such as massive volume, variety, velocity, value, and veracity [3, 12]; it is necessary to make full use of big data mindset and technology to establish a systematic ecological environment information system and drive the overall development of information technology [13].

3. Ecological Environment Big Data Technology System

3.1. Big Data Collection Technology. The ecological environment big data are collected by sensors, satellite remote sensing, Internet, and other technical means, and with the continuous development of science and technology, the continuous deepening of related technology research, and the continuous improvement of the informatization level, the ecological environment big data obtained have become more sophisticated, diversified, and accurate. At present, the ecological environment big data mainly include ground monitoring data, satellite remote sensing monitoring data, geographic information data, and social statistics, as shown in Table 1. As an important big data acquisition technology, satellite remote sensing technology uses ground remote sensing and aerial remote sensing to collect spatial information and reproduce the current ecological and environmental situation in the region in a three-dimensional way to give people an intuitive and clear information experience. Typical big data organization and management modes include NASA's EOSDIS image big data grid organization technology [14–16], Google's global massive spatial big data grid organization technology [16–18], and ArcSDE's spatial data grid index technology [16, 19].

FIGURE 1: Real-time data release system for automatic monitoring of surface water quality in Hunan Province on the website of the Ecology and Environment Department of Hunan.

Ranking	City/Prefecture	AQI	Air Quality	Primary Pollutant
1	Changde City	68	Good	PM10
2	Zhuzhou City	72	Good	PM2.5
3	Changsha City	95	Good	PM2.5
4	Xiangtan City	107	Light Pollution	PM2.5
5	Chenzhou City	18	Excellent	-
6	Hengyang City	30	Excellent	-
7	Xiangxi Autonomous Prefecture	40	Excellent	-

Ranking	City/Prefecture	AQI	Air Quality	Primary Pollutant
1	Chenzhou City	22	Excellent	-
2	Hengyang City	29	Excellent	-
3	Loudi City	32	Excellent	-
4	Yongzhou City	33	Excellent	-
5	Zhangjiajie City	36	Excellent	-
6	Shaoyang City	37	Excellent	-
7	Xiangxi Autonomous Prefecture	40	Excellent	-
8	Huaihua City	42	Excellent	-

FIGURE 2: Air quality information release platform on the website of the Ecology and Environment Department of Hunan.

TABLE 1: Application of big data in the ecological environment.

Type	Content	Application
Ground monitoring data	Land and hydrological indicators such as hydrology, soil, microorganisms, meteorology, animals, and plants	Ecological environmental monitoring and assessment
Remote sensing monitoring data	Topography, land surface temperature, vegetation, humidity, and so on	Ecological environment monitoring and assessment
Social statistics	Per capita GDP, population density, administrative area, land reclamation rate, and so on	Ecological environmental assessment
Internet data	Websites, forums, WeChat, and so on	Public supervision
Geographic information data	Field collection, space remote sensing collection, and so on	Ecological environment assessment

3.2. Big Data Processing Technology. Based on the data collected, big data processing technology employs a variety of processing methods to realize the integration, analysis, and interpretation of the data, so as to provide support for the ecological environment protection work and urge relevant personnel to formulate feasible plans for the management of the ecological environment and the prevention and control of ecological pollution in a better way. Big data come from a wide range of sources, and the data types and

processing methods are very different. Some scholars [20] claim that data processing can be divided into four stages: collection, processing integration, analysis, and interpretation; some other scholars [21] divide it into four stages: preprocessing after collection, storage, analysis, and visualization. Combining the diversified characteristics of big data technology, this paper divides ecological environment big data flow into three parts: preprocessing, deep processing, and deep mining.

4. Construction of the Dongting Lake Area Ecological Environment Information System Based on Big Data

4.1. Overall Framework of the Ecological Environment Information System. For the construction of the Dongting Lake Area Ecological Environment Information System, it is necessary to first determine the overall architecture of the system and build a reasonable “skeleton” before adding “flesh and blood” on this basis. Combining the existing ecological environmental information system and the application of related advanced technologies, this study constructs an ecological environmental information system framework composed of five parts: (1) perception network: focusing on the improvement of the ecological environment monitoring Internet of Things (IoT) and the construction of the ecological environment IoT management platform, following the development of the times, timely updating the perception network, and building a new modern system; (2) cloud services: making full use of big data technology to build an ecological environment big data cloud service platform, focusing on building information infrastructure, improving the level of network security, and realizing the development of ecological environment business on the cloud platform; (3) data center: upgrading the original data center to the ecological environmental data resource center, sorting out and integrating the ecological environment data in the region, standardizing the whole process of data collection, processing, and analysis, and improving the rules and regulations of data management; (4) information platform: building a comprehensive office information platform that integrates all the contents of environmental monitoring, supervision, and service, standardizing the management of departments, and improving work efficiency so as to effectively communicate and share information among various departments; (5) governing body: establishing comprehensive supervision, real-time supervision, and mobile supervision institutions with professional management personnel, effectively managing the working structure of the entire information system, guiding ecological environmental supervision in a reasonable direction, and formulating reasonable and effective ecological environmental monitoring and pollution control plans.

4.2. Technological Process of Ecological Environment Information System Construction. As a new information technology, big data can also be supplemented by traditional scientific data collection methods to obtain more sophisticated and representative data [22]. More importantly, the ecological environment big data can organically integrate multisource heterogeneous data [23]. The big data flow of Dongting Lake Area Ecological Environment Information System is mainly divided into three parts: big data collection, big data processing, and big data analysis (as shown in Figure 3). The specific analysis is as follows.

4.3. Big Data Collection. First, clarify the data source; that is, determine the channel through which the data is collected. Second, collect relevant data through technical means such

as sensors, satellite remote sensing, and the Internet of Things. The data used in this paper includes social statistical data, such as the data owned by the ecological environment authority, data related to the environment, and other municipal government department data; satellite remote sensing data, such as land use types and NPP; ground monitoring data, such as water quality monitoring data and pollution source monitoring data; geographic information data, such as ground elevation, longitude, and latitude of the study area; other data, such as on-site sampling data. Aiming at different data sources and data formats, this paper adopts ETL software to collect data.

ETL, or data warehouse technology, is used to describe the process of data extraction, transformation, and loading from the source to the destination. First, collect relevant data on the water environment, soil environment, and atmospheric environment of the Dongting Lake wetland through network downloads, official website queries, online purchases, and so on and establish a database; then use ETL software to keep the data in the table or view in the data source intact. The ground is extracted from the database; then the ETL engine is used to complete the data conversion and processing; finally, the SQL statement is used to insert, update, and delete operations, and the converted and processed data are loaded into the destination database [24].

In addition, the data collection should be organized and carried out step by step, and the data should not be collected repeatedly, so as to avoid data confusion and increasing workload of subsequent data processing.

4.4. Big Data Processing. Big data flow includes three parts: preprocessing, deep processing, and deep mining, so as to provide intuitive, accurate, and concise data.

Big data preprocessing refers to the simple processing of the collected data, such as integrating all the data, roughly arranging the data, and deleting invalid data and out-of-date data.

On the basis of pretreatment, the data are classified and sorted according to the classification standards of water environmental quality data, soil environmental quality data, and atmospheric environmental quality data. Mark the data with important value; check data errors. If there are unreasonable data or redundant data, the data need to be amended and deleted in time. Clarify data attributes, aggregate the data that are highly related to the ecological environment, and sort out the lowly related data for separate processing. By basic calculation means, the data are preliminarily processed to obtain preliminary calculation results, laying a solid foundation for subsequent analysis.

Big data deep mining is the most complex and important part of big data processing flow. It makes full use of big data, cloud computing, Internet, and other technologies to dig effective information, dig the information contained in the data under the guidance of ecological environment knowledge, and provide intuitive, accurate, and more targeted data for the following data analysis by means of real-time calculation and offline calculation, so as to reduce the data processing load and improve the data processing efficiency and accuracy.

FIGURE 3: Ecological environment big data technology system framework.

4.5. Big Data Analysis. Big data analysis is the most critical part of big data processing flow and an important means of comprehensive data utilization. In the big data analysis process, a variety of analysis methods, such as analogy analysis and correlation analysis, can be used. Models can be constructed by various algorithms to analyze the governance, pollution, distribution, and other circumstances of water environment, soil environment, atmospheric environment, and other environmental elements, so as to transform massive data into ecological information needed by relevant personnel and to provide support for their decision-making. Data analysts must start from an objective perspective, adopt professional data analysis methods, and take advantage of a variety of technical means to analyze the data and fully exploit their value.

5. Application of the Ecological Environment Information System to Dongting Lake Ecological Zone

Ecological environment big data are listed as an important part of the national development strategy in China [25]. The Ministry of Ecology and Environment has launched an ecological environmental big data and environmental protection cloud construction initiative, and the ecological environmental monitoring network systems established involve a variety of monitoring items and have comprehensive coverage. The monitoring network systems listed in Table 2 cover atmospheric, freshwater, seawater, acoustic environment, and ionizing/electromagnetic radiation environment, with a large number of densely distributed monitoring points, including 1940 surface water quality sections (points), 1436 urban atmospheric environment monitoring points, and 2583 ecological environmental quality monitoring points [26]. Regionally, Fujian, Inner Mongolia, and Shandong have launched ecological environment big data-related construction projects [3].

Dongting Lake is of great significance to water security and flood control, national food security, and ecological security in the Yangtze River basin [4]. On December 3, 2018, the National Development and Reform Commission and other six ministries jointly issued the *Dongting Lake Water Environment Comprehensive Governance Plan*, marking the rise of the Dongting Lake water environment governance plan to a national major plan. As Dongting Lake Area is a “land of fish and rice” in the middle and lower reaches of the Yangtze River, the soil quality in the area is closely related to grain yield and quality, which cannot be ignored. In addition, the atmospheric environment quality is also an important part of the living environment quality for the residents in the lake area. Therefore, the ecological environment information system based on big data technology is applied to the Dongting Lake Ecological Area to assess and monitor the water quality and soil and air PM2.5 content of the Dongting Lake basin and analyze the spatial distribution characteristics of the water quality in the Dongting Lake area, the source of water pollutants, soil heavy metal pollution, PM2.5 content, and main sources which are of important reference value for formulating water, soil, and air pollution prevention and control plans.

5.1. Water Environment Monitoring and Pollution Control System in Dongting Lake Ecological Area. By applying big data technology, it is possible to evaluate the water quality and analyze the pollution sources in Dongting Lake.

5.1.1. Groundwater Quality of Dongting Lake. On-site sampling of groundwater and surface water in some farming areas, residential breeding areas, residential areas, and other places in the Dongting Lake Plain. 213 sampling points are evenly distributed in the Dongting Lake Plain; then the main cations, anions, and trace elements in the water are measured. We use the evaluation index system in GB/T14848

TABLE 2: National ecological environment monitoring network systems established by the Ministry of Ecology and Environment [26].

Monitoring category	Monitoring points	Quantity
Atmospheric environment	Urban monitoring point	1436
	Precipitation monitoring point	1000
Freshwater environment	Surface water quality section (point)	1940
	Centralized drinking water source monitoring section (point)	906
Seawater environment	National quality control monitoring point	1649
Acoustic environment	Urban monitoring point	About 80 000
Ionizing radiation environment	Environmental ionizing radiation monitoring point	1410
Electromagnetic radiation environment	Environmental electromagnetic radiation monitoring point	44
Ecological environment	Ecological environmental quality monitoring point	2583

“Groundwater Quality Standard” to evaluate the groundwater quality. The measurement results show that the PH value of the shallow groundwater in the upper reaches of Dongting Lake is between 6.25 and 8, and the conductivity is between 40 and 815 $\mu\text{S}/\text{cm}$. It is mineralized freshwater, and the nitrate in the shallow groundwater in farming areas and residential breeding areas exceeds the standard. The shallow groundwater in the upper reaches of Dongting Lake has a large area of metal (iron, manganese, and lead) pollution and man-made pollution.

5.1.2. Spatial Distribution of Groundwater Quality in Dongting Lake Ecological Zone. The “spatial analysis module” in ArcGIS is used to interpolate the data of each sampling point. The interpolation method is Kriging interpolation, and the interpolation result is shown in Figure 4. It can be seen from Figure 4 that the iron pollution in the western and northwestern parts of the Dongting Lake Plain is obviously more serious than in other areas, while the cadmium pollution in parts of the southeast and western parts is obviously more serious than in other areas. The whole area of Dongting Lake is more polluted by manganese and arsenic. The water quality in most areas is classified into four and three categories.

5.1.3. Analysis of Water Pollution and Main Sources of Pollutants in Dongting Lake. Dongting Lake accepts the inflow of water from Hunan, Zi, Yuan, and Li (four waters for short) and Songzikou, Taipingkou, and Ouchikou (three for short) of the Yangtze River, forming an intricate relationship between rivers and lakes, rivers, and lakes. The general water flow direction is West Dongting Lake $\rightarrow$ South Dongting Lake $\rightarrow$ East Dongting Lake $\rightarrow$ Yangtze River [27]. Through field collection of 3 lake entrance sections (Shahekou, Potou, and Wanjiazui of Sishui), 5 lake body sections (Jiangjiazui, Hengling Lake, Yugong Temple, Yueyang Tower, and Xiaohezui), 1 outlet, the water quality data of the Hukou section (the exit of Dongting Lake) researches the pollutants in the water body of Dongting Lake and infers the sources of the main pollutants. The analysis results show that the average value of total phosphorus (TP) pollutants at the entrance of Dongting Lake is 0.135 mg/L, the total nitrogen (TN) pollutants at the Yugongmiao section are higher, at 2.745 mg/L, and the TP pollution at the Potou section is higher. The

content is low, 1.243 mg/L. Since the section of Yugong Temple is located where Xiangjiang River enters Dongting Lake, the TN pollution of Dongting Lake is likely to come from Xiangjiang River. Secondly, Dongting Lake has developed agriculture and a large population, so the livestock and poultry breeding industry and residents’ sewage discharge are also the main sources of TN and TP pollutants in Dongting Lake.

5.2. Soil Heavy Metal Pollution Analysis in Dongting Lake Ecological Zone. The Xiangjiang River is one of the main supply rivers of Dongting Lake. Because the Xiangjiang River flows through Hunan, the hometown of nonferrous metals, the water environment of the Xiangjiang River presents more serious heavy metal pollution characteristics [28], which leads to serious heavy metal pollution in Dongting Lake [28, 29]. Nowadays, with the increase of research on heavy metal pollution and people’s understanding of the harm of heavy metal pollution, more and more researches have begun to focus on the subject of soil heavy metal pollution [30–32]. In this paper, through field data collection and related calculations, the soil heavy metal pollution in the Dongting Lake Ecological Area is studied.

15 sampling points were selected around the Dongting Lake area, a total of 78 surface soil (0–30 cm) samples were collected, and 10 parallel samples were collected at each sampling point. After that, the soil samples were dried, ground, digested, and dissolved to study the Pb, Cd, Hg, As, and Cu metal elements in the soil of the Dongting Lake ecological zone. Data analysis results show that the average content of Cd and As heavy metal elements in the West Dongting Lake, South Dongting Lake, and East Dongting Lake is higher than the soil environmental background value of the study area and soil risk screening value of farm land in “Soil Environmental Quality Standard” (GB15618-2018). The average content of Pb, Hg, and Cu is higher than the soil risk screening value of farm land in the “Soil Environmental Quality Standard” (GB15618-2018). The maximum pollution value of Cd, Hg, As, and Cu is in South Dongting Lake, and the maximum pollution value of Pb is in East Dongting Lake, indicating that South Dongting Lake and East Dongting Lake are key areas of heavy metal pollution.

5.3. PM_{2.5} Monitoring and Source Analysis of Dongting Lake Ecological Zone. Due to its special geographical and climatic conditions, industrial structure, and urban development

FIGURE 4: Spatial distribution map of groundwater quality in the Dongting Lake Area.

planning restrictions, Dongting Lake suffers serious PM_{2.5} pollution in autumn and winter. Therefore, this paper takes Yiyang City, Hunan Province, as an example and studies the PM_{2.5} distribution and causes of the Dongting Lake ecological zone based on the constructed big data ecological environment information system.

This paper uses Qingdao Laoshan Electronics KC-1000 sampler to collect PM_{2.5} in the air, sampling once every two days, and the sampling time is from 9:00 on the n th day to 8:30 on the $n + 2$ day. A total of 58 effective PM_{2.5} samples were collected continuously for four months from September to December 2019. The analysis results show that the mass

concentration of PM_{2.5} in Yiyang City in autumn and winter is $46 \pm 18 \mu\text{g}/\text{m}^3$, and the variation range is 13–123 $\mu\text{g}/\text{m}^3$, indicating that the PM_{2.5} content in the air in Yiyang City is relatively high and the air pollution is more serious.

Yiyang City is an urban industrial layout with the typical characteristics: “the park is in the city, the city is in the park, and there are chimneys all around.” A large number of companies with serious pollution, such as thermal power plants, garbage incineration plants, and sintered brick factories, have gathered at the transmission port where the northwest wind prevails all the year round. Even though some of these companies have achieved clean production, the overall pollution emissions are relatively large. The surrounding air pollution is more serious and is the main source of PM_{2.5}. In addition, there are many industrial boilers (mainly biomass fuels), kiln emission sources, rare earth smelting, detergent production, and other enterprises in the urban area of Yiyang. These enterprises emit large amounts of nitrogen oxides and particulate pollutants. The pollutants emitted by these enterprises are the main source of PM_{2.5}. However, relevant data show that the PM_{2.5} concentrations in Yiyang City have a downward trend year by year, from 53 $\mu\text{g}/\text{m}^3$ in 2018 to 43 $\mu\text{g}/\text{m}^3$ in 2020 [33]. This shows that the series of measures taken by Yiyang City to prevent and control PM_{2.5} have achieved significant results, such as the development of clean energy, promotion of enterprise transformation and upgrading, rectification, and shutdown of high-polluting enterprises.

6. Conclusions

With the continuous development of information technology, big data technology is playing an increasingly important role in the field of the ecological environment. The use of big data technology is conducive to real-time monitoring of ecological environment areas and full exploitation of useful ecological information to effectively prevent and control ecological pollution. For Dongting Lake Ecological Area, the construction of the ecological environmental information system based on big data can improve the construction and implementation of the ecological environmental management information system in the area and lay a solid foundation for subsequent pollution prevention and control work. With the ecological environmental information system based on big data, the monitoring data in the ecological area can be collected, processed, and analyzed collectively to formulate more effective environmental protection policies accordingly, improve the environmental management, and optimize the ecological environment in Dongting Lake Ecological Area. In the future, it is necessary to establish relatively comprehensive ecological environment big data and build a more mature ecological environment information network, so as to provide more powerful support for the governance of the ecological environment in the Dongting Lake area.

Data Availability

The data used in this paper is statistical data, sampling data, and literature data. Statistical data can be accessed in <http://sthjt.hunan.gov.cn/sthjt/xxgk/index.html>. Literature data can be accessed in the literature cited in the paper. There are no restrictions on data access.

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Conflicts of Interest

The authors declare no conflicts of interest.

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