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Article · April 2023

DOI: 10.5281/zenodo.7878771

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HBRP PUBLICATION

Journal of Water Resource Research and Development
Volume 6 Issue 1
DOI: https://doi.org/10.5281/zenodo.7878771

Water Resource Management Using Artificial Intelligence Enabled RS & GIS

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ABSTRACT
Research and applications of RS & GIS in water resources management were practiced in the last two decades. The pitfalls and shortcomings of GIS technology can be minimized by artificial intelligence. Artificial intelligence (AI)-based techniques have become more prevalent in recent years because of the most appropriate applications with precision. Compared to sectors like energy, healthcare, or transportation, the usage of AI-based techniques in the water domain is comparatively modest. This paper reviews current AI applications for managing water resources and offers some speculative applications for AI in tandem with GIS technology. It outlines the step-by-step implementation of GIS technology with AI for managing water resources. Finally, the future of AI-GIS technology for managing water resources is examined.

Keywords:-*AI, GIS, DSS, GeoAI, predictive modelling, data integration.*

ABBREVIATIONS

RS : Remote Sensing
GIS : Geographical Information System
AI : Artificial Intelligence
GIS : Geographic Information System
ANI : Artificial Narrow Intelligence
AGI : Artificial General Intelligence
ASI : Artificial Super Intelligence
IoT : Internet of Things
DSS : Decision Support System
ESRI : Environmental Systems Research Institute
GeoAI : Geospatial Artificial Intelligence

INTRODUCION

Water resource management is the process of planning, developing, distributing, and managing water resources for optimal usage.[1] Water resource management also entails managing water-related risks, including floods, drought, and contamination (World Bank, 2017). Water resources management is a complex problem even today as it involves whole water cycle incorporating activities carried out by humans. The factors affecting water resources management are climatic conditions, geography, precipitation, ecosystem, runoff, and utilization of it before it accumulates in oceans. Integrated water resources management system involves four basic steps, (i) availability of total water (ii) managing events related to water resources (i.e., losses, flood, draught, landslide etc.) (iii) Utilization of

Journal of Water Resource Research and Development
Volume 6 Issue 1
DOI: https://doi.org/10.5281/zenodo.7878771

water by various stockholders (iv) decision making based on technical, engineering, economical and policies related to water resources.

AI INTRODUCTION

AI (Artificial Intelligence) is a branch of computer science that focuses on the development of intelligent machines that can perform tasks that typically require human intelligence, such as visual perception, speech recognition, decision-making, and language translation. AI systems can learn from experience, adapt to new situations, and improve their performance over time.

AI is based on the idea of creating machines that can simulate human thought processes, such as reasoning, learning, and problem-solving. These machines use algorithms, statistical models, and deep learning techniques to analyse large amounts of data, identify patterns, and make predictions. There are three main types of AI, which is depicted in figure-1.[1]

Artificial Narrow Intelligence (ANI) or Weak AI: ANI is intended to perform a specific task, such as playing chess or translating languages. These systems are focused on solving one particular problem and are not capable of generalizing to new problems.

Artificial General Intelligence (AGI) or Strong AI: AGI is intended to perform any intellectual task that a human can do. These systems can reason, learn, and adapt to new situations, and are capable of generalizing to new problems.

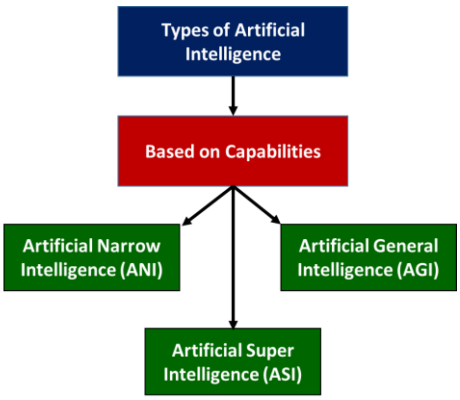

Fig.1:-*Classification of AI based on capabilities (Ref: https://chat.openai.com/)*

Artificial Super Intelligence (ASI): ASI is a hypothetical level of intelligence that surpasses human intelligence in every aspect.

AI has the potential to transform various fields, including healthcare, finance, transportation, and energy, by enabling automation, improving efficiency, and unlocking new insights from data. However, there are also concerns about the ethical implications of AI, such as bias, privacy, and job displacement.

GIS INTRODUCTION

GIS (Geographic Information System) is a computer-based tool that allows users to store, manage, analyse, and visualize geospatial data. GIS can combine different types of data, such as satellite imagery, maps, and demographic information, to provide a better understanding of the geographic relationships between different phenomena. Figure -2 describes the transformation of real-world problem to segregated raster to vector thematic maps and data set generated out of it.

GIS software is designed to manage and process spatial data using spatial analysis

Journal of Water Resource Research and Development
Volume 6 Issue 1
DOI: https://doi.org/10.5281/zenodo.7878771

tools, including overlay analysis, buffer analysis, and proximity analysis. This allows users to identify patterns, relationships, and trends in the data, and make informed decisions about a variety of topics, such as land use planning, natural resource management, emergency response, and urban design.

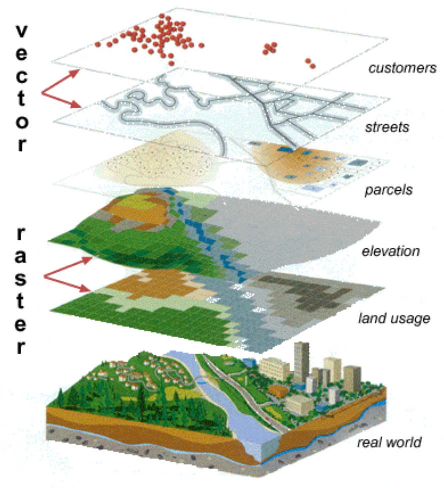

Fig.2:- *The concept of layers (Courtesy-ESRI)*

GIS is used in various fields, including environmental science, geology, forestry, urban planning, transportation, and agriculture. GIS can also be used in combination with other technologies, such as GPS (Global Positioning System), remote sensing, and 3D modelling, to provide a more comprehensive view of the geospatial data.

The benefits of GIS include improved decision-making, increased efficiency, and enhanced communication. GIS can provide decision-makers with valuable insights into complex spatial relationships, enabling them to make informed decisions. It can also help reduce costs and increase efficiency by automating routine tasks and streamlining data management processes. Additionally, GIS can help communicate complex spatial information in a clear and accessible way, enabling a wider audience to understand the implications of decisions related to geospatial data. GIS is a useful tool for controlling land use within a drainage basin because of its capacity to characterise and model regional differences in hydrological processes (Stuart and Stocks, 1993).

Overall, GIS is a powerful tool that enables users to better understand and manage the complex relationships between different geospatial phenomena.

GIS APPLICATIONS IN WATER RESOURCES MANAGEMENT

GIS has emerged as a highly complex database management system for assembling and storing the massive amounts of data required in hydrologic modelling (Bhaskar et al., 1992; Vieux et al., 1989). GIS may be used to quickly compile geomorphic parameters of drainage basins such as drainage densities and channel frequency. GIS is a useful tool for controlling land use within a drainage basin because of its capacity to characterise and model regional differences in hydrological processes (Stuart and Stocks, 1993). Figure 3 represents combined knowledge of Remote Sensing (RS) with the Global Positioning System (GPS) and Geographical Information System (GIS) can be

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Journal of Water Resource Research and Development
Volume 6 Issue 1
DOI: https://doi.org/10.5281/zenodo.7878771

applicable to land use, soil moisture, rainfall, evapotranspiration, availability of surface and groundwater, and the use that could be used in the areas of snowmelt-runoff forecasts, irrigation performance evaluation, drought monitoring, watershed treatment, reservoir sedimentation, and flood mapping and management.

Fig.3:-*Contribution of RS and GIS in water resources management.*

Table 1, gives the track record of contributions in published form from the researchers in the field of "*RS and GIS applications in water resources management*". It indicates that per decade, on average, 21,000 pieces of research were published. But in the last 3 years only, there have been 25000 and above publications available, which indicates that there has been a saturation of research topics in above mentioned subject. Therefore, it is the demand for the time that the researchers need to incorporate new innovative technologies in the fields of both RS and GIS and water resource management.

Table 1:-*Duration and number of publications in the field of RS & GIS applications in water resources management.*

Sr. No.	Duration	Number of Publications*
1	1990- 2000	21,700
2	2001-2010	21,400
3	2011-2020	24,700
4	2021-2023	25, 500
***Data generated from google scholar publications per year**		

COMBINATION OF AI AND GIS

AI (Artificial Intelligence) and GIS (Geographic Information Systems) can be used together for water resources management to improve the efficiency and effectiveness of decision-making processes. Figure-4 depicts the step wise application of combined AI and GIS in water resources management:

Fig.4:- *step-wise process for working with the combination of AI and GIS.*

Journal of Water Resource Research and Development
Volume 6 Issue 1
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Step-1 Predictive Modelling: AI can be used to develop predictive models to forecast water demand, water quality, and flood events. These models can be integrated into GIS to provide spatially referenced information for decision-making.
Step-2 Real-time Monitoring: AI can be used to analyse real-time data from sensors and other monitoring systems, such as satellite imagery, to detect changes in water quality, flow rates, and weather patterns. GIS can then be used to visualize and analyse this data in a spatial context.

Step-3 Data Integration: AI can be used to integrate data from multiple sources, such as weather data, hydrological models, and social media, to provide a more comprehensive understanding of water resources. GIS can be used to store and analyse this data, allowing for better decision-making.

Step-4 Decision Support: AI can be used to provide decision support for water resources management by analysing data, developing scenarios, and recommending actions. GIS can be used to visualize the results of these analyses in a spatial context, allowing for better communication among stakeholders.

Step-5 Resource Allocation: AI can be used to optimize the allocation of water resources, such as determining the most efficient use of irrigation water in agriculture. GIS can be used to map the location of water resources and to analyse the spatial distribution of demand.
The integration of AI and GIS can provide a powerful tool for water resources management, allowing for better decision-making, improved efficiency, and effective communication among stakeholders.

AI IN PREDICTIVE MODELLING OF WATER RESOURCES

AI (Artificial Intelligence) can be used for predictive modelling of water resources to forecast water availability, water quality, and flood events. Here are some examples of how AI can be used in predictive modelling of water resources (figure-5):

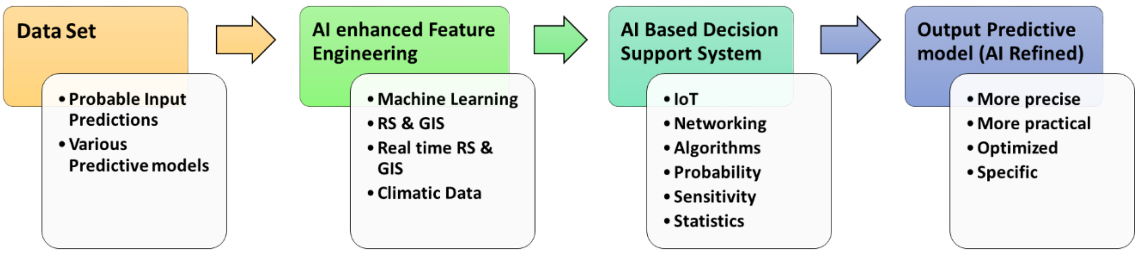

Fig.5:*-AI based predictive modelling of water resources management*

Machine Learning Algorithms: AI can use machine learning algorithms to analyse large datasets of historical water resource data and to develop predictive models based on past patterns and trends. These models can then be used to forecast future water availability, water quality, and flood events.
Remote Sensing: AI can use remote sensing data, such as satellite imagery, to monitor water resources and to detect changes in water availability and quality. Machine learning algorithms can then be used to analyse this data and to develop predictive models. Real-time Monitoring: AI can use real-time monitoring data from sensors and other monitoring systems to detect changes in water availability and quality. Machine learning algorithms can then be used to develop predictive models based on this data.
Climate Data: AI can use climate data to predict future weather patterns and to forecast the impacts of climate change on

HBRP PUBLICATION
Journal of Water Resource Research and Development
Volume 6 Issue 1
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water resources. Machine learning algorithms can then be used to develop predictive models based on these predictions. Decision Support: AI can use predictive modelling to provide decision support for water resources management. By providing forecasts of water availability, quality, and flood events, AI can help decision-makers to plan and allocate water resources more effectively.

AI can provide a powerful tool for predictive modelling of water resources, allowing for better decision-making, improved efficiency, and effective communication among stakeholders.

REAL-TIME MONITORING OF WATER RESOURCES

AI (Artificial Intelligence) can be used for real-time monitoring of water resources to detect changes in water quality, quantity, and flow patterns. Here are some instances of how artificial intelligence can be used to monitor the availability of water in real-time:

Sensor Networks: AI can be used to analyse real-time data from sensors installed in water bodies, pipes, and treatment plants to detect changes in water quality and quantity. Machine learning algorithms can then be used to identify patterns and anomalies in the data.

Remote Sensing: AI can use remote sensing data, such as satellite imagery, to monitor water resources from a distance. Machine learning algorithms can then be used to analyse this data and to detect changes in water quality and quantity.

Smart Metering: AI can be used to analyse real-time data from smart meters installed in households and commercial buildings to detect changes in water usage patterns. Machine learning algorithms can then be used to develop predictive models of water demand.

Predictive Analytics: AI can use predictive analytics to forecast water quality and quantity based on real-time monitoring data. Machine learning algorithms can then be used to provide early warnings of potential water quality issues or water scarcity.

Decision Support: AI can use real-time monitoring data to provide decision support for water resources management. By providing timely and accurate information, AI can help decision-makers to respond quickly to changes in water resources.

AI can provide a powerful tool for real-time monitoring of water resources, allowing for better decision-making, improved efficiency, and effective communication among stakeholders.

DATA INTEGRATION OF WATER RESOURCES

AI (Artificial Intelligence) can be used for data integration of water resources by combining data from multiple sources, such as weather data, hydrological models, and social media, to provide a more comprehensive understanding of water resources. Figure-6 explains the accumulation of data from various sources and then it is refined into the AI based environment.

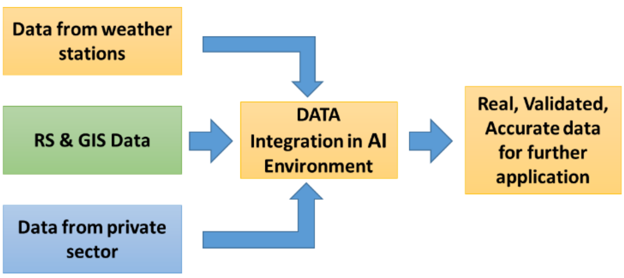

Fig.6:*-Data integration in AI environment*

Journal of Water Resource Research and Development
Volume 6 Issue 1
DOI: https://doi.org/10.5281/zenodo.7878771

Machine Learning Algorithms: AI can use machine learning algorithms to analyse large datasets of water resource data and to identify patterns and trends. Machine learning can then be used to integrate this data with other sources of information.

Social Media Analysis: AI can be used to analyse social media data, such as Twitter feeds, to gather information on water quality and quantity issues. Machine learning algorithms can then be used to integrate this data with other sources of information.

Internet of Things (IoT): AI can be used to analyse data from IoT sensors installed in water bodies, pipes, and treatment plants. Machine learning algorithms can then be used to integrate this data with other sources of information.

Weather Data: AI can use weather data to forecast water availability and to predict the impacts of climate change on water resources. Machine learning algorithms can then be used to integrate this data with other sources of information.

Decision Support: AI can use data integration to provide decision support for water resources management. By integrating data from multiple sources, AI can provide decision-makers with a more comprehensive understanding of water resources.

AI can be a strong tool for water resource data integration, facilitating better decision-making, increased efficiency, and effective communication among stakeholders.

AI IN WATER RESOURCE ALLOCATION

AI (Artificial Intelligence) can be used to allocate water resources by delivering accurate and timely information on water availability, demand, and quality to decision-makers. Figure-7 delineates the allocation of water resources data, processed under AI environment and how it can be applicable to modern usage of AI as modern tool for water resources allocation.

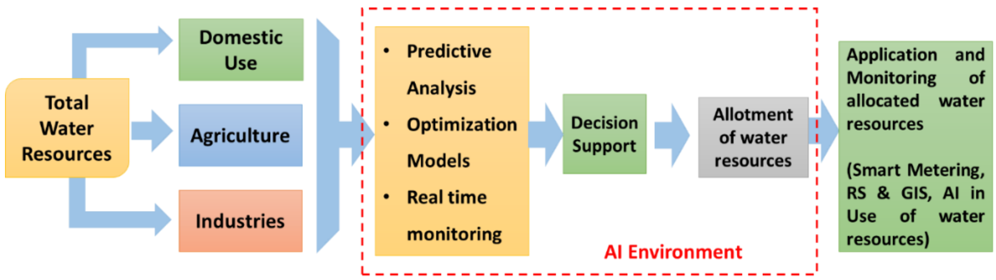

Fig.7:*-AI based water resources allocation*

Predictive Analytics: AI can use predictive analytics to forecast water demand and to identify potential supply shortages. Machine learning algorithms can then be used to develop water allocation plans based on this information.

Optimization Models: AI can use optimization models to identify the most efficient and effective ways to allocate water resources. Machine learning algorithms can then be used to optimize water allocation plans based on real-time data.

Smart Metering: AI can be used to analyse water usage data from smart meters installed in households and commercial buildings. Machine learning algorithms can then be used to develop personalized water allocation plans based on usage patterns.

Journal of Water Resource Research and Development
Volume 6 Issue 1
DOI: https://doi.org/10.5281/zenodo.7878771

Real-time Monitoring: AI can use real-time monitoring data from sensors and other monitoring systems to detect changes in water availability and quality. Machine learning algorithms can then be used to adjust water allocation plans based on this data.

Decision Support: AI can use water resource allocation models to provide decision support for water resources management. By providing accurate and timely information on water availability and demand, AI can help decision-makers to allocate water resources more effectively.

AI IN WATER RESOURCES MANAGEMENT DECISION SUPPORT

Decision support system for water resources management is an interactive field where knowledge of water resources engineering, meteorology, climatology, geology, mathematics, computer programming, and relevant software's. The factors affecting DSS are very large in number hence the database generated from various fields is quantitative but may not be qualitative for further application. To validate data mathematical operations such as statistical analysis, and probabilistic methods are adopted. Computer tools and software are used to facilitate such operations. While doing such operations also for data operations, further decision-making is required. To minimize manual involvement in data operations, the software uses algorithms and they take their own decision and proceed further to carry out mathematical operations. AI (Artificial Intelligence) can be used for decision support in water management by providing decision-makers with accurate and timely information on water resources. Here are some examples of how AI can be used in decision support for water management:

Predictive Analytics: AI can use predictive analytics to forecast water availability and demand, and to identify potential water quality issues. Machine learning algorithms can then be used to develop water management strategies based on this information.

Optimization Models: AI can use optimization models to identify the most efficient and effective ways to manage water resources. Machine learning algorithms can then be used to optimize water management plans based on real-time data.

Real-time Monitoring: AI can use real-time monitoring data from sensors and other monitoring systems to detect changes in water availability and quality. Machine learning algorithms can then be used to adjust water management plans based on this data.

Risk Assessment: AI can use risk assessment models to identify potential risks to water resources, such as drought, flooding, or contamination. Machine learning algorithms can then be used to develop contingency plans to mitigate these risks.

Decision Support Systems: AI can use decision support systems to provide decision-makers with timely and accurate information on water resources. By providing a comprehensive overview of water resources, decision-makers can make more informed decisions about water management strategies.

FUTURE OF AI AND GIS BASED WATER RESOURCES MANAGEMENT

The future of AI (Artificial Intelligence) and GIS (Geographic Information Systems) in water resources management looks very promising. Here are some potential developments that could shape

Journal of Water Resource Research and Development
Volume 6 Issue 1
DOI: https://doi.org/10.5281/zenodo.7878771

the future of AI and GIS-based water resources management:

Increased Data Integration: As more data becomes available from various sources such as IoT sensors, remote sensing satellites, and social media, AI and GIS-based water resources management will become more data-intensive. With machine learning algorithms, data can be analysed and integrated into decision-making models for water resource management.

Advanced Predictive Analytics: With the help of AI, advanced predictive analytics models can be developed to forecast water availability and demand, detect anomalies and changes in water quality, and identify potential risks and hazards in real-time. This will enable water resource managers to take proactive measures to address issues before they become significant problems.

Enhanced Decision Support Systems: AI can be used to develop more advanced and efficient decision support systems for water resource management. These systems will provide decision-makers with real-time and accurate information on water resources, enabling them to make more informed decisions that lead to better outcomes.
Increased Automation: AI can be used to automate routine tasks such as data processing, analysis, and reporting. This will free up water resource managers to focus on more critical tasks such as strategic planning and decision-making.

Improved Efficiency and Sustainability: With AI and GIS-based water resources management, we can expect more efficient and sustainable management practices. This will help conserve and manage water resources more effectively, while minimizing waste and reducing environmental impacts.

The future of AI and GIS-based water resources management is very exciting. As technology advances, we can expect to see more efficient, sustainable, and effective management practices that will help address the growing challenges of water resource management.

GEO-INTELLIGENCE

Geo-intelligence is a broad word that encompasses geospatial visualization, analysis, decision-making, design, and control based on GIS, remote sensing, and satellite positioning technologies. The most distinctive feature that distinguishes GIS from other data technologies is geo-intelligence. It has four stages (figure-8) that contribute to the Geo-intelligence pyramid: Geo-visualization, Geo-decision, Geographic-design, and Geo-control. The complexity of the pyramid increases from bottom to top, while maturity decreases. Geo-intelligence will usher in a new era of technological innovation and create more value with the advent of AI.

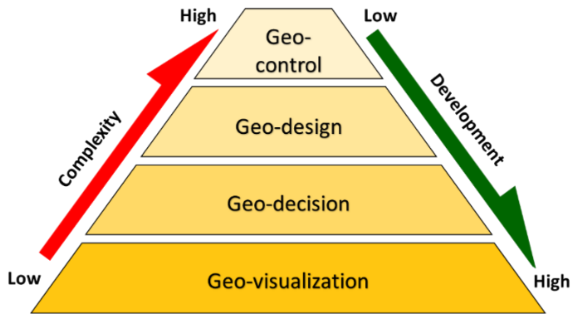

***Fig.8:-** AI Enhanced Geo-Intelligence*

Journal of Water Resource Research and Development
Volume 6 Issue 1
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The basis of GeoAI (AI Enhanced Geo-Intelligence) starts with visualization followed by decision, design and control over AI Intelligence. (Figure-8) The complexity is low at the base of pyramid and it is on the most complex stage when it reached to control level. On the contradiction the control stage is less developed at control level and highest at the visualization stage.

AI for GIS

AI for GIS refers to the application of artificial intelligence (AI) technology to improve the intelligence of GIS software, such as AI Attribute Collecting, AI Survey & Mapping, AI Cartography, and AI interaction. AI Attribute Collecting can contribution users in intelligently classifying and classifying multi-source targets such as video images; AI Survey & Mapping can provide lower cost and more convenient indoor mapping solutions; AI Cartography saves users from the time-consuming process of manual mapping, and style transfer from image to map can be realised through simple operation; AI interaction includes rich application interaction such as voice, gestures, body, and so on.

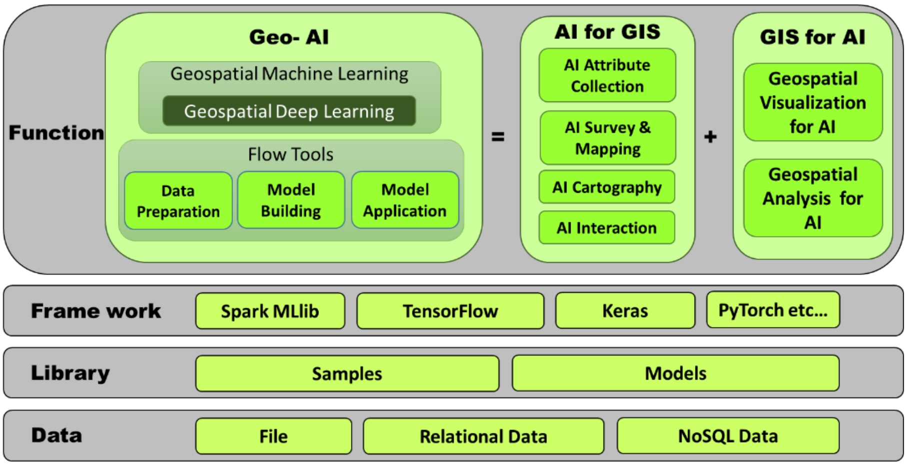

Fig.9:- *AI-GIS Technology for Water resources management*

GIS for AI

When confronted with simulated intelligence acknowledgment results, GIS can additionally process and mine information by utilizing its spatial representation and spatial examination abilities, that is to say, GIS engages computer based intelligence. Applications for map visualization such as traffic flow monitoring, city component management, and cases can offer decision makers a method of information expression that is easier to understand; while inside and out handling and mining of simulated intelligence extraction results can empower constant geo-wall cautions and vehicle following, etc to additionally grow applications.

A relatively complete AI GIS technology system can be constructed using a four-layer structure from the bottom up to effectively support the three components of AI GIS. The domain library follows the data layer at the bottom. Several AI frameworks can be reasonably abstracted and encapsulated in the framework layer. The three parts of the AI GIS that are specifically introduced constitute the top functional layer.

AI GIS Future

An effective solution to the problem of the current intelligent GIS system is to use AI GIS to enhance and develop the next generation of GIS technology systems. AI GIS was the first to use computer vision to

Journal of Water Resource Research and Development
Volume 6 Issue 1
DOI: https://doi.org/10.5281/zenodo.7878771

extract geographic data from videos and photos taken with remote sensing equipment. Moreover, artificial intelligence advances, for example, discourse acknowledgment and language handling can be executed, considering more prominent strengthening. In any case, computer based intelligence GIS is still in the Tight computer based intelligence stage and is quite far from general simulated intelligence (AGI). Consequently, general AI technology is an important path for AI GIS development in the future.

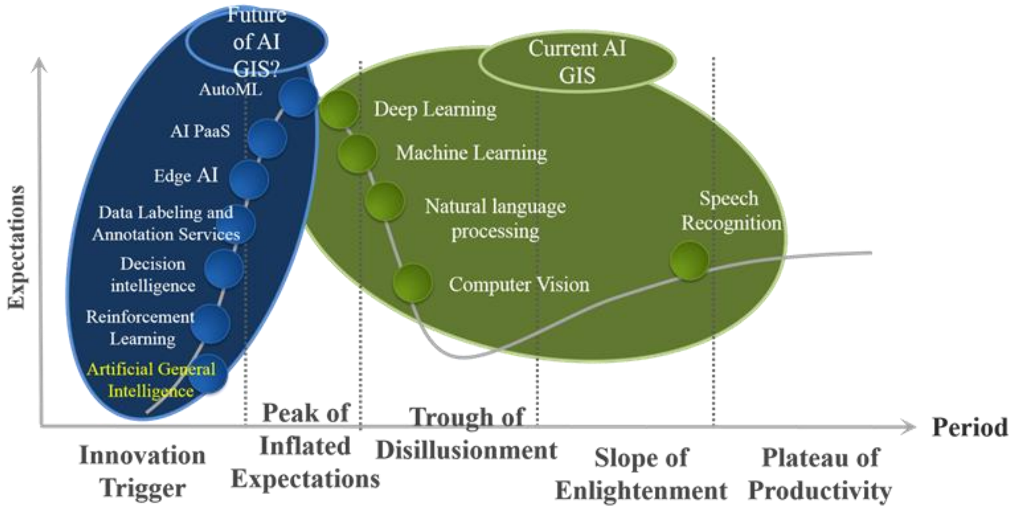

***Fig.10:-** Gartner Hype Cycle for AI (2019)*
(Reference: https://www.supermap.com/en-us/news/?82_2701.html)

ADVANTAGES OF COMBINATION OF AI AND GIS

The combination of AI (Artificial Intelligence) and GIS (Geographic Information Systems) can provide several advantages in various fields, including water resources management. Here are some of the advantages of the combination of AI and GIS:

Improved Spatial Analysis: GIS allows for the analysis of spatial data, while AI can be used to develop more advanced and sophisticated analytical models. Together, AI and GIS can provide more accurate and efficient spatial analysis, such as land use classification, land cover change detection, and habitat mapping.

Enhanced Data Management: With the help of GIS, AI can be used to analyse, process, and manage large volumes of geospatial data. This can be especially useful for water resource management, where large amounts of data from various sources need to be analysed and integrated into decision-making models.

Better Predictive Analytics: AI can be used to develop more advanced predictive models, while GIS can provide the spatial context necessary for such models. By combining AI and GIS, we can develop more accurate and reliable predictive models for water resource management, such as flood forecasting, drought prediction, and water quality modelling.

Improved Decision-making: The combination of AI and GIS can provide decision-makers with real-time and accurate information on water resources. This can help inform better decision-making, such as water allocation, infrastructure planning, and disaster management.

Increased Efficiency: By automating routine tasks, such as data processing and analysis, the combination of AI and GIS can help increase efficiency in water resource management. This can help save

Journal of Water Resource Research and Development
Volume 6 Issue 1
DOI: https://doi.org/10.5281/zenodo.7878771

time and resources, and enable decision-makers to focus on more critical tasks.
The combination of AI and GIS provides a powerful tool for water resource management. By integrating advanced analytical models and spatial data, AI and GIS can help inform better decision-making, improve efficiency, and enable more sustainable management practices.

CONCLUSION

This paper presents a survey and an unpleasant classification of various sorts of utilizations of artificial intelligence in the water space. Modeling, prediction and forecasting, decision support and operational management, and optimization fall into these categories. The reviewed literature on AI in the water domain and the most recent literature on AI and ethics show that the ethical aspects of AI applications in the water domain receive little attention. Late writing on simulated intelligence and morals proposes a rundown of five rules that ought to be considered while creating artificial intelligence applications. Transparency, fairness and justice, accountability and responsibility, privacy, and non-malice are all examples of these.

When compared to its use in other industries, AI's application in the water domain remains somewhat limited. This presents an opportunity to avoid and gain knowledge from past errors. Insights regarding AI-based applications of the water resources domain have been discussed in this paper. AI has the potential to improve theory-guided data science and steer clear of some of the drawbacks of strictly data-driven models. Luckily, man-made intelligence is progressively perceived and there is more than adequate involvement in participatory dynamic in the water space. Water professionals, data scientists, and experts from the social and humanities are required to collaborate on the development and implementation of responsible AI techniques for the water resource domain.

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Cite this article as**:**
Samirsinh P Parmar. (2023). Water Resource Management Using Artificial Intelligence Enabled RS & GIS. Journal of Water Resource Research and Development, 6(1), 29–41. https://doi.org/10.5281/zenodo.7878771