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Use of Digital Technology to Calculate Water Footprints for Different Daily Use Items

Ankit Mishra
Department of Information Technology,
Greater Noida Institute of Technology (Engg. Institute),
Greater Noida, INDIA
Annu Mishra
Department of Information Technology,
Greater Noida Institute of Technology (Engg. Institute),
Greater Noida, INDIA
Dr.Shivani Dubey
Professor, Department of Information Technology,
Greater Noida Institute of Technology (Engg. Institute),
Greater Noida, INDIA

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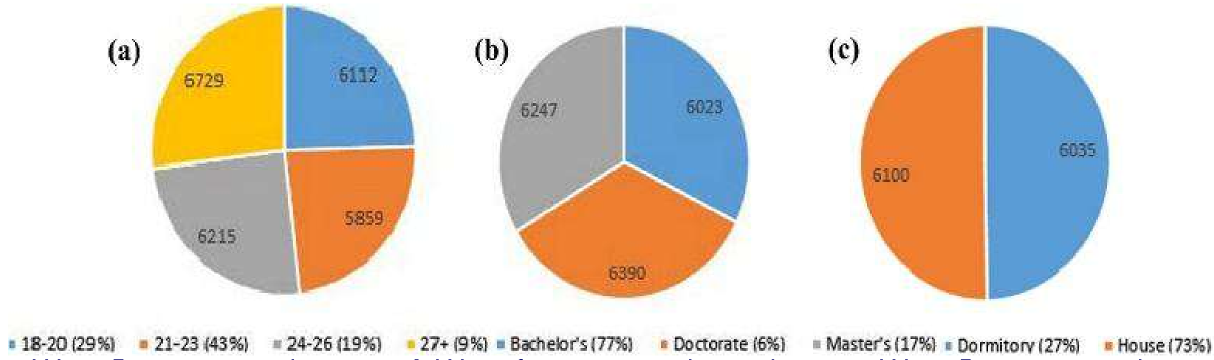
Abstract: Water security is a global concern for utilities due to urbanization and climate change. Although water utilities are directly affected by climate change, greenhouse gas emissions are also a result of their activities. Urban water cycles are becoming more sustainable as a result of the efficient operations of utilities made possible by digital technologies. Nonetheless, there is still a dearth of research on the global advancement of digital water transformation. Here, we report on the findings of an online survey that 64 utilities from 28 countries participated in to learn more about the digital transformation's effects on the water utility industry, its drivers, and the main technologies that make it possible. We discovered that the water distribution system serves as the gateway for additional digital technology adoption throughout the entire urban water cycle. In addition, the main forces behind the adoption of technology are economic gains, governmental regulations, and hydroclimatic conditions. We identify areas for future research aimed at improving our understanding of the role that company culture, consumer involvement, and regulations play in effective digital transformation, based on the survey results.
Keywords: virtual water; water footprint Cite Space; web of science; bibliometrics.

I. INTRODUCTION

Water utilities are thought to consume 10.2 EJ of primary energy year, or between 1.7 and 2.7% of the world's total1. Water supply to end consumers globally is expected to produce yearly emissions of 0.3–2.8 GtCO2, or 0.2–2.6% of global greenhouse gas (GHG) emissions2. The water industry as a whole offers significant promise for energy conservation and greenhouse gas emission reduction. Opportunities to save energy that may be measured include 0.5–1.1 GtCO2/year from conserving water at the point of use and 0.2–0.7 GtCO2/year from utilizing wastewater's energy potential. It is yet unknown how much energy and emissions could be saved by using alternative operating strategies (such decentralization or nature-based solutions). Although they contribute to global greenhouse gas emissions, water utilities' primary operations are also impacted by the effects of climate change. Stress on water abstractions rises in water-scarce locations, where surface water discharge might drop by as much as 30%.3, 4, 5. Furthermore, within the next 30 years, urbanization is predicted to increase water demand in cities by 80%, resulting in an anticipated annual shortage of available water equal to 1386–6764 million m3, which will affect around 440–673 million people globally.6, 7. In some locations, more intense and frequent precipitation extremes, more storm days, and an increase in impermeable areas from urban expansion are predicted to combine to generate a 450% increase in the danger of flooding and consequently induced combined sewer overflow (CSO).

Thus, utilities will face issues in the future related to climate change and shifting water demands that are unmanageable with the tools they currently have for managing their operations and monitoring their infrastructure assets.7, 11. Digital technology have demonstrated efficacy in enhancing the reliability and efficiency of essential operations for water utilities.

Demand management and water demand pattern analysis are made possible, for example, by data collected by advanced metering infrastructure (AMI) from smart meters at high temporal and spatial resolutions12,13. These data sets also provide insightful information about consumer behaviour. Customer feedback generated in this way encourages water conservation behaviour and, when given consistently, may lead to long-term persistence16. Given that water heating at the end-of-use level may account for up to 95% of regional water-related energy consumption, efficiency measures targeted at lowering water demand could also significantly contribute to savings in water-related energy. Reducing leaks in the water distribution network (WDN)18 and at the post-meter level19, as well as optimizing water distribution and sewage operations using automated control schemes (such Model Predictive Control (MPC)), offer additional opportunities to save water and energy. Up to 10% in energy savings should be possible in WDNs with the application of MPC schemes20,21. Similarly, the adoption of MPC can have a significant positive impact on sewage operations, lowering CSO by as much as 98.4% of the potential reducible volume22.

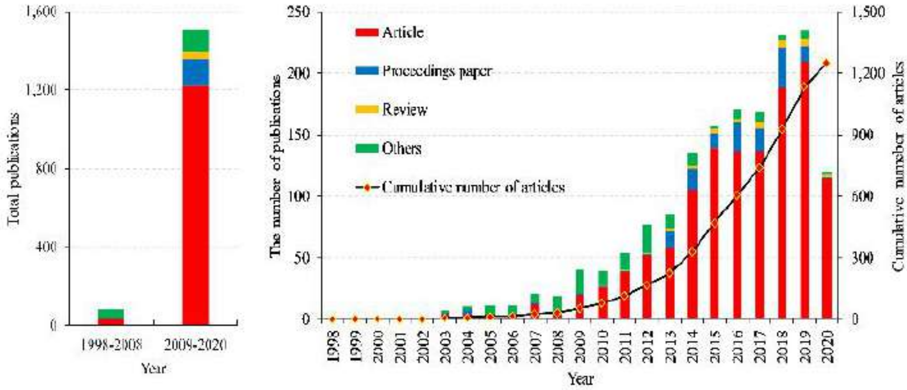


a Water Footprint according to age. **b** Water footprint according to degrees. **c** Water Footprint according to accommodation

2. LITERATURE REVIEW

Ensuring the sustainability of humankind on Earth necessitates addressing the worldwide process of increasing the quality of water for drinking. The Water Quality Index (WQI), which was developed in the 1060s by Horton, is a product of a very old study on water quality. Since then, there are numerous ways to do the aforementioned procedure. The two indices that are used to evaluate the general quality of sources of drinking water are straightforward, adaptable, stable, and only slightly dependent on the input data. Similar information on water quality is provided by the weighted mathematical WQI approach [6]. Despite having significant drawbacks, these WQIs are the most widely used techniques for evaluating water quality because they facilitate comprehension by transforming numerous. Studies show that at least 2 billion people worldwide drink contaminated water contaminated with human waste. The largest danger to the safety of drinking water is now microbiological contamination caused by faces. Having clean water is essential to preventing various tropical and diarrheal illnesses that are disregarded. It is simple to maintain hygiene and avoid many dangerous respiratory diseases when one has access to safe drinking water. Water that meets the standards for high quality is one that is devoid of harmful organisms and perhaps unattractive biological materials. It is transparent and colourless, and it has neither flavour nor scent. It has no chemical concentrations that could harm your health, look unpleasant, or be expensive.

It is non-corrosive, so it doesn't leave behind excessive or unwanted deposits on water-conveying systems like pipes, tanks, and plumbing fittings. The water quality was predicted using conventional machine learning techniques such Logistic Regression (LR), Random Forest (RF), Decision Tree (DT), Support Vector Machine (SVM), XGBoost, and K-Nearest Neighbour (KNN) Classifier. Random Forest had the best performance. Maximum precision. In their study, Guangtao et al. talked about the use of deep learning techniques to the analysis of urban water and wastewater management. Similar machine learning techniques were used by Mahalakshmi and Yogalakshmi to attempt to forecast the water quality of Indian rivers. Ruixing et al. talked about using different water quality indicators to forecast water quality using machine learning techniques. They also discussed methods for cleaning water and assessing how harmful natural water systems are in their paper, Krishnan et al. Illustrated the Internet of Things (IoT), deep learning, and artificial intelligence (AI) together to manage water resources effectively. They created an approach that seeks to provide sustainable water usage from natural resources by utilizing all available technologies. In their work, Castillo et al. simply predicted water quality based on WQI derived from the ecosystem to illustrate the classification of water quality in rivers in Mexico. For their research and experimentation, they employed supervised machine learning [16]. Using Jinal Patel et al. SMOTE (Synthetic Minority Oversampling Technique) is a machine learning technique that is used to keep the dataset balanced across different methodologies. Thegradient boost produced 81% of the findings of the experiment. Explainable AI (XAI) was used to find the optimal characteristics. Water quality is the main emphasis of the effort; each dataset element, such as conductivity, turbidity, organic carbon hardness, sulfate, and trihalomethanes, needs to be investigated. It is essential to use these indications and compare them to predetermined levels constraint in determining the quality of the water.



The number of publications in virtual water and water footprint

3. OBJECTIVE

The objective of exploring the use of digital technology to calculate water footprints for different daily uses is to enhance our understanding of water consumption patterns, identify areas of inefficiency, and facilitate informed decision-making for sustainable water management practices. By leveraging digital tools and methodologies, this research aims to: Improve Accuracy: Digital technologies offer advanced data collection and processing capabilities, leading to more accurate and precise quantification of water footprints across various sectors and geographic scales. Enhance Efficiency: Automation and digitization streamline the process of collecting, analysing, and interpreting water footprint data, reducing time and resource requirements compared to traditional manual methods. Enable Granularity: Digital tools enable the disaggregation of water footprint assessments to finer spatial and temporal resolutions, allowing for more detailed insights into water use patterns at the local, regional, and even individual levels. Foster Innovation: By harnessing emerging technologies such as machine learning, remote sensing, and Internet of Things (IoT), this research seeks to drive innovation in water footprint calculations and develop new methodologies for assessing water use impacts. Inform Decision-Making: The ultimate goal of this research is to provide stakeholders, including policymakers, businesses, and communities, with actionable insights derived from digital water footprint assessments, empowering them to implement targeted interventions and policies to mitigate water-related risks and promote sustainable water stewardship.

Support Policy Description: By generating robust evidence on water consumption patterns and impacts, this research can inform the development of effective water management policies, regulations, and incentives at local, national, and global levels.

Enhance Resilience to Climate change: By quantifying water footprints and identifying vulnerabilities to climate-related risks, this research can support adaptation strategies and resilience-building efforts in water-stressed regions and communities.

Facilitate International Collaboration: Digital platforms for sharing water footprint data and methodologies can facilitate collaboration and knowledge exchange among researchers, practitioners, and policymakers across borders, promoting global cooperation in water management.

Monitor and Evaluate Progress: Continuous monitoring and evaluation of water footprints using digital technology enable stakeholders to track progress towards sustainability goals, identify emerging trends and hotspots, and adapt strategies as needed to achieve desired outcomes.

4. METHODOLOGY

The process of evaluating the sustainability of water includes a description of the approach to evaluating water quality (refer to Figure 1). The procedure must be periodically reviewed because new elements are always entering the picture. Utilizing the newest technological advancements, the approach tends to stray and produces superior outcomes to its earlier iterations. In Order to evaluate the water quality as effectively as possible, the study will concentrate on key components such as turbidity, solids, sulfate, trihalomethanes, pH, hardness, solids, organic carbon, etc. In Order to determine whether or not the provided water samples are potable, a water quality examination is required. The term "potability" describes the state of the water's quality and determines whether or not it is safe to consume.

There are four phases involves in primary strategy:

A. Data Preprocessing:

It entails running the preliminary analyses on the unprocessed data. Data processing occurs when collected data are transformed into insightful knowledge. Appropriate data processing is essential to avoid damaging the data's final result. This process comprises data transformation, source data correction, and the discovery of record inconsistencies. Data exploration analysis (EDA), which is used to import and manage the raw data, is performed using Python 3.7. In order to apply data mining methods, unstructured data must be transformed into well-formed collections of data through the process of data preparation. Unfinished and with inconsistent formatting, raw data is often seen. After it was shown that the data was consistent, 70% of the dataset underwent data preprocessing and data modelling using the SKlearn software. 30% of funds going for testing and training.

B. Model Training:

Then, in order to prevent lower value ranges from predominating while calculating data point distances, the dataset is scaled to make sure that the data points are within an appropriate scale. The dataset can now be used for model training utilizing the six techniques that decision tree classification, k-nearest neighbour classification, support vector modelling, and the XGBoost algorithm. Iterations of the modelling procedure were conducted using default settings.

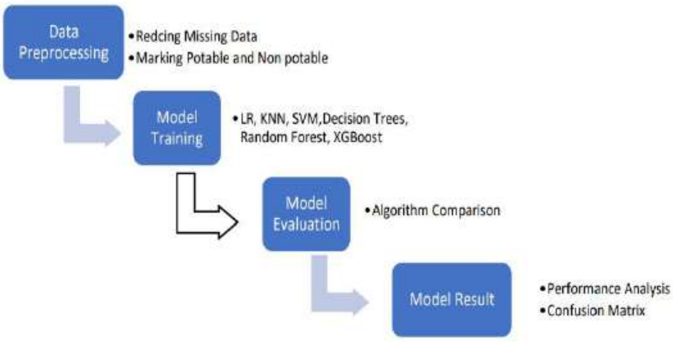


Fig. Methodology for Water Quality Assessment (WQA)

C. Model Evaluation: This procedure covers the main analysis stage, in which each of the six algorithms' particular execution details are examined. The ratio of potable to non-potable data is separated out in the dataset. Every algorithm's output is compared to one another. another leading to the acquisition of some significant findings that would ultimately determine the fate of the water quality: whether the water is suitable for usage by people worldwide or needs to be cleaned up.

D. Model Result: Python is used to generate a confusion matrix that provides detailed output for each of the six machine learning techniques. The accuracy, recall, and F1 Score of each method used to evaluate the water quality are likewise determined by the matrix. Additionally, type II error is computed to assess the water's purity or suitability for drinking. The required results that aid in predicting the most appropriate approach are derived from the confusion matrix and graphical analysis results.

4.1. Definition of water utility subdivisions within the SWS:

The management of the urban water cycle is the fundamental function of every water utility. Resource management, water distribution, wastewater collection, water treatment, and rainwater/stormwater management are all included in this41, 42. We extended water distribution systems to include the piping network and its operating systems into the subdivision of water distribution network & operating systems (WD), and further combined wastewater collection and rainwater/stormwater management into the subdivision wastewater & rainwater management (WW) due to the existence of many combined sewage networks. Although overseeing the urban water cycle is a utility's primary function, it also provides water to its clients. Utilities have been encouraged to involve their customers more and more in recent years, for example, through water demand management programs13. As a result, we expanded the Smart Water Survey to include the segmentation of customers and demand management (CD). Finally, water utilities are cooperatives that operate through organizational procedures. To properly adopt digital technology, they require data management tools and expertise. As a result, we divided the data warehouse and IT systems (IT).

4.2 Technology availability and utility digitalization scores

Participants in the Smart Water Survey were given the option to select one of four categorical answers for each technology-related question that addressed availability or penetration of technology. These answers indicated scalating levels of availability or penetration of a particular technology k for a water utility u: (i) in operation, (ii) implementation ongoing, (iii) planned within five years, or (iv) not planned at this time. The stages of the technology innovation process are represented by these four choices.A technology k is a component of the set of investigated technologies K, and a utility u is a part of the set of surveyed utilities U. We gave each category a numerical value during the survey data analysis process and established the digitalization score (DSu,k) for every combination of water utility and technology. To facilitate aggregate and quantitative comparison, we allocated the subsequent values to the aforementioned categories responses: DSu,k = (i) 3, (ii) 2, (iii) 1, and (iv) 0 are the possible outcomes. The output that is produced is tabular numerical data with individual technologies displayed on one axis and utilities represented on the other. Descriptor blocks: To account for variations in contrast and illumination, the power of the gradient needs to be locally adjusted. Cells must be gathered into bigger, physically connected blocks in order to do this. The sequence of the normalized cell histogram components from each block region yields the Histogram of Oriented Gradients descriptor. Usually, these blocks overlap, indicating that each cell makes at least one additional contribution to the final descriptors. By combining the digitalization scores for each utility, we were able to examine how much of a particular digital technology was used over the entire collection. The following formula is used to create the final technology availability score:

$$\boldsymbol{TAS_k = \sum_{u \in U} DS_{u,k}}$$

4.3 Sensor Networks for RealTime Water Footprint Monitoring: A wireless sensor network (WSN) is an autonomous system made up of numerous large numbers of the system has low power and low cost because to the micro sensor nodes, which have high sensing levels and calculate communication. It is regarded as a very intelligent system that controls many jobs in the monitoring process in accordance with the various environmental conditions. This technology keeps an eye on both the usual application and the water environment. The apparatus is capable of Compare the current automatic and monitoring systems in real time with the WSN, which is based on the water's surroundings to track and identify strong points. To propose and implement the improvements that have occurred for the infrastructure to capture, transfer, and analyze the real-time data, there is a unique need to know the ground water level in real time and its data. The following needs would be satisfied by the proposed system:

1.The Low Costs: There are many sites where the ground water level to be measured is well-known. It made use of to integrate the infrastructure in various locations at a minimal cost, which calls for large-scale infrastructure deployment.

2.Miniaturization: the environmental deployment carried out to collect the sensors' data. The perception In order to make high-end integrated circuits small, intelligences should be adhered to.

3.Flexibility: The design of the sensors should be sufficiently flexible to accommodate changes in the other environmental measurements.

4.Scalability: Each sensor will be able to monitor the undersea space in three dimensions by deploying scalable WSNs. and acknowledge the actions that are specifically done in the surroundings.

5.Modular designs: To facilitate the use of new technologies in different parts (such as data gathering, transfer, and analysis), a modular design is ideal.

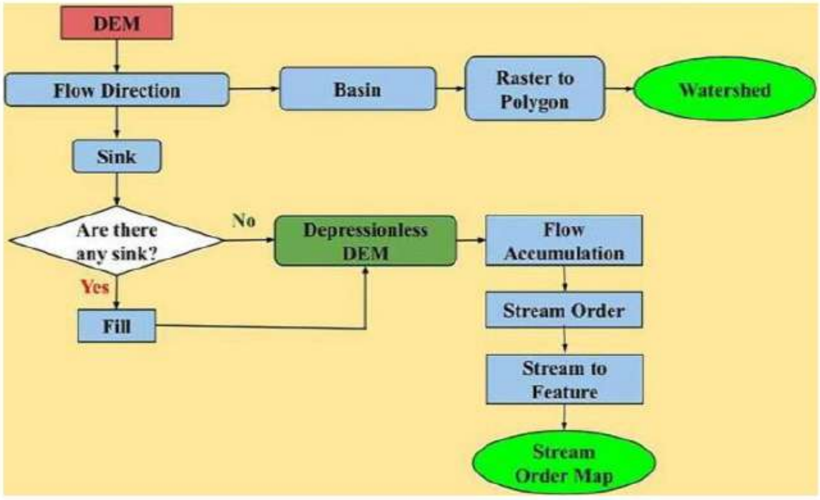
6.Reliable untethered communication: Because the nodes are interconnected, data transmission needs to be dependable even in the case of node failures.

4.4. Remote sensing and GIS: Tools for sustainability of water resources:

Hydrological management: Both in space and time, hydrological processes are dynamic and variable. In the past, conventional methods such as point measurements or in situ observations were used to investigate the hydrological phenomenon. The results of these investigations are then analysed and combined to determine the aerial estimates. These antiquated methods of hydrological variable estimation have the drawbacks of being labour-intensive, time-consuming, and limited to a restricted area or particular location. place. The development of RS and GIS technologies has made it possible to study the hydrological cycle from a number of angles, including the measurement of water balance components, the geographical and temporal distribution of meteorological factors, etc (Kushwaha et al., 2016). In the context of water resource management, the following three RS components are essential: Qualitative assessment: During the first lesson, broad observations were made that connected the qualitative elements of the research (such as the river's colour changes when industrial trash is released, designating a site for observation. Geometric assessment is the process of gathering data about the area, shape, pattern, dimension, and distribution of the study's features. For instance, it involves learning about the land cover in a given area and how it influences soil moisture content, evapo transpiration (ET), runoff, and infiltration. Establishing a relationship between RS observations and a ground truth data site in order to investigate a hydrologic variable such as soil moisture, rainfall, etc. is known as correlation development. Watershed management: For desired production, input resources, such as land and water, must be conserved, which requires careful planning and implementation. RS is successfully employed for periodic supervision, as well as for estimating watershed priorities, potentials, and management requirements. This is achieved, for example, by the deployment of airborne and space-borne sensors (Khan et al., 2001; Kushwaha et al., 2016; Kushwaha and Yousuf, 2017; Pandey and Sharma, 2017).RS data can be used to create a variety of geomorphologic evaluations, such as the area, dimensions, shape, and terrain of the rock formations, drainage density, and watershed. El Baroudy and Moghanm (2014) and Kushwaha and Bhardwaj (2017) revealed that the morphometric study of micro-watersheds could benefit from the use of wavelength ranges of 0.6–0.7 m and 0.8–1.1 m. The drainage network is predominantly determined by the stream structure (stream orders, length, sinuosity, and bifurcation ratio) and the basin's geological behaviour.Using RS approaches, drainage networks and linear characteristics of channels can be easily acquired. (Kushwaha and Bhardwaj, 2016–2017; Kudnar, 2020). In the ArcGIS environment, we go through a number of procedures to delineate watersheds or stream networks. Certain procedures must be completed, while others are optional based on the properties of the input data. A surface's flow will always be directed in the steepest down slope direction. Finding out which cells flow into a specific cell, as well as their number, is possible once the direction of flow out of each cell is understood. Stream networks and watershed borders can be established using this data. The subsequent A flowchart (Fig. 1) illustrates how hydrologic data, like stream networks and watershed borders, can be extracted from a digital elevation model (DEM).Due to their ability to partially replicate all process hydrological parameters for the ground atmosphere system, water balance models are considered to be among the most sophisticated hydrological models.

Methodology for watershed delineation using ArcGIS.

Data processing algorithms need to be created in a way that facilitates automated, comprehensive, and synthetic analysis. To further enhance technological synchronization and user convenience, embedded digital image processing, cartography, photogrammetry, and computer science applications should be implemented. Expert and fuzzy systems for future prediction could be used to analyse artificial intelligence-processed data with professional knowledge kept in a database to generate more realistic judgments.



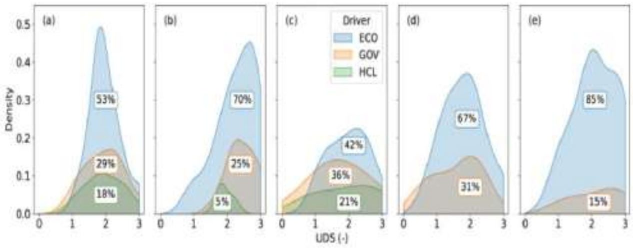
4.5 Related work

The MOBESENs TM project aimed to provide a unique system and the required sensors to allow for ongoing monitoring of lake and ocean water quality. The project's innovations in terms of WSN are presented in this study in order to accomplish this aim. Following a brief overview of the project, the research delineates the routing and localization methods that are specifically engineered to facilitate continuous, long-term monitoring of water quality. To communicate the stored measurements of ion concentrations, the device uses a clever array of ion selective field effect transistors (ISFETs) as a front-end and at post-processing stages. The blind source separation (BSS) algorithm in the smart sensors provides intelligence by continuously learning how to detect the ion concentrations present in the We have shown in the article how a unique design that relies on wireless technology to monitor groundwater and its system networks that are connected to sensors of pressure. The proposed method will make it possible for groundwater researchers and others who are thought of as decision makers to quickly and affordably obtain groundwater data with little effort. While our concept focuses on monitoring groundwater, it can be used to other environmental monitoring domains as well. By deploying the systems, the separated placement of the algorithms will aid in real-time distant sensing of the ocean the apps, which provide us a wealth of data regarding the locations of the sensors that make up the underwater sound network that is being used to identify the area where the event was detected. This article presented a particular idea, as well as the design, fabrication, experimentation, and assessment of smart devices for improved waterborne severability of small fractions. The ultrasonic waves are utilized by the intelligent apparatuses. The article's main focus is on the water business, which has enhanced interactive data capabilities. systems of management to aid in decision-making. Planning for the sustainable use of the environment is made easier by these developments. The most important stage is the real-time application of analytical tools to real-time hydrographic data since it closes the gap between environmental data collection and system management. Data collecting disciplines play a crucial role in the planning and resolution of project operations, design, early warning systems, and prediction models. To investigate the research issues in mobile U.W.S.N designs, a top-down method was used. Along the stratified we roughly moved down the protocol stack from the top application layer to the bottom physical layer. A new set of design nuances were examined at each layer. The conclusion said that creating a mobile U.W.S.N. that is climbable is a challenge that needs to be addressed by multidisciplinary initiatives involving mobile acoustic network protocol designs and auditory communications. The smart thermostat was equipped with strings for tracking temperatures over an extended period of time in a large water body. Body that is said to enable both temporal and spatial measurements that are highly matched and reasonably priced. created an interface circuit for the water quality WSNs that connects the wireless node, the water quality detecting sensor, and a solar power system. To lower the cost of water quality sensor networks and increase their efficiency, use a hierarchical structure. amplify the sensor node deployment density. The Water Environment Monitoring System (W.S.N.) is the foundation for the system; it is composed of three components: the base station, which gathers video data, the nodes that monitor data, and the centre, which specializes in remote monitoring. Together with the Newfoundland Aquaculture Industry Association, the School of Ocean Technology works to give the sector easy access to historical and current data on the state of the marine environment to promote sustainable aquaculture output. The project is situated in the Coast of Bays region, which is the epicenter of the province's quickly expanding commercial salmon aquaculture sector as well as the frontier of the newly forming aquaculture business on the island of Newfoundland.

5. RESULT & DISCUSSION

The operating network and organizational structure of a water utility are mapped out by the Smart Water Survey (SWS), which is separated into the five subdivisions. (1)The first five are water supply and drinking water treatment (WS), followed by (2) water distribution network and operational systems (WD), (3) waste water and rainwater management (WW), (4) consumers and demand management (CD), and (5) data warehouse and IT systems (IT).

In order to eliminate uncertainty and contextualize how the general notion of digitalization may be realized in practice in each subdivision, survey participants were given interactive labels with examples of digital technology and practices. We look into three primary facets of the digital transformation in each subdivision: the degree to which pertinent digital technologies have been deployed, the incentives that motivate people to accept new technologies, and the major hurdles that lie ahead. Further inquiries focus on providing detailed details about the overall configuration, magnitude, duration, and establishment of the utility company, as well as the particular application and implementation of particularly intriguing digital innovations like intelligent control components and smart meters. The survey's independent parts and questions are set up to reduce the possibility of information bias resulting from the utility's impression of digitization. One can find a comprehensive inventory of all inquiries in the Supplementary Notes 1. Overall, it was discovered that, across all subdivisions, economic reasons had the biggest impact on digital transformation (66% of occurrences). In 26 situations, the driving reason is government regulation; in 8% of the cases, it is hydroclimatic variables. The IT subdivision's (Fig. 4e) development is mostly driven (85%) by economic forces. This also holds true for the CD subdivisions (67%, Fig. 4d) and the WD (70%, Fig. 4b). The WS and WW subdivisions (Fig. 4a, c) show a less clear pattern, with increased government regulation and hydroclimatic elements influencing digital transition. Droughts in the WS subdivision (18%) and floods in the WW subdivision (21%), respectively, Drivers of digital transformation reported by the Smart Water Survey respondent water utilities and their relation to the utility digitalization score.



Drivers stated by surveyed utilities are represented by three different groups (hydroclimatic factors—HCL; economic factors—ECO; government regulation—GOV). The relative occurrence of each driver group is annotated in the colored boxes. Estimates for all distributions are performed employing kernel density estimation (KDE) for each driver group and subdivision: **a** WS; **b** WD; **c** WW; **d** CD; and **e** IT. The relative frequencies of driving factors do not sum up to 100% in **c** due to rounding effects and **d** due the low representation of HCL factors, which account for only 2% in the CD subdivision.

Impact of digital transformation in the water utility sector

Three major insights into the state of the water utility industry's digital transformation are offered by our survey and the studies that followed. First off, regardless of the unique situations and difficulties they face, every utility in our sample has begun digitizing their urban water cycle. Digital transformation has already had an impact on utilities data-driven overview of the most important digital technologies that have been adopted, taking into account the level of penetration. This helps utilities prioritize the adoption of these technologies and make well-informed decisions about their strategy. The first step toward the wider use of important enabling technologies throughout the urban water system is the integration of digital technology into water supply and distribution networks. Thirdly, despite local variations our survey that may not have captured, our data show that digitization initiatives across all subdivisions are primarily motivated by potential economic gains rather than by government regulation or hydroclimatic conditions. Although these factors impact a utility's desire to go on a digital transformation journey, there is no empirical proof that these same characteristics also impact a utility's advancement in digital transformation, including the implementation of certain technologies. The process of distinguishing expressed preferences from disclosed ones could be observed in the future when digital technologies are really adopted by the water utility industry.

FUTURE RESEARCH:

An essential first step toward an urban water cycle that is more resilient to climate change is the digital transformation of water utilities. We provide light on this mechanism in this exploratory work, which has only been briefly examined in the literature up to this point. The issues we cover below represent potential avenues for future research to advance our understanding of digital transformation in the water utility industry. All parties concerned, including utility management and staff, regulators, and customers, must widely accept and support the availability and application of digital technologies. Despite the utility sector being the subject of our inquiry, we discover that utilities do not actually consider current regulations when making decisions on digital transformation. Conversely, an inflexible legislative framework could actually impede the advancement of digital transformation. While the adoption of new digital technologies is currently stuttering due to long replacement times and individual aversion to innovation, water utilities may simply choose not to upgrade to digital technologies in the absence of a common regulation on the installation of digital technologies. The research currently in publication, however, does not offer any additional in-depth analysis of current equipment replacement tactics. The relationship between general replacement plans and digital transformation in the water utility industry may be better understood with more research. In addition, a single legislation pertaining to the installation of digital technologies will undoubtedly promote their adoption and empower industry decision-makers.

Future studies should look into how to engage utilities and regulators in conversations about digital solutions and the screening of new technologies in the context of particular issues, both from a motivational and policy perspective. We also urge tech providers to be included in this conversation so that future technological development can be focused and impactful. Furthermore, the transition from analog to digital technologies poses additional cyber security concerns to the operations of water utilities. It is important to understand how these risks are perceived by water utility personnel and what reservations may arise regarding the adoption of digital technologies. While ongoing research is examining threats and risks based on observed incidents, along with technological solutions for stress testing and security it is equally important to understand how these risks are perceived by water utility personnel. In the end, potential security issues could be examined to create corrective solutions tailored to the particular situation.

CONCLUSION

This study uses CiteSpace to quantitatively analyse and visualize data about nations, organizations, and authors that have conducted VW and WF research over the past 20 years. The data is based on the Web of Science Core Collection, and keywords and burst terms are used to analyse how the characteristics of research hotspots have changed over time. Future research areas for VW and WF are further predicted based on this foundation. The following are the primary findings: There were 1592 publications on VW and WF as of July 2020, indicating an overall upward trend. In 1998–2008, the average yearly number of publications was just 7.4, but from 2009–2019, it increased to 126.5. Out of them, environmental science makes up to 618 publications, or 46%. Water resources (371, 28%), engineering environmental (241, 18%), and green sustainable science technology (235, 17%) follow. This indicates that VW and WF have grown in importance as techniques and metrics for environmental impact assessment. Research publications on VW and WF have been published in 84 different countries. The Netherlands had the greatest effect, with a between ness centrality of 0.33, demonstrating its leading position, despite China being the most prolific nation with a total of 344 articles—and eight of the eleven institutions with the most articles were located in China. In addition to being the first author, corresponding author, or co-author of half of the publications that have been mentioned more than 50 times by 1252 papers, Hoekstra has written 82 articles, significantly more than P. T. WU, who came in second place with 25. This indicates his dominance in the field of VW and WF. VW must be included into social water cycle research, and collaboration between industrialized and developing nations, water-rich and water-poor countries and areas, must be strengthened. In addition, studies on the "water-food-energy-land-climate nexus," "footprint family and planet boundary," "material metabolism theory," and "telecoupling sustainability assessment" should be carried out in the future. Another factor contributing to the alteration in facial look is age-related problems. This is yet another important factor raising doubts about the face detection and recognition system's effectiveness. Since humans are biological creatures, aging is a constant process that changes throughout time. It results in erroneous data being provided by face detection. There will be noticeable differences if there is a long interval between picture captures. Changes in a specific person. According to a number of studies conducted by researchers, a person's face look is expected to alter significantly every ten years.