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YOUTH DELEGATES of the World Water Council

YOUTH WATER CONGRESS

Emerging water challenges since COVID-19

6 - 8 APRIL 2022

Editors:
K. Voudouris
E. Kolokytha
D. Karpouzos
D. Latinopoulos

ISBN: 978-960-243-729-2

BOOK OF ABSTRACTS

Online Youth Water Congress

"Emerging water challenges since COVID-19"

6-8 April, 2022

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Organized by

- **UNESCO Center on Integrated & Interdisciplinary Water Resources Management, Aristotle University of Thessaloniki, Greece**
- **UNESCO's Intergovernmental Hydrological Programme (IHP)**
- **Youth Delegates to the World Water Council (YDWWC)**
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PREFACE

The online Youth Water Congress held between 6-8 April 2022. It is co-organized by the UNESCO's Intergovernmental Hydrological Programme (IHP) together with UNESCO Centre on Integrated and Multidisciplinary Water Resources Management (CIMWRM), hosted by the Aristotle University (AUTh), the Youth Delegates to the World Water Council (YDWWC) and the International Association for Hydro-Environment Engineering and Research (IAHR).

The past years are characterized by significant changes in planning, design and management of water resources all over the planet. Structural changes, demographic alterations, technological breakthroughs, expanding populations, climate shifts, demands, the energy crisis, the water crisis, the pandemic and also war all around us set the current scene of complexity, uncertainty and interdependence we are experiencing. All, highlight a pressing need to develop alternative schemes for managing in an integrated way the scarce natural (water) resources.

Today humanity is facing two major challenges: a) sustaining an earth system with a safe environment, and b) adapting human systems to change and building resilient societies. Water is the connector, the delivering mechanism, between climate change impacts and society. A new paradigm on water related issues is needed. Education, in general, is the vehicle to tackle these crises, to provide solution-oriented approaches, as well as to embrace scientific thinking as an effective platform for action.

Young people across the globe, the water leaders of tomorrow, are generating ideas, energy and hope that we will successfully overcome these crises. By learning from each other, we will be able to co-operate, to re-organize, to re-think to broaden the discussion on international cooperation and the role of science and institutions in inspiring young people, to emphasize the need for interdisciplinary new paradigms which incorporate the new context and reflect the change of thinking about the management of this planet. In this Congress, three-days trigger interesting discussions, on the new trends in the water sector since COVID-19. More than 650 attendees from 84 countries, 17 mentors from 15 countries, as well as 5 keynote experts contributed with their innovative ideas, experience, and knowledge. These e-proceedings include fifty-two (52) extended abstracts of 169 authors in four topics:

1. Water related disasters and climate crisis.
2. Resilience of societies and "digital" communication and cooperation.
3. Management Groundwater resources, the "invisible water".
4. Inclusiveness (culture / gender / indigenous people.

We would like to express our gratitude to the authors who contributed to the Youth Water Congress, to the reviewers for their valuable assistance, to all mentors, to all keynote experts, and to the Organizing Committee.

On behalf of the AUTh CIMWRM

UNESCO Center on Integrated Multidisciplinary Water Resources Management

Prof. Dr. Elpida Kolokytha
Director of the AUTh UNESCO CIMWRM, Thessaloniki, Greece

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THEME 1

WATER RELATED DISASTERS AND CLIMATE CHANGE

Evaluation of Aksu Stream water quality under the influence of anthropogenic pollution and climate change

S. Tuzun Dugan[1*], A. Uslu[2], P. Orhan[2], A. Muhammetoglu[2], M. Yesiltas[1], M.A.T. Kocer[1], H. Muhammetoglu[2]
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Introduction

Due to the increase in population and intense industrial and agricultural activities, the water demand is increasing globally which creates pressure on water resources along with the adverse impacts of climate change. In Turkey, total annual usable water potential is 112 billion m^3 and the per capita water potential is approximately 1400 m^3/person/year. Consequently, Turkey is classified as a "water stress" country and is gradually approaching to become "water poor". The expected adverse impacts of climate change in Turkey (increased summer temperatures, reduced winter precipitation, loss of surface waters, more frequent arid seasons, and floods) will cause considerable changes in the quantity and quality of water resources. The most important impact of climate change in Turkey is expected to be on the water cycle by causing decreases in water resources in the future. According to the Turkey's National Climate Change Adaptation Strategy and Action Plan, water resources management is defined as one of the vulnerable sectors. Therefore, sustainable management of water quality and quantity has gained an utmost importance to meet the increasing water demands of agriculture, industry, and urban uses.

The aim of this study is to present an integrated approach for the analysis of pressures and impacts on the water quality of Aksu Stream, which is one of the rivers in the Antalya River Basin and discharges to the Mediterranean Sea at Antalya city. The total drainage area of Aksu Stream is 3652 km^2 with a total length of almost 145 km. Lake Kovada, Karacaoren-1 and Karacaoren-2 Dam Reservoirs are important impounded surface waters in the basin. Karacaoren-1 Dam was constructed to provide irrigation water, prevent floods, and produce energy. Karacaoren-2 Dam was planned to provide drinking water to Antalya city, but both reservoirs were subject to pollution from domestic and industrial wastewater discharges. The downstream catchment of Aksu Stream which extends from the exit of Karacaoren-2 Dam Reservoir till the stream discharge to the Mediterranean Sea is subject to pressures on water quality and quantity due to intense agricultural activities in the north and tourism activities in the south. The stream water is abstracted nearly all around the year for agricultural irrigation which causes rapid decreases in the stream flows and even periodic dryness at several sections. Consequently, the natural flow balance is highly deteriorated as the amount of released water from the upstream Karacore-2 Dam is controlled to provide only enough water for irrigation and to produce maximum energy from hydropower. In addition to the agricultural pressure, the stream is also exposed to a treatment plant discharge as a point source of pollution. This study presents the results of monitoring study for integrated management of Aksu Stream.

Materials and methods

The monitoring study was conducted at 12 sampling stations in the downstream catchment of Aksu Stream for a period of one year. The monitoring study included in situ measurements and analyses of many physicochemical and bacteriological parameters, in addition to pesticides. Temperature, pH, electrical conductivity (EC), salinity, dissolved oxygen (DO) concentration and saturation, and chlorophyl-a were measured in the field using handheld multi-parameter instruments calibrated with standard solutions. A composite water sample of 10 L was collected by manual sampling for analyses of physicochemical parameters. For the analyses of bacteriological parameters (total and fecal coliform, fecal streptococcus and *Ecoli*), water samples were taken by filling pre-sterilized 100 mL amber glass sample bottles. Common anions (fluoride, chloride, nitrite, bromide, sulphate, nitrate and phosphate) and cations (lithium, sodium, ammonium, potassium, magnesium and calcium) in water samples were analysed simultaneously using Ion Chromatography (IC) system. Total Organic Carbon (TOC) and Total Nitrogen (TN) were determined simultaneously by a TOC/TN analyser. Total Phosphorus (TP) was determined spectrophotometrically by ascorbic acid method after persulphate digestion. In Turkey, general water quality classification of inland surface water bodies is based on physicochemical parameters, and it is performed according to the Annex-5 of the national Surface Water Quality Regulation (Ministry of Agriculture and Forestry, Official Gazette No: 31513, Date: 16 June 2021, update) which covers rivers, lakes, coastal and transitional waters. The general physicochemical water quality class is determined by the lowest class of all parameters and there are three quality classes, namely Class-I (excellent), Class-II (good), and Class-III (fair). The achieved water quality class is further assessed by other quality elements of biological, hydro-morphological and chemical groups (for specific pollutants) to determine ecological water status, being similar to the methodology in the European Water Framework Directive.

Results and concluding remarks

The physicochemical water quality of Aksu Stream was assessed based on the measurement and analyses results of color, pH, EC, DO, chemical oxygen demand (COD), 5-day biochemical oxygen demand, ammonium-N, nitrate-N, TN, orthophosphate-P, TP and fluoride. Based on the yearly average values, two downstream monitoring stations were classified as Class-III (fair quality) and the remaining ten stations were classified as Class-II (good quality). The parameter that impaired water quality at the downstream monitoring stations was mostly EC due to mixing of stream water with seawater. The increased concentrations of TP and BOD_5 due to discharged wastewater effluents from a nearby wastewater treatment plant also deteriorated the water quality before the stream discharge into the Mediterranean Sea. The water temperature measurements generally followed the seasonal changes of air temperature values where the yearly average water temperature values were between 15.10 and 20.61 °C. The EC values demonstrated a high spatial variation, and the maximum value was measured as 5.35 mS/cm at the downstream station that is very close to the stream discharge to the Mediterranean Sea. The maximum concentration of ammonium-N (0.351 mg/L) and the minimum DO concentration (1.27 mg/L) were measured at the upstream monitoring station that received the hypolimnetic waters of Karacaoren-2 Dam Reservoir. The maximum concentration of suspended solids (SS) was analysed for one of the tributaries as 227.5 mg/L although the average SS concentrations varied between 3.5 and 18.7 mg/L at all monitoring stations. The yearly minimum and maximum concentrations of BOD_5 were analysed as 1.0 and 11.15 mg O_2/L at the same monitoring station, located very close to the incoming tributaries. The maximum yearly average concentrations of COD (18.46 mg/L), TP (0.189 mg/L) and TOC (6.94 mg/L) were analysed at the downstream monitoring station, that received the wastewater effluent discharge. Nitrate-N concentrations also exhibited wide spatiotemporal variations where the yearly average values varied between 0.203 and 1.044 mg N/L. In case of bacteriological water quality, the maximum total and fecal coliform and E-coli numbers (13600, 1460 and 162 cfu/100 mL, respectively) were obtained at the downstream monitoring station whereas the maximum fecal streptococcus number of 108 cfu/100 mL was analysed at one of the tributaries, that carried mostly drainage water from agricultural lands. The stream water quality was gradually impaired by the influence of the tributaries towards the downstream. The impaired bacteriological quality of the stream, just before the discharge to the Mediterranean Sea, adversely affects the recreational quality of the seawater. The treatment plant effluents cause the main threat on the bacteriological quality of the stream and the seawater, that needs to be resolved immediately. Moreover, operational cycles of the dam reservoirs, reduced precipitation amounts due to adverse impacts of climate change and abstraction of high volumes of irrigation water from Aksu Stream highly influence the flow regime and causes stagnant water and dry stream sections from time to time. There is an on-going study for the preparation of River Basin Management Plan to improve the water quality status of Aksu Stream.

Acknowledgments: Thanks to the Scientific and Technological Research Council of Turkey, TÜBİTAK (Project No: 119Y267), State Hydraulic Works 13th Branch in Antalya, Antalya Water and Wastewater Authority (ASAT), Mediterranean Fisheries Research Production and Training Institute, Engineering Faculty of Akdeniz University in Antalya, Turkey.

Urban floods: the microbial risks to human health

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Introduction

In the UK most drainage infrastructure UK was not designed for a changing climate, and thus with the increase of heavy rainfall events year on year, many sewer systems in densely populated urban areas, are unable to cope– causing flooding. Sewage overflow and surface run off in urban areas can act as vectors for the dissemination of pathogens, known to cause disease among human populations. Most of the previous studies in this field have focused on using faecal indicators such as E. coli when assessing the microbial risk of floodwater (Yard et al., 2014). However, traditional indicators do not accurately reflect the true risk that urban flooding poses (Hussain., 2019). Previous investigations in UK waterlogged soils have shown a clear response of microbial communities to water table variation, temperature, and nutrient availability in soil profiles (Douterelo *et al.,* 2009).

Not only do we need to investigate the pathogenic and disease causing species present, - but also how long they survive after a flood, how many are present, how they move during a flood, and how they travel between the flood water and urban surfaces. To build a better understanding of these processes this project will focus on the specific aspect of transport and survival of multiple species of pathogenic microorganisms in and between urban soils and flood water. Routine sampling in the field as well as analysis using advanced molecular methods, the dynamics of pathogens (i.e. movement through soil, diversity, abundance, and survival rates), and microbial interactions at the soil/water interface will be investigated.

Materials and methods

Two sites were selected in Sheffield in the UK (Figures 1 & 2). The site criteria were that it must be at annual risk of surface flooding, and also nearby to CSO outlets that spill regularly. Sampling is carried out at both sites over a year-with soil and water samples taken after heavy rainfall/flood event as well as several dry weather/background samples. Physicochemical data for both soil and water samples will be collected, as well as genetic data from DNA extraction and analysis to determine pathogen types, abundance, source, and survival rates. Comparing this data with rainfall data and surface flood frequencies will allow us to detect any potential changes in the mentioned parameters following a heavy rainfall or flood event.

Figures 1 & 2. Images of the two sample sites in Sheffield. On the left- a CSO at one site, on the right an urban flood at the second site.

DNA will be extracted from the samples and the 16s RNA gene sequenced using next generation sequencing. After being analysed using bioinformatics software, this will give taxonomic and phylogenetic data, allowing the species of pathogen in the samples to be identified. Flow cytometry will also be used to analyse the microbiological communities present in the samples. This will give data on the number of microbes in a samples, as well as their survival.

Results and concluding remarks

Thus far, water and soil samples have started to be collected in the field from the selected sites. Physico-chemical factors – pH, moisture content, organic matter content- have been analysed, and analysis via flow cytometer has been performed (figure 3).

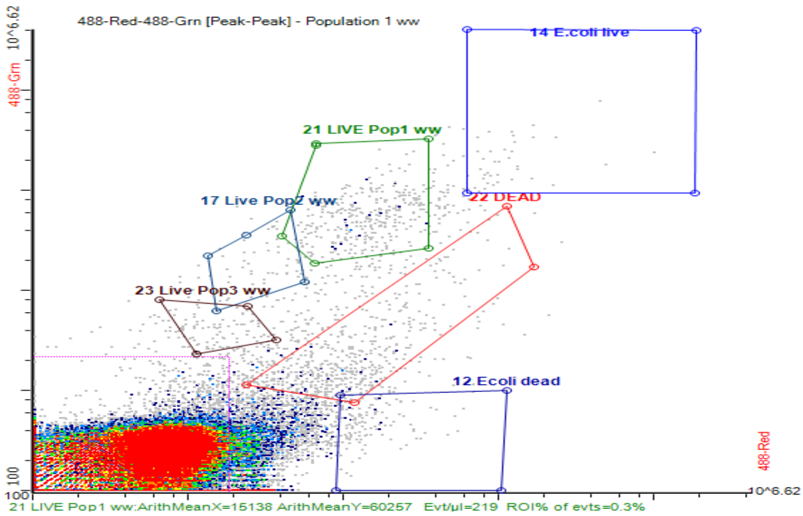

Figure 3. Results of flow cytometer analysis of soil sample taken from a sample site. Cells within 'Gate 14' are live E.coli, with cells with 'Gate 22' being dead.

Both *E.coli* and *C.freundii* pathogenic bacteria has been detected in samples from both sample sites, and DNA extraction and analysis is to take place later on after all samples have been collected, to determine the true range of pathogen species present.

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Communicate Science and Policy: The Making of Boundary Work in WASH Project

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Introduction

The climate crisis has affected urban lives, including in coastal areas. It can be seen from sea level rises that have given an impact a tidal flood in coastal areas. One of the cities in Indonesia, named Semarang, experiences tidal flooding every week. This process has implications for residents in accessing clean water, sanitation, land subsidence and also women's health, especially on reproduction. The project is called Water, Sanitation and Hygiene (WASH)

WASH project is a collaborative research project between Universitas Gadjah Mada (UGM), Indonesia and Monash University, Australia. The WASH project aims to understand the measure of local governments in utilising water and sanitation during the COVID-19 pandemic. In addition, this project examines to what extent women access gender-based roles, who are often seen as vulnerable groups, to access WASH in the COVID-19 pandemic. Therefore, this project paradigm is in line with WASH Sustainable Development Goals (SDGs) framework. As an institution that produces science, universities communicate with water stakeholders to encourage water policy, especially related to hygiene (Francis & Capri, 2021). This collaboration raises questions: how do members of the WASH project negotiate science and policy boundaries with water stakeholders in Semarang? How do members of the WASH project and water stakeholders in Semarang manage the common ground about water hygiene?

Most of the studies tend to analyse the level of contested knowledge between scientific and indigenous knowledge (IK) (Lejano & Ingram, 2009; Maclean & Inc, 2015) or to find boundary objects in science and policy interaction (Star & Grisemer, 1989; Goksu, 2014). On different scales of analysis, several studies tend to focus on the role of organisation which acts as an intermediary agency to solve the boundaries between science and policy (Guston, 2001; Miller, 2001; Guston, 1999). This study analyses a different context by looking up the construction of interaction between science and policy in the water project, especially the WASH project. We proposed a different perception if communication between them is socially constructed, not taken for granted. We use the concept of boundary work from Halffman (2003) which explains that boundaries are 'created' and 'interacted' through three mediums, namely, text, object and person (well-known as TOP Model). By using this framework, we argue the absence of a boundary person leads to the failure of interaction between science and policy in the WASH project.

Materials and methods

We took a case study from the WASH research project in a coastal area by using qualitative research with a historiography approach. The research project was conducted from September to December 2020. The primary data is based on documents, namely call for paper “The Impact of Covid-19 on Indonesia’s Economy and Society” with a sub-focus on health; meeting notes from September 2020 to November 2020; research proposal entitled “The Impact of Covid-19 on Women’s Access to Water, Sanitation, and Hygiene in an Indonesian Fishing Village”; document research agreements from Australia Indonesia Centre (AIC) and Department of Foreign Affairs and Trade Australia; grant letter acceptance, transcripts phone interview with twenty-five women residents in *Tambak Lorok* (one region in the north of Semarang) and nine stakeholders, two times of focus groups discussion with stakeholders and research instruments.

Results and concluding remarks

We argue that the relationship between science and policy in the WASH project has unconsciously formed a 'boundary' between them. In terms of knowledge, science and policy have not interacted with each other because of the absence of a boundary person who operates in two different worlds. Therefore, the collaboration was not completely successful and gave impact to failure to manage a common ground of knowledge about water hygiene between UGM, Monash University and water stakeholders at the moment of the Covid-19 pandemic. Halffman (2003) argues if the one medium in the TOP model is missing, thus it gives an impact on the failure of the interaction of science and policy (Halffman, 2003; Halffman & Hoppe, 2005). The evidence from our argument is based on the Halffman framework. Halffman (2003) divides boundary work into three mediums that could 'form' boundaries but also bridge their interactions. In the first medium, the type of text is characterised by rhetoric, language and literary tools (Halffman, 2003, p.60). Furthermore, it refers to the social nature (habits, social networks), language (protocols, concepts), or even material objects (measurement networks, testing equipment, buildings) (Hoppe & Halffman, 2005). Our findings show that "Small Rapid Research Grants' document from The Partnerships for Australia-Indonesia Research (PAIR) dan The Australia-Indonesia Center (AIC) contribute to the establishment of science and policy boundaries. The document contains a specific requirement, for instance, a list of universities and sub-topics.

In the second medium, the object becomes a material boundary device that is used to be a landmark of the boundary (Halffman, 2003, p. 60). This idea explains objects that are understood differently between both actors so that it has implications for differences in activities between them, but they still refer to these objects as the basis of their activities. We find research reports become the boundary object. The research reports separate practices between scientific and policy activities.

The person as the last medium describes the agency that stands between the two social worlds, which can play a role and move by being a representative of the relationship between science and policy (Halffman, 2003, p.61). These positions are identified differently as gatekeepers or knowledge brokers. In this WASH project, the role of the boundary person is missing which has been proven by demarcation from small rapid research grants from PAIR-AIC.

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Resilience of Urban Water Supply Systems to Climate Change in Cameroonian Cities

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Abstract
Climate change and rapid urbanization have increased pressure on fragile water supply systems in Sub-Saharan Africa. Despite reliable rainfall that recharges surface and groundwater systems, urban water crisis has escalated in Cameroonian cities. Drawing insights from the city of Bamenda, the water supply system has proven resilient, despite lapses in water governance. There has been diversification of water supply system to supplement the main water distribution company (CAMWATER) through community water systems and individual efforts, such as drilling of private wells and boreholes. Despite these efforts, water scarcity has remained the order of the day. It is recommended that watersheds and wetlands be protected through Nature-based Solutions and Ecosystem-based Adaptations to ensure sustainability.
Keywords: adaptation, scarcity, water security, vulnerability

Introduction

Climate change affects water supply systems in multiple ways, with complex spatio-temporal patterns, feedback and interactions between physical and human processes (Bates et al., 2008). These effects are already adding challenges to sustainable water resources management, which are already under severe pressure in many regions of the world and subject to high climate variability and extreme weather events (Stewart et al., 2020). The main effects of climate change on water resources include accessibility, availability, quality and quantity of water for basic human needs (water security), threatening the effective enjoyment of the human rights to water and sanitation. Although the effects can be highly individual at the local scale (Intergovernmental Panel on Climate Change-IPCC, 2019), current trends and future projections indicate major shifts in climate, and more extreme weather events in many parts of the world (IPCC, 2014). It is therefore paramount that water resources managers consider the potential impacts of a changing climate when planning for water resources development in urban areas of sub-Saharan Africa and other parts of the world.

Materials and methods

Data was collected using a household questionnaire, where the sampled population were asked to identify their domestic water sources and coping mechanism during water scarcity. Climatic data were collected from the Regional Meteorological Service.

Results and concluding remarks

Rainfall in Bamenda increases from the onset of the wet season to a peak in July to September and gradually drops as the dry season sets in. The lowest rainfall is recorded from December to March. From 1963-1972, rainfall had an excess of 26.39 mm and has been declining over time. Between 1973-1982, the rainfall had dropped by 13.59 mm and 2.98 mm from 1983-1992. Since 1993, Bamenda has witnessed rainfall deficits (-1 mm from 1993-2002, -12.9 mm from 2003-2012 and -41.5 mm from 2013-2019). The average rainfall declined from 1963-2019 is -2.07 mm (Tume, 2021).

Sources of water in Bamenda are public taps, streams, private taps, boreholes, protected springs, protected wells and unprotected springs. The sampled neighbourhoods have at least one of the water sources, meaning that water is relatively accessible. The most accessible water sources are public taps, streams, private taps in homes and unprotected springs (at watersheds). The population gets water through head portage, wheelbarrow, cars and private water lines in households.

Water accessibility in terms of distance to the nearest water point is related to water security. Water security is the sustainable access, on a watershed scale, to adequate quantities of water of acceptable quality, to ensure human and ecosystems health (Norman et al., 2010). It is a multi-dimensional concept that recognizes that sufficient good quality water is needed for social, economic and cultural uses while, at the same time, adequate water is required to sustain and enhance important ecosystem functions. In another perspective, water security is the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability (UN-Water, 2018). In Bamenda, the majority of the people cover distances of less than 50 m water points.

Both climate and water management require mechanisms for oversight and coordination. Sectoral fragmentation and bureaucratic competition may pose serious challenges for the integration across scales. This calls for greater public participation to discuss and manage climate risk; building adaptive capacities at multiple levels; and prioritizing risk reduction for socially vulnerable groups. Upscaling Nature-based Solution (NbS) and Ecosystem-based Adaptation (EbA) are central to achieving the 2030 Agenda for Sustainable Development. Sustainable water security will not be achieved through business-as-usual approaches. NBS work with nature instead of against it, and thereby provide an essential means to move beyond business-as-usual to escalate social, economic and hydrological efficiency gains in water resources management. NBS show particular promise in achieving progress towards sustainable food production, improved human settlements, access to water supply and sanitation services, and water-related disaster risk reduction. They can also help to respond to the impacts of climate change on water resources.

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From monitoring pollutants dynamics in the catchment to the development of Ecohydrological Nature-based Solutions

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Introduction

The UNESCO Intergovernmental Hydrological Programme (UNESCO IHP) has contributed to the development of aquatic and environmental sciences from structure-descriptive towards problem-solving. From 1996, due to the recognition of the important role played by ecosystems in water cycle regulation, both in terms of water quantity and quality, the concept of ecohydrology (EH) has become a priority theme in IHP (Zalewski et al., 1997). Under the programme of EH, the concept of using ecosystem processes to manage the quality of the aquatic environment was formulated. With a greater understanding of biogeochemical cycles, and in concert with ecological engineering (Mitsch & Jorgensen, 2003), EH approach can be used to support development and implementation of Nature-based Solutions (NbS). The importance of NbS is comprehensively discussed in the World Water Development Report (WWDR, 2018), and has been closely linked to the EH in a number of studies (e.g. Bridgewater, 2018; Jarosiewicz et al., 2021).

Considering the current impact of anthropogenic pollution on aquatic ecosystems, we can observe two directions. On the one hand, biogenic compounds intensify eutrophication, and thus cause a disturbance of the trophic structure and a decrease in biodiversity, and on the other hand, mixtures of organic pollutants (emerging pollutants) can negatively affect the genetic, hormonal and population levels. The occurrence of both types of impacts in aquatic systems may lead to unpredictable effects. Therefore, EH-NbS removal of nutrients and emerging pollutants (e.g. pesticides), already confirmed in several studies, should be considered as a tool in water management. Here, we analysed the spatial-temporal dynamics of pollutants in selected catchments to identify processes responsible for their removal and proposed advanced EH-NbS.

Materials and methods

To elaborate and propose systematic solutions, three principles of ecohydrology were used (Zalewski, 2021). As the research area 4 catchments were selected with area ranging from 92,3 to 225,4 km^2; all Pilica river tributaries in central Poland. As the starting point we identified the temporal loads of pollutants for 2 consecutive years (2018-2019). We also analysed the structure of catchment, with the total share of horticulture and arable land in gradient from 57.3 to 80.6%, while in the orchard area only from 0.1 to 62.9%. With applied methodology, 95 pesticides, inorganic nutrients, total forms of phosphorus and nitrogen, as also physico-chemical parameters were monitored. Precipitation, river discharge and land cover were analysed to determine their impact on pollutants transfer.

Moreover, we analysed the efficiency of currently used EH-NbS, evidencing the necessity to enhance the pollutants removal and management (Jarosiewicz et al., 2021). In the end, we proposed optimisation of the existing EH-NbS to fit local conditions. Methodology was presented on Fig.1.

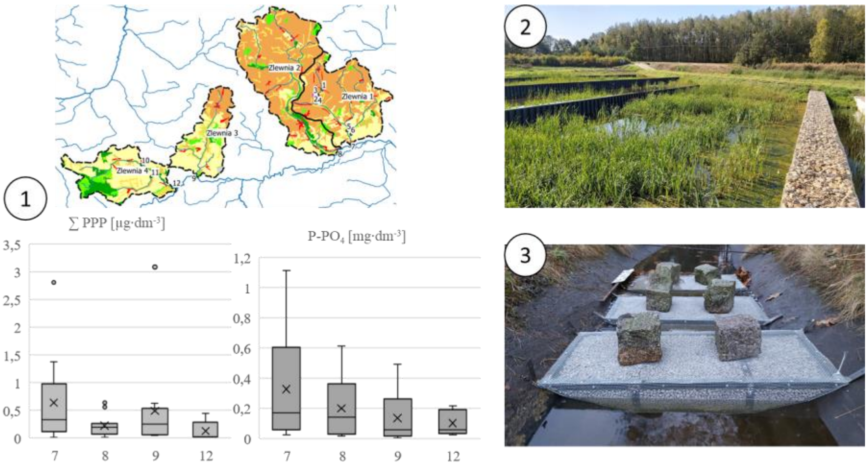

Figure 1. Methodology of the study was focused on the analysing of the spatial-temporal dynamics of pollutants in selected catchments (1) and to propose EH-NbS (2) and to optimise their efficiency (3) towards local conditions.

Results and concluding remarks

A total of 30 pesticides were identified, being present in 89% of all collected samples (n = 144). Spatial structure of the catchment in terms of the orchards presence was the main factor determining the level of pollution, and yet, positive effect of riparian buffer zones, limiting maximum concentrations, was observed in one of the catchments, suggesting it as the high-potential management tool to prevent pollution, as it was confirmed by other authors (e.g. Izydorczyk et al., 2018). The temporal presence of pesticides was positively correlated with short-term rainfall (up to 3 days before the collection date). The influence of orchards was also observed in the TP concentration in rivers, that was additionally correlated with precipitation. The efficiency of self-purification was related to the temperature, which confirms the significant role of biotic factors (river metabolism). Lower potential for self-purification was observed in winter.

Our study clearly evidences the need to take legal actions on the farmland level, with the education of farmers. As the available methods, we can name the use of time-controlled fertilizers and integrated protection methods using e.g. biological plant protection products to eradicate the pressure of pesticides. However, to increase the resilience of catchments, these activities have to be complemented by EH-NbS. To increase their efficiency during cold months, we proposed new type of adsorption material with high efficiency towards P and pesticides removal. BioKer, is material which is developed from light expanded clay aggregates coated with calcite or biochar. Our research revealed that Permeable Reactive Barriers (Fig. 1 – 3) made with BioKer are six times lighter and provide 20 times higher efficiency for P-PO_4 removal compared to dolomite-based barriers. The Intellectual Property Rights for BioKer are protected by patent No. Pat.238640 (Jarosiewicz and Zalewski, 2021).

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Assessment of climate change impact on surface water regime in Serbia

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Introduction

At the beginning of the new century in Serbia there were three dry years, 2000, 2003 and 2012, with extremely high temperatures and long dry periods. Taking into account complete damage caused by droughts those years, consequently agriculture in Serbia is still affected. On the other hand, frequent and heavy rainfall periods were recorded at the first half of 2010, 2014 and 2016. The damage estimated in 2014 was EUR 2 billion and contributed not only into the lesser annual income, but also in lower grain yield in the later period. The main purpose of the analyses presented in the paper is to create a rational basis for technical, technological and other measures to mitigate the negative effects of the obvious changes in the climate system.

For the purpose of adopting the most appropriate methodology, four river basins were selected on the territory of Serbia with long-term measurements of the main water balance elements. The regional climate model (RCM) EBU-POM was used for meteorological parameters determination. The outcomes of mathematical model VNC presented in the paper are projections of hydrological regime in the upcoming period till the end of 21th century. Research purpose is to define guidelines in line with the strategy of sustainable development, according to the current floods and storms, as well as those that would occur in a changing climate conditions.

Materials and methods

For the design of the future climate state in Serbia and the needs of scientific projects, a regional climate model Eta Belgrade University-Prinstone Ocean Model was used (Djurdjevic & Rajkovic, 2008; Prohaska et al., 2013). Some meteorological parameters for the location of the meteorological stations were defined by method of dynamic scaling (down scaling) in order to estimate the water regime in the river basins with an outlet at profiles of the hydrological stations.

The analysis has been done for the period 1961 to 2100. For the period 1961 to 1990, observed GHG concentration values were adopted, while in period 2001 – 2100 GHG estimated concentrations vary according to the climate scenarios of the Intergovernmental Panel on Climate Change (Institute for Development of Water Resources “Jaroslav Černi” (IJC), 2010). The two scenarios have been analyzed: the scenario A1B was selected as an average, while A2 was selected as an extreme. For both scenarios monthly series of precipitation and air temperature were established for the defined time frames. The impact of climate changes on water resources has been estimated upon projected changes of meteorological variables.

VNC mathematical model is the basis for all assessments (IJC, 2010). This model relies on the none-linear correlation that is used to generate a time series of mean monthly flow rate on unstudied hydrological basins (Prohaska, 2006). The initial assumption was that there was monotonous nonlinear regression between the observed values at different measuring stations in the same time frame. In this case, the correlation among their standardized variables is linear. According to the initial assumptions, the following equation was established:

$$U_{j0} = \alpha_{01} \cdot U_{j1} + \alpha_{02} \cdot U_{j2} + \ldots + \alpha_{0i} \cdot U_{ji} + \ldots \alpha_{0L} \cdot U_{jL} \quad (1)$$

α_{0i} are coefficient calculated using determinants of standardized correlation coefficients, while U_{ji} are calculated standardized hydrological parameters values.

Results and concluding remarks

The reference state of water resources was entirely determined by using the available time series applied on the GIS maps to form representative figures, like as for the annual precipitation and specific runoff. The series for the A1B and A2 IPCC scenarios were completed for the identification period 1961-1990 based on GCM reduced to local RCM (EBU-POM) following the series of measured meteorological parameters.

The established VNC model, after its calibration and verification for the basins: Nišava, Kolubara, Raška and Mlava, has produced the results of climate change impacts on mean monthly flows like as presented in Table 1 expected.

Table 1. Preliminary results of the effect of climate change on mean monthly flows at selected hydrological stations

River Basin	**Nišava h. s. Niš**		**Kolubara h. s. Draževac**		**Raška h. s. Raška**		**Mlava h. s. Veliko Selo**	
Period	**Q (m3/s)**	**Δ (%)**	**Q (m3/s)**	**Δ (%)**	**Q (m3/s)**	**Δ (%)**	**Q (m3/s)**	**Δ (%)**
1961-1990 (RHMSS)	30.37		22.29		6.96		9.73	
2001-2030 (VNC)	30.11	**-0.86**	19.96	**-10.45**	6.31	**-9.34**	9.47	**-2.67**
2071-2100 A1B (VNC)	29.91	**-1.51**	21.26	**-4.62**	6.38	**-8.33**	9.31	**-4.32**
2071-2100 A2 (VNC)	28.48	**-6.22**	21.74	**-2.47**	6.24	**-10.34**	9.59	**-1.44**

According to data published in the draft version of Spatial Plan for the Republic of Serbia, for the period 2010-2014-2021, expected increase in average annual air temperature in Serbia by the end of this century will be about 3-4^{o}C higher than in the reference period 1961-1990, and the amount of precipitation would be reduced about 12% per year, or 24% in the summer season.

The results produced by implemented analyses in EBU-POM upon IPCC 4 fully confirmed the Spatial Plan forecasts. For two out of the four basins additional analyses will be made upon IPCC 5 and results compared with the results made upon IPCC 4.

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The impact of SUDS implementation in the water metabolism of an urban catchment

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Introduction

The performance of an urban drainage system is usually measured through the changes in the characteristics of the flood hydrograph in reference to a baseline. When designing and assessing the performance of Sustainable Urban Drainage Systems (SuDS), we must consider other impacts on the catchment, such as changes in the hydrological regime and contributions to the water supply system. The Urban Water Metabolism concept considers input, output and retained water flows in an intent to replicate the resource efficiency of a natural system (Renouf et al., 2018). The growing surface imperviousness and the centralization of water supply systems are one of the causes that make urban catchments metabolically-inefficient. SuDS impact directly on hydrological indicators and can enhance the efficiency of the urban water metabolism by replicating the capacity of recycling and adaptation of natural systems. This study quantifies indicators of the water metabolism of a small catchment in Brazil for an extreme event considering the implementation of SuDS.

Materials and methods

The Ramadinha catchment (128 ha) is composed mostly of residential lots and public equipment and open spaces very unevenly distributed over its area. The water balance flows, numerically simulated, were used to generate indicators of urban hydrological performance of the catchment's water metabolism. It is important to emphasise that we analysed the metabolism of water for one single extreme rainfall event which occurred in 2020, of 60 mm of precipitation during 1 hour and 20 minutes. These results do not represent the catchment metabolism as long-term figures, as usually calculated in metabolism studies. However, they demonstrate how the catchment metabolises the collected rainfall during such an event. We focus on urban water flows, simulating the following scenarios:

Baseline: Current catchment conditions, without implementation of SuDS.

Scenario 1: Baseline + The implementation of SUDS based on infiltration processes (bioretention systems, permeable pavements, infiltration trenches).

Scenario 2: Scenario 1 + The implementation of rainwater harvesting systems (tanks with a capacity of 200L placed in all the 1884 catchment’s households).

For the composition of Scenario 1 and Scenario 2, we placed SuDS according to the availability of urban and physical components throughout the catchment (Alves et al., 2022). Flooding volume, flooding spots, total runoff, peak flow in the catchment’s exutory, and rainwater harvested volume were computed from hydrological simulations using the Storm Water Management Model (SWMM).

The parameterization of the current land use and occupation considered several physical characteristics of the catchment, such as area, slopes, flow directions, and surface imperviousness. For this simulation, we discretized the catchment according to the boundaries of each block, totaling 199 sub-catchments endowed with each parameter. For the scenarios involving SuDS measures, we modified the subcatchment’s parameters according to each SuDS specificity and using SuDS data from the literature. The model was parameterized to identify flooding whenever water depth exceeds a particular value above street level which makes walking and vehicle access difficult, as well as entering the houses. The runoff process throughout the sub catchments was modelled using the dynamic wave routing model.

Results and concluding remarks

Location of all SuDS measures (bioretention systems, permeable pavements, infiltration trenches, and rainwater harvesting) are shown in Figure 1. The simulation results, summarised in Table 1, shows the relevant role SuDS may have in improving the metabolism of water in the catchment. SuDS significantly reduced the traditional flooding indicators, such as the peak flow and flooding volume. Besides, the total runoff is also reduced, maintaining water inside the basin, contributing to augment infiltration and evapotranspiration, and alleviating high temperatures and heat. Additionally, reduced runoff causes less impact on flooding in areas downstream the catchment. The reduction of flooding spots along the basin is an indicator which reveals how everyday activities are less impacted if SuDS are implemented. The use of rainwater harvesting systems, as proposed in this study, can have a major impact on the reduction of flooding and runoff throughout the catchment, and help to decentralise the conventional water supply system. Although the simulated 200L tanks do not greatly reduce the dependability of the basin to the centralised water supply source, bigger tanks may be implemented according to space availability inside the lots, case by case.

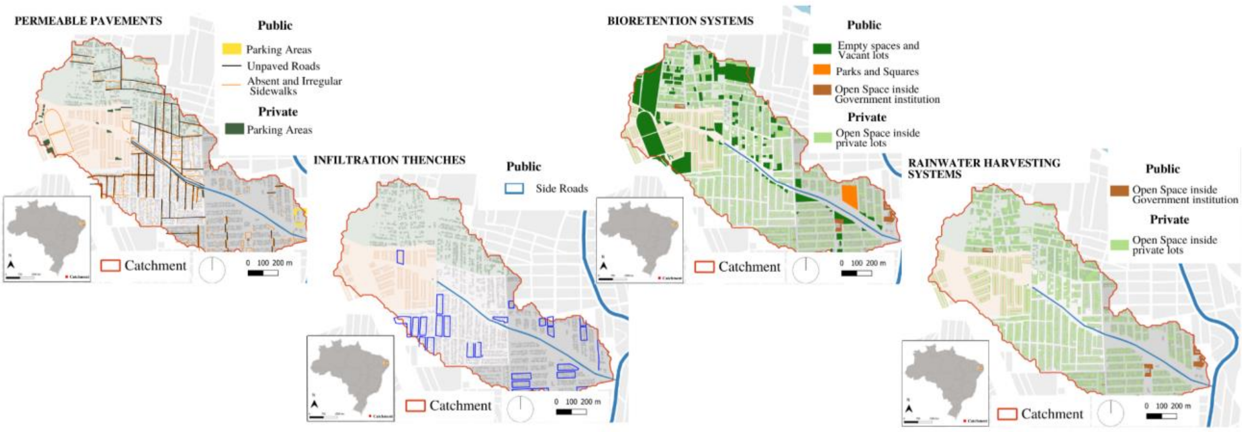

Figure 1. Location of SuDS along the catchment

Table 1. Comparing the hydrological performance of the simulated scenarios

Scenarios	Peak flow (m^3/s) / % of peak flow reduction in the catchment's exutory[1]	Flooding volume (m^3) / % of flooding volume reduction[1]	Total runoff (m^3) / % of total runoff reduction[1]	Number of flooding spots / % of flooding hotspots reduction[1]	Volume of rainfall harvested for attending urban water demand (m^3)
Baseline	0.400 / 0%	2042 / 0%	8450 / 0%	18 / 0%	0
1	0.068 / 83.5%	710 / 65.2%	2930 / 65.3%	6 / 66.7%	0
2	0.028 / 93.2%	230 / 88.7%	1370 / 83.8%	3 / 83.3%	380

[1] Values compared to the baseline scenario

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Eco-hydrology for Sustainable Water Resources Management and Climate Change Adaptation: A need for Intensive Youth Mobilization

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Introduction

Water resources are among the world's most impacted ecosystems. The degradation of rivers, coastal areas, wetlands, floodplains, and other water resources has currently been exacerbated jointly by the growing pressure on these precious ecosystems and the impact of climate change. Transboundary water resources face a special risk, especially if they are not holistically managed by the parties. Massive pollution, catchment, and watershed degradation are some of the threats to water resources (Kupiec et al. 2022). Ecohydrology has been currently growing with more insights as a systemic solution to curb these challenges by enhancing the resilience and carrying capacity of water ecosystems (Zalewski et al. 2010). To this end, its promotion requires a solid justification of its revealed efficiency, and meaningful youth involvement globally to make it sustainable and fasten its adoption. This study seeks to provide the evidential application and performance of Ecohydrological Nature-based solutions and calls for a meaningful youth mobilization to continuously protect water resources sustainably, using Ecohydrology.

Materials and methods

The application of Ecohydrology was explored in different parts of the world, both developed and developing. In Europe, the investigation involved Ecohydrology interventions in Poland while Africa was represented by Ethiopia and Kenya. An extensive and critical review was done regarding the restoration of rivers and lakes, controlling pollution, and urban climate change adaptations. Specific attention was made to the analyses of the efficiencies and performance of the novel Ecohydrological solutions.

Results and concluding remarks

Ecohydrological methods that have been widely applied include constructed wetland, sedimentation-biofiltration, and sequential biofiltration systems for water quality enhancement and pollution control. Blue-green infrastructure has been used in the same context to increase resilience and as an adaptive strategy to urban climate change. They both count for enhancing the resilience of water ecosystems, addressing pollution and hydro-climatic risks, and increasing the adaptive capacity of both societies and ecosystems. Biofiltration systems are made of the biological component consisting of vegetation matter, to mimic the natural absorptive and filtration role of ecosystem components. Sedimentation-Biofiltration systems were prioritized in Poland to enhance stormwater, agricultural run-off, and effluents treatment before reaching the rivers and lakes. They have proven an efficient removal of Nitrogen (73%-NO_3^-,70%-NO_2^-, 99%-NH_4^-) and Phosphorus 52% from agriculture and point-source pollution from reaching the Jelonek Lake (Kupiec et al. 2022), and thus controlled the symptoms of eutrophication and accumulation of Harmful Algal Blooms (HABs). In Kenya, Constructed Wetlands equipped with macrophytes (native aquatic vegetation) significantly activated the denitrification process and biological decomposition of harmful pollutants to less harmful materials that are metabolically bio-absorbed by plants. Macrophytes incorporated in the system enhance the settling of suspended particles and trigger nitrogen removal by denitrification. This significantly helped in the restoration of Lake Naivasha by reducing the amount of total dissolved solids and conductivity by 64 and 29% respectively (Kimani et al. 2012). Sequential biofiltration systems were adopted in Ethiopia to restore the Assela Lake from anthropogenic pollution and degradation (Zalewski et al. 2010; Negussie et al. 2012). The systems were able to remove Nitrogen, Phosphorus, Organic matter, and Minerals by 76, 93, 36, and 67% respectively.

To increase the resilience to urban climate change, Blue-Green Infrastructures were constructed in Radom City, Poland to create a green city, reduce urban heat effect, cut off the extent of greenhouse gases from the local scale, and reduce the risk of city flooding. The installation of the demonstrative interventions in public areas and schools, and involving a wide range of stakeholders (government and private companies) allowed for a greater adoption rate and replication.

The revealed usefulness of Ecohydrology needs to be amplified and promoted globally from the grassroots (community level). Strategies are also needed to further the initiatives and to make sure it becomes sustainable and widespread. Youth presents a wide community able to act but, in some cases, overlooked. Active youth mobilization in Ecohydrology deserves special attention for a sustainable nature, water resources management, adaptation to climate change and variability, and inclusive green and circular economy. They play an intermediary role between the present and future generations. They are already experiencing the impacts of climate change, including that of water resources degradation. Being the most active group in the population necessitates their urgent consideration to make Ecohydrology spread. This in turn calls for the urgent need for an inclusive youth mobilization strategy to curb the challenges of sustainable water resources management and combat climate change impacts.

In Africa for instance, where youth constitute more than half of the population, creating a platform that will be a coalition for youth professionals to bring about horizontal and vertical integration between stakeholders is of important consideration. This will ease planning and action that merge science, planning, practice, management, policy, and implementation from a molecular to catchment scale as a whole in a systemic approach to ensure water security, ecosystem management, and addressing climate change in the perspective of Ecohydrological Nature-based Solutions. The foundation of the African Young Ecohydrologists Association is foreseen to bring about a meaningful achievement through international cooperation on water education and capacity building, networking, multidisciplinary and transboundary experiences, inclusiveness, green jobs, the circular and blue economy that count for sustainable development while leaving no one behind.

In the perspective of climate change adaptation, youth are far-reaching agents for behavioral change via climate change governance, influencing policies, awareness, and capacity-building programs on green energy, jobs and entrepreneurship, circular economy, climate advocacy and justice, and ecosystem restoration using the interdisciplinary ecohydrological approach. Sharing successful cases (from the local context) and outreach programs across the African continent will motivate practice. Its implementation and fruition would be enhanced training and demonstration in schools, universities and, the young generation to create a sustainable and climate-sensitive generation committed to fighting against the climate change crisis. A meaningful and motivational mobilization can be strengthened via authorization, networking, collaboration, and partnership with relevant stakeholders and authorities, including UNESCO-IHP. This would enhance youth contribution to ensuring science for a secure world in a changing environment through involvement in scientific investigations, inclusive water education and sustainability, collecting and utilizing scientific data and information from the field, to justify the realization of climate change for immediate mitigation, adaptation, resilience and adaptive action, and strategies.

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Risk Assessment of Flooding prevention in construction works at Balearic Islands, Spain

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Introduction

Our works are frequently subject to the effect of climate action both on construction or in preventive maintenance. This is typically due to storms, winds and in some areas tides.
Climate conditions during construction and maintenance works have a great impact on the work schedule and can be the source of major cost, delays, contractual issues and in extreme conditions and during flooding: property damage and life threatening situations.

The aim of this paper is to assess the level of scientific evidence on related risk during construction works; to summarize recommendations for best practice and case studies related to climate and to encourage cross-sector knowledge sharing of successes and lessons learned from risk assessment. (e.g. LLatas 2020; RISK DURING THE CONSTRUCTION OF MARINE WORKS).

Materials and methods

By considering different scenarios based on weather Forecast, it is possible to link planning and design stages. Two case studies are explained, both in Spain:

- Case study 1 is the storm in Balearic Islands in October 2018, Palma de Majorca.

Due to the flooding in 2018 six corrective actions were undertaken by different construction companies according to the drawing below (Figure 1): Corrective actions included: walls demolition, walls repairs, foundations protection, vegetation (including trees) removal, wastes and obstructions removal.

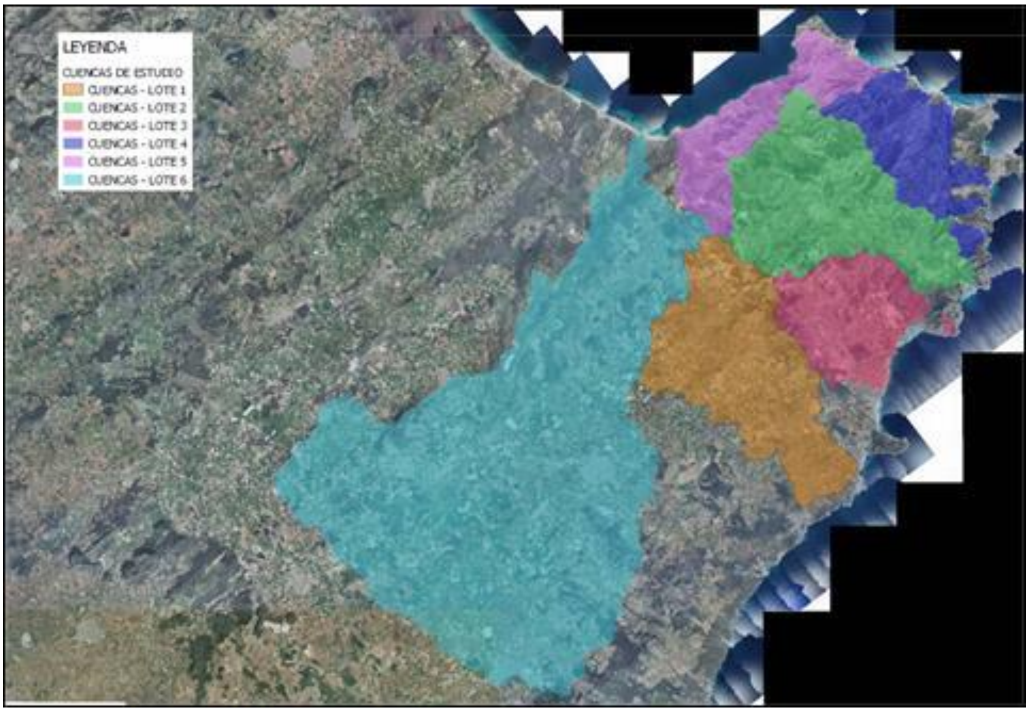

Figure 1. Corrective actions drawing 2018, Mallorca.

- Case study 2 are the DANA storm in September 2021, Menorca (Figure 2).

An Environmental impact assessment is in progress because corrective actions are to be doing in a protected area.
Most of the recommendations and best practices included:

- Risk analysis
- Climate analysis
- Water table levels studies
- Resilient design
- Seasonal construction
- Statistical simulations
- Contractual framework

This qualitative research aimed to produce real- world knowledge about how by considering different scenarios based on weather forecast, it is possible to link planning and design stages.

Figure 2. Due to Dana Storm in September 2021, Menorca.

Results and concluding remarks

Climate change involves climate disasters and extreme weather and temperatures. To consider risk at the design stage involves high first cost. Nevertheless, it is key to avoid unexpected impacts, risk of delays, property damage, claims and contractual issues. A previous climate study including water table levels, rainfall, and seasonal construction may be key to achieve the project milestones. Satellite mapping allows to monitor. Coastal retreat has a substantial potential to contribute risk reduction (Bhuiyayan and Dutta, 2012). Nevertheless, without increased adaptation action and no action to held subsidence, coastal flooding will contribute very substantially to increasing risk (Khan et al., 2013; Takagi et al., 2016; Carvalho and Wang, 2019).

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Study on post Environmental, Economical and Socio-cultural effects to the Sri Lankan western coastal belt due to X-press pearl disaster

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Introduction

The X-press pearl disaster is known as one of the most devastating and worst Environmental destruction that happened along the Sri Lankan western coast. The vessel was transporting highly toxic chemicals including 25 tons of Nitric acid, caustic soda, methanol and 9,700 tons of epoxy resins (Madushika Sewwandi, Oshadi Hettithanthri, S.M. Egodage, A.A.D. Amarathunga, Meththika, 2022). Also with 78 tons of plastic pallets, 350 tons of fuel oil and other environmentally hazardous N.O.S (Not otherwise specified) category substances which can be anything from toxic substances to heavy metals (Nanayakkara, 2021). There were many immediate consequences raised after the fire eruption and explosion of the vessel on 20th of May 2021 including higher cases of marine fauna carcasses, beach pollution with plastic pallets and social community actions regarding the issue. The government of Sri Lanka together with tri-forces and other authorities directly intervened to minimize and control the situation.

Research method

The main objective of the study is to identify how the disaster can gradually affect the environment, economy, and socio-culture of the community with respect to the time.

Still there are number of aquatic fauna carcasses appearing around the western coastal belt with burn marks and filled with plastic pallets inside them. Nearly 145km of shoreline along the western coast from Hikkaduwa to Negombo can be pointed as the death traces for the above animals. Varieties of dolphins and turtle species are also among those carcasses.

The government has restricted fishing and economic activities around 50 miles of the submerged ship area due to chemical and hazardous waste which can be harmful for human in different ways. This incident created new economic issues to the community around the island which were suffering post Covid-19 pandemic effects and lack of tourism. Also there were oil spilling around the ship. Government, forces, other responsible authorities and environmental organizations were readied for a worst case which can expect. Fortunately, there was a minor level oil spill was recorded and finally the situation was controlled. As there are huge number of plastic pallets and other shipping materials were deposited in the shore and floating in sallow sea shore, people tried to collect those toxic substances without considering the warnings of Sri Lankan government.

Therefore, primary data for the paper were collected through visiting 05 selected areas mostly affected. Sarakkuwa, Wellawatta, Hikkaduwa and area closer to Negombo lagoon and beach were visited for detailing purposes. Details were gathered by interviewing 07 persons from each selected area and also collected details regarding economic and social problems they are currently facing due to disaster. Secondarily data collected by available literatures, news articles and expert's comments published. They were mainly used to identify the post destruction of the marine aquatic environment including flora and fauna and possible seawater pollution measurements.

Results and concluding remarks

Mainly there are huge environmental pollution and destructions happening due to plastic pallets and toxic chemicals which released to the water with the explosion of the vessel. There are huge number of Turtle species such as olive ridley (*Lepidochelys olivacea*), hawksbill (*Eretmochelys imbricata*), leatherback

(*Dermochelys coriacea*), green turtle (*Chelonia mydas*) and dolphins were mainly can be seen along the shore of the coastal area along 154km trace mainly including the Sarakkuwa area (Nanayakkara, 2021). Mainly small fish carcasses only were filled with plastic pallets, while some large creatures like turtles and dolphin carcasses showed burn marks. Plastic pallets can absorb the chemical substances and exist for a longer period in the aquatic environment. As pallets are floating substances they can travel across the sea bed and surface. Not only surface, but also the shallow water bed is also considerably covered by plastic pallets which destroy aquatic environment completely. Small fishes and little creatures which mostly living in shallow water dies due to clogging their gills. It can be identified as the most dangerous effect which can destroy aquatic environment globally in international waters too. Marine avifauna mostly adopted to consume above mentioned aquatic fauna carcasses which leads to enter toxic and heavy metals into animal food chain system.

Relevant Authorities in Sri Lanka and Owner of the vessel tried to carry the vessel away from the coastal line to minimize the harmful effects of the disaster. Along this attempt the ship started to sink gradually and finally part of it was settled at the sea bed, 22 meters (73ft) deep in the immediate area. This can cause severe damages to the sea bed and immediate sensitive aquatic life including valuable flora and fauna resources. The amount of revealed cases of carcasses of aquatic fauna nearly after one year is significantly high, despite that unrevealed truth below the polluted sea water must be a more devastating. As sea water is a continuously moving, the consequences of the disaster is not only affect to the Sri Lanka, but also to the nearby countries like India, Maldives and Seychelles.

In the case of Sri Lanka is an island, most of the community’s livelihood mainly depends on the ocean. Most of the experts showed that there is a higher possibility to enter the contaminated toxic and hazardous chemicals in to human body through marine aquatic based food resources. Therefore, there is still low demand for most of the aquatic based foods such as fishes, cuttlefish, shrimps. According to the findings, there is an economical issue in the fishing industry, fisheries society, and general public due to lack of demand all over the island. In another case, Negombo is mostly populated with foreigners and tourists as there are huge number of villas and hotels. Specially, there was a sudden boom of tourism in Sri Lanka after Covid 19 pandemic. But with the following disaster, the tourism of the following specific area is crashed.

As there are still unrevealed most of harmful and hazardous substances which released out from the ship, the general public and community can be harmed due to being exposed to the highly toxic chemical substances which can cause adverse health effects.

Media should attempt to show the risk to the general public and avoid gatherings and promotions as their national responsibility. The government and other responsible authorities should take necessary actions and steps to restore the environmental damage by removing oil spills, plastic pallets as much as possible by using oil booms, skimmers and fasten the damage valuation process to claim the funds from relevant liable organizations. Regulatory bodies can implement rules, regulations and safety measures for vessels which carrying environmentally hazardous and toxic to avoid these type of disasters in future. Sea bed, which most of sensitive aquatic fauna lives should be clean step by step removing pallets and oil.

Acknowledgments: Acknowledge showing gratitude to all the environmentalists, experts, and professionals who sacrificed their valuable time for the protection of the global environment.

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Debris flow monitoring and assessment using UAV, South-West Tajikistan

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Introduction

Every year, numerous natural disasters occur in the Tajikistan, unfortunately, often lead to loss of life (The Second National Communication 2008, Yablokov 2009, Saidov et al. 2019). The minimum potential damage can be achieved by monitoring and creating a disaster forecasting system that makes it possible to study and determine the conditions for the emergence and spread of these processes and related disasters. The use of remote sensing and UAVs make it possible to conduct research (Safarov et al.) and the effectiveness of the use of various types of remote sensing of the Earth (ERS), as well as their use for monitoring and collecting data in mountainous areas of Tajikistan subject to debris flows risk, is an urgent task, as it allows obtaining results in a short time and assessing the situation in conditions of rapid climate change.

Materials and methods

For monitoring natural disasters in Tajikistan remote sensing data with high spatial resolution are considered promising, providing the necessary quality of the obtained results of interpretation of aerial photographs [Safarov et al. 2018]. In order to monitor and map the area affected by the mudflow, aerial photography was carried out in July 2020 in the Khuroson district (Figure 1), in South Tajikistan using a UAV. The area experiences little rain throughout the year, with the highest amount being approximately 217mm in April and the lowest in August (table 1).

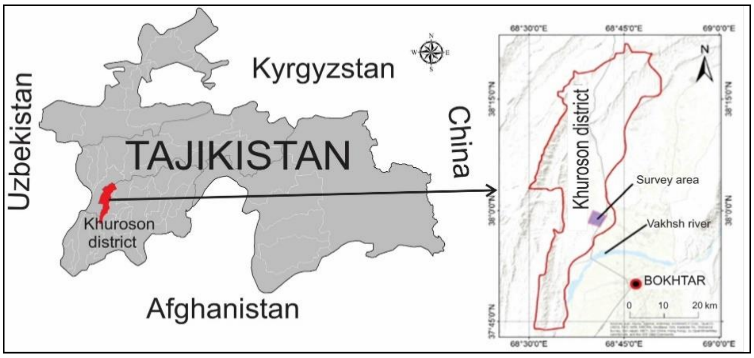

Figure 1. Location of the study area.

Table 2. Average monthly, maximum and minimum precipitation (1952-2017).

Month	Jan	Feb	March	Apr	May	Jun	July	Aug	Saint	Oct	Nov	Dec
average monthly precipitation	39.5	43.8	71.4	59.4	42.8	6.0	3.2	0.8	0.6	9.8	22.1	31.5
max	112.6	90.2	118.5	217.9	162.7	79.3	28.0	14.3	15.5	75.4	84.4	85.7
min	5.0	11.1	12.9	9.7	0.1	0.0	0.0	0.0	0.0	0.0	0.4	6.2

During the study of the area, images from the satellite and Google Earth service were used in order to obtain information about the area in previous years, as well as UAVs in order to obtain high-quality images of the area, create digital maps of the area, determine the area of debris flows and damage. Obtaining high-resolution aerial photographs allows you to immediately assess the damage from a mudflow in a few hours and coordinate rescue teams, survey the area from the air, and prepare a map of the area in a short time.

Results and concluding remarks

Based on the results of the research, images with a resolution of 5.62 cm/pixel were obtained. When comparing UAV data performed on July 10, 2020 (Figure. 2) and satellite images from the Google Earth resource from 2019 (the newest available ultra-high resolution data for this territory), performed in 2019, were identified the destruction of the house, the zone of formation and deposition of mudflow, destroyed roads and other affected objects. Since the mudflows descended on May 14-16, 2020, it is recommended to carry out monitoring closer to the date of the collapse in order to be able to assess the damage before most of the destroyed objects are dismantled.

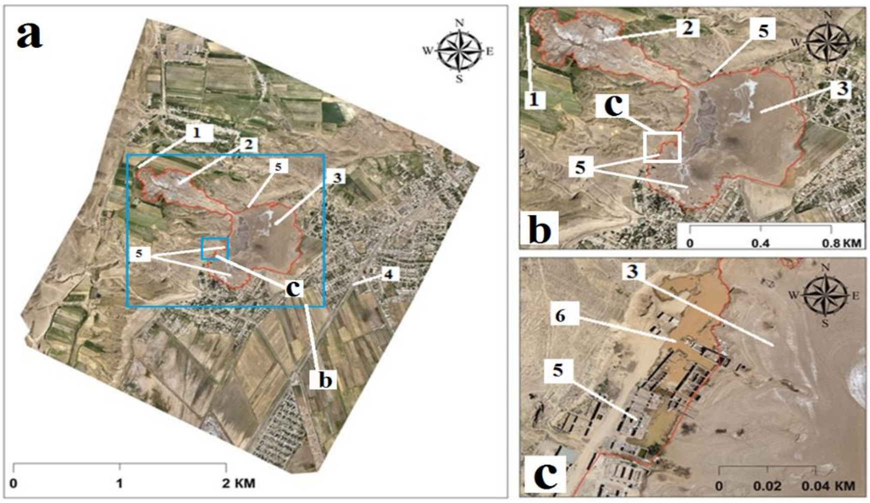

Figure 2. Aerial photography of the study area with the using of UAV. Designations: 1 - water channel on the upper side of the debris flow basin, 2 – debris flow formation zone, 3 – debris flow deposits, 4 - Dushanbe - Bokhtar A384 highway, 5 - residential buildings destroyed after the debris flow, 6 - destroyed road between settlements. Resolution - 5.62 cm/pixel, area 12 km^2.

Based on the data obtained, we prepared a digital model of a mudflow in the Khuroson district according to UAV data. The images obtained with the help of UAVs make it possible to study the terrain in detail, including the relief (the UAV also makes it possible to obtain a digital terrain model and a digital surface model), its change after a mudflow, and in the future to carry out possible forecasting of mudflow manifestations and the development of appropriate anti-mudflow measures. In areas where there is a risk of debris flow, landslides and floods, UAVs can help with disaster prevention and resilience work, as well as disaster response and recovery efforts. UAVs can be used for monitoring, assessing the ice conditions and outburst lakes, determining the boundaries of basins, watersheds, observing the coastline, observing snow cover, observing vegetation, etc., which affect the formation of mudflow processes.

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Analysis of COVID-19 Biomedical Waste Generation in India and its impact on water Resources

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Introduction

At the beginning of 2020, world has seen a devastating pandemic which was named as COVID-19. SARS-CoV-2 virus was supposed to be responsible for spreading of this infectious disease (cdc.gov). Almost all developed and developing nations on the earth has suffered, both in terms of loss of life as well as economical loss, due to COVID-19. The first outbreak of COVID-19 in India was felt in March 2020 and till date lakhs of humans have lost their life due to this pandemic. The principal mode by which people were infected with SARS-CoV-2 was through exposure to respiratory fluids carrying infectious virus. When an infected person came close to a person, he can transmit the disease to other one. Thus, doctors have advised to use surgical masks, face shields, gloves, shoe covers and personal protective equipment (PPE). These medical care accessories need to replace every day. Thus, these accessories have been disposed of as part of household waste. On many occasions, it has also been discarded by the roadside, behind hospitals, on beaches, in parking lots, in landfills. Infected persons have also used overdoses of some of the medicines which were suggested by doctors to cure COVID-19. In India, it has also been observed that few COVID-19 infected people after death, has been dumped in river (BBC News). As per Central Pollution Control Board (CPCB) India, the biomedical waste generation has increased due to this pandemic (Manzoor and Sharma 2019). In the present study, an analysis of biomedical waste generation in India during COVID-19 during 2020-21 has been done and its possible impact on water resources has been discussed.

Materials and methods

In the present study, an analysis of biomedical waste generation during COVID-19 has been done for India (Fig.1). India is a country in Asia. It is the seventh-largest country by area, the second-most populous country, and the most populous democracy in the world. Since it is densely populated, the spread of COVID-19 virus has also affected a large part of population.

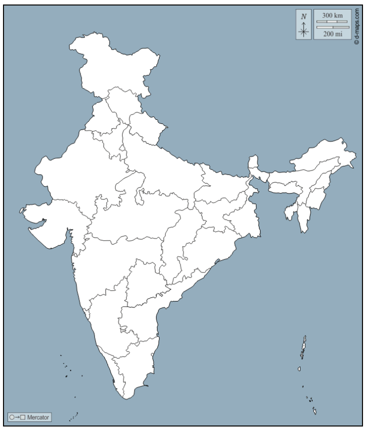


Fig. 1 Outline map of India.

Source of data and methodology

Data for individual affected from COVID-19 has been obtained from World Health Organization (WHO).

WHO is part of United Nations, responsible for international public health. Data for biomedical waste (BMW) has been taken from Central Pollution Control Board (CPCB), India. Data from 2021 to 2022 has been used for study. The collected data was then organized and sorted in excel sheet for analysis and the key statistical parameters measured for the analysis are mean, maxima, minima and standard deviation and then, employed for the analysis of data. The comparison point in the study is the biomedical waste generated in India in the COVID-19 years 2020 and 2021 and the control is the normal biomedical waste generated in India pre-COVID-19 year 2019.

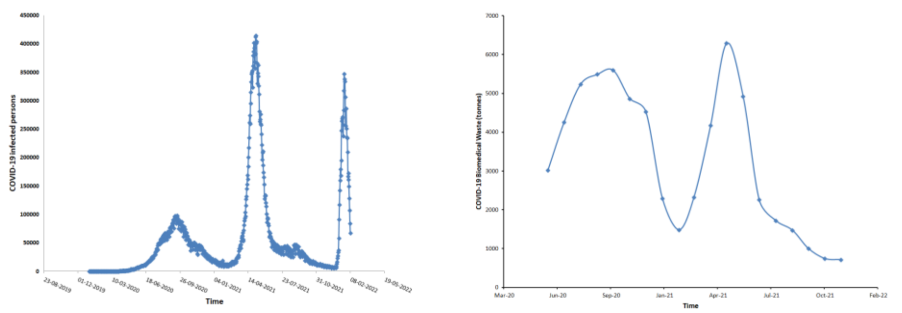
Biomedical Waste

Biomedical waste in the present study has been defined as per the definition given by Biomedical Waste (Management and Handling) Rules, 1998 of India which states that it is "any waste which is generated during the diagnosis, treatment or immunization of human beings or animals or in research activities pertaining thereto or in the production or testing of biologicals". Waste like discarded medicines, waste sharps like syringes, hypodermic needles, plastic casts, dressings etc. will fall under this category.

For data gathering, CPCB has developed a mobile application namely 'COVID19BWM' to update the data of COVID-19 biomedical waste generation. CPCB has deputed dedicated sanitation workers separately for biomedical waste and general solid waste so that waste can be collected and transferred timely to temporary waste storage area.

Results and concluding remarks

As seen from Fig. 2, till January 2022, three waves of COVID-19 have hit India. The number of infected person was maximum during April-May 2021. The biomedical waste generation has also reached maximum in April-May 2021 (Table 1). These biomedical wastes may have been dumped in landfill site or may be burned. In both cases, it may have resulted in pollution of air or water.



(a) (b)

Fig. 2 (a) Persons affected from COVID-19 in India; (b) Biomedical waste generation in India

Table 1 Statistical analysis of BMW of India during 2020-21

Biomedical Waste (tonnes) due to COVID 19			
Mean	Maximum	Minimum	Standard Deviation
3283.66	6293	713	1853

The process through which different water bodies will contaminate by biomedical waste has been expressed in Fig. 3.

The generation of the huge amount of biomedical waste has strained the India's biomedical waste management system. The waste has overflown the capacity of the biomedical waste treatment and disposal facilities. The waste is either dumped in water bodies or disposed in land pits; both affecting the water resources adversely.

The possible water resource contamination which might have caused by biomedical waste is as follows:

- The leachate from dumping of biomedical waste at landfill site has capability to percolate the sub-surface and cause groundwater pollution.

- Due to unawareness among citizens, biomedical waste has also been dumped in rivers, ponds or lakes. Thus, there are chances that pathogen contamination might be present in water bodies.
- The chemical components of Pharmaceutical medicines may come into the water bodies through urination. Thus, concentration of these contaminations may have increased in water.
- Animals and human bodies have also been dumped in water bodies, which may cause pathogenic contamination in water.
- Due to inadequate waste management during the lockdown in India, waste load in rivers and other water bodies might have increased.
- Plastic contamination in water bodies might has increased due to excessive use of plastic materials for biomedical accessories.

The research on the effect of biomedical waste on COVID-19 in India on water bodies is still in nascent stage and due to lack of proper data and equipment, it may take time to quantitatively prove the facts. The current study only focuses on the qualitative study of the effect of biomedical waste disposal on water resources. There are no such solutions proposed for the identified problem in this study.

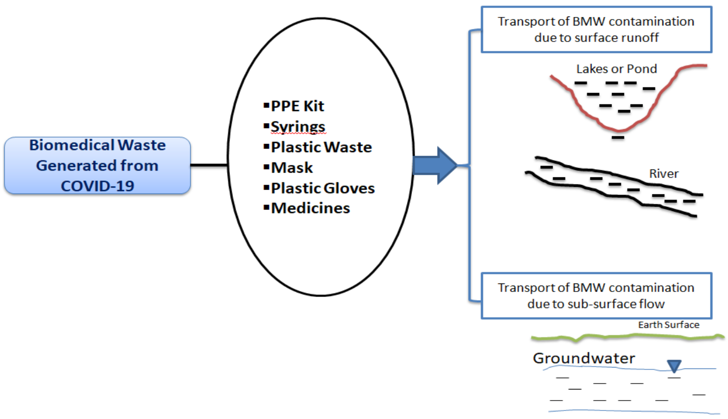


Fig. 3 Water Bodies contamination through BMW

Acknowledgments: Authors are thankful to Department of Soil & Water Conservation Engineering, GBPUA&T Pantnagar for providing the necessary facility to conduct this research.

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Trends in climate variables and their effect on water requirement for tea cultivation in the northeast region

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Introduction

Due to its production and harvesting system, tea (Camellia sinensis L.) is unlike any other usual crop. It's a sort of crop that can grow in a variety of temperatures and soils all over the world. Sylhet accounts for 94 percent of total annual production (63 percent in the Moulvibazar area), with the remainder coming from other regions of the country. While Bangladesh is grappling with how to deal with rising domestic tea demand and a global competitive market, climate change poses a threat to tea production. Tea is affected both directly and indirectly by climate change. In general, rising temperatures will have two effects: direct effects on tea growth and scarcity of water for irrigation. As a result, both the direct effect of climate on agricultural productivity and the effective water supply and availability of water for irrigation must be considered. The scope of this research includes a review of several meteorological variables such as rainfall, temperature, solar radiation, wind speed, and relative humidity, as well as their combined impact on crop water needs. The northern and eastern zones of Bangladesh are considered for a thorough analysis. Individual characteristics are examined and compared in order to create a link between climatic influence and irrigational water demand.

Materials and methods

In this study, two stations named Sylhet and Srimongal station were selected and data for a period of 55 years ranging from 1961 to 2016 were collected from Bangladesh Meteorological Department (BMD). Trend analysis of climatic parameter was made as it is of great importance in determination of crop water requirement. In this study Non parametric Mann-Kendall test (helsel &Hirch,1992) has been conducted for trend analysis. Both parametric and nonparametric method is used for significance test of trends of climatic variables. Upon analysing the trend of different variables prediction was made for 2030s 2050s, and 2080s. The "FAO Penman-Monteith method" is used to estimate reference crop evapotranspiration (ETo). The FAO Penman-Monteith method is maintained as the sole standard method for the computation of ETo from meteorological data.To calculate net irrigation requirement (NIR) crop evapotranspiration (ETc) and effective rainfall (ER) were calculated from the data available. In the crop coefficient approach the crop evapotranspiration, ETc, is calculated by multiplying the reference crop evapotranspiration, ETo, by a crop coefficient, Kc

$$ETc = Kc\ ETo \tag{1}$$

Net irrigation requirement (NIR) of tea production is estimated by the following formula

$$NIR = ETc - ER + S + P \tag{2}$$

Where, S=seepage loss and P=percolation loss.

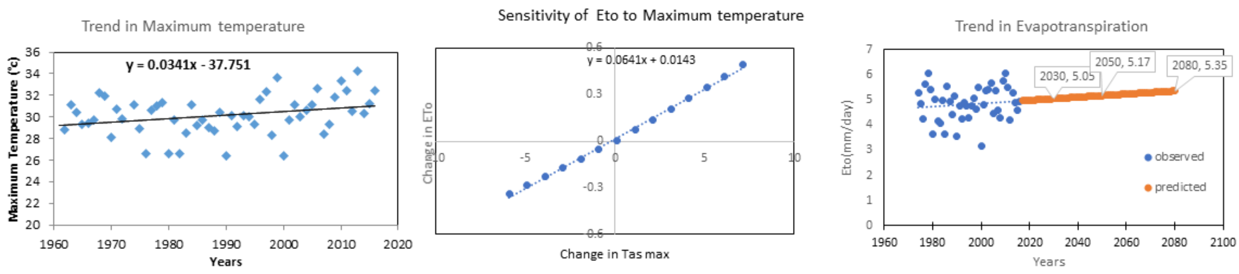
Results and concluding remarks

It was found from the trend analysis result of the climatic variables at Sylhet and Srimongal stations. Maximum temperature, minimum temperature, relative humidity has increasing trend. Sunshine hour, wind speed, solar radiation has decreasing trend, rainfall has increasing trend in summer and winter season (Table: 01). It was also evident from the analysis that minimum temperature has higher increasing trend than that of maximum temperature. It was found that ETo is most sensitive to temperature among the climatic variables. ETo is more sensitive to maximum temperature than minimum temperature. Increasing each percentage in maximum temperature ETo increased by 3.6%.

Table 1. Trends in Climatic variables

Variables	Average trend per decade	
	Sylhet	Srimangal
Maximum temperature(°C)	0.3	0.1
Minimum temperature(°C)	0.4	0.4
Relative humidity (%)	1.1%	0.2%
Sunshine hour(hr)	-0.4	-0.4
Wind speed (m/d)	0.1	-0.3
Solar radiation ($Mjm^{-2}D^{-1}$)	-0.4	-0.4

Eto and NIR analysis reveal an increasing tendency. According to the analysis Eto has a increasing trend of 0.1mm/day/decade. From prediction it was found that Evapotranspiration will be 5.05mm/d, 5.17 mm/day and 5.35mm/day by2030s, 2050s, and 2080s respectively (Figure01). As a result, more irrigation water will be necessary as the temperature rises. Furthermore, rainfall studies revealed that monsoon rainfall is declining, although pre-monsoon and post-monsoon rainfall is increasing. This irregular rainfall pattern will result in a water scarcity as well as a shift in tea phenology. Changes in other climatic parameters, according to the study, suggest a considerable change in NIR, which will have a long-term impact on tea growing and production.



(a) (b) (c)

Figure 1: Figure showing (a) Trends in Maximum temperature (b) Sensitivity of Eto to Maximum temperature (c) trends in Evapotranspiration

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Computer simulation of leakage water flow in pipes

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Introduction

The latest report by the Smart Water Networks Forum (SWAN) showed that most of main capitals of the world have a level of non-revenue water greater than the maximum 25% recommended by the International Water Association (IWA). There is still no consensus in the literature of universal equations that can be used to quantify and detect water leaks, so more experimental and numerical studies need to be carried out.

A systematic literature review conducted based on the Web of Science database indicated that the variation of the discharge coefficient (C_d), presented below in the Torricelli equation, is usually neglected in hydraulic leakage models. Despite this, recent experimental studies indicated a dependence of this coefficient on geometric, hydraulic, and hydrodynamic parameters (Shao et al., 2019; Yu et al., 2019). Then, this work aims to study the variation of the C_d with the above parameters through computational fluid dynamics (CFD).

$Q = C_d.A.(2g.H)^{1/2}$

Materials and methods

CFD studies were performed on the ANSYS FLUENT software to simulate experimental data available in the literature. Thus, the inputs were the pressures and velocities at 30 cm upstream and downstream of the orifices in the DN 25, DN 50, and DN 100 pipes with circular orifices of 3 and 6 mm in diameter as presented in the experimental work by Yu et al. (2019). A mesh convergence study was performed. A mesh of the DN 100 pipe with a 6 mm diameter circular orifice is shown below (Figure 1).

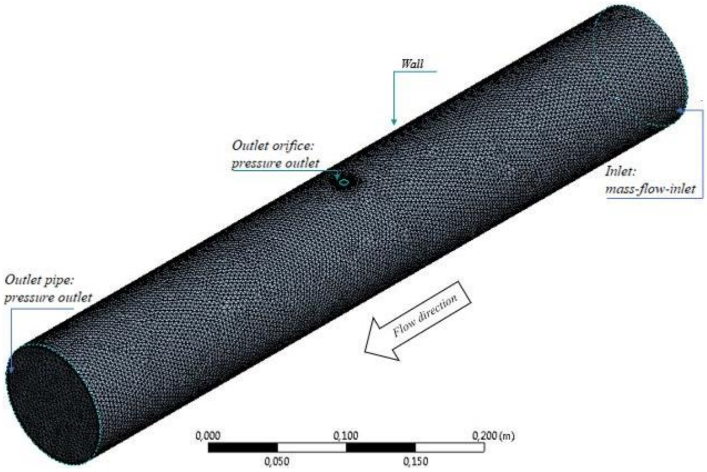

Figure 1. Pipe mesh DN 100 with 6 mm diameter circular orifice with the types of boundary conditions used.

The main RANS models were tested, i.e, the k-ε and k-ω model families. The empirical constants of the models were not changed because their calibration would require a great database of experimental results. Instead, only well-known functions in the literature such as production Kato-Launder and production limiter were used. The calibration of the models was carried out through the parameters: turbulent intensity and turbulent viscosity ratio. Then, the models were validated with the experimental data available in the literature.

The C_d of each simulation was calculated using the Torricelli equation considering the hypothesis that the orifice area does not deform with pressure, because: this work proposes to study steel pipes; simulated head did not exceed 50 mH_2O; circular orifices do not easily deform; the theoretical value of the exponentiation constant of 0.5 of the Torricelli equation remains constant for circular orifices (Greyvenstein and Van zyl, 2007; Cassa et al., 2010). At the end, a non-linear multiple regression analysis using the Levenberg–Marquardt algorithm was performed.

Results and concluding remarks

More than 120 boundary conditions were simulated. In the k-ε family of turbulence models, the standard k-ε presented the best results with an average deviation of 4.80%. Meanwhile, in the k-ω family of models, the k-ω SST model presented the best results with a mean deviation of around 3.88% when compared with the C_d of the experimental data from Yu et al. (2019) in geometries with a 6 mm circular orifice. Such results indicate that CFD modelling can be a promising tool in the study of water leaks.

The results indicated a tendency that for the same boundary condition, the smaller the diameter, the greater the number of streamlines that converge to the orifice, and the higher the C_d as shown in the example below (Table 01). The results are consistent with the experimental works in the literature.

Table 2. Typical simulation example with a 6 mm circular orifice for a head of 4 mH_2O as a function of the diameter.

	Head (mH_2O)	Measured C_d	Simulated C_d	Amount of flow coming out of the orifice (%)
DN25	4,07	0,6971	0,7346	49,30
DN50	4,00	0,6814	0,7200	30,42
DN100	4,02	0,6686	0,7027	14,91

The dimensionless coefficients that presented the highest R^2 were d/D (orifice-diameter ratio), ΔH/D (head-diameter ratio) and Re (Reynolds number), consistent with the work of Shao et al. (2019) and Yu et al. (2019). When combined, they present great R^2 as shown in the graph below that indicates the correlations with the simulation data (R^2 79.08%) and with the experimental data from the literature (R^2 95.01%).

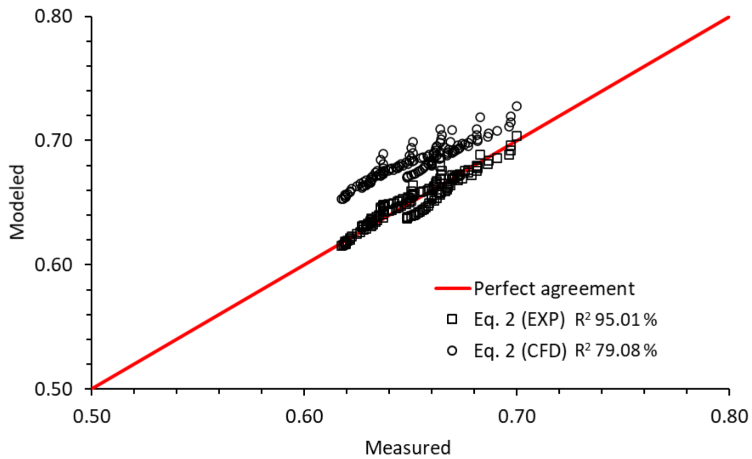

Figure 2. Comparison between the correlations Eq.2 (EXP) and Eq.2 (CFD) of type $Cd=A.(d/D)^B.(\Delta H/D)^C.Re^D$.

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Analysis of the influence of socioeconomic variables on urban water demand

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Introduction

Mekonnen and Hoekstra (2016) estimated that four billion people worldwide live in areas that experience water shortages at least once a year. It is necessary to know the aspects that interfere with urban water demand for an efficient water resources management. In this context, decision trees (DTs) have been used in studies to build water demand projection models (Shuang and Zhao, 2021; Abu-Bakar et al., 2021). Several studies consider different socioeconomic factors (Darr et al., 1976; Alamanos et al., 2020; Panagopoulos, 2014). In addition, the recent study of Brentan et al. (2017) reported that social and environmental aspects should be considered when building water demand projection models.

In this scenario, this work aims to identify the socioeconomic variables that contribute most to the water demand of Fortaleza city, the fifth largest city in Brazil by population, using DTs in conjunction with the Gini index.

Materials and methods

The Water and Sewage Company of the State of Ceará (CAGECE) provided data on water consumption for Fortaleza from 2009 to 2017. A data treatment was carried out, and the data were grouped by census tracts into 6 classes: Class 1: 0 to 50 l/cap/day; Class 2: 50 to 200 l/cap/day; Class 3: 200 to 400 l/cap/day; Class 4: 400 to 600 l/cap/day; Class 5: 600 to 800 l/cap/day and Class 6: above 800 l/cap/day.

Then, a set of variables was chosen to assess their potential relationships with urban water consumption. The dataset is from the last demographic census of 2010 conducted by Brazilian Institute of Geography and Statistics (IBGE). A summary of the variables analysed is presented in Table 1.

Table 3. Variables analysed with potential in relation to urban water demand

Name	Description	Unit
PCI	Per capita income	R$/cap
LEAB	Life expectancy at birth	years
UNR18M	Unemployment rate people aged 18 years and over	%
PTWATER	Percentage of population with access to sanitation facilities and drinking water	%
PPOP5to6	Percentage of population aged 5 to 6 years attending school	%
PSA6to14	Percentage of population aged 6 to 14 years attending school	%
PELS11to13_all	Percentage of the population aged 11 to 13 attending the final years of elementary school or who have already completed it	%
PELS18to20	Percentage of population aged 18 to 20 with elementary school education.	%
PELS15to17	Percentage of the population aged 15 to 17 with elementary school education	%
PELS18O	Percentage of population aged 18 or over with elementary school education	%
MHDI	Adult education level*	0 - 1
POP1114	Population aged 11 to 14 years	inhab.
POP65	Population aged 65 and over	inhab.
TOTMEN	Male resident population	inhab.
TOTWOMEN	Female resident population.	inhab.

*Municipal Human Development Index (IDHM)

To select the variables that have the greatest influence on the urban water demand in Fortaleza, a DT was built based on the Gini index.

Results and concluding remarks

According to the decision tree in Figure 1, the variable with the greatest influence on the urban water demand in Fortaleza is the per capita income. The result also indicates that only the following variables significantly influence urban water demand: PCI, UNR18M, PSA6to14, PELS15to17, POP1114, POP65, TOTMEN, TOTWOMEN.

For the lower consumption class, it was observed that the higher the rate of unemployed and the lower the number of young people attending school, the lower the per capita water consumption. This factor may reflect the socioeconomic status of these groups.

To sum up, the urban water demand is affected by socioeconomic factors. Such factors may allow the development of better consumption projection models. The results obtained in this work, therefore, show socioeconomic variables that can be incorporated into demand projection models for large metropolises such as Fortaleza city.

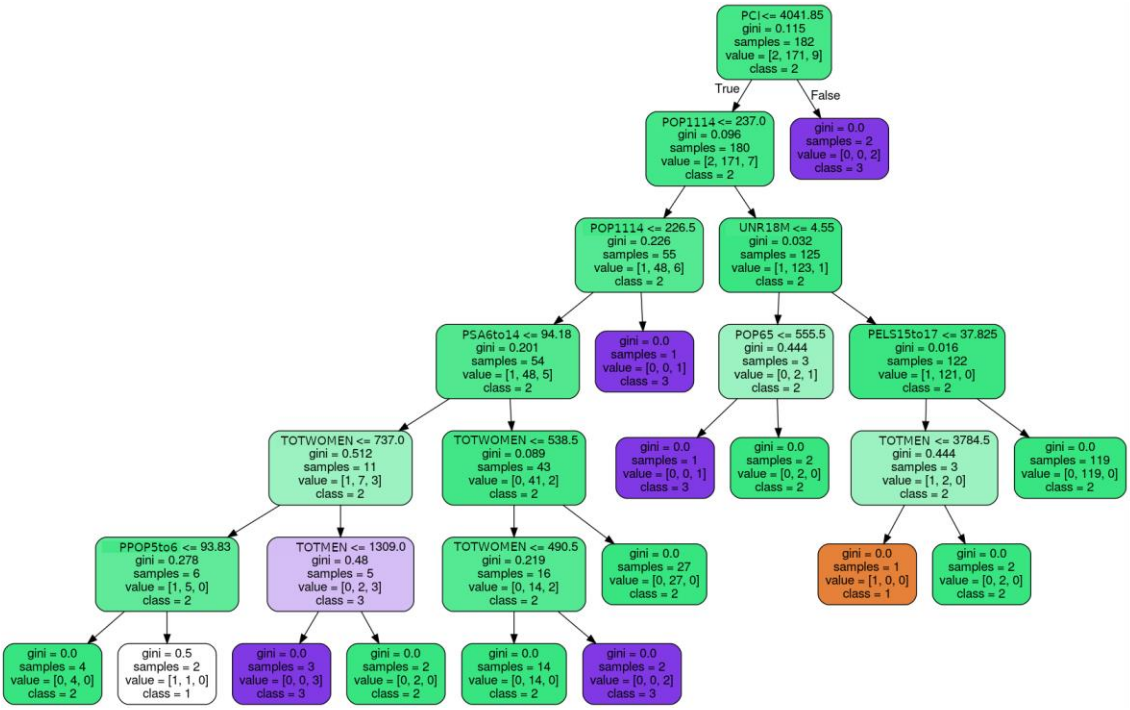

Figure 1. Decision tree of variables with influence on urban water demand in Fortaleza.

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Groundwater Potential zones mapping of Nanak Sagar catchment using GIS, Remote Sensing and MIF technique

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Abstract

For the hill agrarians, water shortage is a major issue. Growing population and industrial growth have created a need for land for food and fodder, posing a challenge to the trade in land and water resources. The present study emphasizes the effectiveness of the integration of Weighted Overlay Index Analysis (WOIA) and Multi-Influencing Factor (MIF) techniques with Remote Sensing (RS) and Geographic Information System (GIS) in groundwater management, specifically in the delineation of the groundwater potential zones. In this study, various geo-environmental factors, such as lithology, geomorphology, land use/land cover, the density of stream network, slope and soil texture are used to identify the GWPZs and to classify the spatially distributed groundwater potential of the Nanak Sagar catchment, Uttarakhand. The WOIA is performed in ArcGIS, using the weights of different themes for delineation of the GWPZs of the basin. Results indicate that, out of 407.20 km^2 area, 108.66 km^2 (26.67 %) have very good potential of groundwater while 124.77 km^2 (30.62 %) have good potential of groundwater. Among the different geo-environmental factors, lithology, geomorphology and soil texture have decisive roles in the occurrence of groundwater of the basin. Thereafter, feasible methods for sustainable groundwater management are given.

Keywords: Sustainable groundwater management, Groundwater potential zones (GWPZs), GIS, WIOA, MIF

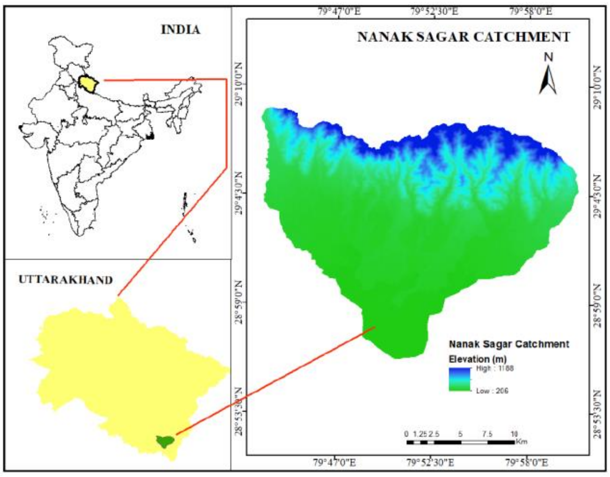

Figure 1. Location of the study area.

Groundwater potential map

The thematic maps of lithology, geomorphology, soil, slope, LULC and DD were considered for identifying GWPZs in the Nanak Sagar catchment. Areal distribution of delineated zones is listed in the Table 1. Finally, groundwater potential zones were classified as very good, good, moderate and poor which are shown in the Fig. 2. Most of the area covered by good and moderate potential zones with an aerial extent of 124.77 km^2 (30%) and 120.36 km^2 (29.54) followed by very good groundwater zones with an area of 108.66 km2 (26.67 %). Remaining area was categorized as poor potential zones with an aerial extent of about 53.70 km^2 (13.17%).

Table 1. Areal distribution of groundwater potential zones in the Nanak Sagar catchment.

Sr. No.	Groundwater Potential Zone	Area (km^2)	Percentage area covered
1	Poor potential zone	53.50	13.17
2	Moderate potential zone	120.36	29.54
3	Good potential zone	124.77	30.62
4	Very good potential zone	108.66	26.67

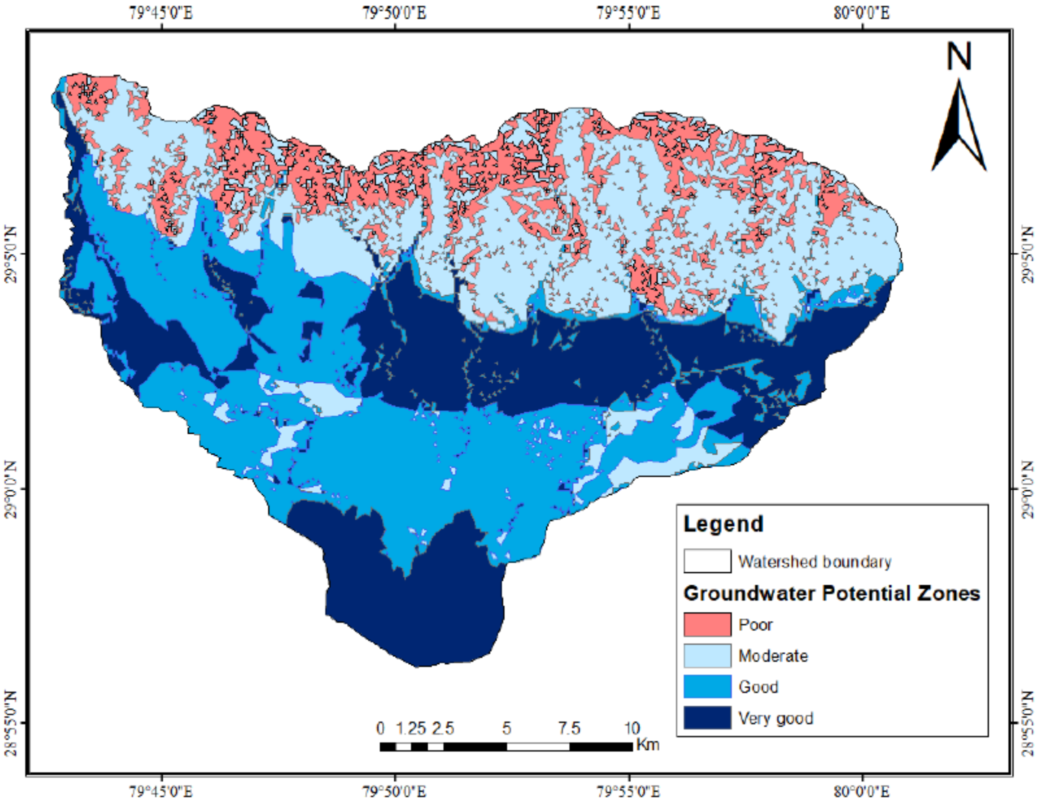

Figure 2. Groundwater potential zones map of Nanak Sagar catchment

Conclusions

This study applied WOA tool after obtaining the ranks and weights for the parametric layers. Thus, the application of this integrated tool was used to delineate the ground water potential zone for Nanak Sagarcatchment. 6 layers, DD, geomorphology, LULC, lithology, slope and soil texture were combined using WOA to delineate GWPZs of area. The results obtained were grouped into five classes, viz. 'very poor', 'poor', 'moderate', 'good' and 'very good'. After demarcating GWPZs, it was found that, 30.6 % and 29.5 % of study area has good and moderate potential of groundwater while, out of 407.2 km^2 catchment area, 26.7 % (108.66 km^2) have very good potential of groundwater. This study testifies the efficiency of the weighted overlay tool in the demarcation of groundwater potential zones and can be successfully used elsewhere with appropriate modifications. The given measures can be found helpful in sustainable groundwater resource management. The delineated zones should be verified with the help of available tube well and open well data.

COD Fraction as Means of Enhancing Wastewater Treatment – South Africa Based Case study

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Introduction

Traditionally, the complexity associated with implementing and controlling biological nutrient removal (BNR) in wastewater works (WWW) has been primarily in terms of balancing competing requirements for nitrogen and phosphorus removal, particularly with respect to the use of influent chemical oxygen demand (COD) as a carbon source for the microorganisms (Jwara, 2021; Jwara et al., 2019). Successful BNR optimization and modelling using WEST (Worldwide Engine for Simulation and Training) depend largely on the accurate fractionation of the influent COD.

The different COD fractions have differing effects on the BNR process. Therefore, the influent characteristics need to be well understood, especially in the age of contaminants of emerging concern in order to build robust wastewater treatment systems. This study presents the fractionation results of primary wastewater effluent COD at one of South Africa's wastewater works treating 65ML/day of mixed industrial and domestic effluent. COD can be characterized into four fractions i.e. readily biodegradable COD (Ss), slowly biodegradable COD (Xs), soluble inert COD (SI), and particulate inert COD (XI).

Materials and methods

In the research approach adopted for this study, a respirometer was used to conduct the experiments. The percentage fractions of the COD i.e. the bCOD and Ss were determined and thereafter the fractions of bCOD and the iCOD were determined using a set of equations and mass balance (equations 2-12). The bCOD can be fractionated into Ss and Xs whereas the iCOD is fractionated into XI and SI.

The respirometry principle is based on the oxygen uptake rate (OUR) by the microorganisms contained in the activated sludge in a biological reactor of the treatment plant to biodegrade a carbonaceous substrate. It works on a closed-circuit batch mode. The sludge inoculum was collected at the end of the aerobic reactor since there is a low risk of having residual bCOD. The collected sludge was aerated for a minimum of 24 hours before use. This allowed it to reach the endogenous phase (the oxygen consumption rate in the absence of substrate from external sources). The sample was then filtered to remove larger particles present. A litre of the filtered sludge was used in a respirometer.

Results and concluding remarks

On average the primary effluent bCOD was found to be higher than the iCOD and Ss was higher than Xs. The Ss is the most valued substrate as it is easier for the microorganisms to break down. This, therefore, means that primary effluent has sufficient substrate for the COD removal and the biological nutrient removal process. The primary effluent of WWTW is seen to be similar to domestic wastewater as the amount of bCOD was 70.5% and domestic wastewater to be 75%; however, it is seen that the Ss fraction is significantly higher (75%) than the Xs fraction (25%). This can be directly linked to the industrial effluent coming into the plant. Oil (VFA) and Dairy have a high Ss content.

Particulate organic matter which is Xs was found to be 25%. The lower fraction is beneficial for the treatment process as this fraction is degraded slowly by a series of microbial actions, such as adsorption, hydrolysis, and metabolism. The SI, was found to be 49.2% of the iCOD. The SI, is quite refractory in biodegradation and is contained mostly in industrial effluent. Aromatic compounds which are used in various industries and are typical examples of SI. It includes varieties of soluble compounds, which can pass through the microbial wall but cannot be degraded due to their refractory nature. As a result, the SI leaves the activated sludge reactor unaltered in concentration and characteristics. Darvill WWTP SI fraction is significantly higher than that of medium concentrated domestic wastewater influent adopted which is 17%. This shows that Darvill receives both industrial and domestic effluent.

Non-biodegradable Particulate COD (XI) fraction was found to be 50.8%. This fraction becomes absorbed in the activated sludge and is removed by sludge wasting in a WWTP. The XI significantly affects the volume of wasted sludge and forms part of considerations for WWTP reactor design. Both SI and XI cannot be biologically degraded further in a WWTP and therefore can pass through the activated sludge system unchanged.

Hence, precise COD characterization is important for the efficient operation of the biological nutrient removal wastewater treatment process. Several methods have been developed for COD characterization, but the two most commonly used processes are the biological and physical-chemical characterizations. The COD characterization results are represented in Figure 2 below.

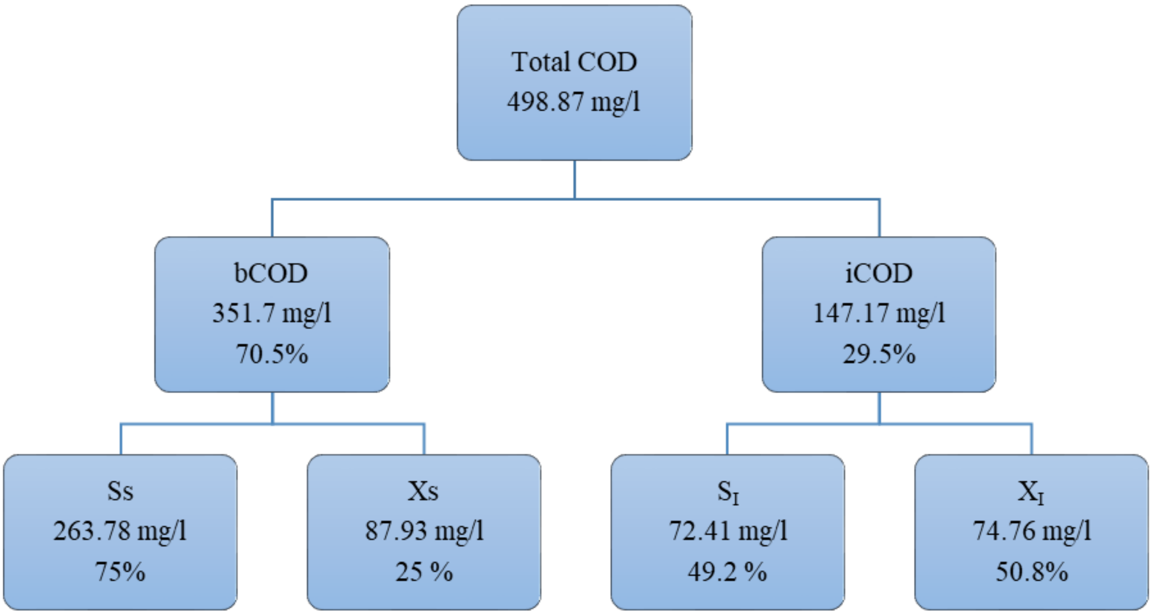

Figure 2 COD characterization results

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Antibiotic Resistance and Biofilm Formation Potentials of *Plesiominas shigelloides* from Selected surface waters in Southwestern, Nigeria

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Introduction

Plesiomonas shigelloides are ubiquitous and are mostly found in association with water-borne infections (Kandakai, 2017). This organism has been reported to be the causative agent of various types of gastroenteritis diseases, which include acute secretory gastroenteritis, invasive shigellosis-like disease, and a cholera-like illness (Kelly, 2011). This organism has been isolated as a sole and co-pathogen of various disease conditions (Janda *et al*., 2016). Antibiotic resistance in *P. shigelloides* has gained attention as a topic of interest due to the intrinsic resistance and recombinant gene acquisition exhibited by this organism. *P. shigelloides* isolates from the Southeastern and Western parts of Nigeria have been reported to show a significant resistant pattern to readily available antibiotics such as tetracycline, ampicillin, and trimethoprim-sulphamethoxazole (Adesiyan *et al*., 2019.). Hence, this study tends to investigate the prevalence of *P. shigelloides* in surface water in Osun State, Nigeria, and to screen its antibiotic resistance and Biofilm formation pattern.

Materials and Method

Sampling and isolation of presumptive *P. shigelloides:* samples were collected aseptically at 3 different sampling points along the riverbank in each of the two rivers over a period of 6-month (3 months each across the two seasons). Processing of samples was done within 6 h of collection, following the procedure recommended by American Public Health Association (APHA, 2012) and isolation using Inositol Brilliant Green Bile agar.

Extraction of DNA and Molecular confirmation of *P. shigelloides* isolates: The presumptive *P. shigelloides* identities were confirmed using polymerase chain reaction technique, with primer sequence of PS23FW3/PS23RV3 developed by González-Rey *et al*. (2000).

In vitro antibiotic susceptibility test: The test isolates of *P. shigelloides* were subjected to antibiotic susceptibility test using Kirby-Bauer disc diffusion method and interpreted by National Committee for Clinical and Laboratory Standard Institute (CLSI, 2016).

Detection of Extended-Spectrum Beta-Lactamase (ESBL) phenotypes: using Double Disc approximation test (DDST). A clear extension of greater than 5 mm inhibition zone between any of the four Cephalosporins towards the disc containing Clavulanic acid was interpreted as positive for ESBL production (Chaudhary, 2004)

Biofilm Formation Test Protocol for *P. Shigelloides:* Using the test tube technique, Experiments were carried out in duplicates and read as absent, weak, and strong (Castelo-Branco, *et al*., 2016).

Results and discussion

In total, 111 (W1 =20/68, W2 = 14/43) confirmed isolates. In this study, the antibiotic susceptibility profile of *P. shigelloides* across rivers revealed multiple antibiotics resistance to antibiotics like tetracycline, cefuroxime, ceftriaxone, ceftazidime, and cefotaxime. This is in conformity with previous research by Chen *et al*., (2013) and Adesiyan *et al*., (2019).

Antibiotic-resistant index (ARI) is an excellent tool for analyzing the distribution of bacterial resistant phenotypes in a given population at a specific location (Mohanta and Goel (2014). Based on the ARI value obtained, it lay above the acceptable threshold of ≤ 0.2. This is indicating that the burden of antibiotics being discharged into the rivers, is far greater. It can be deduced that the rivers are heavily polluted. This study, reveals a high prevalence of ESBL producing phenotypes in both the dry and wet season across the sampled rivers. It has been discussed that Plesiomonads contain an innate resistance to various beta-lactam antibiotics by producing Beta-lactamase enzymes. This study presumptively confirms the production of Cefotaximase responsible for inactivating Cefotaxime. Biofilm formation is a major virulence factor, it provides both homogenous and heterogenous bacterial contact in a superimposed layer by shielding against host immune responses and exchange of genetic materials (Pozzi, *et al*., 2012). In this study, most of the strains showed significantly homogenous strong slime formation (Hassan, *et al*., 2011). A study by Castelo-Branco *et al.,* (2016) supports this finding, which is indicative of the potential to evade antibiotic leather effect if found in biofilm

Conclusions

From this study, the distribution, virulence, and antibiotic resistance of P. *shigelloides* vary across the sampling sites, indicating that source, geographical location, and anthropogenic activities appear to influence the pathogenicity and resistance of Plesiomonads. Which further emphasizes the need to include antibiotic resistance gene surveillance in epidemiological studies.

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The effects of the combination of *Chlorella* and *Lemna minor* on Textile Industry Wastewater Treatment

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Introduction

The textile industry is one of the greatest generators of liquid effluent pollutants due to the high quantities of water used in the dyeing processes. Textile wastewater contains dyes mixed with various contaminants at a variety of ranges. It is therefore essential to treat properly these effluents before discharge into the receiving watercourses.

The aim of this work was to investigate the combined effects of *Chlorella* and *Lemna minor* on Textile Industry Wastewater Treatment.

Materials and methods

In the first trial, we evaluated the effect of the microalga alone or in combination with the aquatic macrophyte, on decolorization of indigo blue dye under various set of factors (temperature, pH, dye concentration and shaking). Second, we examined their effects on effluent quality after the third cycle of treatment.

Results and concluding remarks

The experimental results showed that the maximum percentage reduction of COD, color and conductivity was obtained at pH of 8 after 7 days of treatment (combination between *Chlorella* and *Lemna minor*), 10 days (using *Chlorella* alone) and 21 days (*Lemna minor* alone). The maximum removal percentage of color (combined effet of microalga with the aquatic macrophyte) in the textile industry wastewater (86.03 %) is higher than the removal of color of indigo blue dye (63.17%).

Estimation of On-Farm Carbon and Greenhouse Gas Emissions across spatially and climatically variable locations in Texas

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Introduction

The United States Department of Agriculture (USDA) has ranked Texas 4th in the most agriculturally productive state in the United States (U.S.), making about $20.2 billion in income as of 2020. However, Texas agriculture contributes up to 0.75% of total GHG emissions in the U.S. (USDA Farm Income Atlas, 2022). Because the agricultural industry must maintain its productivity to support the demand for products for an exponentially growing population, adequate conservation and sustainable practices are necessary to minimize GHG emissions while targeting the maximum yield from crop fields. The USDA has developed a web-based tool, called COMET-Farm, that calculates the amount of full-net GHG balance for present-day management practices and future projections (Eve et al., 2014). Several studies have used COMET-Farm to calculate cover-crop biomass, understand the effect of windbreak systems on carbon sequestration, and develop an organic farm calculator (McClelland et al. 2021; Ziegler et al. 2016; Carlson et al. 2017). The specific objectives of this study are to apply COMET-Farm for: (a) evaluating the impact of different management practices (e.g., tillage type, planting period, fertilizer application rates) on GHG emission and (b) quantifying the spatial variation of GHG emission from different regions (climate and soil type) across Texas.

Materials and methods

To better understand the spatial variability aspects of GHG emission, we selected the agricultural parcels across the climate divisions of Texas. The locations can be found in Table 2 of the Results and Concluding remarks section. The major crops selected for each scenario were corn, cotton, and sorghum. This crop rotation was implemented for all areas in the present day and ten-year future projections. The fallow crop was applied during the off-season cycle in all scenarios. The fertilizer used were Elemental Nitrogen for sorghum and Ammonium Nitrate for corn and cotton. Irrigation rates were obtained from the Irrigation Management System (IMANSYS) tool, which calculates weekly, biweekly, monthly, and annual water budget components, including irrigation requirements is a calculation model based on different water management practices. In the COMET-Farm, sprinkler irrigation is selected for all scenarios, and the irrigation data includes a one-time monthly irrigation amount for each crop.

Table4. Scenarios considered in this study.

Scenario Number	Management Practice
1	Baseline
2	No till
3	Intensive Tillage + shifting planting date (+15 days)
4	Intensive Tillage + shifting planting date (-15 days)
5	Intensive Tillage + fertilizer (+ 25%)
6	Intensive Tillage + fertilizer (- 25%)
7	Intensive Tillage + fertilizer (+5%)
8	Intensive Tillage + fertilizer (- 5%)

Results and concluding remarks

The difference between the baseline value and the value of a given scenario indicates the amount of greenhouse gas released or absorbed during the cropping period. We can conclude that although some scenarios produced a large amount of carbon absorption, the ones with the maximum amount involve no-tillage practices. The least recommended practice would be Scenarios #3 and #4, regardless of which location across Texas. Excessive amounts of fertilizer will release harmful greenhouse gases, such as nitrous oxide, into the atmosphere.

Table 2. Comparing management practices to baseline scenarios in locations across Texas in tonnes of CO_2 equiv./year.

Location	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
East Texas	57.2	**5.3**	69.9	47.4	60.6	56.7	58	57.2
North Central	48	**-13.3**	62	42.5	60.2	50.3	49.4	48
Upper Coast	117.2	**40.9**	133.7	106.8	130	111.2	121.2	117.2
South Central	82.9	**-7.1**	96.7	75.3	109.8	68.7	91.6	82.9
Southern	66.8	**13.1**	77.4	64.5	84.3	57.3	72.4	66.8
Edwards Plateau	120.2	**65.6**	164.4	105.7	154.7	97.9	131.6	120.2
High Plains	165	**60.6**	188.6	151.8	199.2	142.2	176.4	165
Trans Pecos	47.4	**21.4**	53.1	46.8	57.5	40.6	50.8	47.4

This study evaluated GHG emissions for eight different management practices across selected fields in each of Texas' ten climate divisions using COMET-Farm. The results reveal that non-tillage practices have the highest sequestered carbon among analyzed scenarios.

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Comparison of removal performance of SARS-CoV-2 in wastewater by membrane bioreactor and conventional activated sludge processes

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Introduction

The potential risk of SARS-CoV-2 in treated effluent from wastewater treatment plant (WWTP) is concerned during COVID-19 outbreak. However, removal of SARS-CoV-2 in WWTP is virtually unknown. The objective of this study is to clarify removal performance of SARS-CoV-2 in a WWTP and superiority of membrane bioreactor (MBR) process in SARS-CoV-2 reduction. Influent wastewater, secondary treatment effluent, and final effluent after chlorination were collected from a WWTP in Japan during the second wave of COVID-19 outbreak in Japan from May 28 to September 24, 2020. The target WWTP had MBR and conventional activated sludge (CAS) processes. As a result, SARS-CoV-2 RNA was detected 3.3-6.0 log10 copies/L in influent. Log removal value (LRV) of MBR was 3.47 ± 0.65 log, while LRV of CAS process 3.06 ± 1.10 log. The total LRV by the target WWTP was estimated over 3.47 log after chlorination. Consequently, removal performance of SARS-CoV-2 in a WWTP were better than typical reduction of other enteric viruses. A MBR process has more stable reduction than CAS process.

Materials and methods

Wastewater samples were collected at a WWTP, which had CAS and MBR processes treating the same influent wastewater. During the second wave of COVID-19 outbreak in Japan from May 28 to September 24, 2020, 250 mL of influent wastewater, 10 L of secondary treatment effluents from CAS and MBR, and 10 L of final effluent after chlorination were collected twice a month. Influent samples were concentrated by polyethylene glycol (PEG) precipitation according to Hata et al. (2021). First, 40 mL of a sample was centrifuged at 3,000xg at 4℃for 5 min to collect solid fraction. Then, the liquid phase was concentrated by PEG precipitation. the SARS-CoV-2 RNA amplification was detected by real-time PCR system (QuantStudio 5, Thermo, USA) with CDC 2019-nCoV_N1 (CDCN1).

Results and concluding remarks

Time-series change of SARS-CoV-2 in influent

Among 18 samples of the solid fraction and the liquid fraction concentrated by PEG precipitation, 8 samples were positive (over 2.6 log10 copies/L) and 8 samples reached over 3.2 log10 copies/L, which were quantifiable concentration level. In all samples, CDCN1 concentration in solid fraction was higher than PEG concentrate of liquid fraction expects on Aug. 11. Significant correlations were not observed between CDCN1 concentrations in wastewater and confirmed cases of COVID-19 in the target city, probably because the sampling interval was too long to capture the increasing/decreasing trend of infections.

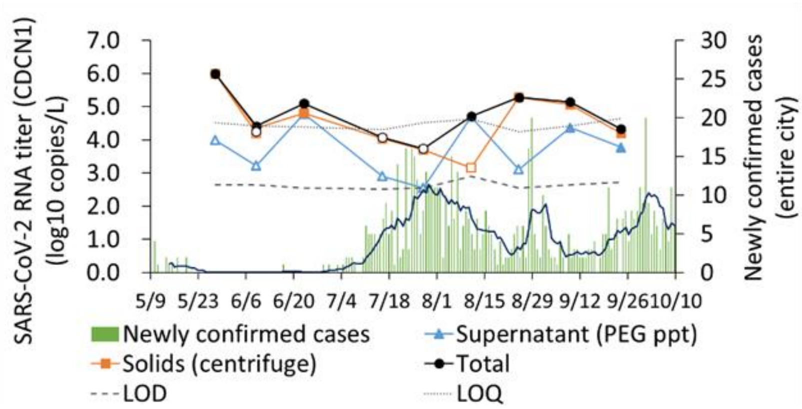

Figure 1. Comparison of SARS-CoV-2 RNA concentration in influent and newly confirmed cases (water sampling from May 28 to September 24, 2020). Blank plots stand for below the lower limit of quantification (LOQ), indicating that the true value is possibly lower than the plotted value.

Removal of SARS-CoV-2 in WWTP

Each process of 9 effluent samples was in CAS, MBR and after chlorination. The number of 1 and 3 positive samples were in CAS and MBR, respectively, no positive sample was in final effluent by chlorination. 1 sample was over-limited of quantitation (LOQ) in CAS, no samples were over-limited of quantitation (LOQ) in MBR and final effluent by chlorination, respectively. Limited of detection (LOD) of MBR and CAS was 1.10± 0.15 log10 copies/L, 1.11± 0.15 log10 copies/L, respectively. detected range of SARS-CoV-2 RNA concentration in CAS effluent was N.D-2.9 log10 copies/L (Fig. 1.2a), while that in MBR was N.D-2.0 log10 copies/L (Fig. 1.2 b). the concentration of effluent in MBR was stably lower 2 log copies/L although the average was not significant different (Fig. 1.2). LRV in MBR reached 3.47 ± 0.65 log, while LRV in CAS process reached 3.06 ± 1.10 log (Fig. 1.2). LRV by MBR was 2.5 log compared to LRV by CAS process was 1.3 log in the lowest, which indicated that MBR has the better stable reduction of SARS-CoV-2 RNA than that by CAS. The entire reduction of SARS-CoV-2 RNA by the WWTP was over 3.47 log. The estimated removal of SARS-CoV-2 RNA by after chlorination was 0.85 ± 0.54 log.

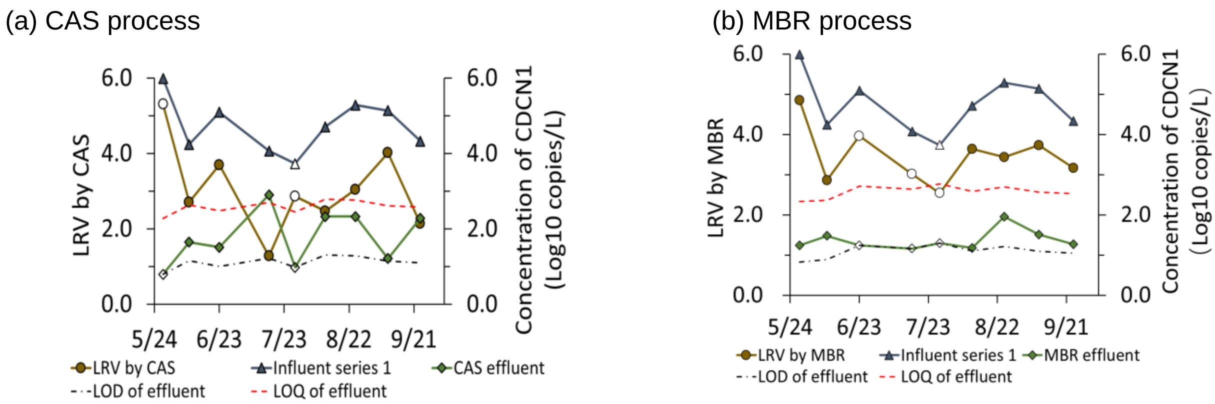

Figure 2. CDCN1 concentrations in effluent and log removal values (LRV) in (a) CAS and (b) MBR process. The blank mark means below the LOD (undetected).

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Modelling Nature-Based Solutions to control flooding in Kibera slum, Nairobi, Kenya

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Introduction

Africa is rapidly urbanising, and its population growth is predicted to triple by 2050. The combined pressures of urbanisation and climate change have an influence on the ecosystem and the services it provides. As a result, there are additional dangers, which include, but are not limited to, greater flooding risk, economic disruption, and environmental concerns.

Already, hydrological and climatological events have caused damages rising to USD 4.8 trillion worldwide between 1980 and 2018, of which 40.5% and 11.6% (Debele et al., 2019). Wider use of structural and non-structural measures as mitigation measures in Africa remains inadequate.

Additionally, poor housing and sanitation problems, prevalent poverty levels raise individual's reactions and vulnerability to flooding risk and impacts (Ajibade & Tota-Maharaj, 2018). In some most cities, blockage of the existing drainage from either unkempt vegetation exacerbates the problem (Charlesworth, 2017). In a typical storm event, flash floods underpin poverty, insecurity, the risk of ill-health, on top of the existing poor housing causing loss of lives, livelihood, disruption of transport etc. whose recovery process is low.

Cities in Africa must develop innovative and adaptive solutions to minimise the effects of growing urbanisation in order to meet the United Nations Sustainable Development Goals. Evidence suggests that Nature Based Solutions (NbS) have the potential to reduce flooding risk while also delivering other benefits such as biodiversity sustainability, improved sanitation through greywater management, increased water and food security, and reduced climate change impacts (Cohen-Shacham et al., 2019; Seddon et al., 2020). NbS is defined as a collection of integrated ecosystem-associated approaches inspired by and copied from nature, which must sustainably minimize flooding risk and impacts to the society while preserving biodiversity. Despite successful demonstration projects across Europe, Asia and United States, application and implementation of NbS in Africa, specifically in informal settlement remains limited.

Therefore, this paper aims i) to explore the potential of NbS in controlling flooding in informal settlement in Africa, ii) gathering socio-cultural, and environmental challenges, and opportunities surrounding adoption of NbS in informal settlement and iii) conduct hydrological modelling to map flood prone areas and define suitable NbS types to adopt. To this end, Kibera slum in Nairobi, Kenya is the study location. Although this research is ongoing, the projected outcome will add to the existing literature a replicable procedure of community co-designed, co-delivered, and co-managed NbS projects implemented in informal settlements.

Materials and methods

This study will utilise the following methods; Interviews**-** A combination of semi-structured interviews and questionnaires will be used to collect data on past flooding events, their frequency, impacts, and any adaptation or mitigation measures implemented at the household or community level, as well as their perception of sustainability and willingness to try NbS concept.

GIS participatory mapping- Involving the community in annotating the most vulnerable or regularly flooded areas on the map (printed catchment map), in order to provide relevant information on the precise sites that need to be prioritised and the type of NbS that is appropriate given the local surroundings.

Hydrological Modelling**-** Following that, selected or identified NbS types will be modelled to test their effectiveness in minimising localised floods. The catchment parameters of the identified places, such as rainfall-run-off estimation, soil infiltration rate, land cover, and elevation, will be examined.

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Water-Food-Health Nexus for Better Understanding on Relationship of Covid-19 and Water Productivity: Simulated Case Study on Sugarcane

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Introduction

Agriculture is one of the Covid-19 pandemic's afflicted sectors, and it is also a key element of Indonesia's economy. Agriculture is being impacted by a rise in input prices, a decline in consumer ability to buy, re-budgeting of government agriculture programs, farmers' health issues, and the supply chain being disrupted by the social restriction program. Due to the economic sector being damaged by the epidemic, increases in input prices such as fertilizer, seeds, and crop protection materials were unavoidable throughout the pandemic (Rozaki, 2021). Farmers responses due to pandemic situation affect food production since limited access to agriculture input resulting on difficulty to achieve optimum yields. Field management shifting also influence water productivity both directly and indirectly. Thus, there is a significant link between crop yields and water availability (D’orocio *et. al.*, 2018). The concept of water productivity recently must be linked to factors of nutritional value. This might give a comprehensive approach to enhancing human health during pandemic by combining water, agriculture, and nutrition (Mabhaudhi *et. al.*, 2016).

The water-food-health nexus may be used to gain a better understanding of how Covid-19 affects water and agriculture, and vice versa. The nexus concepts between water to other resources has been promoted as a tool to interconnect multiple resource-use practices rather than isolated sectors. This helps in the understanding of a more holistic, integrated approach to managing water resources and allowing for actual actions as outputs. However, interlinkage between water, food, and health corresponding to pandemic has not been deeply understood. This paper aims to simulate farmer response post Covid-19 to their farm management resulting to sugarcane yields and water productivity.

Materials and methods

Water-Food-Health Nexus framework for Agriculture post Covid-19 was defined by following steps (Avellán *et. al.*, 2018), i.e. a) determine the nexus problem; b) define scope of work; c) identify nexus options through research; d) implemented selected nexus options; e) evaluate the impact. Interconnection between water and food, water and health, as well as food and health were determined in the scope of post Covid-19 situation.

AquaCrop model were used to simulate sugarcane yields and water productivity due to farmer response post Covid-19 on their farm management. AquaCrop model has been widely used to simulate water balance and crops yields under certain conditions, e.g. field management or climate change (Revathy and Balamurali, 2019). Two different field management scenarios were simulated and compared each other. The first scenario assumed existing practice where the farmers still applied good agricultural practices. The second one assumed that farmers neglect weed management and mulch application for reducing production cost due to higher input price during Covid-19.

Crop yield (Y) and Water productivity (WP) is determined based on FAO (2018). Crop yield equation is described below:

$$Y = f_{HI}.HI_0.B \qquad (1)$$

where f_{HI} is a multiplier which considers the stresses that adjust the Harvest Index from HI_0 that has value of 74% and B is above ground biomass produced. Otherwise, water productivity (WP) is determined by the following equation:

$$WP = B/Tr \quad (2)$$

where B is above ground biomass produced and Tr is water transpired by crops.

Results and concluding remarks

Water-Food-Health Nexus framework for Agriculture impacted by pandemic Covid-19 are described by Figure 1.

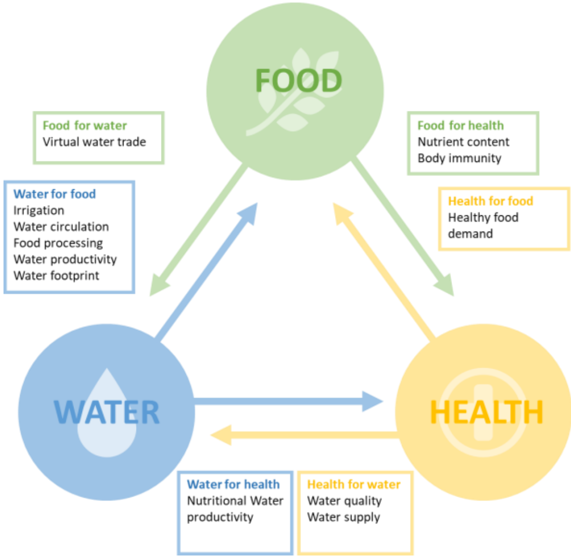

Figure 5. Water-Food-Health Nexus framework for Agriculture impacted by pandemic Covid-19.

After Covid-19 emerged, farmers put more concern on water quality for their field, although water supply for irrigation decreased due to higher water demand for health sector withdrawal. At the same time, the demand for highly nutritious food is increasing along with the awareness of the importance of immunity during the pandemic. The response of farmers to the Covid-19 situation as of decreasing farm management will certainly have an impact on not obtain both healthy food demand and nutritional water productivity.

Water absolutely affect crop growth by providing vigorous plant as required water amount is adequate hence nutrient content in the plant is also optimum. Furthermore, the harvested crops will be processed as nutritious food for supporting human body immunity. In contrast, disturbance on water and food interconnection will eventually reduce the people health.

Simulated case study using AquaCrop shows that farmers response post Covid-19 to lowering farm management result on decreasing sugarcane yields from 106.3 ton/ha to 97.4 ton/ha. Water productivity on fair farm management also higher than poor management, i.e. 4.09 kg/m^3 and 3.59 kg/m^3, respectively.

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Analysis of water levels fluctuations in Prespa and Ohrid Lakes (period 2010-2021)

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Introduction

Prespa Lake and Ohrid Lake are located in SE Europe and divided between Albania, Greece and North Macedonia. The lakes are very important wetlands, supported by Ramsar Convention, with significant biodiversity, included in the European Network of Protected Areas NATURA 2000. The elevation of Prespa Lake is about 153 m higher than this of Ohrid Lake and they are separated by Galichica mountain chain with the highest peak of 2288 m a.s.l. Lakes Ohrid and Prespa and the karst aquifer system, developed between them, have hydraulic communication via underground karst conduits. For this reason, the changes in the water level of the two lakes are examined in detail.

Materials and methods

Water levels data from both lakes, provided by the Institute of Geosciences, Energies, Water and Environment were used to study the fluctuation of lakes' water level. The mean monthly values of Ohrid Lake are shown in Table 1. Water levels fluctuation of both lakes during the common period 2014-2019 is shown in Figure 1 and the scatter plot showing the relationship between the water levels of two lakes in Figure 2. Descriptive statistics, as well as cross-correlation analysis, were applied in order to study the water level fluctuations.

Table 1. Statistical and linear regression parameters of water levels (period 2014-2019).

	Prespa Lake	**Ohrid Lake**
Min value	844.71	692.08
Max value	847.47	693.85
Mean value	846.07	692.80
Standard deviation	0.855	0.320
R^2 (coefficient of determination)	0.506	0.190
R (coefficient of correlation)	0.711	0.430
Slope of trend line of linear regression	-0.001	0.0002

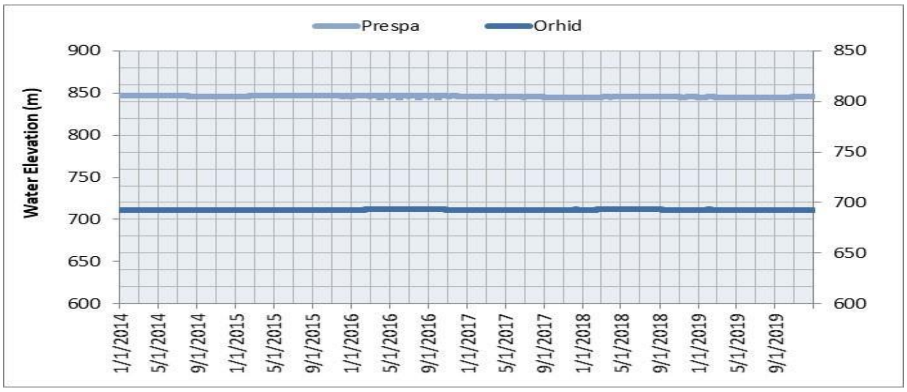

Figure 1. Fluctuation of daily water levels of both lakes during the period 2014-2019

Results and concluding remarks

Big Prespa water level during the period 2014-2019 ranged between 844.7 m and 847.47 m above sea level (a.s.l.) with a mean value of 846.07 m and standard deviation 1.011. The water level trend during the period 2014-2019 is negative (decreasing) but not quite statistically significant (R^2=0.5). According to the Institute of Hydrometeorology of Tirana during the period 1963-2002 the Prespa Lake water level was lowered 8.49 m (Eftimi, 2019). The decreasing water trend is 21.7 cm/yr. In addition, according to Popovska and Bonacci (2007), during the period 1951-2000 the Prespa Lake water level was lowered 7.79 m. The decreasing water trend is 10.9 cm/yr. According to Eftimi (2019), the maximal historical level was 852.91 m a.s.l. (1963) and the minimal historical level 844.12 m a.s.l. (2002). Besides, Van Der Schriek & Giannakopoulos (2017) suggest that prior to 1995 water levels had never fallen below 847.5 m since historical observations started in 1917. In addition, the same researchers consider that the Prespa lake surface area decreases significantly below the water level of 847 m a.s.l.

Based on Table 1, Ohrid water level during the period 2014-2019 ranged between 692.08 m and 693.85 m above sea level (a.s.l.). The mean value is 692.8 m and the standard deviation is 0.346, indicating that the water level values fluctuate around the mean value, showing relative stability. The water level trend during the period 2014-2019 is slightly increasing, but not statistically significant (R^2=0.19).

The hydraulic residence time of a lake (also called transit time) expresses the average time that water spends in a particular lake. It can be calculated by dividing the lake volume by the outflows of the lake (Kiri, 2021). This might be regarded as the first step towards an evaluation of the renewal time of water. Based on the aforementioned term, the residence time of Prespa and Ohrid lakes are approximately 11 and 70 years, respectively (Matzinger et al., 2006).

Based on cross-correlation analysis, it is concluded that the two series are not strongly correlated as the cross-correlation is not statistically significant at most lag numbers. The strongest correlation occurs at lag 0, with a correlation equals to 0.122. This shows that the water levels of two lakes are strongly contemporaneously correlated. Furthermore, the only negative significant correlation occurs at lag 1 and is equal to -0.151. This negative cross-correlation suggests that higher than average water level of Ohrid leads to lower than average water level of Prespa Lake one (1) day later. However, this correlation slightly exceeds the 95% confidence interval.

The continuous and prolonged decline of Prespa water level could be associated with climate change which affects the hydrological parameters), anthropogenic activities (increased water use for irrigation purposes, diverting of Devoll River), and/or tectonic and earthquake induced changes, e.g. lowering of lake bottom and widening of underground karstic channels to Ohrid Lake (Eftimi, 2019; Popov & Anovski, 2009; Matzinger et al., 2006; Popovska & Bonacci, 2007).

Finally, the protection and the sustainable management of the lakes is a specific target today. The Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention-Helsinki 1992), the Transboundary Diagnostic Analysis of Prespa Lake (2009), and the International Convention on transboundary water management (2020) are the legal documents which support and reinforce transboundary cooperation.

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Improvement of water management for irrigation in Mediterranean basins combining remote sensing, weather forecasting, and artificial intelligence

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Introduction

The Mediterranean region is an area of special incidence of climate change, with significant reductions expected in mean annual precipitation, increases in temperature and potential and actual evapotranspiration, hotter and drier summers, and more frequent and intense droughts (MedECC, 2020). Said increase in atmospheric temperature, combined with a significant reduction in rainfall, will cause a greater incidence of extreme phenomena, in particular droughts (Marcos-Garcia et al., 2017). This increase will pose a great challenge for the management of water resources since in most Mediterranean basins there is an already fragile balance between resources and demands (Garrote et al, 2015). The expected meteorological changes will lead to regional water scarcity, with important impacts on the ecological status of water masses, food security, desertification, and reduction of the fertile surface available for food production.

This situation is expected to particularly affect the southeast of the Iberian Peninsula, where large areas of intensive agriculture are currently concentrated, mostly for export, on which various regions of Spain depend economically (Ruiz Rodriguez et al, 2018). In addition, in the management of water resources, one of the fundamental problems in water management for irrigation, in general, is to achieve maximum efficiency in the management and use of the resource. However, at present, most farms make their decisions based on a predetermined irrigation plan based on the type of crop, regardless of the weather and their current state. At most, some services such as the Irrigator Advisory Services (SIAR) offer irrigation recommendations based on the weather of the previous week. These practices can lead to inefficient use of water, and the consequent loss of agricultural production and added value. However, the development of remote sensing tools, which allow the current state of crops to be estimated more and more reliably; and weather forecasting systems, which are capable of estimating the weather days or weeks in advance; can offer very valuable information to improve the yield obtained from the water resource and, in turn, avoid its overexploitation.

Materials and methods

The thesis project will be part of the eGROUNDWATER, will reinforce two of these sources (hydrometeorological predictions and remote sensing). The integration of advanced tools and methods of remote sensing, weather forecasting, artificial intelligence, and management models of water resources systems will allow a more integrated use, efficient and sustainable water. We do not have results but we will work with the following methodology since the research project has just started

The thesis project integrates two fundamental methodologies: on the one hand, data acquisition, and treatment and analysis methods and, on the other, mathematical models. Both parties will interact in an orderly manner throughout the process, alternating phases of data acquisition, processing, and analysis with the definition, improvement, and execution of mathematical models. In this way, weather forecasts and measurement networks will be combined with hydrological models to obtain hydrological forecasts (resources); weather forecasts and remote sensing will be combined with agronomic models to obtain agronomically (demand) forecasts, and resource and demand predictions will be combined with water resource management models to derive the most efficient water management decisions

Information sources

The thesis project is based on three main sources of information: Measurement networks: these sources will be used in the reconstruction of the climatology and hydrology of the historical period (1993-2015). The meteorological data will be obtained from the AEMET, the Automatic Hydrological Information System (SAIH,http://saih.chj.es/chj/saih/?f) of the Júcar Hydrographic Confederation (CHJ), and of the SIAR of the Autonomous Communities. All these sources offer open data since 1950 and are regularly updated. Remote sensing: these sources will be used to estimate potential evapotranspiration, irrigation needs and crop dynamics.

Mathematical models

The thesis project will use several mathematical models to generate predictions of resources and demands that allow improving water management for irrigation. For this, existing mathematical models will be used, updating them to allow them to work with predictions. These models are: Hydrological models: to transform meteorological information into hydrological contributions. Agronomic models: to estimate water needs and crop production. The existing models for the Júcar basin will be used, developed in Macian-Sorribes (2017), used in the IMPREX and ADAPTAMED projects

Analysis of data

The data analysis processes will fulfill two objectives: Convert raw data into usable information in models and decision making. These analyses will consist of pre and post-treatment of the raw information to guarantee that it adjusts to the characteristics of the case study and of the models, and of the treatment of the raw results of the models to enable their use in other models and their use. For decision-making. In particular, artificial intelligence methods (neural networks, Bayesian networks, fuzzy logic systems, decision trees) will be used to perform these operations, given their recognized potential and future possibilities (Düben et al, 2021), combined with statistical methods. Evaluate the reliability of the predictions obtained.

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Modelling the Climate Change and Land Use impacts on Land-Water Energy Nexus over Nigerian Hydropower Generation

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Abstract

The nexus across land-water-energy are great potential for improved hydropower generation and efficiency in Nigeria. Very few studies have been conducted on environmental assessments of energy generation from Kainji Lake, though it is the largest hydropower plant in Nigeria. The research investigated the impacts of climate change and different land use types on hydrological ecosystem services and water availability in the Lake Kainji. The reduction in loss of water in the Lake, especially during the dry season (November-May) has been one of the major factors responsible for reduction in hydroelectric production from 86.97% capacity in 1974 to 20.90% in 2011. This study aims at accessing the socio-environmental and climatic factors affecting Kainji hydropower generation using the geospatial technology approach. To achieve this aim, Land Use/Land Cover assessment was carried out. Also, change detection, environmental impacts on water-reserve and usage in Kainji Lake were evaluated using multi-temporal Landsat imageries and meteorological datasets within the period of 1972-2018. Satellite images from MSS (1972), TM (1986), ETM+ (2001) and OLI (2018) sensors were used to obtain geospatial information such as the Normalized Difference Built-Up Index (NDBI), Normalized Difference Vegetative Index (NDVI), Modified Normalized Difference Water Index (MNDWI), Land Surface Temperature (LST) and Land Use/Land Cover (LULC) using ArcGIS 10.5 and ERDAS Imagine 2015 software. Rainfall, temperature, evaporation and sunshine duration are the most important climatic factors affecting the area of water area of the Lake.

The Lake increased by an area of 90.9 km^2 between 1972 and 1986, followed by shrinkage in 2001 (20.4 km^2) and 2018 (95.2 km^2). In total, there is an area loss of 24.7 km^2 between 1972 and 2018. The Lake shrinkage is more prominent during the dry season (November-May) with estimated area reduction in the range of 900-950km^2. The area lost by the lake is been replaced by farmlands and marshland, with the former increasing to 1151km^2 in 2018. With respect to socio-environmental factors, settlements around Kainji Lake have increased in area covered trends of 2.5km^2, 73.58km^2, 437.77km^2, and 627.52km2 in 1972, 1986, 2001 and 2018 respectively, giving rise to about 250% increase in built areas. Similar to the lake, forested areas have reduced from 2175.5km^2 in 1972 to 1950.7 km^2 in 2018 (ca. 10.3%), converting the areas to cultivated farmlands, croplands, rangelands and (bare lands as observed in the dry season). Mitigating the impacts therefore advocates for greater cooperation, and the strengthening of the decision makers to ensure sustainable regulation and resources management of the drying Lake.

Keywords: Degradation, Hydropower, Management, Technology

THEME 3

RESILIENCE OF SOCIETIES AND DIGITAL COMMUNICATION AND COOPERATION

Digital management of irrigation water and agriculture: Transparency and accountability towards resilience and sustainable development

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Introduction

This research reflects the outcomes from an ongoing project based on continuous collaboration (stakeholder engagement) and scientific support towards sustainable and resilient water management. A multi-disciplinary platform is used to bring together all relevant stakeholders of Thessaly, a Greek rural region facing multiple water management problems, historically. The problems, causes and potential solutions are analysed in a series of virtual meetings (March 2021 – June 2022) in order to develop business plan(s) for the improvement of the situation in multiple levels. A basic result from the project so far, a commonly acceptable measure, refers to the digital agriculture – irrigation water management, which has multiple benefits and enhances resilience to different future challenges.

Such measures are supported by the international practice, research, and policy agendas: Geographical Information Systems (GIS) and interactive maps have been used successfully for agricultural monitoring and management in the context of informed decision-making (Jhariya 2019) and guidance for targeted measures (Mockler et al. 2016), while they support the use (and adaptation) of new technologies by multiple users (Mustafi et al. 2021). The main objective of this work is to analyse the multiple benefits of such digital management tools from a new perspective: as a means for transparency and accountability to speed up progress and support informed decisions, as resulted from a multi-disciplinary stakeholder group. The methodology developed and followed for this project, the way of reaching to common visions, and the proposed actions for the specific study area are the novel elements of this work.

Materials and methods

The study area is Thessaly (Central Greece), the country’s driest region and more intense agricultural supplier. The area faces several water quantity and quality issues, ambitious production-economic objectives, continuous (historically) drought and flood events, conflicts, administrative, institutional, regulation and economic issues, under serious climate change impacts (Alamanos et al. 2022). For the first time to our knowledge, a multi-disciplinary platform is used to bring together all relevant stakeholders (27 representatives from the government, local authorities, experts and experienced professionals, start-ups and technological solutions, agricultural co-operations, and local agencies). The methodology followed is the Systems Innovation Approach (SIA) consists of two processes:

- A continuous scientific support: to enhance the understanding of interactions within the various sub-systems and challenges, and provide examples from international practice and research, as well as the techno-economic support to the proposed measures. For this component, a whole-of systems multi-disciplinary approach is followed, combining all socio-economic (social, economic, influential relations, behavioural) and environmental components (water, soil, atmosphere, climate, biodiversity), as analysed in Alamanos et al. (2021; 2022).
- A proper stakeholder analysis and engagement, integrating local knowledge: to collaborate, co-design future visions and ensure a healthy two-way feedback with the scientific support.

The goal is to reach to a feasible commonly acceptable measure, to be applied (and supported), providing multiple benefits. This will be innovative, scientifically supported (perception and development of business plan), making use of new technologies and allowing for overall support by the various stakeholders.

Results and concluding remarks

During the meetings and through SIA, the group has reached to a common understanding of the main problems and future challenges of the area (economic, environmental, social, political, technological). Each measure of the River Basin Management Plans, the ones scheduled under the Resilience and Recovery Plans, and other efforts from all different actors (state, academics, private sector, local initiatives, etc.) have been evaluated, and a sincere analysis of priorities for action (including current obstacles) has been achieved. A commonly acceptable measure, with the most benefits so far, is the development of a GIS-based platform (digital record) providing basic and necessary information to facilitate management and cover existing data limitations. The idea is to collate various data (e.g. agricultural, agronomic, natural-soil-topographic, water use, water supply sources, pollutants emissions, cropping data, irrigation methods and other agricultural practices) and combine them in an accessible multi-layer map. This initiative is considered realistic and doable, and the participants have relevant experience to support its development.

Multiple benefits will arise from the effort and the implementation of the proposed measure:

- Transparency as a form of effective governance: Creates a sense of responsibility, informal control (and inspection), accountability, commitment, and a culture of improvement (motivation to find data and/or make them reliable).
- It can facilitate the work of all individual actors (project's participants and other stakeholders) at many levels (speed, effectiveness, data accessibility, guidance for targeted measures, accountability, informed decision-making).
- Contributes in a practical and simple way to most of the activities proposed individually by the participants-stakeholders during the living labs so far. These include project completion, demand management measures (including precision agriculture, crop replacements, pollution control, more efficient irrigation methods), modernisation of existing management practices and tools, adoption of new technologies, enhanced communication and information, etc.
- The use of new technologies (digital management) as a path towards modernisation will majorly assist the capacity building of the area's stakeholders and will promote a human-technological efficient cooperative intelligence. This will bring the local management up to speed with the international practice and will set a good example to be followed by other Greek regions.
- Space for support-cooperation (Greek Ministry of Environment – through the General Directorate of e-Government and Geospatial Information & Water Secretariat, academic institutions, practitioners, private sectors, etc.), including various scientific fields and expertise's.

The current and future stages of the project focus on the development of a business plan to implement the solution. The design must be careful, take into account many different factors, to ensure the proper development, operation and management of this tool, so any form of cooperation and support to this project and effort is welcomed.

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Local water monitoring activities as inclusive, modern ecological education - Poland perspective and proposal

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Introduction

Raising the awareness of climate change and environmental pollution among the youth is one of the most important educational challenges of our times. The equally important subject is the need to teach and show examples of cooperation and working together by including people of all gender, races etc., based on their skills not by prejudices. We would like to discuss here an opportunity to merge these two issues by showing the potential of a local environment monitoring programme as an additional, outside-school activity and the examples of recent similar activities in Poland.

The state of affairs

Nowadays, during this pandemic reality, the detachment of young people from the real world increased when restrictions locked youths at home and gradually dissolved live interactions with colleagues. The quality of mental health of the youngest students was reported to be in danger in Poland (Babicka-Wirkus et al., 2021). Besides that, even during normal circumstances, in typical school classes, there was a gap in developing various talents, interests and teaching mutual respect and the value of cooperation. Currently, with passive online teaching, it is even more problematic. Group activities could be a remedy. They should be free-to-participate (but encouraged) team projects, with roles fitting pupils' abilities, without grades but visible results and finally, made for fun and excitement. The requirements of the use of modern technology paired with real physical challenges outdoors and the need to share/find appropriate knowledge should develop problem solutions and social skills. The environment monitoring through field trips tackles all those points.

Poland is one of the water-poorest countries in Europe. An increasing number of extreme weather conditions is predicted to cause a lot of droughts and flash-floods events, not only in central Europe. This calls for immediate actions in terms of water control, which is also done by river monitoring. What is more, the awareness of the dangers connected with these phenomena is possibly best learned on the live cases, e.g., river and lakes observations along with the environment in their vicinity. That would also provide an opportunity to teach about many qualities of having strong and healthy water bodies, its benefits both for the environment and for human communities. What is more, showing the actual water infrastructure like weirs, wastewater inlets, etc., can help to imagine how big an impact the water system has on our civilization. Combining these two aspects of water - its role in the natural environment and its importance for us is necessary for better understanding how climate is dictating our lives and surroundings.

In Poland, there are not many initiatives involving youths in water-related environmental issues. A recent example was the involvement of children, supervised by their teachers, to take photos through the year of vegetation cover at the small river reaches. The activity was a part of the international BRITEC project (Bringing Research into the Classroom), conducted with the cooperation of the Institute of Geophysics Polish Academy of Sciences. Participants showed an eagerness and determination, not even much disturbed by the pandemic as all the work was outside. Various ecological activities in Poland are also organized by the Center for Citizenship Education, whose mission is to "support teachers to bring to school methods and topics that help students engage in their education and better cope with the challenges of the modern world". One of the organisation's departments deals with global and environmental education with a particular interest in "migration, climate change, consumption patterns, gender equality and other related to Sustainable Development Goals".

Mutual collaboration with them could create a perfect opportunity to prepare actions centred around water quality, importance and dangers. It is also worth mentioning that initiatives such as "Operation Clean River 2021" had wide support in Poland from both the private sector companies and the government side (Bank of Environmental Protection).

The proposed activity

We want to propose activities that could simultaneously be inclusive, modern, team-based and promote ecological awareness. The baseline of the idea is to go out and observe the water bodies in the surrounding area.

At the very beginning, pupils should choose unusual spots - outlets, islands, wetlands, bridges, public beaches, piers, weirs, etc., and for comparison - the typical natural river reaches or lakeshores. Then, the next task is to describe chosen places using available resources, i.e., GIS maps, satellite images, monitoring gauges data, local news and others. The scope of the information should enhance info research skills and include various sources. It can describe statistical hydro- or meteorological data, geology, human activities, urbanization, even history. But most importantly, the biological aspect should be described - what kind of biosphere is present around the place, at the banks, at the bed and what kind of animals and vegetation is likely to be found. Participants should divide scopes of search between them and can ask for help if needed. The results should be briefly presented by all authors. It is important not to force anything - the presentations are not to be judged but to share the obtained knowledge, to ignite curiosity, to let young people dive deeper into topics they find most comfortable with. Then, it would be the most fun part - field investigation.

Let the first trip be conducted with all the participants - choose a day with fair weather, find the optimal path to visit all the places, agree on what to do afterwards - a campfire, fast food restaurant, whatever, make the trip worth something pleasant at the end. Then decide about tasks according to data gathered earlier. For example - who showed the plant species - let him take photos and catalogue what he found. There is trash present - let someone take photos and describe what type, how many and where it was mostly found. If you have a laboratory in school - take the water or sediment samples and do simple experiments with the teachers. Measure the water level at a characteristic place, make photographs/videos. Count the animals and describe any signs of human activities in the area. The tasks should be conducted in small teams and repeated for example each month through one year to see how the environment is changing. At the end of the project, a report showing the timeline of monitored characteristics across all places should be collectively produced with the help of teachers. They would be responsible for guiding the pupils into making the connections between various ecological factors and deriving conclusions about our impact on the environment. The workload of pupils needs some kind of reward - let their achievements be shown in the local newspaper, discussed during assembly of estate residents or municipal council or even in the fishing club. If possible, contact business owners or organisations operating nearby that care about the environment, to sponsor some kind of gratification for the participants in exchange for sharing the results.

The proposed plan of activity is a chance to include river monitoring in ecological education, consistent with what was presented in Rech et al. (2015). It can be also an opportunity for organisations like IAHR Young Professionals Networks to help in evaluating results and show the pupils how young people of diverse backgrounds can contribute to the common goal of caring about water resources.

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Building Infiltration Well: How Does Digital Solution Help?

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Introduction

Indonesia placed 6th in the country with the most affected by flood disasters. The disaster recapitulation gathered by BNPB in 2020 shows 2,830 disaster events, with flood disasters contributing the most of them (1030 events, 36.39%). In Jakarta Metropolitan Area alone, only 13% of the water is infiltrated to the ground, because there is only 10% of the land surface is not covered by concrete and asphalt. On the other hand, there is 1,28 million m^3 potential from rainwater—and this number equals 2 years of water needed by Jakarta's citizens!

For the consequences of its complexity, we, as a society, need to focus more on Low Impact Development solutions. Low Impact Developments (LID) refers to methods and practices that use or mimic natural processes that result in stormwater infiltration, evapotranspiration, or usage in order to protect water quality and aquatic habitat—one of them is Zero Run-Off. Run-Off is a concept where we are responsible for the runoff created by our building. It could be implemented by applying artificial recharge (i.e. Infiltration Well), rainwater collection (i.e. Rainwater Harvesting), and other technologies. Zero Run-Off is a good concept in water management and could be flood-prevention simultaneously. Even though this concept has been outlined in Indonesia's regulations, there are some difficulties encountered by the government for implementing Zero Run-Off, especially for the artificial recharge.

SolusiBanjir.id, as a social enterprise to develop One Stop Solution for Zero Run-Off technology did market research to determine people's willingness in implementing these technologies in their building. One-Stop Solution refers to a digitalized system where consumers, contractors, producers, and financial partners are connected through one platform to ease the implementation. In addition, it shows what factors should be taken into account in communicating and connecting between complex problems and the solutions needed integrative.

Materials and methods

The market research was conducted through online survey for 250 people in Jabodetabek (Jakarta, Bogor, Depok, Tangerang, and Bekasi) and Bandung Raya. Besides, we did an in-depth interview with 20 respondents to obtain a more holistic point of view, experiences, feelings, and perspectives. These 20 respondents were grouped by economic level and year of birth.

The questions are divided into three major topics, namely:

1. Willingness to implement Zero Run-Off technology in their building;
2. Interest in using One-Stop Solution as a medium for solution implementation;
3. Factors that should be considered in communicating about Zero Run-Off technology.

After the data was collected, the data was then analysed using descriptive statistical methods. Since Zero Run-Off technology varies in the technology type (i.e. Infiltration Well, Rainwater Harvesting, etc.), this paper will only discuss Infiltration Well implementation in the household.

Results and concluding remarks

1. **Willingness to implement Zero Run-Off technology in their building**

   The majority of respondents stated that the problem of flooding is the responsibility of all entities: the community, the government, and the private sector. From the results, 96.5% are interested in building infiltration wells in their building. The majority are interested and very interested in building, regardless of whether or not they have experienced flooding. Research also shows that the more people know about Infiltration Wells, the more interested people are in building them. In fact, some respondents had only ever heard of Infiltration Wells but stated that they wanted to implement it in their respective buildings.

In addition, based on homeownership, 87.5% of people living in private homes are willing to have an infiltration well as a supportive environment in their yard.

2. **Interest in using One-Stop Solution as a medium for solution implementation**
   For respondents who are interested in building infiltration wells, 62.04% are interested in using the One-Stop Solution to connect technology providers, contractors, and financial partners in implementing Infiltration Well.
3. **Factors that should be considered in communicating about Zero Run-Off technology**
   From the results of in-depth interviews, there is a gap between the flood problem and the Zero Run-Off solution, which is the level of public understanding of the Zero Run-Off concept itself. Several respondents stated that education was needed to communicate the importance of building this technology in their homes. In addition, the community also needs to know what benefits they will get if they spend a few rupiahs to build infiltration wells.

Based on its function and way of working, Infiltration Well is a technology that must be applied in an integrated manner with other flood solutions, such as reservoirs, river normalization, etc. The urgency of the construction of infiltration wells is very high—shown by the many regulations that include infiltration wells as infrastructure that must exist in every building. Infiltration wells have many functions, among others, to reduce runoff as well as absorb water to replenish groundwater reserves. Therefore, in its application, infiltration wells have many technical criteria that need to be explored further (SNI-8456-2017). Based on the research results, respondents who already know about Infiltration Wells tend to want to apply it at home. However, the availability of data on how it works and the effectiveness of Infiltration Wells is still minimal.

One-Stop Solution as a digital solution based on accurate data will make it easier for people to implement Zero Run-Off technology. With this platform, the community can provide input on the location of residential buildings, and the system will recommend whether the Infiltration Well is a suitable technology for the area. In addition, with the One-Stop Solution, the financing system for the construction of infiltration wells can also be arranged in such a way that it does not burden the buyer (e.g. the installment system). Therefore, to create a proper environment for people to be actively involved in Zero Run-Off Implementation, these factors should be considered:

1. Data-based information is crucial. to determine which locations are suitable for the construction of Infiltration Wells. However, the effectiveness data after the Infiltration Well is built is no less important, because the data can be used
2. Education about the various types of flood solutions needs to be intensified. The community needs to know that the flood solution is not only in the form of large infrastructure and comes from the government, but there are many things that can be done as a collective and massive action.
3. Law enforcement can be an initial approach for the application of infiltration wells in buildings.

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Using societal Resilience and "digital" communication and cooperation to reduce Global "Emerging water Challenges since COVID-19"

Bunmi Deborah Millennial-Oriagbo

Introduction

Water is important for drinking, sanitation, and meals production; for billions of human beings, however, water access and high-quality are restricted. The COVID-19 pandemic has similarly amplified the influences of these water inequalities. COVID-19 has, like not anything that has gone earlier than, discovered the structures wiring of the modern-day, globalized international, and the way damaging disturbances to those structures may be. Water is a connector throughout the society systems, and as a result has essential implications for each of the effectiveness of COVID-19 reaction efforts and for promoting increase and building resilience in a submit-pandemic globally.

understanding, measuring, and assessing society resilience calls for an eager attention of the links and relationships among the extraordinary scales of governance and exceptional systems which are at once and indirectly affecting groups. Developing techniques for building and enhancing society resilience calls for an understanding that vulnerability at any stage interprets to an extended vulnerability in different areas of the bigger society [2].

Digital communication is the ability to communicate efficiently in digital media and spaces. Digital media can be used as follows:

- To guide an effective study, e.g. through webinars, tutorials, mentoring, on-line lectures, email, chat.
- offer remarks to beginners in approaches which might be digitally difficult to understand.
- Discuss thoughts in a number of virtual/digital media and according with exceptional cultural, social and communique norms.
- Aid novices to talk efficiently in educational and expert contexts and apprehend the extraordinary norms of communication in one-of-a-kind settings.
- Recognize others in public communications; keep privateness in private communications.

Digital Cooperation is the ability to participate in digital groups and running groups. Participants of the digital groups can:

- Participate in digital groups and working organizations eg around curriculum improvement and overview.
- Cooperate effectively in digital spaces eg constructing shared sources, wikis, net pages, digital writing and shows.
- assist learners to cooperate with the use of shared digital tools and media, and to paintings successfully throughout cultural, social and linguistic boundaries.

Water technological know-how and control contain enormous amounts of information and facts that bring with them challenges examine complicated facts to improve operations and higher needs of purchaser [1].

Internet of things: IoT refers to the relationship of all computing devices that acquire records and it sensors and other IoT devices may be used within organizations, agriculture, infrastructure and home automation organization and thus gearing some organizations toward digital transformation. IoT can also be used among digital groups for societal resilience and digital communication and cooperation and to reduce global "emerging water challenges" since Covid19.

Big data: This is the data that is so large and it's variable in phrases of the 4Vs, it often can't be dealt with without standard sustainable development and resilience.

Artificial intelligence: AI is a tool for huge data analysis; it is a wide era that makes use of device gaining knowledge of capabilities (Blockchain) that cannot be broken, replicated or destroyed. it may be used in an array of industries to control of this precious and limited aid.

Blockchain: A public ledger that information and digitally links transactions (blocks) using cryptographic math related to volume, range, velocity and veracity (the 4Vs) [1].

Conclusions

As climate change accelerates and water are getting more contaminated. The upward push in commercial interest has accelerated demands: there are facts and software control Examples such as the artificial intelligence or similar big data information analytics, internet of thing IoT and blockchain technology that had been implemented in many digital society as a means of building society resilience to reduce the enormous water challenges faced since covid19.

Through society resilience and digital communication and cooperation like: twitter, webinar, zoom, email, chats, facebook, etc. All hands must be on deck to curtail the widespread of the “emerging water challenges since Covid19”. This paper will explain in phases the effect and usage of society resilience and digital communication and cooperation in reducing globally “Emerging water challenges since Covid19.”

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THEME 4

MANAGEMENT OF GROUNDWATER RESOURCES, THE "INVISIBLE WATER"

Estimation of intrinsic aquifer vulnerability at continental scale: The case study of South America

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Introduction

Groundwater is the main source of freshwater in the world. Broadly, more than half of world's population depends on subsurface water for any kind of utilizations such as drinking, irrigation, domestic and industrial purposes. The year 2022 has been proclaimed as the year of groundwater resources with the slogan "Making the invisible visible: 2022, the year of groundwater" pointing out as groundwater is also a vulnerable resource, which requires a forward-looking approach in its management. Accordingly, assessing intrinsic aquifer vulnerability to pollutant leaching represents a key preventive tool in terms of screening and management. Recently, vulnerability assessments have started to be developed at very big scale worldwide and pan continental maps of groundwater vulnerability have been yet developed in Europe (Kumar et al., 2020) and Africa (Ouedraogo et al., 2016). In South America, aquifer vulnerability has attracted the attention of researcher only in the last two decades, having most of the indexed works published in the last 10 years. Despite land use change is a main and actual topic for groundwater depletion in South America, aquifer vulnerability and water quality degradation, are two environmental topics only recently well understood. This work shows the first vulnerability assessment of groundwater in South America realized by Rama et al. (2022) which provides a single continental map that maximizes the local resolution of hydrogeological features to allows a consistent cross-boundary management of the risk.

Study area

The study area is represented by the fourth largest continent in the world: South America. It includes 13 countries and many other territories. From a hydrogeological point of view, the Andes divide South America into two major regions. On the one hand, the Pacific region (i.e., tectonically active), with small basins and aquifers, limited by the topography of the intermontane valleys. On the other hand, the Atlantic region, which is tectonically inactive, with large basins, plains of extremely low slope and transboundary groundwater bodies (e.g., Guarani aquifer across Brazil, Uruguay, Paraguay, and Argentina). South America presents a variable regime of temperature and precipitation on the land surface, presenting most of the climates of the world in a single continent. In terms of land use, about 50% is covered by forests, followed by grasslands 26%, agriculture 24%, barren 3%, and water bodies 1%.

DRASTIC methods

DRASTIC is a rating methodology based on the overlapping of a set of factors (i.e. indexes), related to local hydrogeological settings in a certain area (Aller et al., 1987). Those settings define the attenuation capacity of that location, which affects the sensitivity of an aquifer to a potential pollution from the land surface (i.e. intrinsic), without involving the role of specific land uses or chemical characteristics of dissolved compounds (e.g. persistence, mobility, adsorption). In DRASTIC, the indexes included in DRASTIC are Depth to water table (D), net Recharge (R), Aquifer type (A), Soil media (S), Topography (T), Impact of vadose zone (I), and hydraulic Conductivity (C) combined linearly and each multiplied by a characteristic weight.

Results and concluding remarks

The intrinsic aquifer vulnerability of South America assessed by DRASTIC were classified in 5 classes of vulnerability from very low (dark green) to very high (red) (Figure 1a). The results indicate that most of the continent is characterized by a very low to moderate intrinsic vulnerability (~70%), mainly due to quite deep aquifers, very rich/heavy soils and extended areas with outcropping crystalline formations that may prevent infiltration The Amazon Forest suffered the higher vulnerability, consequently, countries with extended regions of Amazon rainforest, showed more vulnerable groundwater resources, in order: Colombia (63%), Peru (41%), Ecuador (35%), Guyana (32%), and Brazil (32%) (Figure 1b). In those regions, a strong land use change at the expense of rainforest coverage may lead to a fast degradation of groundwater resources. Conversely, most extended areas with low vulnerability are concentrated in Argentina (72%), Chile (60%), and Bolivia (45%) due to their arid climate and deep aquifer systems. Overall, the present DRASTIC map of South America, in combination with detailed hydrogeological surveys at local scale, may represent a valuable initial step to achieve a sustainable land-use and water management, promoting cooperation among states for shared water resources**.**

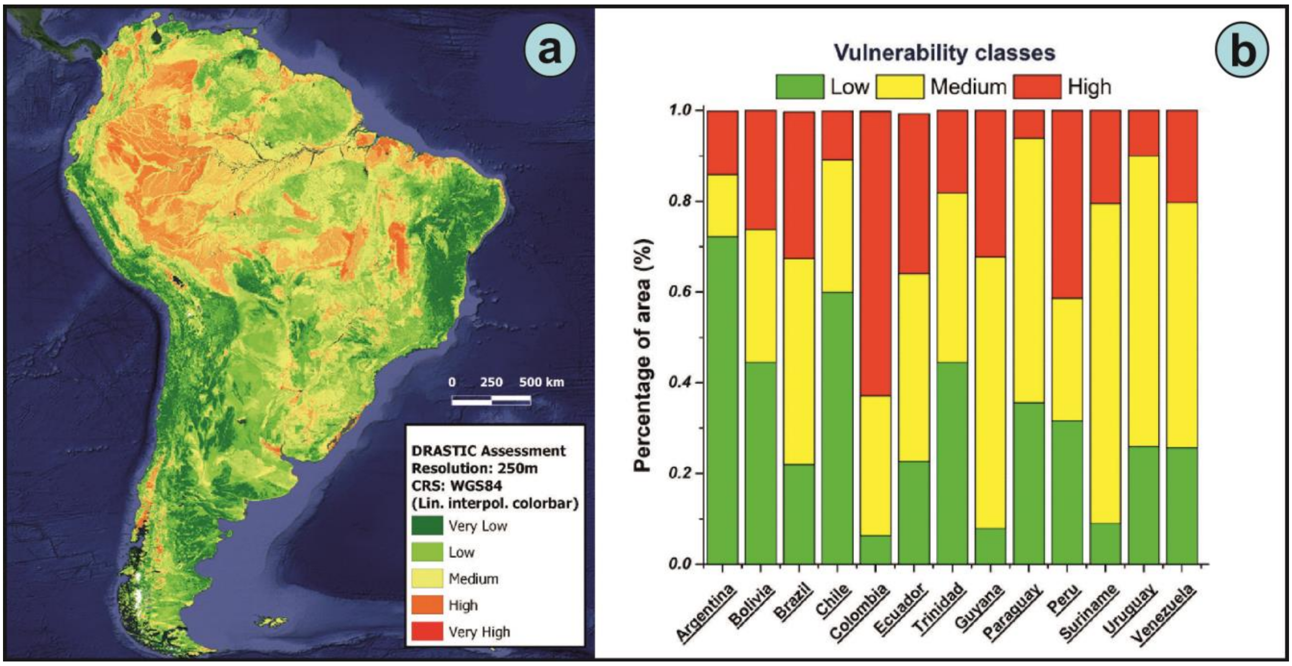

Figure 1. a) Intrinsic aquifer vulnerability map of South America based on a DRASTIC assessment, b) Stacked bar chart of intrinsic vulnerability classes in each country of South America from Rama et al. (2022).

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Development and Management of Groundwater Resources in a Hard Rock Terrain of Southwestern Nigeria

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Abstract

Access to potable water facilitates rapid civilization, health and social stability in different regions of the world. Subsurface exploration involving detailed geological, geophysical; very low frequency electromagnetic (VLF-EM), electrical resistivity method using vertical electrical sounding (VES) techniques and hydrogeological survey was carried out to characterize the subsurface geological and hydrogeological conditions with a view to developing a contemporary groundwater resources scheme. This is to meet the demand for water and improve the lives of the residents in the study area. Groundwater flows from eastern, northeastern and northern directions to the central, northwestern, southeastern, southern and western parts of the area. Conductive zones within the subsurface established by the VLF-EM survey constitute the forty-seven (47) locations further investigated by VES techniques. Three to five geologic layers were identified, while the weathered and fractured bedrock form the aquifer units with depth in the range 3.5 to over 100 m. The fractured aquiferous unit represents the target aquifer due to its thick sandy geological formation (mean resistivity; 602 ± 140 Ohm-m) being more prolific in its yielding capacity. Bedrock depressions with thick overburden (> 25 m) were identified as viable groundwater potential zones. Hydrogeological maps generated give insight into geological conditions of the aquiferous units, while the groundwater potential map distinctively categorizes the area into low, medium and high aquiferous zones. High groundwater potential zones of the area can be harnessed for massive groundwater development scheme. Other zones can be of use as the need arises.

Keywords: Groundwater development, electromagnetic investigation, geoelectrical characteristics, hydrogeological parameters, aquifer characterization, groundwater flow pattern

Introduction

Water, essential natural resources needed by man plays major roles in the economic development and social stability of the world. Man derives water through surface water (water from rivers, lakes, streams and storage reservoirs) and groundwater (water from hand-dug wells and boreholes) through water bearing rock layers (aquifers). Access to potable water facilitates rapid civilization in different parts of the world and can be supplied by groundwater. Thus, attention is diverted to groundwater abstraction because of its numerous advantages over surface water and consideration as available world's safest fresh water (Ademila and Saloko, 2018). Many people have been exposed to water-borne diseases due to inadequate water resources and consumption of unsafe drinking water. Continuous demand for water in Iju, the study area has constituted pressure on water resources due to increase in population of the town. Bridging the gap between water supply and the rising demand of people, expansion plans to improve the lives of residents prompted this study to delineate the water bearing zones and preferential groundwater flow pattern of the study area. This is with a view to have a contemporary water resources scheme in the area that would meet the needs of people in substantial quantity.

Materials and methods

The study involves geological, geophysical investigation employing very low frequency electromagnetic (VLF-EM), electrical resistivity method (vertical electrical sounding (VES) technique) and hydrogeological measurement. This is to investigate the subsurface condition of Iju (the study area), in order to understand the geostructural disposition and hydrogeological characteristics for appropriate siting of groundwater abstraction points to cushion the effects of health problems associated with inaccessibility to potable water in the area. Field geological mapping was conducted to describe the various rock formation encountered. Combined very low frequency electromagnetic method (VLF-EM) and vertical electrical resistivity sounding techniques were utilized. Ten (10) traverses in the range 400 and 1200 m were established with respect to the existing roads along which the geophysical data were acquired. The hydrogeological investigation involves static water level measurement of forty-six hand-dug wells distributed across the area. Most of the wells visited during the survey are seasonal in groundwater yield.

Results and concluding remarks

The field geological mapping resulted in production of the geological map of the area. Forty-seven major conductive geological interfaces were identified from the VLF-EM survey, which constitute the locations further investigated by VES techniques. These conductive zones are indicative of faults/fractures, lithologic contacts, weathered bedrock and other weak zones that enhance accumulation of water and form pathways for groundwater. Nine different curve types were identified from the study; A, AA, HA, KH, HK, AAA, HAA, HKH and KHA curve types. They represent three to five distinctive lithologic layers; topsoil, sand, weathered bedrock, partially weathered/fractured bedrock and fresh bedrock. The HA-curve type dominates the study area with percentage frequency of 55.3%. The existence of fractured bedrock in the subsurface with mean resistivity 602 ± 140 Ohm-m indicate sandy facies of the aquifer that would boost substantial and perennial groundwater yield. The generated series of relevant hydrogeological maps from the estimated hydrogeological parameters give detailed knowledge to the hydrogeological formation properties of the aquifer units. These series of hydrogeological maps were integrated to produce the groundwater/aquifer potential map of the area which categorizes the water bearing layers of the study area into different class of groundwater yield (Fig. 1). High aquifer potential of the area is noted with overburden thickness > 30m with evidences of fractures within the bedrock, with respect to the geoelectric parameters (resistivity and thickness) of weathered basement and fractured bedrock. Geological condition, overburden thickness and topography of the area influenced the groundwater distribution. The identified recharge zones must be free from human activities that could threaten groundwater quality. This study has shown the different aquiferous zones in the area with their class of productivity for successful groundwater development scheme. Approximately 30% of the areas categorized as high aquifer potential zones are underlain by coarse porphyritic granite and migmatite gneiss.

This subsurface investigation has provided detailed information useful to characterize groundwater condition and geologic formation properties of subsoil for elaborate groundwater development. It is recommended that this study be carried out prior the design and execution of any civil engineering construction work in a complex geological terrain.

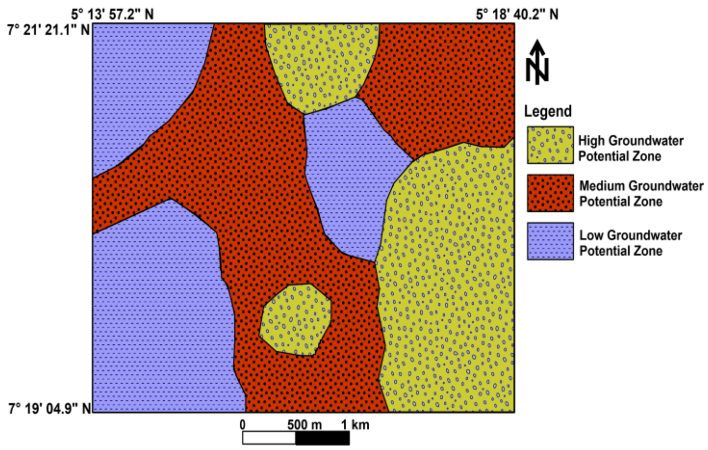

Figure 1. Groundwater/Aquifer potential map of Iju.

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Improvement of the drinking water supply guarantee in the province of Castellón (Spain)

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Introduction

The COVID-19 crisis has shown us the need to guarantee basic services, such as water supply. The province of Castellón, located in the east of Spain, has 585,590 inhabitants and the main source of water supply is groundwater. The coastal strip bears the highest population density, increased in the summer period by an important tourist inflow. There is a strong water deficit in this area. Conversely, the interior area of the province, scarcely populated and with an economy based on livestock farming, is considered a water surplus area but there are difficulties in extracting groundwater, mostly due to its depth. Moreover, climate change scenarios predict a decrease in water resources throughout the 21st century in this area (CEH-CEDEX, 2017). This will produce a situation of greater water stress in the near future.

Traditionally, in the Province there has been a lack of planned and continuous hydrogeological research on the account of economic, technical, administrative and competence difficulties, which has held back the development of supra-municipal drinking water distribution networks. A consequence of this situation are the existing water infrastructures built in the past, which are not used or are underused. To remedy this issue, the Drinking Water Supply Master Plan was approved at the plenary session of the Provincial Council of Castellón (2019).

This project develops the Drinking Water Supply Master Plan. It promotes the maximum connectivity in the province of Castellón through the construction of a water pipeline network that connects relevant drinking water collection points with municipal water tanks. The aim of this project is to increase the available water resources in the province, improve the guarantee of supply, leverage underused existing infrastructures, establish a balanced price within the province for recovering the costs of water production and distribution, energy self-sufficiency, deploy high-speed internet connection, encourage economic activities that prevent the emptying of rural areas and creation of rural tracks coinciding with the pipelines layout with the aim of connecting isolated areas and using them in the prevention and extinction of forest fires.

Materials and methods

This work integrates the province's hydraulic infrastructures for collection, regulation, distribution and management in one single network, the Provincial Strategic network. This includes pipes, water storage tanks, pumping systems and all the elements needed to transport drink water from the intakes (wells or desalination plants) to the municipal water tanks.

The Public Interest Primary Network is an extract of the Provincial Strategic network which integrates hydraulic infrastructures that are not currently in use or are underused and have been declared of Public Interest by the Spanish Government, such as Canet-I, Canet-II, Canet-III and Alcalá-II wells and the Oropesa-Cabanes and Moncofa sea water desalination plants. This network includes the pipeline system, water inlets, connections to the power supply grid, solar parks, micro hydropower turbines, control centres, etc. Moreover, an optical fibre network will be installed to improve the internet connection of rural municipalities, using the already dug water line trench.

The Network is designed with the aim of meeting water demand for urban, livestock and industrial uses. For the water demand calculation, the province as a whole has been considered, since there would be the possibility to transfer water resources from areas with surplus to shortfall areas. To estimate the available water resources, all the wells of the Provincial Strategic Network and unconventional resources (sea water desalination) have been considered. Finally, so as to achieve a sustainable territorial development, this work has also taken into account land uses, orography and geomorphology of the land, geology, seismology, hydrology and hydrogeology, risk of flooding, availability of land and materials for the construction works, climate change effects, impacts on environmental and landscape and economical and social factors.

Results and concluding remarks

The Public Interest Primary Network is made up of 331 km of high-capacity pipelines and generally with the possibility of bidirectional flow, 11 wells (6 new and 5 reconditioned) and 15 new water tanks (Figure 1). Where possible, hydraulic energy generated by hydraulic micro-turbines and solar energy are used. A provincial control and operation centre will be installed for supervision and control of drinking water supply facilities. This will allow the continuous operation and monitoring of the network, promoting the digitalisation of the water sector.

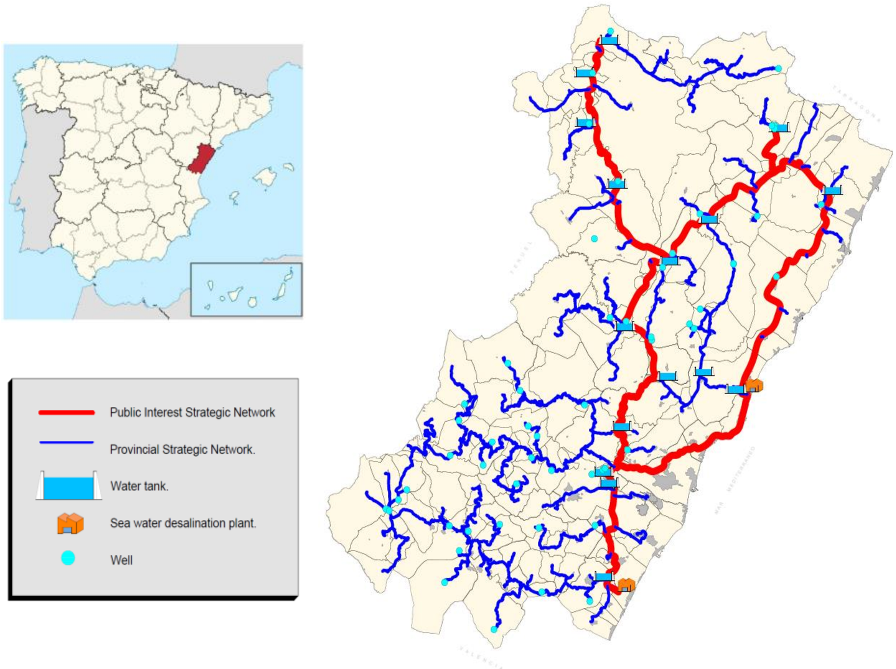

Figure 1. Provincial Strategic Network and, highlighted in red, the Public Interest Strategic Network, including wells, desalination plants and water tanks.

An annual volume of 26 hm^3/year could be extracted in Castellón from operating existing and new water boreholes. The two desalination plants could produce 64 hm^3/year at full capacity. In total, 90 hm^3/year could be mobilised, which would be enough to supply the entire province of Castellón, even in the most unfavourable long-term scenarios (25 years) considering population growth and a considerable reduction in groundwater resources. The estimated budget for implementing the Public Interest Strategic Network is 130 M€ (including materials, labour and machine costs).

Transferring the existing water resources from the interior of the province to the coastal areas, whose aquifers suffer from water stress, would avoid their overexploitation and marine intrusion, favouring environmental regeneration. This network would provide enough water resources and high-speed internet connection with optical fibre for disadvantaged areas in the interior of the province to avoid rural emptying and encourage the implementation of new activities in the territory. Using a global solution to address various local problems will improve the resilience of the province and the security of water supply.

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Strategies to mitigate the phenomenon of groundwater depletion in the Mediterranean region

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Introduction

Groundwater is a primary source of drinking water for almost two billion people worldwide (Gleeson et al., 2010). Moreover, it is critically important for energy, food security, human health and ecosystems (Gleeson et al., 2015). Yet, depletion of groundwater reserves is a common phenomenon in both humid and semi-arid regions of the world. Although non-sustainable groundwater exploitation has been documented on both regional and global scales (Gleeson et al., 2012), specific spatiotemporal characteristics need to be further studied and quantified. The phenomenon of groundwater depletion occurs when extraction from an aquifer exceeds the recharge, with the extent of the depletion effects being also determined by the aquifer type. A number of research challenges prevail, the most significant being the quantification of factors triggering groundwater depletion. Inevitably, depletion leads to increased pumping costs and the reduction of groundwater discharge to streams, springs and wetlands affecting ecosystems (Sophocleous, 2000). Additionally, lowered water tables induce groundwater flow, which can lead to salinization by seawater intrusion in coastal aquifers (Konikow and Kendy, 2005). Eventually, groundwater depletion can even lead to dry wells. The main cause of groundwater depletion is the excessive extraction for irrigation especially in cases where an aquifer is only replenished in a slow manner, while climate change could potentially exacerbate the phenomenon in some regions (Weider and Boutt, 2010). Global food production has increased dramatically since 1970 due to advances in well-drilling equipment and electrical pumping, and a large number of wells has been operated in a largely unregulated manner, often replacing surface-water resources. Accordingly, in some areas, groundwater levels have declined at rates even exceeding 1 m per year. On the other hand, climate-related changes might also influence recharge rates and aggravate groundwater depletion as recharge rates are influenced by the distribution and seasonality of snow coverage as well as drought events. Within this study a detailed analysis of hydrogeological, hydrological and climatological data was obtained in order to quantify groundwater depletion develop a software to optimize hydropower generation and managed aquifer recharge.

Materials and methods

In the framework of this study was selected three case studies in Greece and one in Italy. The case studies include the coastal aquifer in Anthemountas and Marathonas basin, the inland basin of Mouriki and Campania region in Italy (Figure 1). In all sites field and laboratory measurements was obtained including water level measurements, physicochemical analysis of surface and groundwater samples, water flow measurements and UAV mapping. Climatological data were collected from meteorological station and satellites in order to project hydrological balance and groundwater recharge variation. All available data were used for the simulation of surface-groundwater interaction in the hydrosystems using ArcSWAT. future climate data, for the period from 2030 to 2040, were automatically generated using the SWAT weather generator considering RCP 4.5 scenario. The final step was the development of a simulation model for hydropower generation and Managed Aquifer Recharge. The model is solved by the harmony search algorithm and the whole process is organized in Python language.

Results and concluding remarks

In the coastal aquifers of Greece, groundwater depletion phenomenon is continuously exaggerated due to overexploitation. Future scenarios project increasing of evapotranspiration amounts and decline of groundwater recharge in the coastal aquifers. In the inland aquifer of Mouriki basin and in the mountainous part of Campania region there are no significant variation in the hydrological components. The simulation scenarios for dam operation and MAR application clearly showed increasing trend of groundwater table, while energy production is not neglectable. Groundwater mis-management constitute the main driver for groundwater depletion. The use of small dams as mini-scale hydropower facilities can provide clean energy production, reduce CO_2 emissions and lead to an economically feasible and eco-friendly strategy against groundwater depletion. Nevertheless, the inversion of groundwater depletion requires holistic and versatile approaches including detailed monitoring, use of treated wastewater, crop type changes and awareness raising of local community and end users.

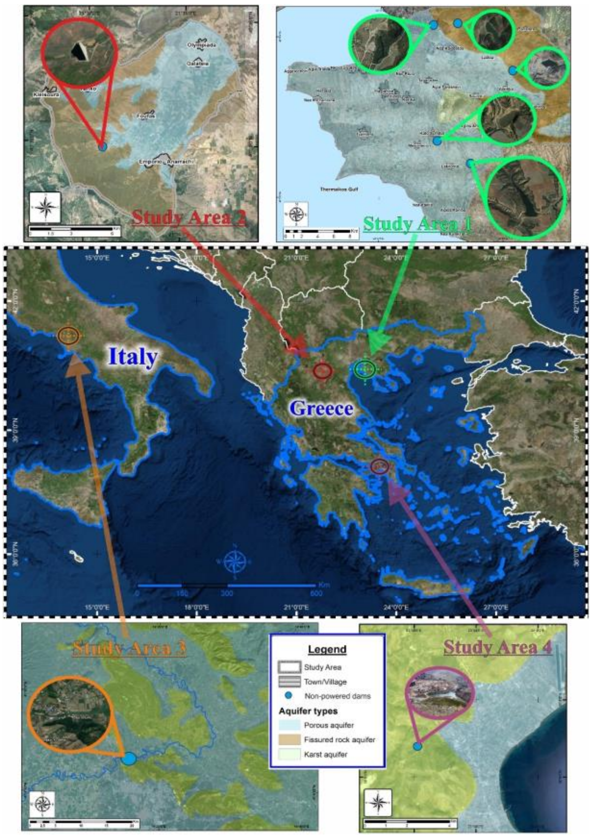

Figure 1 Study areas and non-powered Dams.

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Modelling Nature-Based Solutions to control flooding in Kibera slum, Nairobi, Kenya

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Introduction

Africa is rapidly urbanising, and its population growth is predicted to triple by 2050. The combined pressures of urbanisation and climate change have an influence on the ecosystem and the services it provides. As a result, there are additional dangers, which include, but are not limited to, greater flooding risk, economic disruption, and environmental concerns. Already, hydrological and climatological events have caused damages rising to USD 4.8 trillion worldwide between 1980 and 2018, of which 40.5% and 11.6% (Debele et al., 2019). Wider use of structural and non-structural measures as mitigation measures in Africa remains inadequate.

Additionally, poor housing and sanitation problems, prevalent poverty levels raise individual’s reactions and vulnerability to flooding risk and impacts (Ajibade & Tota-Maharaj, 2018). In some most cities, blockage of the existing drainage from either unkempt vegetation exacerbates the problem (Charlesworth, 2017). In a typical storm event, flash floods underpin poverty, insecurity, the risk of ill-health, on top of the existing poor housing causing loss of lives, livelihood, disruption of transport etc. whose recovery process is low.

Cities in Africa must develop innovative and adaptive solutions to minimise the effects of growing urbanisation in order to meet the United Nations Sustainable Development Goals. Evidence suggests that Nature Based Solutions (NbS) have the potential to reduce flooding risk while also delivering other benefits such as biodiversity sustainability, improved sanitation through greywater management, increased water and food security, and reduced climate change impacts (Cohen-Shacham et al., 2019; Seddon et al., 2020). NbS is defined as a collection of integrated ecosystem-associated approaches inspired by and copied from nature, which must sustainably minimize flooding risk and impacts to the society while preserving biodiversity.

Despite successful demonstration projects across Europe, Asia and United States, application and implementation of NbS in Africa, specifically in informal settlement remains limited.

Therefore, this paper aims:

i) to explore the potential of NbS in controlling flooding in informal settlement in Africa,

ii) gathering socio-cultural, and environmental challenges, and opportunities surrounding adoption of NbS in informal settlement, and

iii) conduct hydrological modelling to map flood prone areas and define suitable NbS types to adopt. To this end, Kibera slum in Nairobi, Kenya is the study location.

Although this research is ongoing, the projected outcome will add to the existing literature a replicable procedure of community co-designed, co-delivered, and co-managed NbS projects implemented in informal settlements.

Materials and methods

This study will utilise the following methods; Interviews**-** A combination of semi-structured interviews and questionnaires will be used to collect data on past flooding events, their frequency, impacts, and any adaptation or mitigation measures implemented at the household or community level, as well as their perception of sustainability and willingness to try NbS concept.

GIS participatory mapping- Involving the community in annotating the most vulnerable or regularly flooded areas on the map (printed catchment map), in order to provide relevant information on the precise sites that need to be prioritised and the type of NbS that is appropriate given the local surroundings.

Hydrological Modelling**-** Following that, selected or identified NbS types will be modelled to test their effectiveness in minimising localised floods. The catchment parameters of the identified places, such as rainfall-run-off estimation, soil infiltration rate, land cover, and elevation, will be examined.

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Impact of physicochemical parameters on groundwater quality and biodiversity in Tiko, Cameroon

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Introduction

Groundwater is water that flows beneath the earth's surface, filling the porous spaces in soil, sediments and rocks. It is the source of water for aquifers, springs and wells. It is the main source of drinking water reservoir on earth, but also a major ecosystem in terms of biological diversity. Maintaining groundwater quality and conserving its biodiversity are converging goals towards ensuring healthy wellbeing for the population. Groundwater ecosystems contain many endemic species adapted to live in an environment with no light and limited resources (Lou and Bloomfield, 2012). Rapid population increase, unplanned urbanization and intensive industrial activities have led to poor and unsustainable management of groundwater resources, leading to water scarcity. The supply of potable water remains a problem in Cameroon due to the unequal distribution of this resource on the earth's surface, fast and anarchistic urbanization, various pollutions that denature the quality of the continental hydro systems and the high poverty level of Cameroon. The population cannot access potable pipe borne water and therefore, many households depend entirely on groundwater for their water supply (Zebaze Togouet *et al.,* 2009).

In Cameroon and especially in rural areas, water quality is a call for concern due to higher poverty levels and large disregard towards the environment. Consequences of inadequate supply of water and sanitation are very evident especially with the outbreak of diseases and illnesses related to water quality (Gorham *et al.,* 2017). The main objective of this work was to determine the water quality of some wells in the town of Tiko by measuring the physicochemical parameters. It was also intended to identify potential biodiversity indicators of groundwater quality and to reinforce public awareness of the necessity to conserve the quality and quantity of groundwater and its biodiversity by emphasising on its economic, social, and scientific value together with its detriment on the health of the population when its quality is bad or not suitable for consumption.

Materials and methods

The sampling for physicochemical and fauna analyses was carried out from January to December 2017. A total of ten sampling points were chosen for this study and sampling cut across both the rainy and dry season for a period of one year. Water for physicochemical analysis was collected in 250 mL and 1000 mL polyethylene bottles and transported to the laboratory in a cooler at approximately 40^{o}C. The physicochemical properties were measured following standard techniques described by APHA (1998) and Rodier *et al.,* (2009) using appropriate devices.

Groundwater fauna was collected from the bottom of the wells using a Phreatobiological net sampler (Cvetkov, 1968) with the net having a mesh size of 180-200 µm (Dumas and Fontanini, 2001). In the laboratory, the fauna was rinsed, sorted, identified and counted using a binocular magnifying loupe of the Wild M5 brand and an optical microscope IVymen R system using appropriate identification keys (Tachet *et al*., 2010). The software SPSS 20.0 and Microsoft Excel 2016 program were used to analyse the results.

Results and concluding remarks

The lowest mean seasonal value of temperature was obtained in the rainy season (25 °C) and the highest value was obtained in the dry season (28.4 °C) with a mean seasonal value of 27 ± 0.83 °C. The value of colour varied from 10.50 mg/L in the dry season to 52.00 mg/L in the rainy season with a mean seasonal value of 32.17±13.35 mg/L. Turbidity values oscillated between 3.00 FTU in the rainy season and 29.00 FTU in the dry season and the U test on Mann Whitney showed a significant difference between the rainy and the dry season ($p < 0.05$). The value of electric conductivity varied from 98.50 µS/cm in the rainy season to 416 µS/cm in the dry season, with a mean seasonal value of 256.95 ± 104.52 µS/cm and no significant difference was observed for this parameter. The mean seasonal value of pH varied significantly during the study period, with lowest value being 5.63, obtained in the rainy season while the highest value was 7.24, obtained in the dry season. A significant difference was observed between the dry and rainy season as shown by the U test of Mann Whitney ($p<0.05$). Orthophosphates values fluctuated between 0.17 mg/L in the rainy season with a mean of 0.51 ± 0.15 mg/L and 2.40 in the dry season whereby the U test of Mann Whitney showed a significant difference from one season to another ($p = 0.007$). Dissolved oxygen values were distributed from 47.70 % to 75.75 %, with all values obtained in the dry season with a mean value of 59.57± 6.48 %.

A total number of 6290 organisms were collected during the study period in the sampling points, belonging to 02 phyla (Annelida and Arthropoda), 09 classes, 29 families and 26 identified genus/or sub families. This community was dominated by Ostracods (46.51%) followed by Copepods (43.3 %) while the least taxa were Hirudinea (0.24 %) and Arachnids (0.35 %). The taxonomic richness of the wells varied between eight taxa in TK 10 and 19 in TK7. The fauna collected showed that, the wells in Tiko are largely dominated by the class Crustacean with principal representatives being families of Cytherididae, Cyprididae and Cyclopoidae. Cyclopoidae were present in all the 10 sampling points and were abundant in sampling points that showed high organic matter and that are fairly mineralized as far as the physicochemical analyses are concerned. Cyprididae (Ostracods) stygophiles or stygobites taxa, very small in size, widespread and less studied, were present in all the wells except for TW10. Insects of the family Chironomidae were abundantly collected. Out of the 6290 organisms collected, 43 organisms were stygobites represented by three families; Stenasellidae, Darwinulidae and Asellidae and a total of 20 Stenasellidae was collected in six out of the ten wells that were sampled (TW3, TW5, TW7, TW8, TW9 and TW10). The second stygobite family was Asellidae (Proasellus), collected in TW7 with a total of just one individual. The third group was Darwinulidae whereby a total number of 22 individuals were collected in TW1, TW6 and TW8. The diversity index (H) of Shannon and Weaver showed that the fauna in Tiko was more diversified in the rainy season (1.19 ± 0.48) than in the dry season (1.06 ± 0.4) and the equitability index (J) also showed that the rainy season was more equitable (0.57 ± 0.25) than the dry season (0.51 ± 0.13). Groundwater in Tiko was rich in mostly epigean taxa and very poor in groundwater dependent organisms (hypogean taxa) due to the poor management and protection levels of the wells and also due to the relationship between ground water and surface water. The results obtained showed that the water is not suitable for consumption by the population without treatments. There is therefore need to sensitize the population of Tiko on the development of positive habits towards their water points in order to prevent them from water borne diseases.

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Hydrogeological model of Northeastern Attica

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Introduction

The present study aims to construct an integrated hydrogeological model in the wider area covered by the municipalities of Marathon, Dionisos, and the eastern part of Oropos, in north-eastern Attica. The study area consists mainly of the non-metamorphic formations of the Sub-Pelagonian Unit and the metamorphic rocks of Attic-Cycladic massif with a significant neotectonic overprint (Lozios, 1993). The carbonate platforms of the Triassic limestones and marbles due to their thickness and fractured mass are capable of developing karstic forms with the ability to contain and transfer water (Morphis, 1995, Mellisaris and Stavropoulos, 1999). Moreover, the Neogene lacustrine formations are capable of hosting big amounts of water due to their significant extent and thickness. Researchers studying the quality of groundwater in Neogene and Quaternary formations have detected high concentrations of pollutants and specific toxic trace elements including Arsenic, Chromium, Uranium, and Vanadium (Stamatis et al., 2011). The Arsenic bioaccumulation was detected in the lacustrine travertine limestones of Kalamos and Varnavas and its origin is natural (Kampouroglou and Economou 2017). Furthermore, the karstic systems that develop in the study area also require specific protection (Cost Action 65, 1995) because of the potential for pollution and contamination, as well as flooding.

In this study, modeling is used to assist in the following topics: **i)** investigating the hydraulic interconnections between the geological formations of the area, **ii)** the hydrodynamic pattern of the aquifer systems and the aquifer mass transport evolution.

The final objectives of this study are, a 3D model of the geology and tectonic structure of the area, a 3D model of the aquifers and adjacent recharge area, a characterisation of the aquifers and their interconnections, and a model of groundwater drainage.

Materials and methods

For the 3D model to be more reliable, it was necessary to construct geological sections based on the available data from previous research at the study area, and then virtual drillings along them. The following methods were utilized to prepare the data for analysis: **i)** Preprocessing and preparation of basic data such as geologic, stratigraphic, and tectonic data (cross-sections, maps) geophysical data, rock properties, borehole and virtual borehole lithological and aquifer sections, groundwater level data from springs and wells. **ii)** Quality check and evaluation of data, data conflict resolution, homogenization, and transfer to importable data format. **iii)** Building a geological 3D model using RockWare Rockworks. Importing of basic data and further evaluation. Creation of 3D surfaces and 3D body models. **iv)** Importing of additional data concerning specific research targets: water levels, aquifers base, hydrolithology, etc. **v)** Refining and specification of 3D models with the delineation of the aquifers in the geological formations. **vi)** Export of data answering to research questions such as maps, 3D visualizations, profiles, transport models, lithology, hydrogeology fence diagrams and cross-sections of the aquifers.

Results and concluding remarks

Geological Model: Description of geology and tectonic structure of the research area and construction of the final geological map. An accurate depiction of the geological formations thickness and alternations with the tectonic relationship between them was held for the area. Extraction of 3D model snapshots, 3D fence diagrams, and cross-sections of lithology.

Aquifer model: Description, characteristics, and geometry of aquifer systems in the research area and construction of the hydrogeological map. Five aquifer bodies were identified in the area and their boundaries were delineated. The piezometric surface and the thickness were examined for each aquifer with the extraction of the respective maps, cross-sections, and 3D model snapshots of the aquifer systems.

Groundwater drainage model: Final report on the interconnections and groundwater paths from the recharge areas to the discharge areas of each aquifer and depiction of the drainage network supported by piezometric maps, cross-sections, and fence diagrams (*figure 1*).

Some crucial results of this study as the 3D geological, aquifer and groundwater drainage model suggest are following: **i)** Groundwater pollution of the aquifer in the Neogene basin of Kalamos area is possible due to the significant extent of travertine limestones and the normal faulting of the area which allows the formation to expand at greater depths and favours groundwater flow at the travertine limestones, **ii)** This is also the case for the Neogene aquifer at Varnavas area, north of Marathon Lake, due to the presence of the karstic formation of Agios Georgios marbles, which favours the leaching of trace elements to the groundwater, **iii)** The karstic aquifers of Grammatiko and Marathon basins are in hydraulic connection as the formations where they are developed are in contact due to the geometry of the basement formation of schists, north of the city of Marathon.

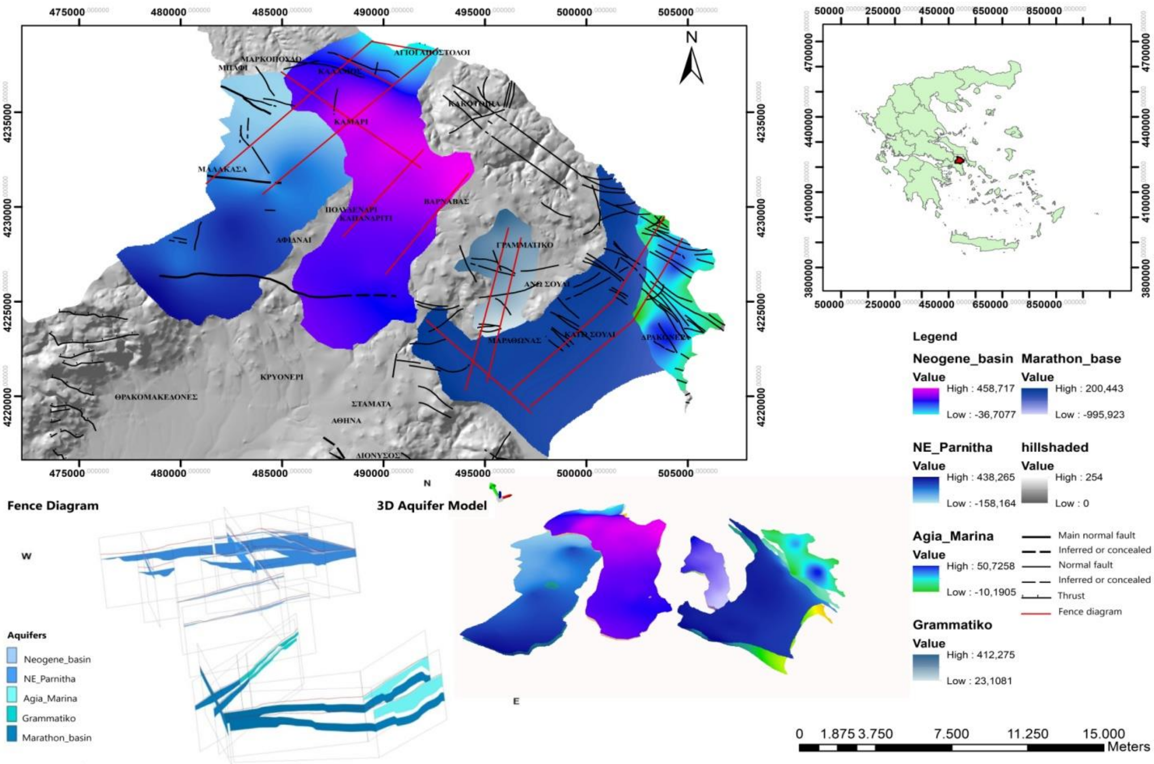

Figure 3. Groundwater drainage model together with Snapshot of 3D aquifers model (green arrow points the north) and a fence diagram. The red line on the fence diagram indicates the ground surface.

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Entrapment of air in unsaturated zone and its impact on groundwater recharge

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Introduction

Groundwater recharge is affected by the movement of fluid phases in the unsaturated zone (Nimmo, J.R. 2005; Kim et.al. 2009). During infiltration, the wetting waterfront will displace the pore air present in unsaturated zone downwards and this causes air entrapment (Kuang et. Al. 2013; Bond, W. J. and Collis-George, N 1981; Adrian, D. D. and Franzini, J. B. 1966; Dixon, R. M. and Linden, D. R.1972). This entrapped air reduces the hydraulic conductivity and thereby hampers the groundwater recharge (Wang et.al. 1998; Touma, J., and Vauclin, M 1986). This study aims to improve the infiltration rate (IR) by reducing the impact of entrapped air using soil ventilation. This concept was investigated using ponded infiltration experiments in a laboratory sand column by providing multiple vents. These experiments were carried out over 250 times and results were analysed for its statistical significance.

Materials and methods

The present study was carried out in a partially saturated laboratory sand column having dimensions of 40 cm x 40 cm x 60 cm. The column was open at the top, and the bottom 4 cm of the column was filled with fine gravel and then up to 40 cm with medium sand. A 55 cm long tube of 2 cm diameter was inserted up to the bottom of the column to function as piezometer to measure the water level in the column. Ponded infiltration tests were conducted, and the time taken for decline in surface water level was measured. The experiments were carried out by ventilating the unsaturated zone with pipes of 8 mm, 12 mm, 16 mm and 22 mm diameter and the number of pipes also varied from one to five. The experiments without vents were performed 17 times and those with vents were for 235 times. In total, 252 times the experiments were conducted. The IR measured in every 10 seconds (s) up to 50s were compared. Experiment results were analysed to understand the statistical significance of the values of IR.

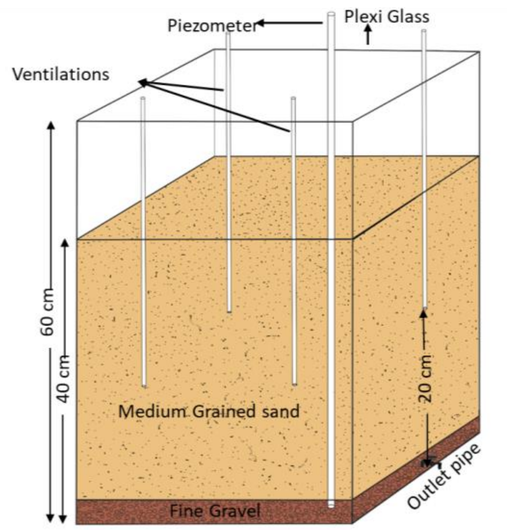

Figure 1. Schematic diagram of the experimental set up

Results and concluding remarks

The IR measured in every 10 seconds up to 50 s were analysed. The analysis has confirmed that providing vents increases the IR. The IR is very high during the first 30 s and with a single vent, IR increased about 0.49, 0.28, 0.25 mm/s at 10s, 20s & 30s respectively. Increase in IR was at least 0.18 mm/s and 0.15 mm/s at 40 s and 50 s intervals respectively (Table 1). Increase in IR for 1, 2, 3, 4 and 5 vents with respect to no vents can be understood from table 1. Thus, the results of these experiments confirm a considerable increase in IR with increase in the number of vents. The recharge increases by about 43% with one vent and about 88% with five vents. The IR is higher in the first 20s compared to ranges from 30s to 50s since the entrapped air releases rapidly during the initial stages of the experiments. This emphasizes that during extreme rainfall events, the rate of groundwater recharge can be increased by providing ventilations. Consequently, this will help in reducing the surface runoff thereby the downstream discharge will be reduced and thus it can be helpful in flood mitigation

Table 6. MIR and % of Increase in MIR Compared to No Vents.

Mean Infiltration rate (MIR) and Percentage (%) Increase in MIR Compared to No Vents										
	10 s		**20 s**		**30 s**		**40 s**		**50 s**	
	MIR	**%**	**MIR**	**%**	**MIR**	**%**	**MIR**	**%**	**MIR**	**%**
No Vents	1.14	-	0.95	-	0.76	-	0.71	-	0.62	-
1 Vent	1.63	42.67	1.17	24.00	1.00	32.50	0.89	25.82	0.77	24.35
2 Vents	1.67	46.44	1.23	29.70	1.01	33.03	0.87	23.40	0.77	24.35
3 Vents	1.74	52.33	1.31	38.58	1.07	41.35	0.90	27.94	0.80	28.87
4 Vents	1.94	70.24	1.39	47.15	1.19	57.20	1.01	43.12	0.94	50.81
5 Vents	2.15	88.41	1.59	68.08	1.30	71.20	1.09	54.18	0.95	53.39

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Intercomparison of Water Resources Management Scenarios in Almyros Basin, Magnesia, Greece

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Introduction

The availability and quality of water in coastal agricultural watersheds is a critical challenge. The following factors contribute to the water resources management issues across most coastal river basins: i) scarce utilization of surface water reservoirs, ii) excessive groundwater withdrawals for crop water irrigation, and iii) excessive fertilization activities for crop productivity amplification. Similar mechanisms have resulted in a substantial water stress over the quantity of Almyros Basin's coastal groundwater system, as well as nitrate pollution and seawater intrusion (Lyra et al., 2021a).

Materials and methods

An Integrated Modelling System developed in a previous study was used to simulate the Almyros Basin which comprises of coupled and interrelated modules for surface (UTHBAL) and groundwater (MODFLOW) hydrology, nitrate leaching/crop growth (REPIC), nitrate pollution (MT3DMS) and seawater intrusion (SEAWAT), and a reservoir model (UTHRL) (Loukas et al., 2007; Lyra et al., 2021a). The quality and quantity of the groundwater system in September 2018 is presented in Figure 1. Two irrigation reservoirs are to be constructed. Regarding the agricultural water requirements, two groups of water resources scenarios have been analysed, the Aquifer Scenarios (S) and Aquifer-Reservoir Scenarios (SR). Alfalfa, cereals, cotton, maize, olive groves, trees, vegetables, vineyards, and wheat are the crops grown in Almyros aquifer that extends to area of 293 km^2. Irrigated area scenarios were examined for the reservoirs' operation the total area A0 of 30 km^2 and A1 of 17 km^2. Firstly, Deficit irrigation was applied to all crops (scenarios S1, SR1) and secondly Deficit irrigation to alfalfa, cotton, maize, trees, vegetables, vineyards, and rainfed to cereals, olives, and wheat (scenarios S2, SR2). The performance of scenarios has been evaluated with indices of crop water and economic water productivity (Lyra et al., 2021a; Lyra et al., 2021b; Lyra et al., 2021, April).

Results and concluding remarks

The scores of water balance/budget, Crop Water Productivity (CWP) and Economic Water Productivity (EWP) are presented in Table 1.

Table 7. Summary of the Water Resources Management and Agronomic Scenarios implemented on the Almyros Basin, (Lyra et al., 2021a; Lyra et al., 2021b; Lyra et al., 2021, April).

Management Scenarios	Annual water budget (hm^3)	CWP tn/m^3	EWP €/m^3
1. S0 (baseline scenario)	– 12	9.8	1.08
2. S1 (Deficit Irrigation)	– 7.9	11.8	1.29
3. S2 (Deficit Irrigation & Rainfed)	– 0.3	6.4[a]	0.82[a]
4. SR0-A0 (operation of 3 reservoirs-irrigated area extent A0)	– 9	11.3	1.24
5. SR1 -A0(Deficit Irrigation - aquifer & reservoirs - A0)	– 6	13.9	1.42
6. SR2 -A0 (Deficit Irrigation & Rainfed - aquifer & reservoirs - A0)	1.6	7.1[a]	0.97[a]
7. SR0-A1 (operation of 3 reservoirs- irrigated area extent A1)	– 10	10.9	1.19
8. SR1 -A1(Deficit Irrigation from aquifer & reservoirs - A1)	– 7	12.9	1.36
9. SR2 -A1 (Deficit Irrigation & Rainfed - aquifer & reservoirs - A0	0.7	6.8[a]	0.90[a]

[a] estimated only for irrigated crop types

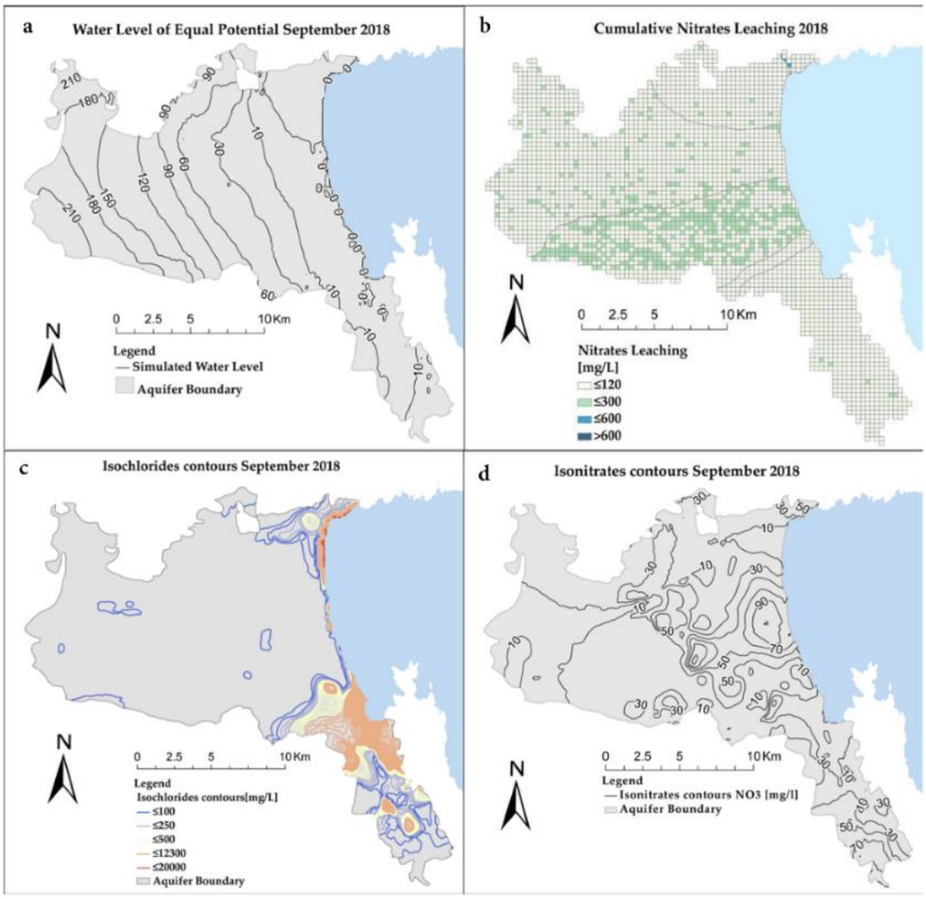

Figure 1. Quality and Quantity of the Almyros aquifer system in September 2018 for scenario S0 (Lyra et al., 2021a).

In conclusion, the implementation of agronomic and water resources schemes can benefit the water system and local agriculture especially when reservoirs can be operated to cover the agricultural irrigation demands.

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Design and application of an open-source 3D/4D geo-database: the case study of the Volturno Plain in Southern Italy

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Introduction

The European Water Framework Directive (2000/60/EC) and Groundwater Directive (2006/118/EC) require member states to identify groundwater bodies and monitor their qualitative and quantitative status. Therefore, a comprehensive knowledge on groundwater bodies characteristics, groundwater quality and groundwater availability should be achieved for a sustainable management of water resources.

In complex hydrogeological settings and in areas characterised by widespread anthropic activities (i.e., agricultural and livestock activities) and urban settlements, such knowledge is usually represented by a huge amount of data, often non-homogeneous in terms of spatial and temporal distribution. Therefore, an appropriate and uniform data collection, storage and management is necessary. The objective of this study is to implement an interactive 3D / 4D hydrogeological geo-database for the optimization of the handling and storage of spatio-temporal data for the Volturno Plain in Campania Region (Southern Italy). An open-source WebGIS version of the geo-database is under development for data visualisation, exploration and query, and it is proposed to water managers and decision-makers for a proper and sustainable management of groundwater resources.

Materials and methods

The 3D / 4D hydrogeological geo-database is implemented for the Volturno Plain in Campania Region (Southern Italy). The Volturno Plain is a coastal plain of about 1340 km^2 constituted of fluvial, volcanic (i.e., pyroclastic) and marine sediments. It is surrounded by Mesozoic limestone mountains of the Southern Apennines (E), pyroclastic hills of the Phlegrean Fields (SW), adjacent plains (N and SE) and by the Thyrrenian sea (W). The Volturno River crosses the plain from NE to SW. Two main porous aquifers are present (Allocca et al. 2005; Corniello and Ducci 2014): a shallow phreatic one and a deep semi-confined (or confined) one, which are separated by a tuff layer of variable thickness.

The database includes geographical (i.e., base layers), geological and hydrogeological information. Base layers include elevation, hydrography, land cover and land use. Geological data include stratigraphies from more than 400 boreholes. Hydrogeological data include piezometric levels and more than 600 hydrochemical analyses (i.e., physico-chemical parameters, major and minor cations and anions, metals, organic compounds) from 370 wells and piezometers, spanning from 2002 to 2020. At 12 water sampling points, about 60 isotopic analyses on $\delta^{18}O$ and δD for the period 2011-2016 are available. Hydrogeological data were collected by various entities (e.g., Regional Environmental Agency) for different purposes (e.g., monitoring campaigns, remediation activities) and were provided in extremely various formats.

The first step in the realisation of the 3D / 4D hydrogeological geo-database consisted in the collection and homogenisation of the information coming from different sources. Secondly, a quality check on the data was performed to identify errors, missing values and duplicate data. Errors and missing values were flagged, whereas duplicate data were removed from the database. Then, the basic, geological and hydrogeological data were organised in tables, vectorial and raster layers in a geographic information system (GIS) environment, according to the specific information contained in each single database (i.e., borehole stratigraphies, piezometric levels, hydrochemical data). Data formats were adjusted to respect the ISO (International Organization for Standardization) and the OGC (Open Geospatial Consortium) standards to make them accessible on a WebGIS platform. Finally, the 3D / 4D hydrogeological geo-database was tested for visualisation, exploration and query and for furthered data analyses, such as: i) the identification of areas characterised by poor groundwater quality, ii) the evaluation of trends related to both groundwater quantity (piezometric levels) and quality (abundance of specific compounds), iii) the relationship between groundwater quality and geological or anthropogenic conditions.

Results and concluding remarks

The 3D / 4D hydrogeological geo-database summarises all the information collected in the Volturno Plain in the last two decades in a usable and interactive format. The exploration and interpretation of geological and hydrogeological data allow to reconstruct the geological and hydrogeological setting of the plain (Corniello and Ducci 2014; Sellerino et al. 2016), to identify and delineate the groundwater bodies, to recognise the evolution of the hydrogeological characteristics over time, and to highlight missing information in the database.

The hydrogeochemistry of the main aquifers reflects the geological characteristics of the study area, showing waters of calcium-bicarbonate type to sodium-bicarbonate type from the mountains to the seacoast, along the main groundwater flow direction. The high concentrations of As, F, Fe and Mn are strictly related to volcanic sediments and volcanic-related processes, especially in the south-eastern sector of the study area. A specific analysis of the geochemical anomalies allowed to assess the Natural Background Values of these compounds within the groundwater body (Ducci et al. 2016; Sellerino et al. 2019). The spatial and temporal distribution of the main hydrochemical compounds (i.e., Cl^- and NO_3^-), combined with land use and land cover information, highlighted that the extensive presence of agricultural and livestock activities and urban and industrial settlements caused the worsening of groundwater quality in the last 20 years (Ducci et al. 2020): a) coastal areas are affected by marine intrusion; b) several areas of the plain are affected by nitrate contamination, both in terms of high concentration levels and in increasing concentration trends.

A structured and interactive 3D / 4D hydrogeological geo-database, as for the Volturno Plain example, would be a useful support to groundwater managers and decision-makers for a sustainable management of the resource. In particular, it would help: i) exploring and querying the available data, ii) integrating new data, iii) checking the status of groundwater bodies, in terms of water quality and quantity, iv) planning groundwater quality and quantity monitoring campaigns, v) reorganising the monitoring network according to water needs and availability, as well as water quality conditions, vi) keeping the surveillance of the geogenic and anthropic sources of contamination. Lastly, the WebGIS implementation would also allow to interact with the database in a freely and friendly environment.

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Groundwater vulnerability assessment using the DRASTIC method in the Lake Karla aquifer, Thessaly, Greece

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Introduction

The augmentation of human population, agricultural activities, and the over-exploitation of groundwater resources, along with the climate change are contributed not only to the reduction of available water reserves but also to the groundwater quality degradation in the Mediterranean region. The prevention of groundwater pollution is imperative especially where the aquifer is more vulnerable to contamination (Kazakis and Voudouris, 2015) and where there is water scarcity in irrigated and cultivated areas as in the Thessaly region (Loukas et al., 2007; Mylopoulos et al., 2009; Sidiropoulos et al., 2021). In this study, an attempt is made to assess the vulnerability of the aquifer of the catchment area of Lake Karla in Thessaly, Greece, with the DRASTIC method (Aller, 1985). The DRASTIC model combined with Geographic Information Systems (GIS) have been used to identify the vulnerable zones of the Lake Karla aquifer system.

Materials and methods

DRASTIC model uses geomorphological and hydrogeological parameters. Depth to groundwater (Dr), net Recharge (Rr), Aquifer media (Ar), Soil media (Sr), Topography (Tr), Impact of the vadose zone (Ir), and Hydraulic Conductivity (Cr). The final DRASTIC index (DI) and the vulnerability maps are being determined by applying the Equation (1), Dw, Rw, Aw, Sw, Tw, Iw, Cw, are typical weights of the parameters.

$$DI = D_r \times D_w + R_r \times R_w + A_r \times A_w + S_r \times S_w + T_r \times T_w + I_r \times I_w + C_r \times C_w \quad (1)$$

The parameters were rated and weighted from 1 to 5 and 1 to 10, respectively, due to their relative importance to contamination and according to the aquifer characteristics (Aller et al., 1987).

In order to locate areas that are threatened from pollution activities that require further protection, the DRASTIC method has been applied to the Lake Karla region. Lake Karla basin is a rural basin that covers 1171 km^2 of mostly arable land and the underlying aquifer system is located in low altitudes less than 200 m in the eastern part of Thessaly (Loukas et al., 2007). With agriculture being the main economic activity, there is an increasing water and fertilization demand which has led to an over-exploited aquifer and to nitrate pollution (Sidiropoulos et al., 2021).

Water table data, climatic data, hydrogeological data, geomorphological and soil data, for the hydrological years 2004, 2007 and 2015 from have been obtained from previous studies on the Lake Karla groundwater system (Sidiropoulos et al., 2021) and have been used to estimate the groundwater vulnerability to potential pollution.

Results and concluding remarks

The maps of the seven conditioning factors of potential pollution have been used to prepare the synthesis of the vulnerability zone mapping of Lake Karla aquifer. The vulnerability map was generated with the integration of all thematic maps of each parameter. The results of the present study divulged that around 56% of the area is in the low-moderate vulnerability zone and around 18% shows moderate and moderate-high vulnerability, while less than 10% is in the low vulnerable zone (Table 1).

The northeast and southeast part of the aquifer are moderate and moderate- high vulnerable to groundwater contamination. The DRASTIC vulnerability map of Lake Karla aquifer for the dry period of 2007 is presented in Figure 1.

Table 8. DRASTIC vulnerability index for Lake Karla aquifer in dry period of 2007.

DRASTIC Index Score	Vulnerability Group	Area (km²)	Percentage (%)
80-99	Low	40.43	8.41
100-119	Low - Medium	269.30	56.03
120-139	Medium	84.46	17.57
140-159	Medium - High	86.48	17.99

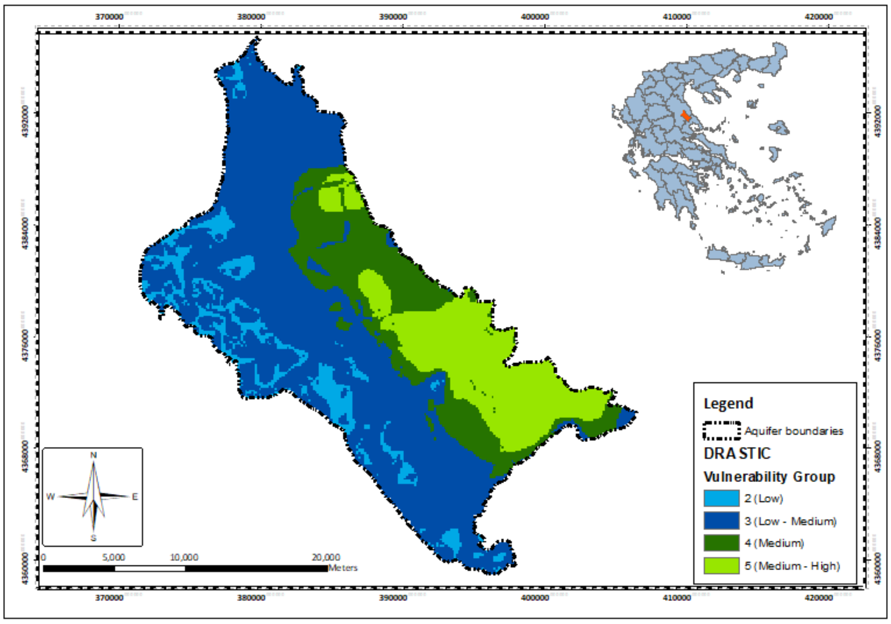

Figure 1. DRASTIC Vulnerability map of Lake Karla aquifer for the dry period of 2007.

There is an urgent need to face groundwater pollution and the anthropogenic activities that cause it (agriculture, fertilization, etc.). The vulnerable areas of the Karla aquifer indicate where protection measures of water resources must be implemented, to safeguard the aquifer's water quality status especially from nitrates. The prevention of nitrate pollution while ensuring the sustainability of the Karla aquifer can also be achieved with the application of good farming practices.

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Analytical Hierarchy Process (AHP) in Aquifer Vulnerability Assessment using the DRASTIC method in Almyros, Greece

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Introduction

The subject of the present study is the assessment of aquifer vulnerability to nitrate pollution using the DRASTIC method in the rural and coastal Almyros basin, in Magnesia, Greece. Unsustainable groundwater abstractions for irrigation have degraded the quality and quantity of the Almyros aquifer system. The Analytical Hierarchy Process (AHP) of Multicriteria Analysis has been used for the modification of the typical DRASTIC index based on the statistics of experts' responses to questionnaires on the influence of hydrological, hydrogeological, and other parameters (Lepuri, 2021).

Materials and methods

The vulnerability indices have been estimated for the period 2010-2015 using the typical DRASTIC index method (Aller et al., 1987; Kazakis et al., 2015) and versions of DRASTIC–AHP method (Lepuri, 2021; Lepuri et al, 2022) while vulnerability results have also been validated against observed nitrates concentrations using the Pearson 's correlation analysis in a recent study (Lepuri, 2021). The weights of the DRASTIC method differ from the weights of the statistical DRASTIC–AHP indexes, for the median, average and mode values of the pairwise comparison tables filed by 15 experts. All pairwise comparison tables have been tested for consistency with the Consistency Ration (CR) (all tables had CR<0.1). For the typical DRASTIC method, the descending order of importance of the method parameters is D, I> R> A, C> S> T. The DRASTIC–AHP (Median) index classifies the weights of the parameters in the following descending order R> I> D> S, C> A> T. The descending order of parameters' importance as estimated by the DRASTIC–AHP (Average) index is D> R> I> S> A> C> T, and the descending order of parameters' importance based on the weights of the statistical DRASTIC–AHP (Mode) is D> I> T> R> S> C> A (Lepuri, 2021).

Results and concluding remarks

The results for the extent of each vulnerability class for the typical DRASTIC and the statistical DRASTIC–AHP indices are presented in Table 1.

Table 9. Area (%) of Almyros Aquifer Vulnerability with the typical DRASTIC and statistical DRASTIC-AHP methods.

Groundwater Vulnerability	DRASTIC	DRASTIC–AHP (Median)	DRASTIC–AHP (Average)	DRASTIC–AHP (Mode)
Very High	17.4	16.5	18.1	15.3
High	21.9	23.3	20.4	19.2
Moderate	26.6	36.2	32.7	25.1
Low	24.0	18.2	22.4	23.0
Very Low	10.0	5.8	6.4	17.4

From the results, it was observed that the very high and high vulnerability areas differ by 1-5% between the typical DRASTIC and the DRASTIC–AHP indices, with the DRASTIC–AHP (Mode) index occupying the smallest total percentage of very high and high vulnerability values as compared to the other indices. All methods agree that the coastal area of the aquifer and the center of the aquifer are more vulnerable in nitrate pollution, as they generally have high vulnerability values. The vulnerability results are presented in Figure 1.

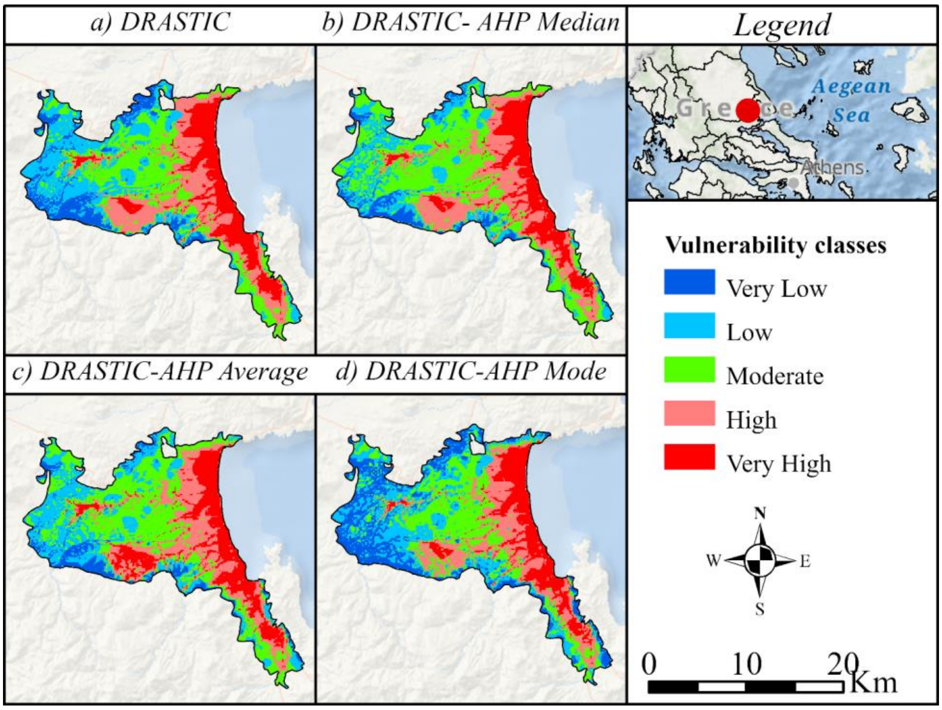

Figure 1. Almyros aquifer vulnerability for the years of 2010-2015 using the methods of a) DRASTIC, b) DRASTIC–AHP (Median), c) DRASTIC–AHP (Average), d) DRASTIC–AHP (Mode).

The highest weights for all methods are attributed to the parameters of the depth of the vadose zone, recharge, while the smallest weights are given to the parameters of the soil media, the aquifer medial, the hydraulic conductivity, except for the DRASTIC– AHP (Mode) index, where the topography parameter receives the greatest weight in relation to the other indices. All indices present a strong Pearson correlation with the logarithmically transformed nitrate concentrations, as the correlation coefficients range from 0.72 to 0.78, with the DRASTIC index showing the strongest correlation as compared to the others, while the DRASTIC–AHP (Mode) index showed the smallest correlation as compared to the other indicators for the period 2010-2015 (Lepuri, 2021; Lepuri et al., 2022). The differences between the indices in the areas of vulnerability are due to the different weights between the vulnerability indices.

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Contribution to rational groundwater management in Korinthia Prefecture, South Greece

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Introduction

Groundwater plays an important role in the covering of water needs for domestic and agricultural use in South Greece, which is characterized by the complete absence of rainfall during the dry period (early April to October). Korinthia Prefecture in NE Peloponnesus (South Greece), covering an area of 2,290 Km^2, is characterized by increasing water needs during the summertime, when the water availability is very low. As a result, groundwater is under pressure, which is exacerbated by rapid urbanization in the coastal, increased demand for agricultural production, quality deterioration, land-use changes, and climate crisis. Climate changes will affect the reduction of rainfalls and the natural recharge of aquifer systems.

The main aquifers of Korinthia Prefecture are developed in the alluvial Quaternary deposits (lowlands) and karstified carbonate rocks (semi- and mountainous area), discharging through many springs (Fig. 1). Water demands have considerably increased over the last 35 years and are mainly covered by groundwater abstracted from the aquifer via numerous wells and boreholes, and partly by the surface discharge of the Asopos River (Voudouris et al., 2007).

The aim of this review is to describe the current status of groundwater resources in Korinthia Prefecture. In addition, some proposals for the sustainable management are proposed.

Materials and methods

Meteorological data, including rainfall and temperature data, were provided by Hellenic National Meteorological Service (EMY). Demographic data were provided by Hellenic Statistical Authority (Fig. 2) and geological data by the Institute of Geology and Mineral Exploration (IGME). Finally, hydrogeological data were collected and evaluated from previous researches (Voudouris and Voudouris, 2022).

Results and concluding remarks

The annual average rainfall is 469 mm at Velo station (appr. 10 m a.s.l.). It occurs mainly in the wet period (85%), which normally extends from late October through April, with sparse storm events during the summer months. In the wet season rainfall peaks in November and December. July is the month of lowest rainfall in the area of Korinthia. The average yearly temperature is 17.5 °C; January is the coldest month and July is the hottest month. A population decline has been recorded during the last decade (Fig. 2).

Due to irrational management, aquifer systems are characterized by poor quality and quantity. The main quality problems are (Hionidi et al., 2001): salinization due to seawater intrusion in coastal aquifers and nitrate pollution of agricultural activities. The coastal aquifer system in Korinthia prefecture is a representative aquifer of South Greece and is characterized by deficient groundwater balance and significantly deteriorated water quality. This coastal aquifer system is the main water source for local use; a percentage of 80-95% of area’s water is abstracted from groundwater. It is pointed out that the coastal part of the Prefecture is an agro-touristic center.

Groundwater will play an important role in adapting to climate crisis, which can be done through rational water management (EEA, 1996). Emphasis should be placed on the circular economy, which aims to reduce, reuse, and renew-retention of water. In the circular economy, the reuse of treated wastewater mainly for irrigation will play a primary role and the collection and utilization of rainwater (harvesting) will play a secondary role. The construction and operation of the dam on the Asopos River in combination with other saving and artificial recharge measures will significantly contribute to the solution of the water problem of the coastal area. In addition, the construction of small interception dams in the main torrents of the hilly region, aiming at retardation of wintertime torrential flows and increased groundwater recharge is of utmost significance (Voudouris, 2007).

Finally, the utilization of water-saving techniques such as spray irrigation and drip irrigation should be applied in order to decrease the groundwater quantities for irrigation use.

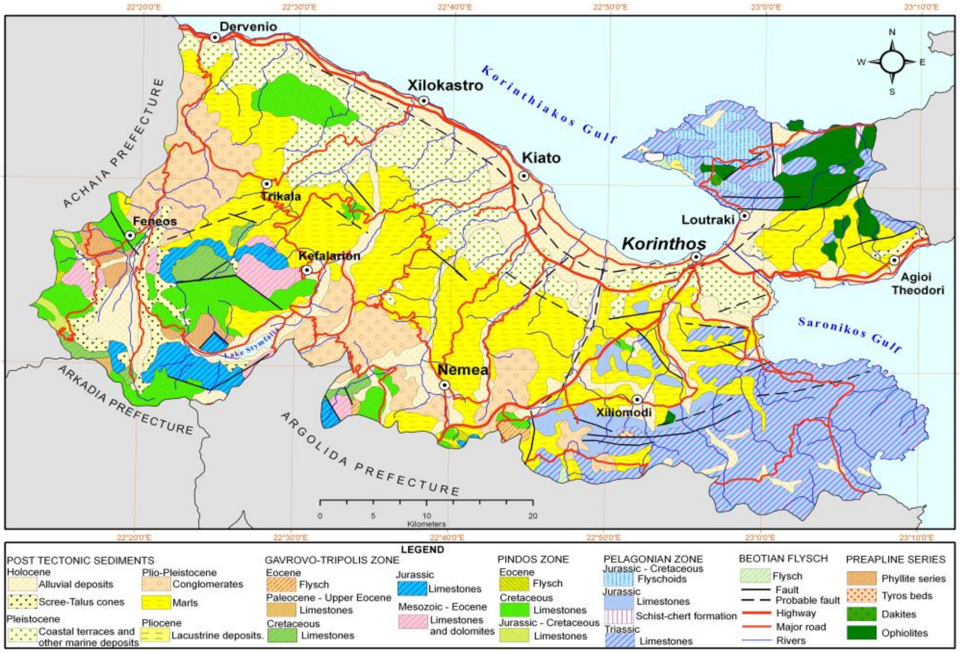

Figure 1. Geological map of Korinthia (Voudouris et al., 2007).

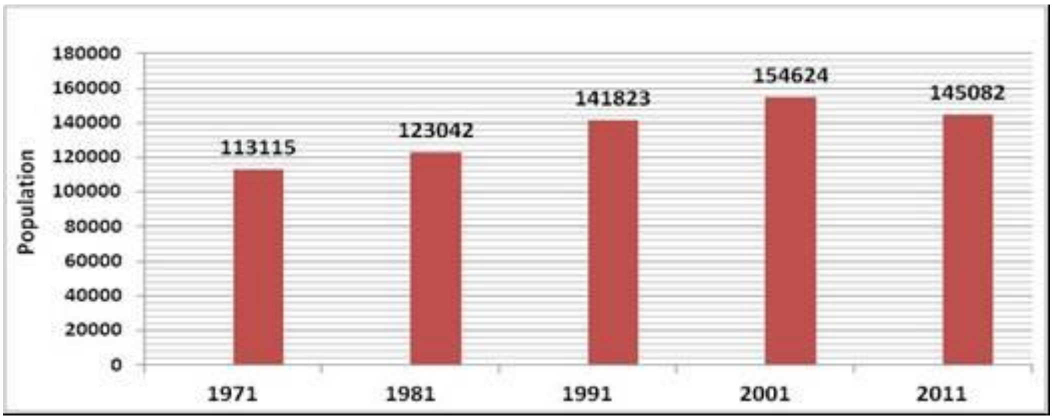

Figure 2. Demographic evolution of Korinthia Prefecture.

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Delineation of groundwater potential zones in hard rock aquifers using satellite images, in Sithonia Peninsula, N. Greece

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Introduction

Hard rock aquifers are the less studied and exploitable aquifers in Greece. The Sithonia Peninsula, located in Northern Greece, in which the water demands have risen the last decades because of the increase of touristic interest of the area. The research is part of PhD thesis and is based on the data that can obtained by satellite images like Landsat 8.

The results from the drilling shows that due to the intense tectonic stress of the area, the fracture zones in hard rocks, mainly of schists, phyllites, quartzites and sandstones, are located at depths that can reach up to 320 m below ground level, thus forming favourable conditions aquifers. The main tectonic lineaments that prevail in the area are NW-SE, NE-SW, E-W and N-S. Out of the four major sets of lineaments in the region, the NE-SW trending lineaments are the more productive.

The usage of lineaments and fault density map can be helpful to delineate groundwater potential zones in order to make new boreholes for water supply.

Materials and methods

Sithonia Peninsula mainly belongs to the Circum Rhodope Belt which composed by Mesozoic sedimentary and metavolcanic rocks. The rest and smallest part of the area belongs to the Serbomacedonian Massif and composed by amphibolites and gneisses (Vergely, 1984). The Sithonia Plutonic Complex is a NW-SE trending plutonic complex which occupies an area of 350 Km^2. Mostly composed of granitoids. The metamorphic rocks of Sithonia peninsula have been affected on multiple deformation facies during the Alpine orogeny. As result is the extend growth of cleavages, macro and micro folds. Despite that, during the middle – upper Miocene until nowadays, the neo-tectonic and seismic activity of the area contribute to the extend fracture of the rocks that act as a secondary porosity. Sithonia is described as a tectonic horst with NNW-SSE direction as part of a bigger transportation zone (Mercier, 1981). The hydrogeological behaviour of metamorphic and igneous rocks is related with the discontinuities which created by tectonic stress (Domenico and Schwartz, 1998).

Lineaments are linear features which act as evidence for a possible tectonic structure. As it mentioned before, the extend tectonic stress in hard rocks create a secondary porosity and a creation of a fractured aquifer. For the lineament’s delineation, Landsat 8 images were used and especially band 8.

Landsat-8 was launched on February 11, 2013, and is still active. It started as the Landsat Data Continuity Mission. Now, we know it simply as Landsat-8. Landsat-8 collects 550 scenes per day and until August 2020, it will reach a total of 1.5 million collected scenes. This workhorse satellite remains a staple of open source land information for the public.

Band 8 is a panchromatic band with 0.50 to 0.68 μm wavelength. The panchromatic band spans are a longer range of wavelengths and can generate 15m spatial resolution panchromatic images. By pansharpening imagery with the panchromatic band, you can sharpen your imagery producing a crisper product. For lineaments extractions was used the automated procedure using the LINE tool from PCI Geomatica. After the identification of the appropriate threshold value, lineaments where extracted. The lineaments were also cleaned visually by the overlaying road layer.

Results and concluding remarks

The lineaments layer which extracted, after the correction, was used to create a fault density map of the research area. The higher the density is the higher the fault stress and the discontinuity of the area. By the map can be determined some prospect areas for more hydrogeological research.

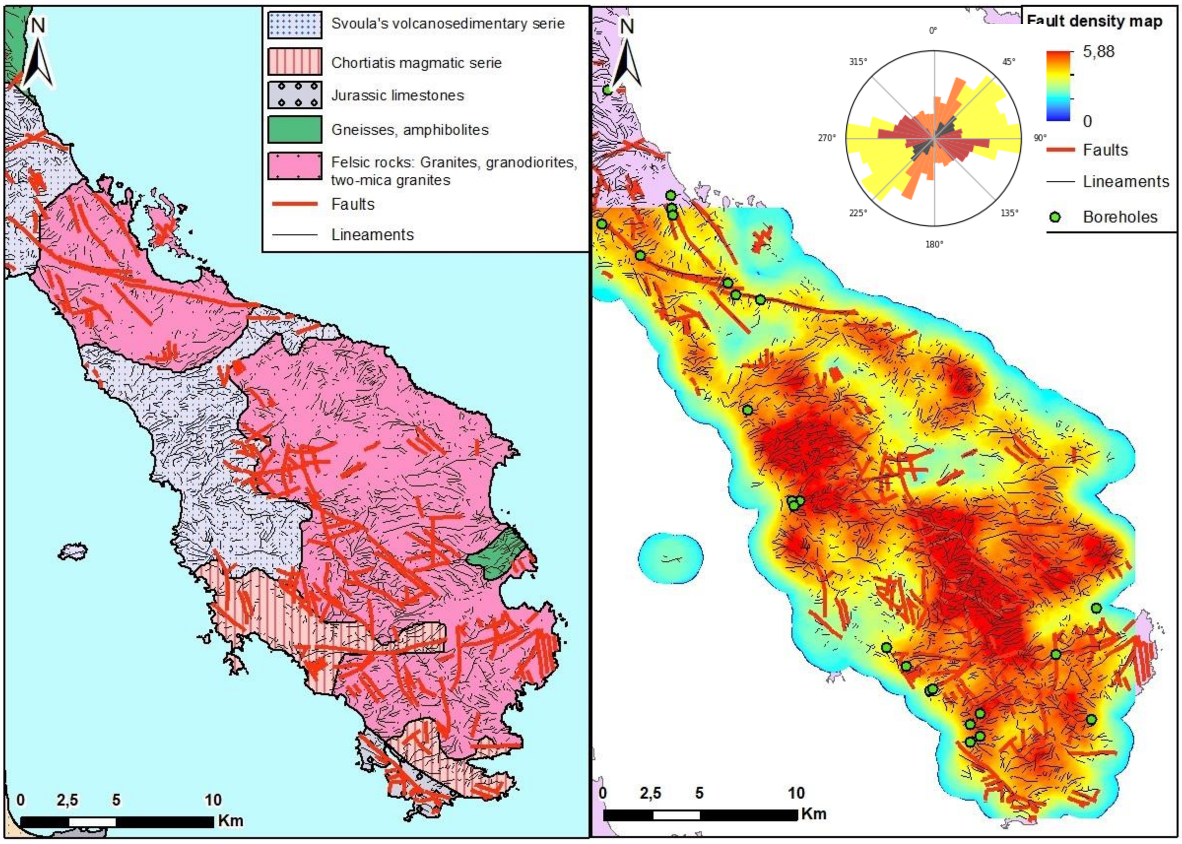

Figure 4. a) Geological map of Sithonia peninsula with the delineated lineaments and the main faults of the area b) Fault density map of the area with the delineated lineaments, the main faults and the existing boreholes of the area.

In figure 1b where the existing boreholes are depicted, we can see that most of them are in areas with high fault density and especially in north there are across a main NNW-SSE fault. We can conclude that tectonic is one of the main factors for the hydrogeological condition on hard rock aquifers.

Next step of our research will be a comparative evaluation between Landsat and DTMs lineament extraction, that will be created from other type of data like topography maps and an evaluation of the target areas with geophysical methods.

Acknowledgments: A part of this research was carried out in the framework of the PhD Thesis of C. Christidis, Laboratory of Engineering Geology and Hydrogeology, Dept. of Geology, Aristotle University of Thessaloniki, Greece (Supervisor K. Voudouris).

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SDG-6 and the relevance of the Water Resources Management Instruments

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Introduction

This study aims to demonstrate how important water resources management instruments are to achieve the Sustainable Development Goal - SDG No. 6 - Clean Water and Sanitation, and thus, to contribute to achieving Agenda 2030 in Brazil. It is worth noting that these instruments are addressed by Watersheds Management Committee in their Water Resources Management Plan.

In Brazil, we have the National Water Resources Policy, established by Law No. 9433 (also known as the Law of Waters), of January 8, 1997, which created the National Water Resources Management System, in addition to establishing the management instruments, as provided in its Article 5.

This abstract will also point out the water resources management instruments, in case of application, they constitute relevant tools to meet the SDG-6.

Materials and methods

Through documental and bibliographic research, in addition to experience in Water Basin Committees the present work aims to show how Brazil can effectively act in favor of the SDGs that make up the 2030 Agenda, prepared within the framework of the United Nations - UN. It's possible to know where in the water basins the management of water resources plan has been in fact applied.

Now entering the proposed theme, these are the Water Resources Management Instruments listed in article 5 of Law No. 9433/97:

> Art. 5 The instruments of the National Water Resources Policy are:
> I - the Water Resources Plans;
> II - the classification of water bodies into classes, according to the predominant uses of water;
> III - the granting of rights to use water resources;
> IV - charging for the use of water resources;
> V - compensation to municipalities; (vetoed)
> VI - the Water Resources Information System. (PLANALTO, 2020)

The Water Resources Management Plan, it has a regional character, and for this reason it is appropriate to the reality of each hydrographic region. Therefore, the Water Basin Committees is responsible for the management of the water resources of its respective basin, in a participatory way, establishing goals, guidelines, use of resources, etc. Thus, its vision was linked to that of a master plan, as mentioned below by ANA (2013).

> Also known as the water resources master plan, it is the programmatic document for the basin, containing guidelines for the use of water resources and related measures. In other words, it is the basin's water resources agenda. (ANA, 2013, p.15).

In summary, the hydrographic basins Plan is a document responsible for the diagnosis and prognosis of a basin that must contain studies, surveys, sector plans, programs, guidelines, goals and projects for the management of the territorial unit. It must also carry out a plan and execute it to solve problems and demands.

Item II of art. 5 of the aforementioned law focuses on framing the taxonomy of water bodies, which is the establishment of the goal or objective of water quality (class) to be, mandatorily, achieved or maintained in a segment of water body, according to the prevailing uses intended over time. Therefore, the framework is fully articulated with the Water Resources Management Plan, establishing the macro view of the basin and the goals to be met in medium and long term, which must be defined based on the Basin Plan. Your objective is to allow the occupation of hydrographic basins and the desired use of water, achieving an adequate level of waste control. It is an active planning process for the water use and zoning activities, as well as actions to control pollution.

Regarding the granting of the right to use water resources, the National Water Resources Policy (Federal Law 9,433/97), in its art. 1, item I, establishes that water is a public domain good (Brasil, 1997). This is the main legal instrument that supports the implementation of the granting of the right to use water resources (Ana, 2013). The National Water Agency defines that "granting is the administrative act through which the public authority (Union, state or Federal District), grants the grantee (applicant) the right to use water resources, for a determined period, under the terms and conditions expressed in the respective act". This is a central element in the control of water resources and the ordering of their uses.

Another management instrument is charging for the use of water resources. The legislation determines that all uses of water resources subject to the grant are also subject to a charge. And in Section IV of that law, in its Art. 19, there are the objectives of charging for the use of water resources.

Last but not least, art. 5 of Law No. 9433 also brings the Information System on Water Resources, a management instrument that consists of an organized system to collect information, as well as treatment, storage and retrieval, as well as aspects for its management.

Results and concluding remarks

Through this research, it was possible to clarify the relationship between water resources management instruments and SDG-6, which aims to "ensure the availability and sustainable management of clean water and sanitation for all." Therefore, the public and private sectors and civil society are important actors to use the tools mentioned above, the water resources management instruments for implementation of the 2030 Agenda, which is a global action plan that includes the 17 SDGs and 169 goals, elaborated in the UN sphere. And thus, Brazil regarding its water resources, it has instruments that allow it to if applicable, act more and more in favor of a sustainable environment.

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Groundwater Monitoring: The Importance of Long-term Data

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Abstract

Owing to its relatively stable yield of high-quality water, groundwater has emerged as an extremely important water resource for meeting domestic, industrial, agricultural and environmental demands. Although groundwater is often relatively well protected from pollution, poor management has resulted in negative impacts such as declining aquifer heads, quality deterioration, and irrational abstraction rates.

Uganda has approximately 40,000 deep boreholes, 30,000 protected springs and 16,000 shallow wells. A total of 73 of the 98 operational water supply systems are dependent on groundwater, accounting for around 75% of all towns and cities. In Kampala City, several industries are reliant on groundwater, including mineral water and chemical industries. The indiscriminate disposal of industrial waste to the ground, coupled with over abstraction by high yielding electric pumps necessitates a renewed focus on groundwater monitoring.

This study examined efforts by several actors undertaking groundwater monitoring, using data loggers as CTD divers, GRT101 remote monitoring devices, and smart hand-pump sensors. Major findings from the study reveal that monitoring data is generated across a range of stakeholders in NGO, private sector, government, with efforts largely uncoordinated. The data is rarely stored for future use as it is lost along the way.

The study recommends that the different stakeholders develop a coordinated and clear data collection, storage, and retrieval system and a systematic database and arrangement for data sharing via the internet be established. The research concludes that there is clearly an unmet need; hence a national effort to track groundwater monitoring data over the long-term is vital given its wide applicability to water resource issues commonly faced by hydrologists, engineers, regulators, and resource managers. It calls for an immediate establishment of a more rigorous and systematic nationwide approach to groundwater monitoring, clearly an elusive goal thus far. The time is right for progress towards this goal.

Assessment of Environmental Flow of Mahananda River in Darjeeling Himalayan Piedmont Region, West Bengal, India

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Introduction

e-Flow is such a concept which refers the minimum flow to maintain the riverine environment. Maintenance of natural patterns of longitudinal and lateral connectivity in river-floodplain systems determine the ability of many aquatic species to move between the river and flood plain or between the main river and its tributaries. Loss of such kind of connectivity can lead to local extinction of species (Arthington, 2003). Iyer (1998) stated that water itself is a part of nature and one cannot presume to allocate water to nature and the minimum flow or environmental flow in rivers is better than no flow condition. The stress is given on the terminology of 'natural flow' than the 'minimum flow'. e-Flows are needed for maintaining the river regime, making it possible for the river to purify itself, sustaining aquatic life and riparian vegetation, recharging ground water and supporting (Sharma, 2005). The emerging science of environmental flow aims to provide the balance between the human use and the conservation of natural water resources. Government of India constituted Water Quality Assessment Authority (WQAA) to look after the rivers to maintain 'minimum flows in rivers to conserve the ecosystem'. The e-Flow assessment should be river and site specific. No research has ever been done under the supervision of State Government of West Bengal as well as India regarding site-specific e-Flow assessment over any river under its jurisdiction. Academic institutions have not even been thought about the necessity of e-Flow assessment of streams. The objective of the present research is to assess the volume of e-Flow in riverine reaches (stretch-specific) of Mahananda river at Gulma under the geomorphic region of Sukna of Darjeeling district of West Bengal. Mahananda river is considered as the primary channel in Sukna geomorphic region. Wetted perimeter method is one of the popular methodologies which are used to determine the environmental flow at a particular reach of a river. Wetted perimeter means the perimeter of the cross-sectional area of bed and bank boundary of stream from wetted edge to wetted edge. Wetted perimeter is calculated on the basis of recorded width and depth of the recorded cross-sections across the studied channel. It is basically a cross-section-based study. Wetted perimeter of the cross-sectional site (CSS) is estimated after California Department of Fish and Wildlife Biologist (King, 2013). This particular methodology is very useful for those rivers, where gauge data is not available. But it demands tedious field work to record the CSS-based seasonal width and depth data at least for a single year. Width and depth of the studied CSS are recorded. Cross-sectional area, wetted perimeter, hydraulic radius has been estimated by using the empirical equations. Stream velocity is determined by using the Manning's equation. Manning roughness factor (n) has been decided on the basis of the observation during field survey. Stream discharge at a particular site is measured by multiplying the cross-sectional area and stream-velocity at that particular GPS location. Graph has been prepared, where the stream discharge and wetted perimeter are plotted in the abscissa and ordinate respectively. Magnitude of wetted perimeter is recorded against several magnitude of stream discharge to get the wetted perimeter-discharge curve for a particular geo-referenced point at a particular CSS. Maximum and minimum discharge has to be incorporated. This kind of curve may able to mark the minimum possible discharge, necessary for the subsistence of aquatic habitat at studied site of Mahananda channel. Effort is given to mark the first, second breakpoints of maximum curvature of that wetted perimeter-discharge curve. The first breakpoint is considered as the threshold discharge (minimum discharge), under which the food production procedure declines rapidly at the studied location of the Mahananda river. The second breakpoint is considered as incipient asymptote (Kim and Choi, 2019; Tharne, 2003) which is assumed to favour the optimum food production at the said location of the

Mahananda riverine environment. The change in slope of the wetted perimeter-discharge curve represents the response of wetted perimeter to a single unit change of stream discharge. The threshold points are identified by the scientific visual observation (Gippel and Stewardson, 1998). A cross-section site (CSS) has been chosen (637714 m E, 2968720 m N), which is located 4 km upstream distance along Mahananda from the Gulma railway bridge over Mahananda. After getting the estimated stream discharges and their corresponding wetted perimeters at Gulma across Mahananda river, a wetted perimeter-discharge graph has been generated to determine the e-Flow of Mahananda river at this particular site.

Results and Concluding remarks

The recorded width of the Mahananda channel is about 105 m at its depth of 1 m with estimated wetted perimeter of 109.4 m. Wetted perimeter gradually increases with the increase of stream discharge. But the rate of change in wetted perimeter is not similar to increase of per unit discharge. The current methodology to determine the e-Flow wants to get the breakpoint which refers the significant change in relation between the increase of discharge and increase of wetted perimeter. The wetted perimeter becomes almost double (238.9 m) at the thalweg depth of 2 m with the estimated discharge of 26.2 m^3s^{-1}. A sharp and significant break of slope has been observed at this threshold of discharge. The curve becomes gentle rate of change in wetted perimeter (WP) is lesser after crossing this particular point. It is thus considered as the minimum discharge under which the food production procedure declines rapidly. The second breakpoint has been detected at the discharge of 450.7 m^3s^{-1} with the estimated WP of 282.3 m which may refer as incipient asymptote. Optimum food production in riverine environment may be assured under this estimated discharge range of 26 to 450 m^3s^{-1}. The maximum flood-prone discharge has been estimated as 1886 m^3s^{-1} in monsoon days at this site at Mahananda river. But, almost the entire river bed of Mahananda becomes water-less in the winter months and no base-flow exists now-a-days. It may necessary to hold a minimum flow (>25 m^3s^{-1}) in Mahananda bed at this Gulma site to fulfil the ecological need of the native riverine ecosystem. The present research on the assessment of environmental flow of Mahananda river at Gulma (Sukna, Darjeeling) is such a virgin attempt of contemporary water resource-based research, which has not been executed in past for the rivers of West Bengal. The methodology, which has been introduced in this present paper is very effective for execution for such ungauged reaches of natural stream. It successfully and scientifically estimates the minimum requirement of flow, which is necessary on the view of environmental approach of resource utilisation. The outcome of this present paper may consider as a model study regarding the useful assessment technique of environmental flow of rivers by executing field-works especially for the ungauged sites of any river. This finding of this paper is not only a case-study based conclusion, but the beginning of journey regarding the research of applied fluvial geomorphology especially on the West Bengal rivers and the rivers of India.

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THEME 5

WATER-RELATED ISSUES OF INCLUSIVITY
(Culture, Gender Indigenous Peoples)

Reassessing the social equity objective of currently popular water tariffs

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Introduction

Water inequity and poverty are challenges that are faced by not only developing countries but also developed ones. Following the full-cost recovery principle in Europe, water utilities have to rely solely on water tariffs to meet their operational costs, maintenance expenses, and investment in new protective solutions against climate change. Additionally, the ongoing reduction in water consumption added more pressure for water utilities to maintain their revenue. Hence, the current increasing trend in water tariffs in many regions in Europe is expected to continue, which might deepen water inequality and intensify water poverty. Currently, increasing block tariff is the most popular tariff scheme in the world. However, researchers and legislators have expressed mixed opinions on its social aspect (Meran and Von Hirschhausen, 2017; Whittington and Nauges, 2020). This study is the first study (to the authors' knowledge) that aims to evaluate water (in)equality of different tariff schemes using empirical data instead of simulation.

Materials and methods

A survey data of more than 1700 households in Wallonia (Belgium) containing household characteristics and total water consumption in 2014 was used to evaluate the social equity of the current tariff as well as several hypothesized ones. Social equity was assessed based on several indexes, including average water price, cross-subsidy, and the ratio of water bill to income. Comparisons were carried out among different income quintile groups. Hypothesized tariffs considered in this study are uniform price (UP), increasing block tariff at the connection level (IBT-con), and increasing block tariff with adjustment for household size (IBT-cap) in combination with different amounts of fixed subscription fees (FSF).

Results and concluding remarks

The current tariff in Wallonia (Belgium) contains a fixed subscription fee (≈€100/household/year) and a volumetric part following the increasing block tariff at the connection level. Currently, poor households are paying more money per m^3 of water from the tap (Fig1-Left). Moreover, the less income a household earns, the more subsidy it has to pay for richer ones, and vice versa (Fig1-Right).

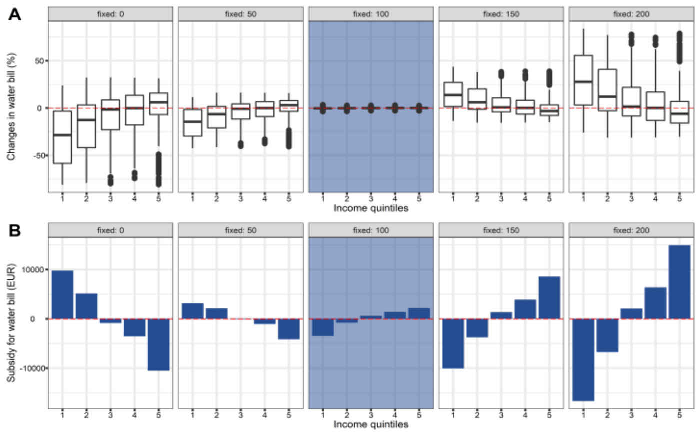

Figure 1. Inequality in water bills caused by the current pricing scheme in Wallonia.

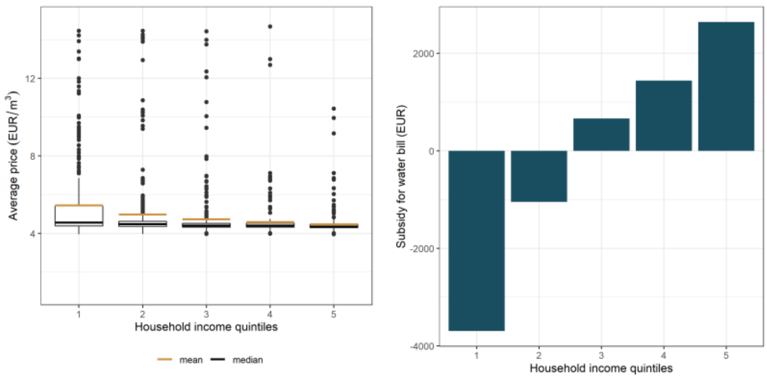

Figure 2. Higher FSF puts more burden on vulnerable households.
The current FSF scheme (shaded) is €100/household/year.

Changes in FSF drastically affect the bill for low-income families, but not so much for those at the top (Fig2-A). Additionally, increasing the FSF will worsen the cross-subsidy situation while reducing it can reverse the trend (Fig2-B).

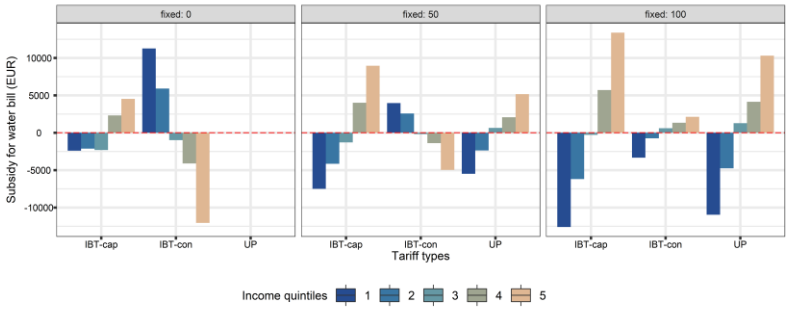

Figure 3. Comparison among different types of volumetric tariff at different FSF scenarios.

Whether a price scheme regressive or progressive is decided not only by the tariff types but also by the share of FSF in the water bill. In all scenarios, the IBT-con appears to be the least regressive (or most progressive) scheme while IBT-cap shows the most regression (Fig3). The only way to reach a progressive scheme is by employing IBT-con with an FSF lower than the current value.

Noteworthily, the situation where the IBT-cap scheme becomes regressive is particular for developed countries like Belgium. In other contexts, with a negative correlation between income and household size (*e.g.,* shared meters by multiple households in poor areas or by multigenerational families), the picture may be very different.

On the other hand, even with IBT-con and no FSF, nearly 14% of families in the first income quintile still used more than 3% of their income for water. Hence, besides tariff tools, other means of social support are still necessary to ensure water affordability for everyone.

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Access to quality drinking water and its health implication among indigenous people

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Introduction and background studies

Globally, the statistics of indigenous people where most of them reside in developing countries was estimated to constitute about 370 million individuals when compared to the non-indigenous people (Jiménez et al. 2017). In other words, they constitute about 5% of the world population, while the non-indigenes constitute about 15%. As a result of this statistics, the indigenous people were observed to be disturbed with situations, such as higher disease burden carriers, higher mortality, poverty, and shorter life expectancy when compared with non-indigenous people (Jiménez et al., 2017). This implies that indigenous people have none and inadequate access to optimal health, constant income, and quality drinking water. Lack of quality drinking water is related to inaccessibility to obtaining accurate data on water situation and water sanitation (Edokpayi et al., 2018; Lam et al., 2017).

Report by the South African Council for Scientific and Industrial Research showed that almost 2.11 million people in South Africa lack access to any safe water infrastructure. Access to clean and safe drinking water is required as a constitutional right for all South Africans in the country's constitution, however sustainable access to a potable water supply by millions of South Africans is lacking.

This warrants the research questions, "how can indigenous people have access to quality drinking water, and what are the roles of indigenous youths in ensuring quality drinking water is available for themselves and other people worldwide"? In search of the answers to the research questions, this study was aimed at exploring quality drinking water and its health implication among the indigenous people.

Materials and methods

This study adopted the scoping qualitative approach where a four-year duration (2016-2020) literature search was used to proffer relevant responses to research questions (Bradford et al 2016). The indigenous people explained that their water goes through a filtering system from the highly treated with strong chemicals community's well water before its domestic distributions with the likelihood of the harmful chemicals to their health.

According to Edokpayi et al, groundwater contamination with high arsenic concentrations was reported in Bangladesh, and high fluoride concentrations was reported in the drinking water from various South Africa provinces.

Results, concluding remarks, and recommendation

According to Bradford et al., involving indigenous peoples in water quality planning has a significant impact and various purposes at different phases (Marshall et al 2020; Bradford et al 2016). As a result, they contribute to decision-making via providing advice on the basis of their contemporary knowledge, historical and traditional information to scientific researchers and raising public awareness.

In conclusion, water education involving holistic views of environment, human health, society need and water should bring enlightenment and empowerment to the indigenous youths on approaches to safe and quality drinking water for them and other age ranks.

Recommendation entails the working cooperation and strategies of the environmental values framework and national water quality management to integrate scientific and Indigenous knowledge in water planning and management.

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Surgical face masks as an emergent pollutant in the environment during COVID – 19 Pandemic: A review

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Introduction

Due to the global COVID 19 pandemic, the use of surgical face masks has increased dramatically in the last two years (Facciolà et al., 2021). Surgical face masks are the most widely used and effective personal protective equipment used against COVID-19 pandemic. Face mask consumption has been estimated approximately 129 billion per month for 7.8 billion people around the world (Akarsu et al., 2021). Discarded face masks have been discovered in both terrestrial and aquatic environment, due to the improper management and uncivil behaviour of the population. They are made of plastic polymer fibbers that contain a high concentration of inorganic and organic compounds that can be released into aquatic environments during the degradation process. This source of micro plastics as well as inorganic and organic substances have been affecting the aquatic ecosystems.

Therefore, this paper thoroughly examines published literature on (a) the effects of improper face mask disposal and their effects on the aquatic environment, and (b) development of eco-friendly face mask disposable methods.

Face mask usage during COVID-19 and the effect to the aquatic environment

The demand for facemasks has been increased as a result of the COVID-19 pandemic, so did the amount of face masks produce. According to Fadare and Okoffo (2021) China had been increased the production of surgical face masks to 14.8 million by February 2020. Furthermore, the domestic demand for face masks in the United Kingdom was approximately 24.37 billion per year (Mittal et al., 2022). Because of the increased production and consumption of face masks around the world, the number of improper disposable face masks has also been increased. These microplastic contaminants, which are added to the water, frequently cause adverse effects on aquatic organisms such as eating plastic, entanglement, and strangulation (Bui et al., 2020) which is vital in the aquatic ecosystem. Therefore, negatively affects the biodiversity in aquatic ecosystems.

Eco-friendly disposable methods of facemasks and applications

Face masks that are improperly disposed of have a wide range of effects on both terrestrial and aquatic organisms. Among the few disposal methods used to sterilize face masks, the approaches that use hydrogen peroxide vapor, UV radiation, moist heat, dry heat, and ozone gas have been shown in the following Table 1 as the most promising disposal methods (Carlos Rubio-Romero et al., 2020).

Table 1 Research related to disposal mechanisms of face masks in relation to covid-19

Title	Findings	Reference
Surgical face masks as a potential source for micro plastic pollution in the COVID-19 scenario	*Microplastics are a major threat to water sources and aquatic life, and are designed to identify contaminated plastics (nano, micro) analysis methods that can cause contamination in the three layers of face masks manufactured under various brands, to minimize environmental problems, and to prevent environmental pollution from plastics. Regulations have been implemented.*	*(Aragaw, 2020).*

Face mask waste generation and management during the covid 19 pandemic	*Biodegradable or Bio-based face masks were used as main substitute to reduce PPE affects to the environment in Peru. By using mechanical or thermal methods, Polypropylene which is contain in facemasks have been recycled. Further, incorporating reusable face masks were significantly reduced the waste generation in Peru during COVID 19 pandemic.*	*(Torresa, Torreb, 2021)*
Potential biodegradable face mask to counter environmental impact of Covid-19	*The multiple Nano-fiber membranes/layers in modified face mask, which is made by natural fibers like cotton, flax, hemp, prevent the penetration of viruses as well as heal the skin, and provide skin care. Application of various plant extracts such as Turmeric, Neem, Basil, and Aloe vera have been enhanced the anti-microbial activity of the face masks. Manufacturing of eco-friendly face masks were done by using electrospinning technology which is helping to produce tiny pores in nano scale to arrest the particular viruses.*	*(Pandit, P., 2021)*
ECO Friendly Mask Guide for Corona Prevention	*This research studies the prognosis and evolution of corona virus infection through eco-friendly face masks using an automated communication device to detect corona-infected objects and surfaces. It can be powered by USB or battery or Bluetooth.*	*(Tumuluru et al., 2020)*

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Water quality in urban rivers: River Fucha Case Bogota, Colombia

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Introduction

The capital of Colombia is Bogota City; it has four rivers that across the city from east to west. Namely Tunjuelito, Fucha, Salitre and Torca. All of them discharge their waters into the Bogota River, which ends in the Magdalena River. Finally, they flow into the Pacific Ocean. Complying with the international commitment, such as Millennium Development Goals (MDG) Goal 6 which Ensure access to water and sanitation for all, and Organisation for Economic Co-operation and Development (OECD) provision on water governance. Colombia created a National Policy for the Comprehensive Management of Water Resources. It dues in the year 2022 period. This policy regulates Planning and Management Plans for Hydrographic Basins (POMCAS) and water quality objectives are proposed - Cerón, Gamarra, Villamizar, Restrepo & Arenas, 2019, Romanelli & Massone, 2016, Trujillo, Cortés Vinasco, Ortega & Cruz, 2020-.

The Fucha River grows up in an exclusive ecosystem: Páramo de Cruz Verde into Andes Mountain range. This important river is located just five kilometres from the edge of the city. Due to city administration, it is divided into four sections, to establish its quality and review fulfilment quality objectives. My research project established General Quality Index for Surface Waters (ICACOSU) for sections 1, 2 and 3 and soon it will be established section 4. The fulfilment of the urban water quality objectives is the input for the achievement of the real decontamination of the Bogota River (Peña, Melgarejo & Prats, 2016). Therefore, knowing the current state of urban rivers is the added value offered by this research project, which allows stakeholders to make significant decisions.

Materials and methods

The research project determined ICACOSU with physical chemical and biological parameters: dissolved oxygen (DO), total suspended solids (TSS), chemical oxygen demand (COD), Electrical conductivity (EC), pH, total coliforms (TC) and biological oxygen demand (BOD_5). Compliance with regulatory quality objectives was analysed. The bibliographic sources of environmental authorities were reviewed, it evidences the use of the land and the territorial entities involved. Bogota has been divided into 16 localities, each one establishes the use of the land and the activities that you can develop. The Fucha river cross five localities: San Cristobal, Antonio Nariño, Puente Aranda, Fontibón and Kennedy.

Reconnaissance tours of the Fucha River were carried out to show and locate the main discharge points. 16 monitoring points were established according to the access to the river, morphology the river and the found discharge points. Water samples were taken at 16 points during the dry season of April 2018 and September 2020. On site the research project has measured parameters DO, EC and pH. In the laboratory the research project measured parameters TSS, COD, TC and BOD5. Samples were analysed according to the guidelines of the standard methods and calibrated equipment.

Last but not least, the ICACOSU was calculated with the following equations.

$$\text{ICACOSU} = ICACOSU_{FA} * 0.8 + \text{ILCAG} * 0.2 \quad (1)$$

$$\text{ICACOSUFA} = (Si_{DO}*0.2)+(Si_{TC}*0.18)+(Si_{TSS}*0.15)+(Si_{BOD}*0.15)+(Si_{QOD}*0.12)+(Si_{EC}*0.12)+(Si_{pH}*0.08) \quad (2)$$

The result is qualitative in ranges, between 0.00 to 0.25 is Very Deficient, between 0.26 to 0.50 is Bad, between 0.51 to 0.70 is Medium, between 0.71 to 0.90 is Good and between 0,91 to 1 is Excellent.

Results and concluding remarks

ICACOSU along the sections has the following trend: section 1 started with a Good range ending with Medium range (Mora & García, 2020), section 2 started with a Medium range ending in Bad range (Mora & García, 2020), section 3 started with a Bad range ending in Very Deficient range (Reyes & Hernández, 2021).

Fucha river in section 1 has greatest recovery capacity, because the river is not channeled there, and organizations such as the Vida Corporation has worked together with the Local Mayor's Office of San Cristobal to preserve and take care of the Fucha River's watershed.

Fucha river in section 2 enters to location Antonio Nariño, it is channeled and begins to across the commercial area of the Restrepo neighborhood. The main problem here is the citizen who lives on the street (Leal, 2019). For these reason Fucha River's watershed is full of waste. Sites like bays, bases of the pedestrian and vehicular bridges are perfect spaces for the accumulation of domestic waste (Leal, 2019). The habitability of the citizen living on the street along the river increases the amount of TC (0.00 MPN/100 ml point #1 to $9.59X10^7$ MPN/100 ml point #16)

Fucha river in section 3 meets the industrial location Puente Aranda and Fontibón. It receives industrial discharges with a high content of organic matter (Reyes & Hernández, 2021) revealing loses concentration of DO from 9.75 mg/l point #1 to 0.17 mg/l point #16. The river lost self-purification capacity in only 6 kilometres.

Fucha river increases concentration of EC (13.75 µS/cm point #1 to 547.0 µS/cm point #16) and TSS (20.17 mg/l point #1 to 69.0 mg/l point #16) by the discharge of water from the canals: San Blas, Albina, Río Seco y and Comuneros.

The objectives of quality are fulfilled in half of the points. For this reason, attainment objectives do not allow to achieve a water of quality, it is necessary to have a baseline and propose real objectives.

Urban water has need agenda from good water governance and formulate policies and strategies with real implementation. Stakeholders’ engagement need data and information to improve policy coherence.

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Analysis of water quality and its consequences on Stakeholders by using Rapid appraisal- A study on Odambogaiyar river, Thiruvarur District, TamilNadu, India

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Introduction

Water is important natural resource and play vital role in everybody's day to day life. In many places, water is worshiped as a god. It is the duty of every citizen to protect such natural resource. Like, Rivers are naturally flowing water courses, used for several purposes and contribute for groundwater recharge. As intermittent rivers flow on a seasonal basis, fluctuations in groundwater level are also frequently witnessed. The stakeholders who have direct stake in the river flow for irrigation purposes, compelled to go for the only alternative source called groundwater. The pressure exerted on the groundwater for drinking, domestic and irrigation activities leads to a great demand on groundwater. This result in the over exploitation of groundwater, which eventually would affect its quantity and quality. The pivot point of the study explains the linkages between river flow, groundwater, irrigation and the stakeholders.

In this study emerged over the general concern on the changing water quality and quantity of the river and on the impact of the water on stakeholders. To address the above, the following objectives are framed to capture the impact of changes in river on stakeholders that is to assess the possibilities of the influence of river source on water usage, the present level of contamination through investigating surface and ground water quality with standard sets and the impacts of the water quality and quantity on the local stakeholders. The area selected for the study is Odambogaiyar river in Thiruvarur district. The selected study area is known as the Rice Bowl of the State of Tamil Nadu in India. It is located in the Cauvery Delta. Agriculture is the main source of livelihood for the people living here. Currently their primary livelihood has become a secondary livelihood due to various environmental and economic impacts.

Groundwater qualities in Thiruvarur district are normally alkaline in nature in some places and it mostly suitable for irrigation purposes (Ramkumar *et al.*2013). Water resources are under severe threat not only because of the ever-increasing demand and competing demand (from various sectors), but also because of the diminishing quality caused by discharge of untreated domestic sewage and industrial effluent (Janakarajan *et al.* 2006).

Materials and methods

To accomplish the research objectives, this study has been divided into 3 parts to find the impact on stakeholders, because of availability and quality status of water flows in the river. Firstly, Surface and ground water were investigated by using various laboratorial methods. Based on the quality status, impact of stakeholders had been analysed by using PRA tool like semi structured interview, Key informant interview, Questionnaire, Focus group discussion (FGD). Finally, sources of water, cropping pattern and secondary data of groundwater resource were analysed to found the Ground water depletion and dependability.

Qualitative study was conducted based on the quality status of water resources, pilot survey, visual observation, etc targeted to found the impact of stakeholders. Secondary data which has been used for analysis were mostly took from government websites or government report. The whole study is interlinked with several factors such as Water quality status, Sources of water, Cropping pattern, Usage of resources, Groundwater level depletion. Interlinked factors given an output as impact on status.

Results and concluding remarks

The analysis of the river data, rainfall data, groundwater data, questionnaire were done based on the methodology. The results obtained from the analysis and field observations were used to find impact of stakeholders in Thiruvarur district.

Water quality analysis: Through water quality analysis, the study found that the surface water which was collected from Thiruvarur (SW4) is more polluted than all collected water samples and it indicated the presence of ammonia, which confirms sewage waste disposal in rivers. All samples are alkaline in nature because pH value of both the surface water and groundwater samples exceeds the value 7. Alkaline water shows disinfection in water. High alkalinity in water indicates the sea water intrusion and over extraction of ground water. Hardness in water samples increased from upstream to downstream. Total Dissolved Solids (TDS) in water samples are exceeding the acceptable limits. Especially TDS in groundwater higher than the TDS in surface water which indicates the presence of organic and inorganic substances more in groundwater. Pollution in Odambogaiyar river is different in different reaches of the river stretch. Upper reach of the river is not that much polluted than the middle reach of the river. Sewage pollution is confirmed in middle reach by the indication of ammonia in water. From the analyses physico chemical parameters indicate that the water is n't suitable for drinking purposes but it is suitable for irrigation. Irrigation suitability of water wasn't able to be found out because of insufficient data of sodium potassium parameters in water. Biological parameters (faecal coliform) were analysed in groundwater. All groundwater has the presence of faecal coliform and results that groundwater is polluted. So, groundwater is not suitable for drinking purposes.

Groundwater access: Due to inadequate water sources from river and rainfall, people are induced to use groundwater. To utilize ground water stakeholders need to put a borehole in his place. But the cost of drilling a deep well is unaffordable for small farmers. Through FGD it was found that some small farmers were getting water for a certain amount from the farmers next to them. Thus farmers are experiencing inequalities in access to water sources.

Influence of source of water: Trend analysis of average discharge and flow period resulted in a downward trend. Over a decade, discharges and flow periods are reduced that cause direct impact on stakeholders and may create a chance to looting of sands, encroachments. Rainfall trend analysis has been done for 30 years data (1989 to 2018). The analysis was done for four different years. From 1989 to 1998 rainfall analysis resulted in no trend to all years except the march month. From 1999 to 2008 rainfall analysis resulted in a rapid downward trend and from 2009 to 2018 rainfall analysis resulted in a gradual upward trend. Over all 30 years (1989 to 2018) trend analysis shows the downward trend. Both the river discharge, flow period and rainfall resulted in a downward trend, which proved that diminishing the availability of water resources.

Groundwater is the precious resource which is degraded day by day because of lack of awareness of people by digging bore well. In pre-monsoon the depth of water level is in decreasing trend and dry during hot season (may, June, July). Subsequently during the post monsoon period, water level increased. In Thiruvarur district groundwater level goes down in the north, west and central part of the district, it all because of infrastructure development in that area. For controlling groundwater extraction, there is no act on groundwater regarding extraction. According to the national water mission, the number of abstraction structures increased. In 2011, the number of abstraction structures was 171071 but in 2013 the number of abstraction structures was 170983. In Thiruvarur district there are 27 assessment units for groundwater resources, from that 10 units were under safe balance 17 were in 9 overexploited, 2 semi-critical, 2 critical and 4 saline in stage.

Impact of changes in and around the river on stakeholders: Stakeholders of Odambogaiyar river are affected due to various issues and impacts. Figure 1 shows the impact of stakeholders. Here the impact of stakeholders is classified into direct and indirect impacts. Direct impacts are caused by the issues of proposed actions. Indirect impacts are caused by both the issues and actions.

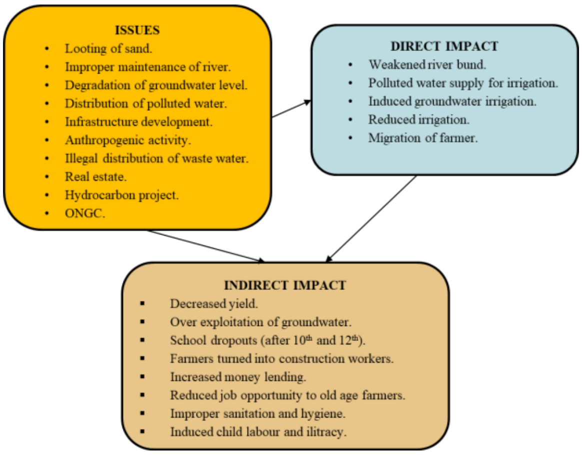

Figure 1. Impact of changes in and around the river on stakeholders

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