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A comprehensive review and analysis of water resource management using WEAP and its integrated models

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ABSTRACT

Global water scarcity is becoming a major issue for billions of people. WHO and UNICEF estimate that billions of people are not available to clean drinking water and many more experience pollution and scarcity of water according to the report of World Health Organization and UNICEF in 2017. Policymakers and stakeholders have significant challenges in allocating water resources to optimize water use for every user. One of the concerning issues facing the modern world is water scarcity, thus many experts in the field are interested in water allocation and its thoughtful usage. With careful planning and design, this issue can be effectively resolved. Sustainable development requires a multidisciplinary approach to water resource planning. Water-based irrigation is one of the most essential inputs for agricultural production worldwide and a way to achieve the highest level of sustainability in production systems. Since water is abundant on Earth, perhaps one refers to Earth as the "blue planet." Regretfully, more than 97.5 percent of the water readily available to us is saline water, which must be desalinated before it can be used. The remaining 2.5 percent of freshwater is available to us. Surface water accounts for around 1.2% of the total freshwater supply and meets the majority of human demands. Twenty-nine percent of freshwater is located in lakes, and the remaining portion is frozen in ice. Surface freshwater is composed of 0.49% rivers. If water supplies were dispersed equally over the planet, the remaining proportion of freshwater would be more than sufficient to practically meet the demands of every individual on Earth. Freshwater availability becomes crucial if any plans or development projects are to be carried out for the protection of the environment, health enhancement, hygiene, and sanitation, establishing housing projects, or changing the use of land. The absence of Freshwater water can impede the growth of industrialization, food production, and society, and ultimately cause harm to natural resource systems. The current work offers a thorough analysis of the applications of the WEAP Version 21 is used as a decision-making tool in water resource planning and distribution issues across a range of domains, such as groundwater modeling, climate change simulations, and water quality analysis. This paper reviews various WEAP models and presents an overview of their results. WEAP offers a broad range of applications, including groundwater evaluation, irrigation, and water quality. There have been many previous research investigations that have used WEAP modeling to maximize the water resources during water administration in India during the past 20 years, taking into account a variety of factors and distinct water resources across the nation. To determine the fields of focus, study limits, and outcomes of the fourteen prior investigations, a review of those studies was conducted to determine the reliability of the WEAP modeling for optimizing the management of sources of water. The Model of WEAP was shown to be dependable for evaluating, organizing, and optimizing the management of water resources.

Keywords: Blue planet; Surface freshwater; WEAP Model; Climate Change; Population Growth, Water quality.

INTRODUCTION

The most crucial element for life on earth is water. Water is necessary for living things, agriculture, and even industry consumes significant amounts of water for various industrial processes. With population growth, the demand for water increases directly and indirectly. Water consumption varies widely by location but it is increasing worldwide as the global population expands. Conflict emerges when the local demand is not met by supply. Water resource management is a shared concern among stakeholders. The majority of rivers worldwide have been dammed to provide water storage crop production, potable water supply, and hydropower generation. In the arid and semi-arid regions around the globe with erratic rainfall, reservoirs are essential storage facilities. These regions are known for their extreme droughts and floods, which make livelihoods unstable. Climatic factors like drought and global warming, water management practices, and overexploitation are putting pressure on water supplies. The problem of climate change is troubling and important to the study of water supplies. It may be necessary to modify the planning approach and water allocation in light of the effects of climate change on water resource systems. The main factor causing climate variability and global warming is CO_2 emissions. In less unpredictable space and time, this is hard to forecast. Comprehensive water resources management is used to address the ensuing uncertainties by addressing water surpluses, shortages, and weather extremes. Rising sea levels are expected to be a serious issue in coastal areas. Many international agencies, including WHO and the

World Bank, have highlighted the global water deficit. Around 3.9 billion people are predicted to reside in regions without access to water by 2050, increasing their vulnerability and expenses. Third-world nations face severe water scarcity, limited food availability, and many health issues. Ironically, these countries are expected to be the only ones seeing projected population growth. There is a significant correlation between the rate of water use, urbanization, and increasing standards of living; these factors are increasing the demand for water resources that are already accessible (Bao & He, 2015; Saraswat et al., 2016). Apart from the above-mentioned causes, climate variability also has a considerable influence on the hydrologic system. (Hong et al., 2016; Oreskes, 2004). The Climate of the earth is shifting, and its effects are unavoidable under the most optimistic situations regarding emissions and climate sensitivity (Sakashita et al., 2017). In emerging nations like India, where climate variability, population growth, and fast population expansion are aggravating water scarcity and placing strain on finite water supplies, there is a serious problem with inadequate water supply (Banerjee & Gulati, 2016). The study conducted by Ahmadi et al. aimed to access the water supply and demand in megacities that are quickly increasing. The study employed a modeling methodology to examine population growth, water accessibility, and water stress indicators to recognize potential hazards and difficulties linked to water shortage in local environments (Ahmadi et al., 2020). The relationship between climate and water resources can be studied using hydrological models. Numerous academics worldwide have employed diverse hydrological models to study water. The WEAP Model findings indicated that by 2030, there will be a 26.7% and 8.3% increase in the concentrations of BOD and E coli, respectively, as a result of both population expansion and climatic change (higher temperatures and precipitation). On the other hand, the water quality of the stream is anticipated to greatly improve by 2030 under the scenario with actions implemented, which anticipates that "all wastewater generated locally will be collected and treated in WWTP with a capacity of 886 million liters per day (MLD)." In particular, compared to the BAU scenario, the model findings showed much lower amounts of BOD and E. coli, by 74.2% and 98.4%, respectively, in contrast with class B (aquatic surface water quality desired by the national government), however, even in the scenario with the measures in place, the quality of water is still a concern, particularly in the approaching area (Kumar, 2018). To address water scarcity, it's crucial to plan and allocate water resources effectively. Different hydrological models that correlate various characteristics and enable the study of the connection between climate and water resources have been developed for this purpose. After integrating these hydrological models with socioeconomic aspects, valuable outcomes are produced (Nivesh & Kumar, 2018; Salman et al., 2021).

The agro-hydrological land surface process model (PROMET) (Degife et al., n.d.), artificial intelligence-based models, the spatial agro hydro salinity model (SAHYSMOD) (Boufala et al., 2022), the modular simulator (ModSim) and the soil and water assessment tool (SWAT) watershed model (Boufala et al., 2022; Goyal et al., 2018). Another study was carried out on the Dhasan River Basin to examine trends in water use and projected demand between 2015 to 2050. The WEAP Model was used to simulate five different scenarios (l, ll, lll, lV, V) as well as external driving factors. The results indicated that, in the first scenario, population growth was the main factor influencing domestic water demand in the Dhasan River BasinThus indicates that adequate flexibility in Dhasan River must be built into the water management system to meet unforeseen changes in service populations (Nivesh et al., 2023). The WEAP Model developed by the Stockholm Environmental Institute is a demand, preference, and priority-driven model for water that offers a modeling framework for evaluating project cost-benefit analyses, consumer demand, flow of river streams, water storage execution, water preservation measures (Yates et al., 2005). The Model consists of two separate systems, as described by Yates a modeling of the evapotranspiration, infiltration process, and runoff that occurs naturally in water, which allows for the evaluation of water attainability inside a watershed; and a modeling of human actions placed on top of the natural system to affect the allocation of water resources, such as consumption and nonconsumption of water, which allows for the evaluation of the effects of water usage by people. The system includes sources of supply (e.g. streams, river water, runoff, Base water, Infiltrated water, inter-basin transfer, storage reservoirs), withdrawal, transmission, and wastewater treatment plants, as well as ecosystem requirements and water demands (typically hydropower, irrigation, and domestic supply). The model effectively accounts for abstractions and inflows by performing a mass balance of flow sequentially down a river system. The model is often implemented by setting up the system to mimic a recent ―baseline‖ year, for which the availability and demands of water can be reliably ascertained. After that, the model is used to simulate different situations, or potential futures based on "what if" scenarios, to evaluate the effects of various development and management strategies (A_Review_on_Weap_2017). The author addressed a research gap in water availability and demand dynamics in the Chennai Basin. The increase in unmet demand for both normal and deficient rainfall scenarios is the main focus of the study. They determined that groundwater recharge is a crucial component in resolving Chennai's urgent water scarcity problem by carefully applying the WEAP model and carefully examining a variety of situations. The study concentrated on increasing groundwater recharge as an effective countermeasure to improve the availability of water. by supporting techniques like improved land parameters. These could include decreases in the need for water as a result of demand-side management, growth rate assumptions, including any technological innovations, and altering the water supply. management, rainwater gathering, and artificial recharge. Planning for water supplies thus requires an interdisciplinary approach that takes into account all of the complexities of the system (Razisadath et al., 2023). Bundelkhand region's Ur watershed has also used the WEAP approach. Nevertheless, the scope of these investigations was micro-watershed (less than 500 hectares). Therefore, the creation of regulations for the distribution of water that incorporate an integrated approach may be the only successful management tactic. Often, supply-oriented simulation models are insufficient. Integrated Water Resources Management is a systematic approach to sustainable water resource development, distribution, and observation. (Agarwal et al., 2019).

AN OVERVIEW OF MODEL DESIGN AND BACKGROUND

The Water Evaluation and Planning (WEAP) Model was created by the Stockholm Environmental Institute in 1988 to assess the sustainability of the water supply and demand patterns that are in place today and investigate future possibilities. The Aral Sea was the subject of the first WEAP model research in 1992 (Raskina et al., 1992). Since it was first used, the WEAP model has undergone constant evolution. Some of the limitations of the earlier versions of the WEAP included treating rivers differently, putting demand sites in upstream locations ahead of downstream locations, and ensuring that demand sites that prioritized groundwater over surface water would receive surface water allocations last. However, the newest model, WEAP21, tackles the challenging issue of allocating water resources by introducing cutting-edge algorithms with a contemporary Graphics User Interface. WEAP21 offers a cutting-edge framework for hydrological modeling that combines conceptual runoff rainfall, an alluvial underground water model, and the quality of river water into a single platform. The WEAP21 model's simulations comprise a collection of scenarios, with time steps ranging from one day to over 100 years. The time steps for the simulations can be retained as one day, weekly, monthly, or even periodically. The real need for water and pollution load, water resource availability, and water supply for the system are all shown via the WEAP model's current accounting feature. It is also referred to as a baseline year at times. A variety of reservoir operating policies, water costs, and other significant variables that impact water demand, such as various approaches to managing water demand, alternate sources of water supply, and hydrological assumptions, are all included in the various scenarios. The scenarios undergo evaluations for water supply sufficiency, average delivery costs, stream flow needs, and watershed hydropower capacity. The integration of a conceptual rainfall-runoff model, an alluvial groundwater model, and a river water quality model offers the user a full hydrological modeling platform. Large river basins have been modeled using WEAP by other researchers. Examples of these basins include the Volta basin in Ghana which includes Small multipurpose reservoirs which are frequently utilized to supply irrigation and drinking water. Reservoirs are utilized for everyday tasks to raise people's standard of living in rural locations with limited surface water. In nations with erratic trends of rainfall, modest reservoirs, and dams have been built on tiny streams and rivers to guarantee a period of cultivation that lasts the entire year and to provide water for residential use and animals. [23], South Africa's O, which shares a border with Mozambique (Lévite et al., 2003a), and Lake Naivasha, Kenya (ERICK AKIVAGA MUGATSIA Grad Eng Tech, 2010). The hydrological module of the weapon modeling tool provides five alternative calibration choices for a rain-runoff model. These modules are part of the modeling tool. Another module that was used in this project was the water allocation module. The latter is a decision support system that maximizes the satisfaction of diverse users' expectations to facilitate water resources management (Alfarra, n.d.). The major advantage of this program is that it generates analytical situations based on boundary circumstances, including priorities, costs, and technological and political constraints, in addition to other factors that influence demand and supply in a certain area. Including these options in the module makes it possible to create variables that are not dependent on any particular scenario, which helps with the model's optimization operations. (Mena et al., 2021). The program is prioritized and utilizes optimization algorithms based on priorities rather than hierarchical rules. It applies the Equity Group idea to distribute water during periods of inefficiency (Mounir et al. 2011). WEAP was discovered to be suitable for single catchments, complex transboundary river systems, and municipal and agricultural systems. As a tool for policy analysis, WEAP can also be used as a forecasting tool in hydrological simulations and as a database system to keep track of water supply and demand data. The fundamental idea behind how WEAP works is a water balance that meets the mass balance of water and pollutants for each node and link at any given time. In addition, a variety of artificial and natural components of these systems can be simulated by WEAP, such as precipitation rain runoff, interflow, and underground water recharge and rainfall; public water demand analyses; water preservation; water rights and distribution preference; recharge operations; generation of hydropower;

tracking quality of water and population; evaluation of vulnerability and ecological requirements. The user can further look at project cost-benefit comparisons with a financial analysis tool.

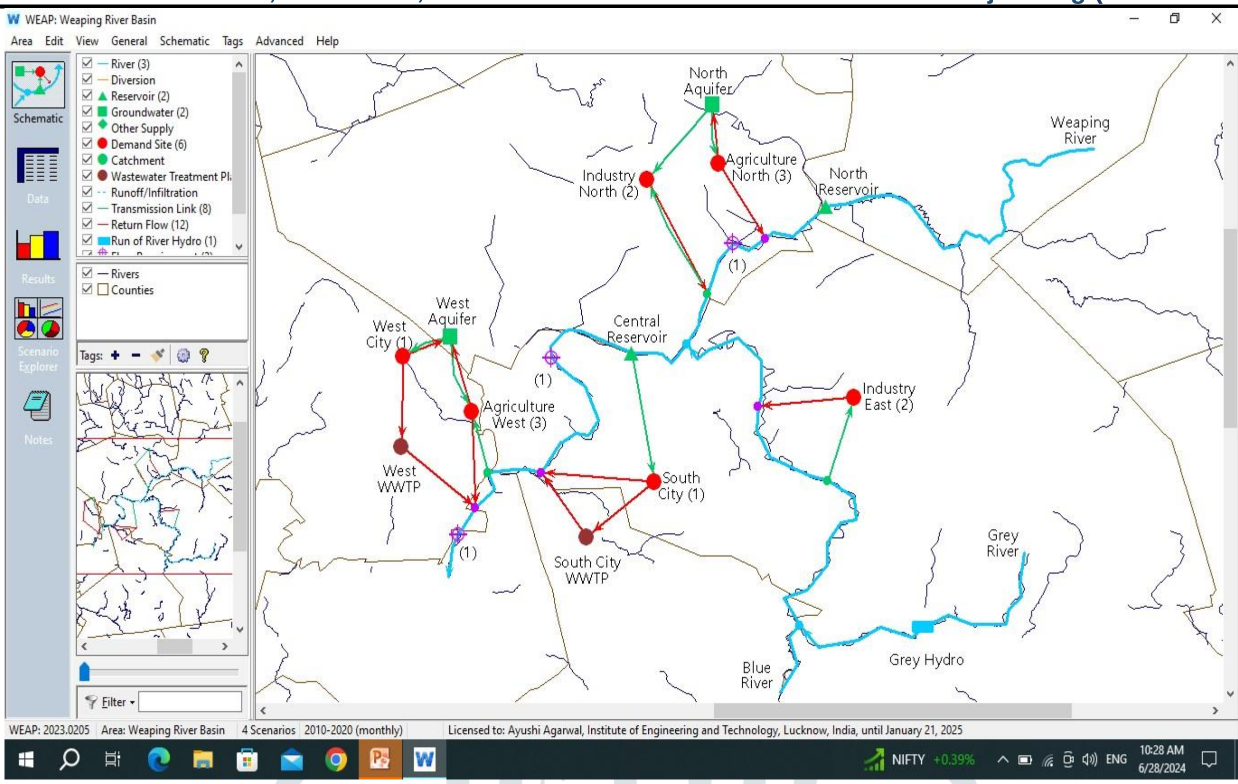
Structure of the Model

The model's structure represents the water resources system in terms of underground water, reservoir extraction, transportation, and wastewater treatment plants. It also takes into account the needs of ecosystems, water demands, and pollutant production. The degree of complexity can be selected by the analyst to satisfy the needs of a specific analysis.
The limitations brought about by restricted data can also be reflected through this modification (Sieber, 1990).

There are five main perspectives in the model:

Schematic

The schematic view defines the study area. This GIS-based program enables the importation of vector or raster layers for usage as background layers. Objects like groundwater supplies, reservoirs, and demand nodes can be positioned using a drag-and-drop technique. This makes it simple to make adjustments and modifications in the region. The figure displays a sample of the schematic view.



Schematic View of WEAP MODEL

DATA

Data is entered into the application through the data view. It enables the creation of variables and different hypotheses based on mathematical correlations. Excel can also be used to import data.

RESULTS

The results are easily accessed. All of the model's outputs are shown. You can export this to Excel as well for additional editing.

OVERVIEW

Key indications in the model can now be easily accessed as a result.

NOTES

Key assumptions can be documented by adding notes to the model.

Modeling Process of WEAP

The processes for simulating a watershed with WEAP are as follows: (Lévite et al., 2003b)

- Define the study area and time frame. The scenario development of the final year of application is involved in the time frame setup.

- The formation of the Current account, which approximately represents the current water resource condition of the area of research. The different current demand nodes and available water supplies are listed under the current account. Since it forms the basis of the whole modeling process. By doing so, the model can be adjusted to better reflect the circumstances that exist in the study area at the moment.

- Creating scenarios based on future assumptions and expected increases in the key indicators. This serves as the foundation of the model since it makes it feasible to implement potential water resources management procedures based on the findings of the model's execution. Numerous "what if" possibilities are addressed by the scenarios, such as what would happen if groundwater resources were completely depleted, what would happen if reservoir operating regulations were changed, and what would happen if population growth occurred. When creating scenarios, variables that vary over time can be taken into account.

- Assessment of the scenarios about the research area's water resource availability. The water resources planner can use the results of creating scenarios to aid in decision-making.

Application of WEAP in hydrological simulations and other areas -:

WEAP21 offers comprehensive watershed modeling with four approaches that replicate catchment processes: rainfall-runoff, soil moisture, MABIA, and irrigation demands. The WEAP has a variety of models and circumstances that are used to explore a variety of water management issues.

Hydrological investigations, groundwater modeling, irrigation management, climate change, and modeling for water quality management are among the many fields in which WEAP is widely used. Each application's research and studies are examined and expanded upon in the parts that follow.

In Seybouse's Wadi watershed WEAP Model was used to carry out the study under five scenarios: current situation, high population growth rate (1.8% to 5%), wastewater reuse and recycling, industrial water reuse, and effects of desalination plants. The model depicts the favorable and unfavorable characteristics of supply and demand, assisting planners in evaluating water demand deficits and planning alternative management strategies (Mansouri et al., 2017). The approach of WEAP-MABIA was used to develop an agricultural water demand model for Madhya Pradesh's Ur River basin. The technique separately calculated soil evaporation and transpiration using a dual crop coefficient approach. The model was calibrated using the PEST tool, and the future water demand was projected. The prioritizing of household water supply led to a higher unmet demand for agriculture usage, according to the results. Potential fixes included rainwater collection and effective irrigation techniques (Agarwal et al., 2019). The potential of WEAP to predict the rainfall-runoff cycle of the mahanadi basin through rainfall-runoff hydrological modeling of the basin is investigated. The hydrological process of the catchment was modeled, and the stress flow simulation at each monthly time step was compared with the available measured flow data.

Two factors (Effective precipitation, kc, and crop coefficient) were used at separate stages to calibrate the model for the year 2007. For several catchments, the range of calibrated values was determined to be ± 5% for Kc and ± 1% for effective precipitation. The majority of the time, there is less than a 10% discrepancy between the stream flow numbers that were simulated and observed, according to the stream flow simulation that was conducted using calibrated values. This indicates a strong agreement with the measured data (Singh et al., 2014). The WEAP model was used to anticipate supply/demand, recharge, and draft in a Narmada

River sub-basin. The WEAP model served as a decision-support tool for managing watersheds in this study. Four scenarios—rainwater harvesting, high industrial growth, high population growth, and the implementation of water storage buildings in the WEAP model—were created. The study's conclusions showed that artificial groundwater recharge and storage facilities should be built to lessen the amount of water that is not used for home and agricultural needs (Carpenter & Choudhary, 2022)

WEAP APPLICATIONS IN CLIMATE CHANGE MITIGATION

Using the WEAP model, the effects of climate change on the Chennai River Basin were evaluated. The impact of three different rainfall scenarios - excess, normal, and deficiency the availability of the water was examined. The growth in unmet demand for both normal and deficient rainfall scenarios is the study’s main focus. The predicted supply of water requirements for irrigation and domestic in the Chennai basin till 2050 was examined. The findings showed that the amount of water needed over time has been increasing. The projected amount of water required in 2023 for residential and agricultural use was 2,110 MCM. This demand is expected to climb to 2,197 MCM by 2030, suggesting a notable increase in the water demand. In the long run, it is predicted that 2,321 MCM of water will be needed in 2040, and 2,445 MCM by 2050. By 2050, the Chennai Basin will likely face considerable issues in satisfying its water demand, according to forecasts. Unmet water demand is expected to increase over time in both normal and deficient rainfall situations. These results underline the necessity of developing efficient mitigation plans to close the anticipated gaps in supply and demand. It is important to carefully consider and put into practice mitigation strategies such as raising groundwater recharge, building reservoirs, improving desalination plant performance, using more storage alternatives, and looking into alternate water sources.

Another study examined WEAP to study water supply and demand in the Gomti River Basin in Lucknow, Uttar Pradesh, in 2015, taking into account climate change and population growth. There were two scenarios used: one was business as usual (BAU) and the other included mitigation measures. After that, many scenarios known as the business as usual (BAU) scenario and the scenario with mitigation measures are used in numerical simulation. In the scenario with mitigating measures, the capacity of WWTPs was 1119 MLD, with a total of 9 WWTPs, compared to 145 MLD in the present and BAU scenario. The simulated BOD value for 2015 (the current stage) ranges from 21.5 to 71.4 mg/L, indicating unequivocally that all of the water samples are moderately very contaminated when compared to class B. In comparison to the current state, the water quality measured by BOD and E. coli will decline by an additional 70.8% and 10.6%, respectively, on average in 2030 due to both population and climate changes. It is reassuring to note that, in contrast to the business-as-usual scenario, the scenario with measures will result in a reduction of 91.7% and 96.4%, respectively, in the concentration of BOD and E. coli throughout the stream. It would therefore be possible to predict the anticipated temporal impact of climate change on the hydrological system and water resources by comprehending the influence of "climate variability" on water resource availability and water demand.

THE UTILIZATION OF WEAP IN MANAGING IRRIGATION.

The WEAP model has a significant impact on agriculture, particularly on irrigation management. The WEAP Model was employed in research on the Sardar Sarovar Project in the semi-arid region of Vadodara district to maximize water use efficiency and raise crop yields in an area with insufficient irrigation, particularly for the cotton crop. During the vegetative phase or the whole growth period, the researchers investigated five distinct scenarios for irrigation water stress, including conventional irrigation, deficit irrigation, and no-stress irrigation. The results suggested that the no-stress allowance scenario, with the highest irrigation volume of 307 mm, resulted in improved crop yield. A different study calculated the quantity of water lost by evapotranspiration by analyzing crop water requirements in the Tandula River's command area in Lohara Village, Chhattisgarh. The WEAP-MABIA approach was employed in the study to determine the monthly requirement of water for crop cultivation and irrigation purposes as well as to simulate the need for water under changing soil, crop, and climate variables. According to the study, crop patterns might be altered and sophisticated irrigation methods could be used to increase output while using less water [35,36].In the study by Malla et al., the Dachigam Stream and Sindh Stream flow data from 1979 to 2010 (the previous thirty years) were used to supply our demand locations and determine the effects of changing climate conditions over them. Because data was only available until 2010, scenarios were created starting in 2011. Analysis was done on Srinagar's water needs, including irrigation needs for farming and water supply needs. The investigation of discharge data for the Dachigam stream showed a decline in flow between 1979 and 2010. Due to the Dachigam stream's nearly ten-fold decrease in flow between 1979 and 2010, there is a lack of agricultural demand in the area, even under minimum requirements. Agriculture Dachigam confronts a shortage, particularly in July. Agriculture fed by the Dachigam Stream needs to be effectively watered to meet home water needs (Malla et al., 2014).

APPLICATION OF WEAP IN GROUNDWATER MODELLING

It is essential to connect a WEAP model to a MODFLOW model in cases where the integrated WEAP groundwater model is insufficiently complex. The USGS developed MODFLOW, a three-dimensional finite-difference groundwater modeling framework. With this close connection. It is feasible to investigate how variations in local groundwater levels impact the system as a whole between the models. A further study projected the amount of water available in the basin of Western Aquifer, Jordan, using the WEAP MODFLOW coupling. MODFLOW -2000 was used to model WAB with a 150–750 m grid size. The period of calibration was from 1951 to 2000, while the validation period was 2000–2007. The flow dynamics are examined across the 56-year model period. The model was updated to 2035 to account for the anticipated circumstances. Three scenarios were produced: a rainfall and management scenario, a pumping scenario that took into account 85% of the aquifer output, and 85% of a 7-year moving average of the expected annual recharge. Furthermore, simulations with and without climate change were conducted under rainfall scenarios, using data from Krichak and Alpert's (2012) climate model. Twenty-four management choices were produced as a result of the model. To maintain water levels and keep drawing from the aquifer, it was also advised to take urgent action and lower the average pumping rate from 310 MCM/yr to 221 MCM/yr and limit the pumping rate to a 7-year moving average (average pumping rate: from 328 MCM/yr to 254 MCM/yr) [38]. The usage of the WEAP-integrated groundwater model is limited to alluvial groundwater aquifers because it only takes into account these types of aquifers (Overview and Objectives

Projecting Water Availability within the Western Aquifer Basin: WEAP-MODFLOW Coupling BRIEFING / 2.6, 2013).

WEAP FOR MODELLING WATER QUALITY

The temperature of surface water rises in response to an increase in air temperature, which influences the chemical and bacterial activity of the stream and also causes a reduction in the amount of DO. The Streeter-Phelps Model is the foundation of WEAP's water quality module. Kumar et al. investigated the detrimental effects on water quality of overpopulation and the changing climate in the future. This study therefore concentrated on projecting the Adyar River's future water quality under the "business as usual" (BAU) and "suitable with measures" scenarios. This was done using the WEAP Model. The analysis shows that Adyar water quality will degrade considerably by 2030 under the BAU scenario. This would make many aquatic creatures unfit to live in the river. According to the findings of the WEAP model, by 2030, there will be an 8.3% and 26.7% increase in E-Coli and BOD concentrations, respectively, as a result of both population expansion and climatic change (higher temperatures and precipitation). On the other hand, the quality of river water is anticipated to greatly enhance by 2030 under the given scenario with actions implemented, which anticipates that "all wastewater produced locally will be collected and treated in the 886 million liters per day (MLD) WWTP. "Specifically, the model results showed significantly lower rates of BOD and E.Coli-74.2% and 98.4%, respectively in the BAU scenario. A supplementary study used the WEAP model to examine the sustainability of water resources in Kathmandu Valley, Nepal. To investigate several WWT alternatives, WEAP was utilized to simulate the water quality conditions of the Bagmati River in the years 2014, 2020, and 2030 concerning BOD and COD. Three main parts made up the analysis: scenario modeling, water quality, and hydrology. With effective rainfall and the runoff/infiltration ratio as the calibration criteria, WEAP was calibrated for monthly discharge and produced a satisfactory result. The Bagmati River is heavily polluted as water flows towards the city center, with lower DO and higher BOD levels. These values will continue to be substantially over allowable limits in 2020 and 2030, proving that both the proposed and renovated WWTPs as well as the ones in use today are essentially insufficient to reduce pollution in the Bagmati River. Politicians are therefore advised to increase the capacity of WWTPs in light of socio-economic development and climate change, with caution being exercised in the disposal of solid waste (Mishra et al., 2017).

CONCLUSION

The ability of WEAP to generate sophisticated models of both natural and artificial ecosystems makes it a popular tool for researchers, stakeholders, and policymakers in integrated water resource management. The following significant conclusions have been drawn from the evaluation of the research conducted in the management of water resources utilizing WEAP:-

- The WEAP decision support system can support the planning and formulation of water resources through strategy. It is also a decision-making tool for managing water resources.
- WEAP21 is an integrated water resources management method that uses an iterative LP optimization algorithm to handle water distribution problems based on demand priorities and supply preferences.

- ❖ Hydrological simulations using WEAP can provide useful insights into supply and demand and help in the development of demand management strategies. This WEAP program supports planning for the anticipated time frame and can assist in appropriate water resource planning to prevent problems with the demand and supply of water resources in the anticipated period.

- ❖ The user can examine various hydrological processes in watersheds, ranging from small-scale micro-watersheds to small-scale basin models due to their applicability to a variety of physical and hydrological models. The model has been effectively used to simulate the water demands of many industries over a vast number of catchments under various scenarios, including population expansion, climate change, demand control tactics, etc.

- ❖ The user may identify the most important quality characteristics in terms of temporal and spatial variation due to its connection with the model of surface water quality QUAL2K. This helps anticipate the quality of surface water in the future.

- ❖ The use of WEAP is not restricted to the aforementioned domains; it is also crucial for managing irrigation water. The agricultural water requirements are estimated using the WEAP-MABIA techniques, and it is possible to even boost crop output by properly allocating and scheduling water in the agricultural field.

- ❖ For simulating groundwater, water quality, and climate change, WEAP can also be used in conjunction with other models. Groundwater modeling is carried out and results and models from programs such as MODFLOW can be connected to WEAP. WEAP is used in conjunction with QUAL2K software to model water quality. By anticipating monthly relationships, a combination of WEAP and SWAT can be utilized to model the influence of climate variability on the hydrological regime.
- ❖ WEAP has been extensively utilized in the analysis of reservoir operating policy for several hydroelectric plant designs under a variety of restrictions, including flood control needs, hydropower generation requirements, and stream flow requirements.

- ❖ WEAP has limitations that were observed when reviewing the study of many authors, even though it seemed to be a helpful instrument with a variety of applications. Only alluvial aquifers are taken into account by WEAP when modeling groundwater; sedimentary and fractured rock aquifers cannot be modeled.

FUTURE PROSPECTS.

The goal of the current study is to demonstrate the advantages of an integrated approach to water resources management, based on the water evaluation and planning model version 21 (WEAP 21) for successful water resource planning in the face of complex water systems. The model may predict future water demands and rank each demand location with the preferred supply source based on user needs, aiding in decision-making for the overall management of water resources. WEAP can improve agricultural management by optimizing water consumption and crop planning, which has not been widely utilized in this field. Rather than using traditional performance assessment techniques, the automatic calibration tool PEST, which is included within WEAP, can be used more often to confirm the model's performance. As a result, atmospheric interactions may very likely be included in future demand projections. It is discovered that water resources and management of agriculture may be carried out, and water stress in crop cultivation can be analyzed for drought-prone regions using the hydrologic catchment modeling module of WEAP. This module serves as a decision-making tool for policymakers and farmers. This demonstration also reveals that WEAP is unquestionably one of the greatest tools for creating policies because of its scenario explorer module, which allows users to establish several management techniques and evaluate them financially to arrive at an affordable solution.

Declaration

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. The authors declare the following financial interests/personal relationships which may be considered as potential competing interests.

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Authors Contributions

Ayushi Agarwal: Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing, Validation. Hrishikesh Kumar Singh: Supervision, Validation, Visualization, Writing – review & editing, Conceptualization.

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