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# A REVIEW ON WEAP21 MODEL FOR MANAGING WATER RESOURCES

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## ABSTRACT

*Water resources allocation for the optimisation of water uses at each user end is one of the major challenges to the policymakers and stakeholders. Water resources planning needs multi -disciplinary approach for sustainable development. The present paper provides an extensive review on Water Evaluation and Planning Model version 21 (WEAP21) applications as a decision-making tool for water allocation problems and water resources planning in different aspects including water quality analysis, groundwater modelling and climate change simulations. From this literature-summarised review, WEAP21 can be concluded as a powerful IWRM tool for priority-preference based simulations under various scenario generations.*

***Keywords:*** *Climate Change, Groundwater, Water allocation, Water Quality, WEAP*

## INTRODUCTION

With the increasing pressure on existing water resources, the present framework of water allocation system is becoming highly inefficient. The inability of the existing system to meet the current water demands is due to the poor water management policies adopted in the past. Different sectors can interact and influence the water strategies for water resource development and management. There is a huge competition to access water resources at the global level, national level and local level due to population growth, climatic variations, economic development. The water consumption rate, urbanization, and rising living standards have a strong correlation, and these factors are putting more stress on the available water resources (Bao and He, 2015, Saraswat et al. 2016). In addition to the above factors, the hydrologic cycle is also significantly affected by climate change (Hong et al. 2016). Earth's climate is changing and even under the most optimistic scenarios of emissions and climate sensitivity, climate change impacts are inevitable (Oreskes, 2004; Solomon,2007). Therefore, water resources planning needs a multidisciplinary approach that brings together all the complexities of the actual system. Hence, the formulation of water allocation policies incorporating integrated approach can be the one effective management strategy. Conventional supply-oriented simulation models are not always adequate. Over the last decade, an integrated approach to water development has emerged that places water supply projects in the context of demand-side issues, water quality and ecosystem preservation (Sieber, 2009). Integrated Water Resources Management (IWRM) is viewed as the systematic process for sustainable development, allocation and monitoring of the water resources considering all the different user groups together in order to achieve socio-economic and environmental objectives (Un-WGWP,2005) The main objective is the optimum allocation of resources to each of the user group ensuring sustainable management without disturbing the ecosystem in order to achieve social-economic and environmental objectives.

The Water Evaluation and Planning (WEAP) model of the Stockholm Environment Institute is a water demand, priority and preference driven model which provides a modelling framework for assessing sectoral demand, stream flow, reservoir operation, water conservation measures, allocation priorities and project cost-benefit analyses. (Yates et al. 2005a; Yates et al. 2005b). Worldwide, WEAP model has been extensively used for managing water resources in drought prone, rainfed areas, for water quality issues, conjunctive use management, etc. The present paper provides an extensive review on WEAP as a decision-making tool for water allocation problems and water resources planning in different aspects. WEAP integrates natural watershed processes together with the socio-economic elements that govern the allocation of available supplies (Yates et al. 2005a). WEAP21 can be used both as a database tool in which it maintains supply and demand information as well as a forecasting tool by simulating water demand based on the priority-preference information input to the model. The manuscript highlights the model development and its' successful applications in hydrologic simulations, climate change studies, urbanisation, water quality modelling, ground water modelling and irrigation water management. Worldwide, WEAP has been applied in many sectors beginning from its development but only few of the applications are put into this manuscript to give a gist of its acceptability around the globe.

## MODEL DEVELOPMENT AND BACKGROUND

The Water Evaluation and Planning (WEAP) model has a long history of development and use in the water resources planning area. WEAP was created in 1988, with the aim to be a flexible, integrated, and transparent planning tool for evaluating the sustainability of current water demand and supply patterns and exploring alternative long-range scenarios. Raskin et al. (1992) first applied it to a study on the Aral Sea, a huge saline lake in the former U.S.S.R. For the Aral region's complex water systems, a detailed water demand and supply simulation was performed for the 1987-2020 period, assuming that the current practices continue.

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The analysis provided a picture of an unfolding and deepening crisis and therefore policy scenarios were generated on the basis of economic and environmental criteria. The older versions of the WEAP had several limitations, including an allocation scheme that treated rivers independently, gave priority to demand sides on upstream sites over downstream sites and assured that demand sites that preferred groundwater to surface water were last in getting surface water allocations (Yates et al., 2005a).

However, the recent version WEAP21 model attempts to address the gap between these deficiencies by introducing a modern Graphic User Interface (GUI) and a robust solution algorithm to solve the water allocation problem. The integration of conceptual rainfall runoff, an alluvial groundwater model, and a stream water quality model gives the user a full-fledged platform for hydrological modelling. Rosenzweig et al., 2004 analysed the application of WEAP models to major agricultural regions in Argentina, Brazil, China, Hungary, Romania, and the US, by simulating future scenarios about climate change, agricultural yield, population, technology, and economic growth. WEAP21 model simulations are constructed as a set of scenarios. Hagan (2007) used WEAP in Ghana to simulate the impact of different sized reservoirs in the Upper Volta. The results revealed that the model performed well and it was found that small sized reservoirs do not have any impact on Upper Volta river basin. Al-Omari et al. (2009) has used WEAP as a water management support system for Amman Zarqa basin in Jordan using advanced wastewater treatment and optimistic scenarios. Arranz & McCartney (2007) have also applied the model to the Olifants catchment in South Africa. In their analysis also, the model performed well in doing quick analysis of current and future water demands. Other investigators have used WEAP for modelling large river basins, for example, the Olifants River basin in South Africa, bordering in Mozambique (Levite et al., 2003) and Lake Naivasha, Kenya (Alfarra, 2004), the Volta basin in Ghana (Condappa et al., 2008). It is a priority driven software, that employs priority-based optimization algorithm as an alternative to hierarchical rule-based logic that uses a concept of Equity Group to allocate water in time of inefficient supply (Mounir et al. 2011).

It was found that WEAP is applicable to municipal and agricultural systems, single catchments or complex transboundary river systems. WEAP acts as a policy analysis tool, which can work as a database system for maintaining water demand and supply information as well as a forecasting tool in hydrological simulations. WEAP operates on the basic principle of a water balance which satisfies the water and pollution mass balance for every node and link at each time. Moreover, WEAP can simulate a broad range of natural and engineered components of these systems, including rainfall runoff, baseflow, and groundwater recharge from precipitation; sectoral demand analyses; water conservation; water rights and allocation priorities, reservoir operations; hydropower generation; pollution tracking and water quality; vulnerability assessments; and ecosystem requirements. A financial analysis module also allows the user to investigate cost-benefit comparisons for projects (WEAP, 2018).

The following section gives a brief review of applications of WEAP in hydrologic simulations, climate change studies, water quality modelling and groundwater modelling.

## APPLICATION OF WEAP IN HYDROLOGIC SIMULATIONS

WEAP21 with its advanced features of catchment modelling can simulate the catchment processes using four methods namely, rainfall-runoff method, MABIA method, Irrigation demands only and Soil moisture method. The following section summarizes the use of these methods for hydrologic simulations.

Metobwa et al (2018) developed WEAP to model water resources and demand in Mara river basin (MRB), Kenya taking 2010 as reference year for the simulation scenarios up to 2045 in order to mitigate the over use practices in the basin. The model was calibrated with Parameter Estimation (PEST) tool for discharge values and the performance of the model was evaluated with NSE, RMSE etc. Reference scenario was done taking linear population growth rate 3%. Water demand projections at all nodes show a remarkable increase in the abstraction levels from 0.3 BCM in 2013 to 2.65 BCM in 2045. The results showed that there is 2% decrease in annual demand in the enhanced scenario with a demand coverage of 95% at all sites throughout the year while under DMS scenarios it showed 96% coverage. Thus, the model showed that basin is projected to experience strain on its resources in the coming years but the proposed scenarios showed that enhanced policies implementation will sustain water resources at all the time in the Mara basin. Kanani et al (2017) applied WEAP to evaluate the drinking water supply scenario in 2014 for Vapi, Gujarat. WEAP was modelled to simulate the future demand with the forecasted population using geometrical increase method. The model was calibrated with measured and simulated demand with an error of 3.73% in 2014. The calibrated model was then used to predict demand with increased population scenario for 2041 which is less than the inflow in Madhuban dam if the dependable flow is 75%. The results obtained showed that model can perform well to assess future demand. Mansouri et al (2017) developed WEAP Model for inter- regional planning of water resources in Seybouse's Wadi basin under five different scenarios namely, the current situation, High Population growth rate (1.8% to 5%), Water Reuse and recycling of wastewater, Industrial water reuse and effects of Desalination Plant to reflect the best and worst conditions of demand and supply to evaluate water demand deficit and to help the planners to alternative management. Berredjem and Azzedine (2017) applied WEAP in the northern region of the Seybouse Valley to simulate current and future water balance to analyse the situation of water in different sectors. Also, a scenario for extended dry climate was generated and simulations showed that the demands will increase drastically. Saxena and Yadav (2016) applied WEAP model in Surat city Water Supply System to assess future water demands with population growth and climate variations. WEAP was run with scenarios including High Population Growth Rate as 3.5% and Low Population Growth Rate as 1.5% and climatic variations by water year method. The results obtained from the formulated scenarios showed an increase in demand. Shahraki et al (2016) used WEAP model to study water resources management under environmental scenarios in Hirmand Catchment, Sistan Region, Iran. In this study, dust stabilization and animal-plant sustainable ecosystem scenarios have been applied and further economic assessment of these scenarios was done. WEAP model was formulated with three scenarios namely, Reference scenario ($SC_1$), Dust stabilization ($SC_2$) and animal plant sustainable ecosystem ($SC_3$) scenarios. The results have shown that under environmental scenarios ($SC_2$, $SC_3$) amount of unmet demand has greatly increased. Since, first priority was given to drinking water allocation, its demand coverage is 100%. WEAP was modelled to assess the economic benefits from the application of SC2, SC3 in the agricultural sectors. The results showed that compared to the reference scenario, economic benefit decreased in the other two. Therefore, it was concluded that there is need to give special attention to environmental scenarios to protect wetland ecosystems. Singh et al. (2014) applied WEAP 21 for hydrologic modelling of Mahanadi basin using runoff-rainfall method to test WEAP's ability to simulate the rainfall-runoff process of the basin. Hydrological processes occurring in the catchment were modelled and stream flow, simulated on a monthly time-step, were compared to the measured flow series available. The model was calibrated for year 2007 using two parameters (Crop coefficient, Kc and Effective Precipitation) at different steps. The range of calibrated parameters was found as ± 5 % and ± 1 % for Kc and effective precipitation respectively for different catchments. The simulation of stream flow using calibrated values revealed that, in most cases, the variation between measured and simulated stream flow values is less than 10%. This shows the good agreement with measured data by using calibrated parameters. The calibrated and validated model can be applied for runoff simulations in other basins with similar hydro-meteorological conditions. Bharati et al. (2008) used WEAP to assess benefits from Polavaram Project, one of the major river interlinking projects linking Godavari and Krishna. Scenarios before and after the construction of Polavaram reservoir and canal under different cropping systems were formulated. The simulations showed that changing cropping pattern will lead to a decrease in unmet demands in the lower Godavari delta. The results also show that the proposed supply system will reduce the seasonal pressure on water resources for the proposed command area of the reservoir. Agarwal et al. (2018) used WEAP-MABIA method for analysis and simulation of agricultural water demands in the Ur river watershed, Tikamgarh district, Madhya Pradesh. WEAP-MABIA method uses dual crop coefficient approach, which helps in computing the separate soil evaporation and transpiration under various water availability situations. The year 2012–2013 was used as base year for customizing WEAP model for 8 subwatersheds. The model was calibrated using PEST tool, available in WEAP. The calibrated model was used for estimating future water demands and unmet demands by using future climate series. The results of the study demonstrate the potential of using WEAP model for water resource management and assessment of future resource development in the basin.

## WEAP FOR CLIMATE CHANGE

Arsiso et al. (2017) applied WEAP to investigate water demand and supply for the city of Addis Ababa, Ethiopia under the impact of Climate Change and urbanization for 2039. Hydrological data was taken as input to WEAP for year 2012 and climate model outputs of NIMR-HadGM2-AO model for RCP4.5 and RCP 8.5 scenarios were used to make assessments on reservoir storage volume in WEAP. Key assumptions such as Population growth rate, water pricing and GDP growth rate etc. were defined. WEAP was tested with the observed and simulated demand data for baseline period 2012. Scenarios of low population growth (2.5%) and high population growth (3.3%) were generated under each of the RCPs. The results showed that for most of the years the unmet water demand with RCP 4.5 climate change is higher than that of RCP 8.5 scenario but with the population growth rate under both the RCP scenarios there will be substantial shortage of supply in the city. Among all the demand management policies adopted, updating water tariffs is suggested as the better option with seasonal price adjustments as the unmet demand in this case turns out to be the least. Yilmaz (2015) applied WEAP to assess the impacts of Climate Change in Gediz basin, an agriculture dominant river basin of Turkey. The simulations of ECHAM5 and RegCM3 are used in WEAP to estimate Supply/Demand ratios, unmet demands and the decrease in the crop yield. the simulations were done till 2100 with the projected time series of rainfall, temperature, evapotranspiration and runoff data. The Model was calibrated for the streamflow and storage volume of the Demirkopru dam of the region. NSE and Pearson correlation coefficient indicated the model performance as very good. The results showed that the basin is under water stress and under the climate change the situation can be worst thus indicating the need of alternate supply sources and demand management strategies. Malla et al. (2014) used WEAP to assess water demand and supply under changing climatic scenarios for Srinagar City, J&K, India. In this study, WEAP was used to view the effect of climate changes in Srinagar City. Discharge data from 1979-2010 (past thirty years) of the study rivers i.e., Dachigam Stream and Sindh Stream was used as supply to the demand sites and also to find the impacts of changing climatic conditions over them due to fast melting of glaciers because of global warming and shrinkage of glacier areas. Different scenarios were developed for supply requirements, unmet demands and supply delivered. The model results reveal that there will be shortages in the requirements met in the urban water needs for some years like 2016, 2017, 2018 and 2020. Also, it was found that, Sindh stream has the potential of meeting the growing demands of water supply to Srinagar city in future, therefore judicious use of water from Sindh stream is necessary. Yahaya et al. (2014) developed WEAP model for simulation and modelling of Climate Change effects on flow discharge of River Awara, Nigeria for effective water management. CLIMGEN was used for stochastic weather generation and WEAP was used to simulate reservoir storage volume and water management simulation at high spatial resolution (0.5*0.5). CLM- based flow was used to evaluate runoff. Regression analysis was done to calibrate discharge and WEAP projections on reservoir storage volume and precipitation showed that climate change would have severe impacts on water supplies. Further, sensitivity analysis was done for measured and simulated air temperature. Droubi et al (2008) applied WEAP to evaluate the future water demand in EAB basin, Syria under the impact of Climate Change for the year 2050. Projections of global temperature and precipitation were done with MAGICC /SCENGEN tool which uses emission scenarios of greenhouse and reactive gases based on A2, B2 scenarios of IPCC. The outputs of MAGICC/SCENGEN model was used in WEAP for demand- supply analysis. The model was calibrated with streamflow data for 1990-2010 dataset with Effective precipitation and Runoff/Infiltration ratio as the parameters. The results showed that under the impact of A2, B2 on EAB basin, water demand and unmet increases as the temperature rate increases and precipitation decreases that too more prominently under A2 scenario. Three Adaptation strategies scenarios were generated to mitigate the effects of climate change and Unmet demands for each case was evaluated to choose the best strategy for policy making as the available supply is insufficient to fulfil the projected demands. The above discussions show the effectiveness of WEAP21 for the assessment of climate change and the water management under the impact of climate change.

## WEAP FOR WATER QUALITY MODELLING

There is a great uncertainty in the magnitude of future temperature changes at regional as well as global scale. Research have received considerable attention in recent years on the impact of climate changes on water quality. With the increase in Air temperature, surface water temperature increases thereby affecting the bacteriological and chemical activities of the river and also results in decrease of dissolved oxygen. Water quality module in WEAP is based on Streeter-Phelps Model.

Mishra et. al., (2017) applied WEAP model to assess the sustainability of water resources of Kathmandu Valley, Nepal. WEAP was used to simulate the current year (2014) and future (2020 and 2030) water quality conditions of Bagmati river in terms of BOD and COD in order to explore alternate WWT options. The analysis had three major components: hydrologic, water quality and scenario modelling. WEAP was calibrated for monthly discharge with effective rainfall and Runoff/Infiltration ratio as the parameters and resulted in a satisfactory performance. The results have shown that a large portion of the Bagmati river is critically polluted as DO decreases and BOD increases as the river flows towards the centre of the city. These values will remain far beyond acceptable limits in 2020 and 2030 thereby demonstrating that the current as well as suggested/rehabilitated WWTPs are largely inadequate to alleviate the Bagmati river pollution. Hence, it is suggested to the policymakers to expand the capacities of WWTPs with the socio-economic development and climate change and care is to be taken regarding the disposal of solid wastes. Lakshmi and Madhu (2014) used WEAP and QUAL2K to model Dissolved oxygen and temperature of Periyar river, South India. Periyar flows through ecologically sensitive areas of Kerala as well as through its highest industrial belt thereby needs a serious attention in quality assessment. QUAL2K is a one-dimensional, steady state stream water quality model which can simulate a number of water quality determinants along a river and its tributaries like pH, BOD, COD, DO etc. In this study, surface water temperature and dissolved oxygen was modelled using QUAL2K with 2007-2008 monthly data. WEAP was used for forecasting of QUAL2K model for temperature and DO for 2009-2030. Variation of DO and temperature was evaluated for 28year period with trend analysis. Correlation analysis of air and surface water temperature shows positive correlation while DO and surface water temperature shows negative correlation. Regression analysis was done to establish relationship between variables. Model was prepared with monthly DO data of river from April 2007-May 2008 and the data was calibrated with DO April-May 2008 & 2013. The results have shown that the model data is in agreement with the calibrated data. The surface water temperature and the dissolved oxygen will be 29 degrees and 3.7 mg/l by 2030. Therefore, immediate plans and management action needs to be done in regeneration and sustenance of DO in Periyar river.

## GROUNDWATER MODELLING

For situations where the built-in WEAP groundwater model is not sufficiently complex, there is the option to link a WEAP model to a MODFLOW model.

MODFLOW is a three-dimensional finite-difference groundwater modelling platform created by the U.S. Geological Survey (USGS). With this tight coupling between the models, it is possible to study how changes in local groundwater levels affect the overall system (e.g., groundwater-stream interactions, pumping problems due to drawdown, lateral groundwater recharge) and vice versa (e.g., infiltration and abstraction). MODFLOW-2000 simulates steady and non-steady flow in an irregularly shaped flow system in which aquifer layers can be confined, unconfined, or a combination of confined and unconfined.

Alslevavni et al (2017) developed model by integrating WEAP and MODFLOW for Nineveh Province, Iraq to analyse the reliability of the supply system. A conceptual Model was converted into numerical model using GMS by mapping the aquifer. Aquifer boundary was delineated, elevation data of reservoir and recharge of precipitation to groundwater was collected from weather station. MODFLOW was calibrated using conductivity and storage coefficients obtained from pumping test data in the selected wells in study area. LinkKitchen tool was used to link

WEAP and MODFLOW to predict the change in the groundwater level under various scenarios of pumping. The results of reliability of supply showed that continuous pumping for years of simulation have substantially reduced the groundwater level and so it was suggested to use an integrated approach on conjunctive use. Abusaada (2013) used WEAP-MODFLOW coupling to project water availability within the Western Aquifer basin (WAB), Jordan. WAB was simulated using MODFLOW -2000 with a grid size of 150-750m. The period of calibration was 1951-2000 and 2000-2007 for validation. The modelled period of 56 years is used to study the flow dynamics. The model was extended to 2035 to represent the projected situation. Three scenarios were generated namely, pumping scenario (considering 85% of the aquifer yield, 85% of a 7-year Moving average of the estimated annual recharge), rainfall and management scenario. Further, under rainfall scenario, climate change (data from climate model, Krichak and Alpert 2012) and without climate change scenarios were run. The outcome of the model was 24 management options were developed. Also, immediate action of reducing the average pumping rate from 310MCM/yr to 221 MCM/yr and limiting the pumping rate to 7-year moving average (average pumping rate: from 328 MCM/yr to 254 MCM/yr) were recommended to maintain water level to continue discharging from the aquifer. The WEAP integrated groundwater model considers only alluvial aquifers (Yates et al. 2005) which puts a limit on its use to alluvial groundwater aquifers.

## WEAP FOR IRRIGATION MANAGEMENT STRATEGIES

Bhatti and Patel (2015) used WEAP model for irrigation scheduling for cotton crop in a semi- arid climate of Vadodara district of Sardar Sarovar Project (SSP), India. Optimising water use efficiency to maximise crop yields has become a necessity under deficit irrigation conditions. WEAP model was used to determine the crop water requirements and effects of irrigation strategies on Water use efficiency (WUE), Irrigation water use efficiency (IWUE) and crop yield were analysed for five different scenarios of irrigation water stress. The irrigation amount was decided on the basis of % Readily available water and fixed depth. Scenarios of Conventional irrigation, deficit irrigation (water stress during flowering and ball formation stages), No irrigation stress during vegetative phase and no stress allowance for the whole growth were generated. The results showed that the amount of irrigation given in the case of no stress allowance is highest(307mm) and thus there is a significant increase in yield of cotton crop while there is not much deviation in WUE. Reduction of transpiration is also noticed in other scenarios comparative to no stress allowance case. Therefore, through this study it can be seen that the simulations carried out by WEAP model can be used in effective management of irrigation water management.

## KEY FINDINGS

In this present study, we aimed to demonstrate the advantages of an integrated water resources management-based Water Evaluation and Planning Model Version 21 (WEAP21) in efficient water resources planning under complexities of a water system. The model can prioritise each demand site with the preferred supply source as per the user’s requirement and simulate future water demands to help in decision making for overall water resources management. We also found that model satisfactorily simulates the behaviour of demand and supply components as the climatic variables changes. Therefore, future demand predictions can very well incorporate atmospheric interactions. It is found that through the hydrologic catchment modelling module of WEAP, irrigation and agricultural management can be done and irrigation water stress can be analysed for semi-arid and arid regions thereby acting as a decision support system to farmers and planners. From the literature it is also found that WEAP is certainly one of the best policy making tool due to its scenario explorer module in which user can define different management strategies and can assess them economically to have a cost-effective solution.

## CONCLUSION

WEAP has been widely used by various researchers, stakeholders and policymakers for the integrated water resources management due to its capability to build complex and integrated models of natural and man-made ecosystems. WEAP21 based on the concept of integrated water resources management, incorporates demand priority and supply preference approach to solve water allocation problems using iterative LP optimisation algorithm. Its applicability to various physical and hydrological models allows the user to analyse various watershed hydrologic processes from large scale basin models to small scale micro-watersheds. The model has been successfully applied to enormous number of catchments in simulating water demands of different sectors under different scenarios like climate change, population growth, demand management strategies etc. Its surface water quality module allows the users to assess the water quality parameters and pollution loads at different reaches. Its interaction with the surface quality model QUAL2K allows the user to identify the most critical quality parameters with respect to temporal and spatial variation thus assists predicting the future quality of surface water. Linkage of WEAP21 with MODFLOW accounts for the dynamic transfer of water between the stream and aquifer and allows the user to model groundwater recharge and withdrawal characteristics. The new WEAP and LEAP interaction needs more attention of the researchers as the linkage allows integrated water-energy-emissions analysis and effect of one component over another in efficient policy making. WEAP also has been widely used in reservoir operation policy analysis across several hydropower projects under various constraints as stream flow requirements, hydropower generation, flood control requirements. In this summarised-review, the paper presents applicability of the model in various sectors. WEAP model needs more attention of the planners especially when it comes to interaction with other models like SWAT in order to represent the system more efficiently. Also, WEAP should be used more in agricultural management including water use efficiency and optimal crop planning as not much of the work has been done in these areas. For validating, the performance of the model, automatic calibration tool PEST, inbuilt in WEAP, can be practice more rather than the conventional methods of performance assessment.

## REFERENCES


1. Abusaada. M., 2013. Projecting Water Availability Within the Western Aquifer Basin: WEAP-MODFLOW Coupling, Palestinian Authority, Glowa Jordan River, Briefing 2.6, Palestine Hydrology Group (PHG), Jerusalem
2. Agarwal, S., Patil, J. P., Goyal, V. C., and Singh, A., 2018. Assessment of Water Supply–Demand Using Water Evaluation and Planning (WEAP) Model for Ur River Watershed, Madhya Pradesh, India. Journal of The Institution of Engineers (India): Series A, 1-12.
3. Alfarra, A., 2004. Modelling Water Resource Management in Lake Naivasha (Master Thesis). International Institute for Geo Information and Earth Observation (ITC), Enschede, The Netherlands.
4. Al-Omari, A., Al-Quraan, S., Al-Salihi, A., and Abdulla, F., 2009. A water management support system for Amman Zarqa Basin in Jordan. Water resources management, 23(15), 3165.
5. Alslevavni, N., Imran, K., and Almohseen, A., 2017. Integrated Application Of (MODFLOW) And (WEAP) Model in Nineveh Province, Journal of University of Duhok, Vol. 20, No.1(Pure and Eng. Sciences) pp 680-690 e-ISSN: 2521-4861 p-ISSN: 1812-7568 https://doi.org/10.26682/sjuod.2017.20.1.59
6. Arranz, R. and Mc Cartney, M., 2007. Application of the Water Evaluation and Planning (WEAP) Model to Assess Future Water Demands and resources in the Olifants Catchment, South Africa (Working Paper 116), International Water Management Institute.
7. Arsiso, B. K., Tsidu, G. M., Stoffberg, G. H., and Tadesse, T., 2017. Climate change and population growth impacts on surface water supply and demand of Addis Ababa, Ethiopia. Climate Risk Management, 18, 21-33.
8. Bao, C. and He, D., 2015. The causal relationship between urbanization, economic growth and water use change in provincial China. Sustainability, 7, 16076–16085. [Cross Ref]
9. Berredjem, A. F. and Azzedine, H., 2017. Modelling Current and Future Supply and Water Demand in The Northern Region of the Seybouse Valley. Journal of Water and Land Development, Vol 33 (IV-VI): 31-38 PL ISSN 1429-7426
10. Bharati, L., Anand, B. K., and Smakhtin, V., 2008. Analysis of the Inter-basin water transfer scheme in India: a case study of the Godavari–Krishna Link. Strategic Analyses of the National River Linking Project (NRLP) of India Series 2, 63.
11. Bhatti, G. H. and Patel, H. M., 2015. Irrigation Scheduling Strategies for Cotton Crop in Semi -Arid Climate using WEAP Model, Journal of Indian Water Resources Society, Vol 35, No.1.
12. Condappa, D. de, Chaponnière, A., Andah, W. and Lemoalle, J., 2008. Application of WEAP in the Volta Basin to Model Water Allocation to the Akosombo Hydropower Scheme under Different Scenarios. Water Research Institute, Accra, Ghana. pp.303–313.
13. Droubi, A., Al-Sibai, M., Abdallah, A., Zahra, S., Obeissi, M., Wolfer, J., Huber, M., Hennings, V., and Schelkes, K., 2008. A Decision Support System (DSS) for Water Resources Management–Design and Results from a Pilot Study in Syria. In Climatic changes and water resources in the Middle East and North Africa (pp. 199-225). Springer, Berlin, Heidelberg.
14. Hagan, I. S. A. A. C., 2007. Modelling the Impact of Small Reservoirs in the Upper East Region of Ghana. Master Thesis, TVVR 07/5008, Division of Water Resources Engineering, Lund University, Sweden
15. Hong, X., Guo, S., Wang, L., Yang, G., Liu, D., Guo, H. and Wang, J., 2016. Evaluating water supply risk in the middle and lower reaches of Hanjiang river basin based on an integrated optimal water resources allocation model. Water, 8, 364
16. Kanani, H., Yadav, S. M., and Waikhom, S. I., 2017. Evaluation of drinking water supply demand for peri-urban region, international journal of advance research in engineering, science & technology, e ISSN: 2393-9877 p-ISSN: 2394-2444 Vol. 4 Issue 4
17. Lakshmi, E., and Madhu, G., 2014. Modelling of Dissolved oxygen and Temperature of Periyar river, South India using QUAL2K, International journal of computational engineering research (IJCER), Open Access Journal Page 24, ISSN (e): 2250 – 3005 Vol 04 Issue 8
18. Levite, H., Hilmy, H. and Julien, C., 2003. Testing Water Demand Management Scenarios in a Water stressed, Basin in South Africa: Application of the WEAP Model. Physics and Chemistry of the Earth, Parts A/B/C. 28 (20-27), 779–786
19. Mansouri, S., Ouerdachi, L., and Remaoun, M., 2017. Inter-region planning and analysis of water resources by using WEAP model Seybouse (Annaba) and Coastal East of Constantine (El-Taref). Journal of Water and Land Development, 33(1), 115-122
20. Metobwa, M. G. O, Khaldoon, A. M. and Lars R., 2018. Water Demand Simulation Using WEAP 21: A Case Study of the Mara River Basin, Kenya, International Journal of Natural Resource Ecology and Management. Vol. 3, No. 1, 2018, pp. 9-18. doi: 10.11648/j.ijnrem.20180301.12
21. Mishra, B. K., Regmi, R. K., Masago, Y., Fukushi, K. and Saraswat, P. K. C., 2017. - Assessment of Bagmati river pollution in Kathmandu Valley: Scenario-based modelling and analysis for sustainable urban development, Sustainability of Water Quality and Ecology (9):67-77

22. Mounir, M. Z., Ma. M. C., and Amadou, I., 2011. Application of Water Evaluation and Planning (WEAP): A Model to Assess Future Water Demands in the Niger River (In Niger Republic) Modern Applied Science, Vol.5 No. 1 February 2011
23. Malla, M. A., Ahmad, U. F., Rather, M. A., Teli, M. N., and Kuchhay, N. A., 2014. Assessing Water Demand and Supply For Srinagar City (J&K) India, Under Changing Climatic Scenarios Using Water Evaluation And Planning Model (WEAP), IJMER, ISSN: 2249–6645, Vol. 4, Iss. 4
24. Oreskes, N., 2004. The scientific consensus on climate change. Science, 306(5702), 1686-1686
25. Raskin, P., Hansen, E., Zhu, Z., and Stavisky, D., 1992. Simulation of water supply and demand in the Aral Sea Region. Water International, 17(2), 55-67.
26. Rosenzweig, C., Strzepek, K. M., Major, D. C., Iglesias, A., Yates, D. N., McCluskey, A., and Hillel, D. 2004. Water resources for agriculture in a changing climate: international case studies. Global Environmental Change, 14(4), 345-360
27. Saraswat, C., Kumar, P., and Mishra, B. K., 2016. Assessment of stormwater runoff management practices and governance under climate change and urbanization: An analysis of Bangkok, Hanoi and Tokyo. Environ. Sci. Policy 2016, 64, 101–117.
28. Saxena, S. and Yadav, S. M., 2016. Application of Water Evaluation and Planning Model to Assess Future Water Demands of Surat City, Global Research and Development Journal for Engineering, Recent Advances in Civil Engineering for Global Sustainability, March 2016 e-ISSN: 2455-5703
29. Shahraki S. A., Shahraki, J. and Monfared, S. A. H., 2016. An Application of WEAP Model in Water Resources Management Considering the Environmental Scenarios and Economic Assessment Case Study: Hirmand Catchment, Modern Applied Science; Canadian Centre of Science and Education. Vol. 10(5), ISSN 1913-1844 E-ISSN 1913-1852
30. Sieber, J., 2009. WEAP: Water Evaluation and Planning system. Report published in Project and Tools at https://www.sei.org/projects-and-tools/tools/weap/ Last assessed on 02 August 2018
31. Singh, M., Shinde, V., Pradhan, S. K., Chalodiya, A. L. and Shukla, K. N., 2014. Hydrologic Modelling of Mahanadi River Basin in India Using Rainfall-Runoff Model, Nature Environment and Pollution Technology ISSN: 0972-6268 Vol. 13 No. 2 pp. 385-392
32. Solomon, S., 2007. Climate Change 2007—The Physical Science Basis: Working Group I Contribution to the Fourth Assessment Report of the IPCC; Cambridge University Press: Cambridge, UK, 2007; Volume 4.
33. Un-WGWP, 2005. Integrated Water Resources Management Plans. Training Manual and Operational Guide. Published with the support of the Canadian International Development Agency, CIDA, in the framework of the PAWD program, Partnership for African Waters Development.
34. Yahaya, O, Rodiya, A. A., Nathaniel, E., & Micheal, O., 2014. Simulation and Modelling of Climate Change Effects of Awara Flow Discharge Using WEAP Model For Effective Water Management, International journal of technology enhancements and emerging engineering research, Vol (2) Issue 7, ISSN 2347-4289
35. Yates, D, Sieber, J., Purkey, D. and Huber-Lee, A., 2005a. WEAP21 – a demand, priority, and preference-driven water planning model: part 1: model characteristics. Water Int 30(4):487–500. doi:10.1080/02508060508691893
36. Yates, D., Sieber, J., Purkey, D., Huber-Lee, A., and Galbraith, H., 2005b. WEAP21: a demand, priority, and preference driven water planning model: part 2, aiding freshwater ecosystem service evaluation. Water Int 30:487–500. doi:10.1080/02508060508691894.
37. Yilmaz, B., 2015. Assessing Climate Change Impacts on Gediz Basin Water Balance with WEAP Model, Journal of Multidisciplinary Engineering Science and Technology Vol.2 (11)