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Innovations in Smart Cities Applications Edition 3

The Proceedings of the 4th International Conference on Smart City Applications

Springer

Lecture Notes in Intelligent Transportation and Infrastructure

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Preface

This book is one of the important series which encompasses recent and advanced research on Smart City Applications. It is an interesting manuscript that will help newer and advanced researchers, industrialists and policy-makers to understand, to attract and conclude new ideas, new solutions and applications in this area. It is also an opportunity to learn about the exiting scientific contributions to literature in order to develop and think about new ones.

The paradigm of the future life of humanity is of great concern to scientists, researchers, sociologists and governments around the world. As a general scope of SCA19, the concept of smart cities is one of the most attractive models because in principle it brings together all the frameworks of human life: health, transport, education, energy, water, agriculture, pollution and environment, etc. Several researchers in various disciplines related to this field continue to delve extensively and through new information and communication technologies and using the latest advances in the field of applied artificial intelligence.

In its third edition, this book lists original research in new directions and advances focused on multidisciplinary fields and closely related to the fields of smart cities and their applications. This edition is the result of a reviewed, evaluated and presented work in more than fifteen sessions opened and listed in SCA19 conference as followed:

Smart E-Business and Governance–Smart Vehicles–Smart healthcare–Smart Education–Smart Citizenship–Smart Logistics and Mobility–Sustainable Building and Smart Earth–Smart Security Management–Smart Water Management–Smart Energy Management and Electrical Engineering–5G Technologies–Modeling and Algorithms–Networks and Wireless Communications–Image Processing.

The present book contains selected and extended papers of the Fourth International Conference on Smart City Applications SCA19 co-organized conjointly by Medi-Ast Association and EHTP school of Casablanca and held on October 2–4, 2019, in Casablanca-Morocco.

The SCA19 conference scope also discusses how smart cities are currently being conceptualized and implemented, examining the theoretical underpinnings and technologies that connect theory with tangible practice achievements. Using numerous examples from different city contexts and countries, this book, thus, constitutes a precious contribution to the ongoing discussion of this urban phenomenon.

We thank all authors from across the globe for choosing SCA19 to submit their manuscripts. A sincere gratitude to all keynote speakers for offering their valuable time and sharing their knowledge with the conference attendees. A special thanks go out to all the organizing committee members, to local chairs and the local committee in EHTP school, to all program committee members, to all chairs of sessions for their efforts and the time spent in order to make this event a success.

Many thanks to Springer staff for their support and guidance. In particular, our special thanks to Dr. Thomas Ditzinger and Ms. Varsha Prabakaran for their help, support and guidance.

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Geoinformatics Approach to Water Allocation Planning and Prognostic Scenarios Sustainability: Case Study of Lower Benue River Basin, Nigeria

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Abstract. Water allocation planning in an equitable and sustainable way is intrinsically complex. This study proposes a water resource allocation system using an integrated Soil and Water Assessment Tool and Water Evaluation and Planning tool (SWAT-WEAP) model for hydrological simulation and prognostic scenarios sustainability prediction. The study explores the use of Digital Elevation Model (DEM), soil and land raster image in deriving physiographic information for land degradation impact assessment, quantification of optimal water allocation and generation of minimum ecosystem water requirement. Consequently, the SWAT quantifies the catchment water yield before been allocated optimally based on percentage dependable flow rates of 70% and 85% reliability flow regime at Makurdi, Nigeria discharge station. The WEAP model assesses the water resources utilization following scenarios adaptation by riparian users. Both models performed satisfactorily for streamflow and water yield prediction and resource sharing both in the calibration and validation phases with a correlation coefficient (R^2) of 0.57–0.74 and root squared error (RSR) of 0.66–0.82. The results show how drainage network, channel length, drainage boundary, slope, and sub-catchment geometric properties demonstrate Geographic Information Systems (GIS) utility in morphoclimatic impacts assessment as a data management, scenario analysis, and decision support tool in water management for the Lower Benue River Basin, Nigeria. Planners and decision-makers need to consider several integrated plans as alternatives to adapting to climate change impacts and anthropogenic human activities in resolving the unmet demands.

Keywords: Morphoclimatic · Dependable flow · GIS · SWAT · WEAP · Water allocation sustainability

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1 Introduction

The concepts of morphoclimatic represents a branch of geomorphology that investigates the influence of present-day and past climate on morphogenetic processes and land forms [20]. The land is the most valuable natural resource, which embodies soil, water and associated flora and fauna involving the total ecosystem [1]. Traditionally, land use and land cover (LULC) mapping are obtained from maps or field surveys, whose processes and methods are labour intensive, time-consuming and are done relative infrequently not minding it's outdated in this era of rapidly changing environment. Geoinformatics approach with the advent of GIS provides tools and methods that can promote intrinsic system operations, as well as facilitate the process-policy planning to identify acceptable interventions or strategies for sustainable water allocation among the different uses and users [2–4]. Hence, an understanding of the hydrological cycle in a watershed area through geoinformatics approach provides insight and serves as a pre-requisite for the determination of efficient, equitable and sustainable water resource allocation strategies [5]. The grid-based Flow routing method in GIS approach appears to be a very suitable tool for spatio-temporal distributed hydrologic modeling using a digital elevation model, soil and land raster format. Flow routing method can thus be achieved by tracking the water throughout the cell network along topographic flow paths in relation to their morphoclimatic impacts to know the available water for sharing.

Research on water resources allocation has attracted considerable new development theories such as integrated water resources allocation based on sustainable development [6], balanced development [7], low carbon use [8], green development [9] and eco-hydrological approach that views watershed managing from the water flow and water use perspective in classifying them into Greens and Blues [10]. Despite the rich literature based on integrated water resources management (IWRM) which compare and evaluate the performance of two or more hydrological models on a basin base [11], for example, the evaluation of the satellite rainfall products was undertaken through hydrologic simulation in semi-distributed (SWAT) [12] and fully distributed (MIKE-SHI) hydrologic models [13] in small watersheds in the Upper Blue Nile Basin. Also, [14] uses two modern tools, the System of Economic and Environmental Accounts for Water (SEEAW) and the WEAP, in combination to assess in a holistic way the available water resources and the socio-economic water needs within a selected river catchment. In addition, [15] uses General Circulation Models (GCMs) with the emission scenarios RCP4.5 and RCP8.5 (Representative Concentration Pathways) as inputs for the WEAP System model to support river discharge modeling. Several other studies have also evaluated GIS-SWAT and WEAP adaptation singly [16–18]. However, very few studies have included their spatial and temporal distribution and the control of climatic parameters on the rates at which water processes operate on landform changes. The IWRM models tend to focus either on understanding how water flows through a watershed in response to hydrologic events or on allocating the water that becomes available in response to those events. Most of these approaches are basin-specific. This current study seeks to understand and extend the process knowledge application based on their level of spatial disaggregation when combined offline.

An explicitly geoinformatics water resources allocation framework based on dependable flow constraint and sustainability index is proposed in reference to the previous studies on water resources allocation planning and sustainable watershed management. The study is important both in the field of IWRM from the resources and uses perspective to analyze scenario in decision making. This paper thus presents a study to assess the consequences of climate change due to changing rainfall patterns and land use and land cover dynamic on water demand and supply integrated plans scenarios in SWAT-WEAP framework for sustainable in the medium and long terms.

1.1 Scaling of Modeling and Emerging Processes

The regulation of spatially distributed flows, pollutants, and demands have to be considered in an integrated river basin model using the proper scales including basin, district, and user's decisions in river basin management. The connections between water supply and demand and between upstream and downstream users are important when considering return flows in the basin. [19]. Thus, offering the water allocation planning process-mechanism to go beyond the provision of adequate water supply to competing needs in recent decades; to issues such as tradeoffs among conflicting objectives, investigates potential adverse impacts on infrastructure, and proposes benefits sharing to address the concerns and desires of all stakeholders in a river basin. [20]. Among the most common river basin modeling tools that are related to water allocation planning and sustainable watershed management are: VENSIM-DSS [21], MODSIM-DSS [22], Waterware [23], HEC models (HEC-3, HEC-5 and HECResSim) [24], RIBASIM [25], CALSIM [26], Riverware [27] and Mike Basin [28]. Others include, REALM [18], RIBASIM and OASIS [29]. The Analytical Hierarchy Programme (AHP) technique within a Multi-Criteria Decision Making (MCDM) has also been applied if there are constraints and criteria to allocate water. Recently, AQUATOOL, REALM, and eWater source have been applied for resources allocation. Consequently, new modules of the Decision Support System (DSS)-AQUATOOL incorporate tools that support the proposed simulation and optimization methods for quantifying Marginal Resource Opportunity Cost (MROC). None of these tools has the capacity for groundwater inclusion but eWater source has recently added a new module for groundwater interaction. For water allocation in semi-arid regions, rainfall-runoff models such as CN3S, stochastic generation models including SAGE [30], coupled MODSIM and AcquaNet models have found applications for temperate regions. Geoinformatics water resources allocation modeling brings spatial dimensions into water resources database, and capable of better integrating social, economic and environmental factors relating to water resources planning and management for decision-making [16]. An integrated geoinformatics modeling provides a way of assessing current conditions and exploring scenarios for changes in the future. GIS offers a spatial representation of water resources systems, not only limited to analytical capabilities for solving water resources problems but also making the concept of modeling water resources abstraction to be an interacting component of Hydrology, Environment, Life (aquatic), Policy and Sensitivity (HELPS) as a collective response of the basin [5].

1.2 Study Area Description

Nigeria is a country well-drained by two of the major rivers in Africa called River Niger and River Benue including other tributaries [31]. The study area which is River Benue watershed is situated between Latitudes 07°48′N and 09°30′N and longitude 06° 45′E and 12°10′E and has an estimated landmass of 231,000 sqkm consisting 156,500 sqkm for upper Benue basin and 74,500 sqkm for lower Benue [32].

2 Sustainability Framework

There are several frameworks around which sustainable indicators can be developed, classified and organised [33–35]. Hence, there are no agreed indicators for every purpose. Therefore, indices are used in evaluating one or more variable severity impacts, which help to avoid a biased decision-making process in a complex task like IWRM. In the context of work by [36], assessing the water allocation performance could be as stated in Eq. 1:

$$\mathrm{SI} = \frac{100}{M}\sum_{i=1}^{M}\left(\frac{S_i}{D_i}\right)^2 \tag{1}$$

Where M = number of years in the planning and horizons
Di = annual water demand in the year i
Si = annual water supply in the year i
SI = sustainability Index

while [37] advocates Sustainability Index (SI) to be the ratio of aggregated possible water demand relative to the corresponding supply at the prevailing time as shown in Eq. 2.

$$SI = \begin{cases} \frac{(S-D)}{S} & S > D \\ 0 & S \leq D \end{cases} \tag{2}$$

where S is the available water supply and D is the water demand.

3 Materials and Methods

3.1 SWAT-WEAP Model Development

Water allocation between competing uses is best addressed at the river basin scale using combined economic and hydrological models. In order to investigate the spatial and temporal variation of water resources allocation through this means, the Soil and Water Assessment Tool (SWAT), a physical semi-distributed model was used to simulate the hydrological process while the Water Evaluation and Planning (WEAP) model, a lumped model, was used for the water utilization allocation simulation. To this end, this study employed an integrated approach of Geographic Information System (GIS), and priority-driven dependable allocation scenario to evaluate the water allocation sharing in order to choose the most reliable sustainable water use preference. Water discharge from surface and groundwater within the safe yield of the system has been touted as the viable option for conserving the use of water resources and preservation of the natural environment [38]. The SWAT model was used to simulate the main hydrologic processes into Hydrological Response Unit (HRU) which combines digitized elevation model (DEM), land use, and soil maps, with observed daily meteorological time series to predict discharge hydrographs and spatial distribution of hydrological water balance for the catchment. Rainfall excess from the hillslopes qh (ms^{-1}), is incorporated with the surface flow using the continuity equation to produce the kinematic wave approximation shown in Eq. 3 to the Saint Venart equations for overland-flow routing on the watershed:

$$\frac{\partial q}{\partial x} + \frac{\partial d}{\partial t} = q_h \tag{3}$$

where q is water discharge per unit width (m^2s^{-1}), d is flow depth (m), x is distance (m) and t is time (s). Flow velocities are determined from Manning's equation shown in Eq. 4:

$$v = \frac{d^{\frac{2}{3}}S^{\frac{1}{2}}}{n} \tag{4}$$

Manning's equation (Eq. 4) and Velocity are then used in the Rating equation as shown in Eq. 5 for continuity:

$$q = vd \tag{5}$$

The Channel-flow routing is described by the kinematic wave approximation as shown in Eq. 6:

$$\frac{\partial q_c}{\partial x} + \frac{\partial d_c}{\partial t} = q_{lat} \tag{6}$$

where q_c is water discharge per unit channel width (m^2s^{-1}), dc is flowing depth of the main channel (m) and qlat is lateral inflow to the main channel (m) derived from the combined inflow from the two lateral hillslopes. Channel-flow velocities are determined from Manning's (Eq. 4) and velocity is then used as in Eq. 5 for continuity. This serves as the basis for initiating a system for allocating the available water resources while subsequent future water use projection was based on per capita use and the geometric population projection. The frameworks for water trading which encourage water use efficiency was implemented in an Integrated Water Resources Management (IWRM) lumped model (WEAP) to assess the catchment water utilization sustainability.

The contribution of each sub-catchment gives the basin total water yield at the outlet. Water yield of a river catchment is estimated by the model using Eq. 7:

$$WYLD = SURQ + LATQ + GWQ - TLOSS \tag{7}$$

where WYLD is the quantity of water yield, SURQ is the surface runoff, LATQ is the lateral flow contribution to streamflow, GWQ is the groundwater contribution to streamflow and TLOSS is the transmission losses from tributary channels in the HRU via transmission through the bed. All measurements are in mmH_2O.

Furthermore, the Map window GIS interface of the SWAT version 1.2.0.9 was used to develop the basin water balance model. The model's workflow included phases such as input data, GIS processing, configuring input files, model run, and reading outputs. On the other hand, WEAP is relatively straightforward and user-friendly for testing the effects of different water management scenarios. Records of hydrology, meteorology, and water supply for the study area have been collected and arranged as an input data source to fit the WEAP model. The results are easy to view for comparisons of different scenarios. The Sustainability Index (SI) as proposed by [37] and shown in Eq. 2 was used in this study to validates the medium and long-term water fulfillment for both supply and demand at varied dependability flow conditions.

4 Results and Discussion

4.1 Resultant SWAT Input Simulation

The resultant SWAT input simulation gives 286 delineated sub-basins Hydrological Response Unit (HRU) Fig. 1 while Figs. 2 and 3 depicts the simulated average monthly and maximum water yield contributed by each of the sub-basins to the watershed for the period 1996–2015.

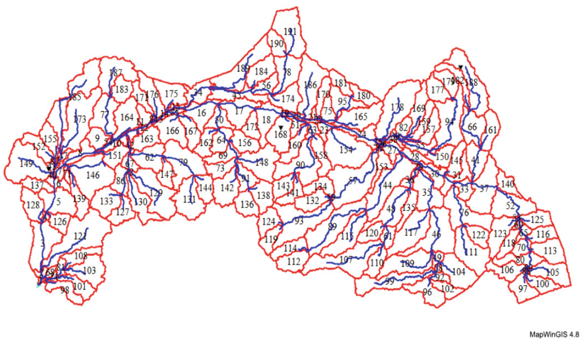

Fig. 1. Delineation of the watershed into sub-basins.

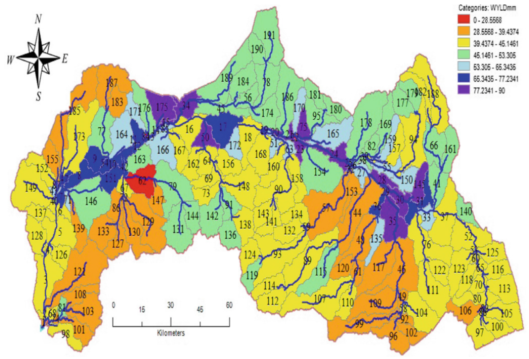

Fig. 2. Simulated average monthly water yield of the sub-basins.

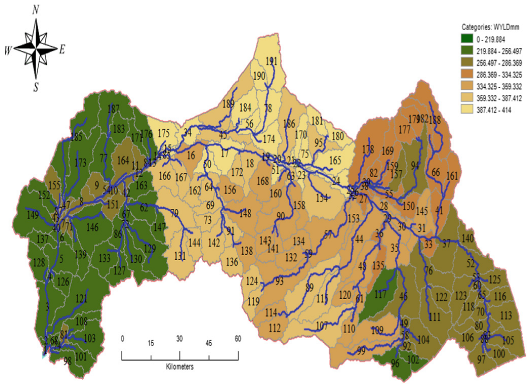

Fig. 3. Simulated maximum monthly water yield of the sub-basins.

The physiographic parameters were measured from DEM, stream networking and the delineated watershed using ArcGIS tools to compute important morphological parameters of the basins as shown in Table 1. This is useful in assessing the impacts of the watershed characteristics on runoff abstraction.

Table 1. Morphological parameters used for modeling SWAT.

Description	Symbol	Measured value
Watershed area	AE	18,504 Km^2
Maximum elevation	H_{max}	566 m
Minimum elevation	H_{min}	31 m
Slope	S	0.999
Predominant land use	Savannah (SAVA)	>88%
Predominant soil type	Loam	23.84%

4.2 SWAT Results Discussion

On a monthly average as shown in Fig. 2, the maximum water yield value of 926 mm was obtained in sub-basins located on the river catchment and on the major tributaries while sub-basins not located within the tributaries gave less water yielding potential. Surface water potential of the lower Benue was low as surface runoff of 10% was predicted due to the shallow slopes of the area. Sub-surface water components of soil water, percolation, and groundwater flow values were 29%, 12%, and 10% respectively thereby yielding a cumulative result of about 52% of the water balance. These results indicate that sub-surface water development is viable as an alternative water resources potential for the basin. Analysis of the annual water yield potentials shown in Fig. 3 revealed that the maximum water yield contribution to the Benue River basin occurred in 2009 with a value of 162,862 mm representing 8.74% over the 20 years period while the lowest water yield for the period occurred in 2015 with 45,458 mm representing just 2% of the total water yield for the period.

4.3 Dependable Water Allocation Assessment

Water allocation was considered at Makurdi (7°44′N, 8°31′E) discharge station. Based on the SWAT simulated estimated available water, allocated water was made based on percentage dependability of 70% and 85% reliable water abstraction flow regime. It consists of the use of a probability distribution function for projected water availability forecast and the use of a Flow Duration Curve (FDC) for the monthly flow magnitude quantification. The weilbil ranking was used for choosing the dependable flow, based on a reliable gross annual yield. Table 2 depicts the dependable water allocation at 85% reliability.

Table 2. Water allocation for Gross annual yield at 85% dependability.

Gross annual yield at 85% dependability		
	Surface water requirement at Makurdi	212,093
Irrigation (60%)	127,255.80	
Domestic (20%)	42,418.60	
Industrial (10%)	21,209.30	
Regeneration (+)	424.19	
Sub-total of water balance at 85% dependability		212,093

The results reveal irrigation water uses occupied the largest part - 60% of the basin's total water requirements, while domestic users constitute about 20% as the second-largest user sector. The outstanding 20% is shared by the industry, environmental and ecological uses. In addition, the challenges confronting water regulation among the contending different uses and users reveal societal activities of commercial irrigation, dryland, and subsistence agriculture as it interrupts the basin hydrological runoff and seasonal variability in streamflow. The RSR is the ratio of root mean squared error (RMSE) to the standard deviation. Its values from $0 < RSR < 0.70$ were the statistical indicators used for evaluating the SWAT model performance. The R^2 values of 0.79 and 0.74 were obtained for the calibration and validation of the model respectively. This indicates a good match and strength of the relationship between the observed and simulated flow values. As the values approach 1, the model predictions are considered perfect. In addition, the RSR values of 0.45 and 0.51 obtained respectively for the calibrated and validated models are considered good performance.

4.4 WEAP Prognostic Scenarios Results

Several hypothetical scenarios of climate change, population growth, and managerial policies were generated by the WEAP models in order to determine the impacts of their variations on water usages in the catchment, and their sustainability for varied dependable flow conditions for the period 2010–2050 as shown in Table 3.

Table 3. The sustainability index (SI) for varied dependable flow conditions.

Variables	Scenarios	70%	85%
A-SI	Business as usual (BaU)	0.25	0.36
B-SI	Climate change (Precipitation varies in 10%)	0.24	0.30
C-SI	Irrigation-improvement	0.23	0.25
D-SI	Integrated scenario	0.20	0.22

The SI values lesser than 0.25 corresponds to a low or no stress on water supply whereas SI greater than 0.25 reflect vulnerable conditions indicating that water demand is greater than 85% of the potential water supply [39]. Values of zero represent an unsustainable water supply indicating that water demand already equals or exceeds all available local water resources. The result of the integrated scenarios (B+C) of the sustainability index at varied dependability conditions in relation to the basin storage does not only predict the likely hydrological dynamics at a given time but also revealed the need for increased storage capacity to cater for the unmet demand. The integrated scenario (D) combines rainfall variation (B) with improved irrigation water use efficiency (C) gives optimal sustainability performance (0.25) of the system at 70% dependable flow over a long time.

4.5 WEAP Model Basin-Wide Water Balance

The simulated WEAP basin-wide water balance shows that Otukpo (2,726,492 m^3) and Gboko (356,604 m^3) have the highest consumption demand for water. The water allocation summary for the catchment area for the base year 2010 is shown in Table 4.

Table 4. Simulated base year water allocation summary.

Inflow (cu.m)	Outflow (million cu. M)			
Supply-side		Demand side	Actual demand	Consumption
Precipitation	6,271,196	Agasha	105,083	90,424
Reservoir	10,498	Katsina- Ala		93,352
		Otukpo		2,726,492
Total		Gboko		356,604
	6,281,694			6,281,694

However, despite its fluctuating pattern, rainfall constitutes the major source of water in the catchment. The average rainfall over the catchment area for the 2010 baseline period was 6.2 million m^3 while the projected future rainfall for the watershed is in the range of 5.2–7.3 million m^3 from the year 2011–2050. This result can be attributed to the type of soil prevalent in the study area as the major part of the land use is for agricultural purpose including forestry and scrubland as well as other usage such as urban development but with varying head flow water requirements as indicated in the summary of simulated water allocation to the various users. This result further corroborates the SWAT dependable flow allocation which reveals irrigation water uses occupied the largest share - 60% of the basin's total water requirements. The projected water requirements impact from climate scenarios, however, showed that the available water cannot meet the competing sectoral demands due to population growth, socio-economic activities and environmental degradation. Therefore, the development of some mechanisms to ensure equitable distribution between man and nature is needed.

5 Conclusion

Considering the extent of rainfall fluctuation leading to a paucity of water resources and its uneven allocation at the study area, water allocation planning will snowball as water demand and usage amidst population growth have further adversely altered the hydrologic cycles and threatens to worsen the current supply-demand imbalance. A shared water allocation plan consisting of a set of rules and managerial policies for the sustainable use of water resource will be needed to cope with the climate change impacts on water resources allocation planning. This study assesses the consequences of climate change due to changing rainfall patterns in the area and proposes different prognostic scenarios adaptation on the current and future water allocation sharing in the area. Increasing population and intensification of agriculture practices were identified to provoke increased water usage. The study has offered criteria and indicators of system sustainability and strategies for IWRM as a viable option to smaller sub-basins for its modeling and consumptions imbalance accomplished. Since comprehensive and multi-sectoral planning and execution of water projects within all basins are still lacking, the study recommends strengthening water security, capacity building, adaptability and resilience for the future planning and management of water resources.

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References

1. Flaschsbarth, I., Willaarts, B., Garrido Colmenero, A., Xie, H., Pitois, G., Mueller, N.D., Ringler, C.: The role of land and water for trade and food production in Latin America: environmental trade-offs of agricultural intensification versus extensification. PLoS One **10** (1), 1–24 (2015)
2. Zare, F., Elsawah, S., Iwanaga, T., Jakeman, A.J., Pierce, S.A.: Integrated water assessment and modelling: a bibliometric analysis of trends in the water resource sector. J. Hydrol. **552**, 765–778 (2017)
3. Rahman, K.U., Balkhair, K.S., Almazroui, M., Masood, A.: Sub-catchments flow losses computation using Muskingum-Cunge routing method and HEC-HMS GIS-based techniques, case study of Wadi Al-Lith, Saudi Arabia. Model. Earth Syst. Environ. **3**(1), 4 (2017)
4. Dixon, B., Uddameri, V.: GIS and Geocomputation for Water Resource Science and Engineering, 2nd edn. Wiley, Hoboken (2016)
5. Amoo, O.T.: Integrated hydrological modelling for sustainable water allocation planning: Mkomazi Basin, South Africa case study, Doctoral dissertation (2018)
6. Loucks, D.P., Van Beek, E.: Water Resource Systems Planning and Management: An Introduction to Methods, Models, and Applications, 2nd edn. Springer, New York City (2017)
7. Hu, Z., Chen, Y., Yao, L., Wei, C., Li, C.: Optimal allocation of regional water resources: from a perspective of equity–efficiency tradeoff. Resour. Conserv. Recycl. **109**, 102–113 (2016)
8. Mantovani, D., Veste, M., Boldt-Burisch, K., Fritsch, S., Koning, L.A., Freese, D.: Carbon allocation, nodulation, and biological nitrogen fixation of black locust (Robinia pseudoacacia L.) under soil water limitation. Ann. For. Res. **58**(2), 259–274 (2015)
9. Hellegers, P., Leflaive, X.: Water allocation reform: what makes it so difficult? Water Int. **40** (2), 273–285 (2015)
10. Basco-Carrera, L., Warren, A., van Beek, E., Jonoski, A., Giardino, A.: Collaborative modelling or participatory modelling? A framework for water resources management. Environ. Model. Softw. **91**, 95–110 (2017)
11. Al-Jawad, J.Y., Alsaffar, H.M., Bertram, D., Kalin, R.M.: A comprehensive optimum integrated water resources management approach for multidisciplinary water resources management problems. J. Environ. Manag. **239**, 211–224 (2019)
12. Sinnathamby, S., Douglas-Mankin, K.R., Craige, C.: Field-scale calibration of crop-yield parameters in the Soil and Water Assessment Tool (SWAT). Agric. Water Manag. **180**, 61–69 (2017)
13. Bayissa, Y., Tadesse, T., Demisse, G., Shiferaw, A.: Evaluation of satellite-based rainfall estimates and application to monitor meteorological drought for the Upper Blue Nile Basin, Ethiopia. Remote Sens. **9**(7), 1–17 (2017)
14. Gutiérrez-Martín, C., Borrego-Marín, M., Berbel, J.: The economic analysis of water use in the water framework directive based on the system of environmental-economic accounting for water: a case study of the Guadalquivir river basin. Water **9**(3), 1–16 (2017)

15. Shahraki, A.S., Shahraki, J., Monfared, S.A.H.: An application of WEAP model in water resources management considering the environmental scenarios and economic assessment case study: Hirmand Catchment. Mod. Appl. Sci. **10**(5), 1–8 (2016)
16. Mekonnen, M., Melesse, A.M., Keesstra, S.D.: Spatial runoff estimation and mapping of potential water harvesting sites: a GIS and remote sensing perspective, Northwest Ethiopia. In: Landscape Dynamics, Soils and Hydrological Processes in Varied Climates, pp. 565–584. Springer, Cham (2016)
17. Jingwei, H., Xingang, F., Rentao, L.: Geospatial techniques for improved water management in Jordan. Water **8**(4), 1–22 (2016)
18. Wicaksono, A., Jeong, G., Kang, D.: Water, energy, and food nexus: review of global implementation and simulation model development. Water Policy **19**(3), 440–462 (2017)
19. Alexandra, J.: Evolving governance and contested water reforms in Australia's Murray Darling Basin. Water **10**(2), 1–18 (2018)
20. Donadio, C., Magdaleno, F., Mazzarella, A., Kondolf, G.M.: Fractal dimension of the hydrographic pattern of three large rivers in the Mediterranean morphoclimatic system: geomorphologic interpretation of Russian (USA), Ebro (Spain) and Volturno (Italy) fluvial geometry. Pure Appl. Geophys. **172**(7), 1975–1984 (2015)
21. Drogoul, A., Huynh, N.Q., Truong, Q.C.: Coupling environmental, social and economic models to understand land-use change dynamics in the Mekong Delta. Front. Environ. Sci. **4**, 1–19 (2016)
22. Ahn, S.R., Park, G., Kim, S.J.: Assessment of agricultural water supply capacity using MODSIM-DSS coupled with SWAT. J. Korean Soc. Civil Eng. **33**(2), 507–519 (2013)
23. Ezzati, S.: Geospatial multicriteria decision analysis in forest operational planning. In: Spatial Modeling in GIS and R for Earth and Environmental Sciences, pp. 85–116. Elsevier (2019)
24. Hassan Zadeh, E., Elshorbagy, A., Wheater, H., Gober, P.: Managing water in complex systems: an integrated water resources model for Saskatchewan, Canada. Environ. Model. Softw. **58**, 12–26 (2014)
25. Nguyen, D.C., Maier, H.R., Dandy, G.C., Ascough, J.C.: Framework for computationally efficient optimal crop and water allocation using ant colony optimization. Environ. Model. Softw. **76**, 37–53 (2016)
26. Draper, A.J., Munévar, A., Arora, S.K., Reyes, E., Parker, N.L., Chung, F.I., Peterson, L.E.: CalSim: generalized model for reservoir system analysis. J. Water Resour. Plann. Manag. **130**(6), 480–489 (2004)
27. Greco, S., Figueira, J., Ehrgott, M.: Multiple Criteria Decision Analysis. Springer, New York (2016)
28. Velasquez, M., Hester, P.T.: An analysis of multi-criteria decision-making methods. Int. J. Oper. Res. **10**(2), 56–66 (2013)
29. Bekri, E., Disse, M., Yannopoulos, P.: Optimizing water allocation under uncertain system conditions for water and agriculture future scenarios in Alfeios River Basin (Greece)—Part B: fuzzy-boundary interval combined with multi-stage stochastic programming model. Water **7**, 6427–6466 (2015)
30. Yaseen, Z.M., Fu, M., Wang, C., Mohtar, W.H.M.W., Deo, R.C., El-Shafie, A.: Applcation of the hybrid artificial neural network coupled with rolling mechanism and grey model algorithms for streamflow forecasting over multiple time horizons. Water Resour. Manag. **32** (5), 1883–1899 (2018)
31. Ladokun, L.L., Ajao, K.R., Sule, B.F.: Hydrokinetic energy conversion systems: prospects and challenges in Nigerian hydrological setting. Niger. J. Technol. **32**(3), 538–549 (2013)
32. Nkwunonwo, U., Malcolm, W., Brian, B.: Flooding and flood risk reduction in Nigeria: cardinal gaps. J. Geogr. Nat. Disasters **5**, 1–12 (2015)

33. Safavi, H.R., Golmohammadi, M.H., Sandoval-Solis, S.: Scenario analysis for integrated water resources planning and management under uncertainty in the Zayandehrud river basin. J. Hydrol. **539**, 625–639 (2016)
34. Vieira, E., Sandoval-Solis, S.: Water resources sustainability index for a water-stressed basin in Brazil. J. Hydrol.: Reg. Stud. **19**, 97–109 (2018)
35. Collet, L., Ruelland, D., Estupina, V.B., Dezetter, A., Servat, E.: Water supply sustainability and adaptation strategies under anthropogenic and climatic changes of a meso-scale Mediterranean catchment. Sci. Total Environ. **536**, 589–602 (2015)
36. Rao, Y., Zhou, M., Ou, G., Dai, D., Zhang, L., Zhang, Z., Yang, C.: Integrating ecosystem services value for sustainable land-use management in semi-arid region. J. Clean. Prod. **186**, 662–672 (2018)
37. Chaudhary, A., Gustafson, D., Mathys, A.: Multi-indicator sustainability assessment of global food systems. Nat. Commun. **9**(1), 1–13 (2018)
38. Yates, D., Purkey, D., Sieber, J., Huber-Lee, A., Galbraith, H.: WEAP21: a demand-priority- and preference-driven water planning model: part 2: aiding freshwater ecosystem service evaluation. Water Int. **30**(4), 501–512 (2005)
39. Nwilo, P., Olayinka, D., Adzandeh, A.: Flood modeling and vulnerability assessment of settlements in the Adamawa state floodplain using GIS and cellular framework approach. J. Hum. Soc. Sci. **12**(3), 1–11 (2012)

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