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Using scenario modelling for adapting to urbanization and water scarcity: towards a sustainable city in semi-arid areas

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ABSTRACT

Sustainable development on a global scale has been hindered by urbanization and water scarcity, but the greatest threat is from decision-makers ignoring these challenges, particularly in developing countries. In addition, urbanization is spreading at an alarming rate across the globe, affecting the environment and society in profound ways. This study reviews previous studies that examined future scenarios of urban areas under the challenges of rapid population growth, urban sprawl and water scarcity in order to improve supported decision-making (SDM). Scholars expected that the rapid development of the urbanization scenario would cause resource sustainability to continually be threatened as a result of excessive use of natural resources. In contrast, a sustainable development scenario is an ambitious plan that relies on optimal land use, which views land as a limited and non-renewable resource. In consequence, estimating these threats together could be crucial for planning sustainable strategies for the long term. In light of this review, the SDM tool could be improved by combining the cellular automata model, water evolution and planning model coupled with geographic information systems, remote sensing and Analytic Hierarchy Process (AHP) method. Urban planners could use the proposed tool to optimize, simulate and visualize the dynamic processes of land-use change and urban water to overcome critical conditions.

Keywords: Sustainable, Scenario, Simulation, Urbanization, Water security

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1. Introduction

An important UN summit in September 2015 led to the adoption of 17 Sustainable Development Goals by 193 heads of state around the world. To cope with future threats, such as water shortage, urbanization and climate change, they hoped to achieve these targets by 2030 [1]. Since 2000, more than 2.4 billion people have been living in countries with water scarcity, and this number is expected to rise to 4.8 billion by 2025 [2,3]. In the meantime, approximately half of the earth's population has moved to urban areas, which is expected to increase to approximately 70% by 2050 [4,5]. Furthermore, decision-makers and scientific research institutions should consider the universal aspect of urban sprawl related to land-use change [6]. After coronavirus wreaked havoc on the global system, it is imperative that the global community focus on sustainable development and set priorities to manage global challenges such as urbanization, climate change, poverty and water shortages [7].

In this paper, we review the literature relevant to sustainability, land, water and the environment. The initial collection of papers was conducted using the advanced search option of reliable online databases, such as Science Direct, Web of Science, and Scopus database. In this process, a keyword search based on a topic's title (Using scenario modelling for adapting to urbanization and water scarcity and working towards a sustainable city in semi-arid areas) helped to assemble more than 400 papers related to our research topic. In addition, a Similarity Quality Latest (SQL) filtering process was conducted to obtain the latest articles that covered the research topic and were of high quality. Finally, the Keyword, Sequences and Importance (KSI) technique was used to organize the research [8], dividing the work into three parts: subject, techniques and parameters. It dealt with literature review gradually, from a general to a detailed perspective, like a cone. Figure 1 shows how the SQL technique and KSI method were used in this review.

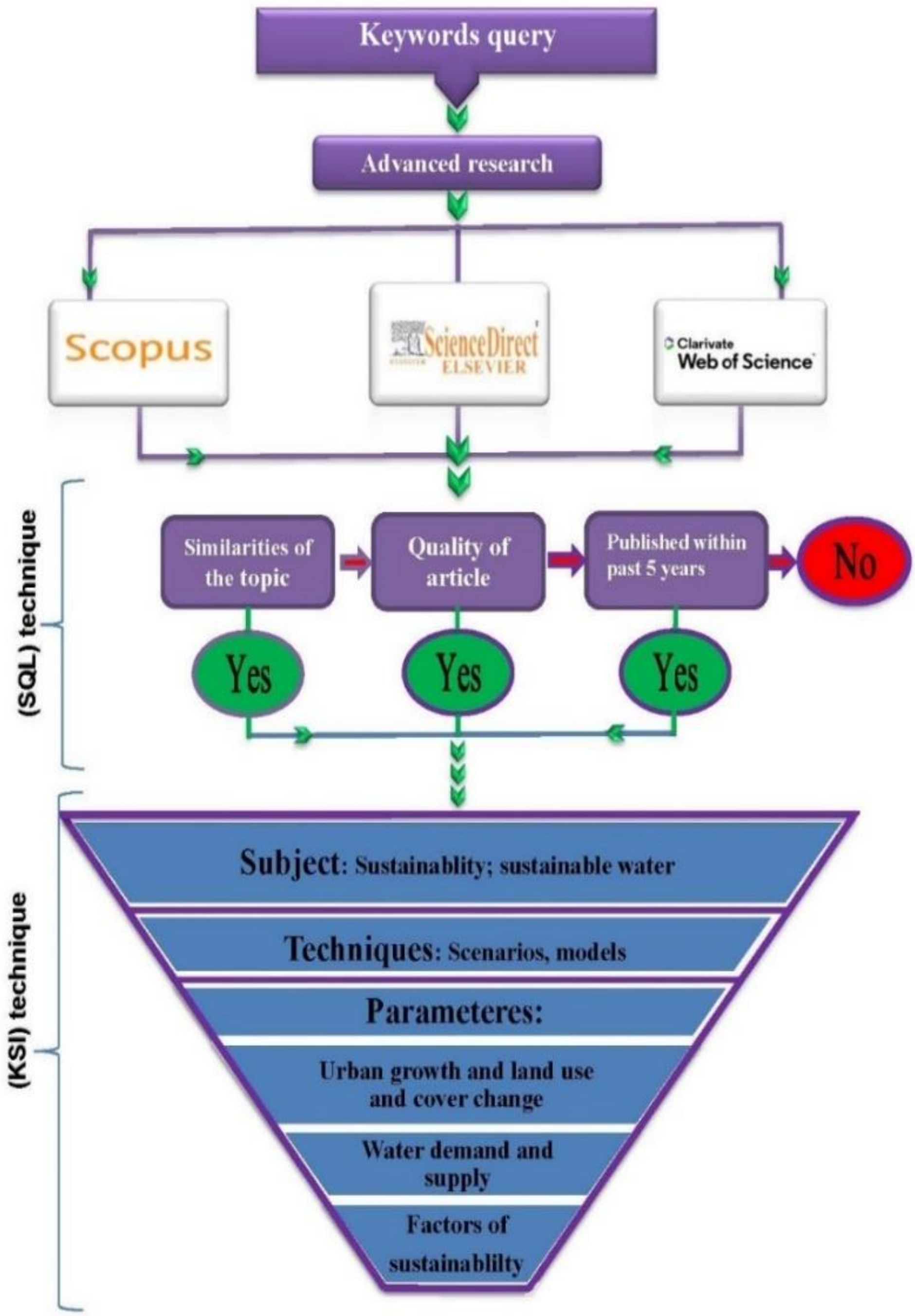

Figure 1. Application of the Similarity Quality Latest (SQL) and Keyword, Sequences and Importance (KSI) techniques to the literature selection process

2. Subject

2.1 Sustainability

The Cambridge Dictionary defines sustainability as "the quality of being able to continue over a period of time" [9]. The sustainability concept has been presented as a way to achieve a balance between economic development and exhaustion of natural resources in city logistics. Accordingly, sustainability indexes rise from the philosophy to define a development that provides the present social and industrial demands and conserves resources for future generations [10]. This concept was practiced by most ancient civilizations, such as the Mohenjo-Daro, Mesopotamians, Romans and Chinese [11]. Likewise, in recent years, sustainability has attracted authorities and urban planners [12]. It has been an irresistible objective for environmental issues in the circumstances of accelerated urban growth, and many studies have devoted efforts to supporting sustainable urbanization [13].Therefore, sustainability is a collective-action puzzle considering the significance of environmental issues, economic growth and social equity concerns on citified scales [14].

However, the conflict between sustainable development and urbanization poses a major puzzle around the protection of human beings and the earth's future [15]. Whereas rapid urbanization has caused excessive exploitation of natural resources [16], sustainable development is a fundamental goal that must be achieved to prevent the exhaustion of these non-renewable resources [17]. Furthermore, water consumption has increased worldwide because of rapid urbanization, population growth, and climate change. Although critical water shortage, dryness and severe weather phenomena, unsustainable water use is still dominant globally [18].

2.1.1 Sustainable water

Due to the emerging challenges of water resource management, which represent climate change, urbanization and resource scarcity, most regions of the world have faced acute water shortages [19,20]. In addition, many issues, such as rapid population rise, industrial growth and urban sprawl, have led to swelling water demands to the point that it is impossible to satisfy them [21,22]. However, sustainable urban water with decreased uncertainty in supply and demand will remain a significant element in citizens' lives and cities' resilience in the face of drought [23]. Therefore, predicting water supply and demand quantities is an essential process to secure urban water for the short and long term in a sustainable city framework [24].

Although water supply management is essential to guarantee the sustainability of natural resources, the standards of sustainability demanded for intergenerational (cross-generational) equity have not been incorporated into water distribution problems [25]. Consequently, urban planners often face the challenge of integrating all the possible water resource management methods for achieving sustainable solutions under different scenarios [26]. Fan et al. (2020) stated that the setting of quantitative indices for sustainability is possible by using environmental security scenarios [27]. Therefore, improving the water management systems by connecting flexibility with urban planning is an important task in enhancing the sustainability of cities and improving their society's resilience [20].

3. Techniques

3.1 Scenarios of urbanization and water management

Most previous studies have not fully considered the impacts of urbanization and water use on land use and cover change (LUCC) policies to refine current land-use procedures and strengthen the integrated management of land and water resources. Comprehensive evaluation of these impacts is still lacking, and this will be a challenge in the future [28]. Although creating and proposing different scenarios and setting various parameters are necessary for urban sustainability, scenario-based land-use simulations have not adequately considered environmental security [16,29].

The land use and cover simulation that takes into account the environmental constraints and societal superiorities provides significant outcomes that support decision-makers in sustaining biodiversity and affording ecosystem services to communities [30]. Such perspectives help to increase knowledge about the ecological consequences of growing pressures for additional investigation as methods of gaining awareness of future threats [31]. However, predictive scenarios of (LUCC) could be applied for simulating both urbanization and water management, these scenarios drive decision-making alternatives for those who pursue sustainability and guide urban growth with enhanced sustainability [16,32]. Although alternative land-use scenarios, such as the Business as Usual Scenario (BAUS), Ecological Protection and Rapid Urban Development, are appropriate in forecasting (LUCCs), none of these three scenarios alone can describe all the probabilities that could happen in the future if climate change situations and political indications are not consolidated into the expected LUCC simulation [33].

In the context of the sustainability concept, scenarios that cover the two essential dimensions of sustainability (economic growth and ecological security) provide tangible evidence to countries' leaders of the feasibility, opportunities and difficulties associated with achieving long-term sustainability goals [34]. Therefore, strict environmental policies should be considered in scenarios that cannot follow the reference scenario, in which current growth patterns would proceed with no change [35,36]. Moreover, desertification and water insecurity scenarios could explain the relationship between land-use policy, water degradation and migration residents [1]. Therefore, scenarios of protecting water resources and green space under homogeneous urbanization could help to reduce water deficit issues in semi-arid countries [37]. In addition, they should consider various climate change scenarios to guarantee sustainable water management [38].

Consequently, to support the spatial-temporal forecast capability of the models in supervising planning and policy efforts, more studies are required to simulate expected land use following various scenarios through anticipated financial, social, demographic, geophysical and climatic situations [39]. Furthermore, future research should examine any accomplishments of ecological sustainability to orientate governance of ecological sustainability in order to improve innovative activities and sustainable urban plans [14]. Likewise, Ruben et al. (2020) recommended following the governance (Gov) scenario for the long term, as it is ecologically sustainable and economically useful for the regions that have been faced with runaway population growth and fast urbanization problems [40].

3.1.1 Types of scenarios

Although many scholars and authors have used various scenarios to predict future situations under conditions of water scarcity and rapid urbanization, they have not taken into account the problematic effects of land-use changes. They have only promoted environmental assurance aims, without considering the future uncertainty and the results of human activities [33]. Four development scenarios simulated by Li, Ouyang and Zhu (2021) demonstrated that the size of development areas would be the largest in applying the economic-centric scenario, whereas an environment-centric one would achieve optimal land use and the highest environmental indicators [41]. Moreover, another four possible scenarios – a desert, an urban area expanded into desert lands, a city extended into agricultural lands and a green landscape – were presumed by Wang et al. (2019), who determined that urban–agriculture conversion provides a suitable method of boosting the sustainability of water [23].

Furthermore, land-use scenario dynamics have been used to adjust the urban landscape pattern and to avoid filling critical natural territories and corridors [42]. Likewise, cultivated land protection has positively impacted the effects of land-use change on ecosystem services [43]. Although a scenario of urban densification has been a suitable solution due to limited land and to reduction of greenhouse gas emissions [44], it increases air pollution, which extensively accelerates pandemic spread [45]. Therefore, policies related to reducing environmental pollution and protecting ecologically sensitive areas should be prioritised in drawing sustainable development goals [31].

In urban water management, what-if-scenario analysis (WISA) is usually used to evaluate water management options to understand, assess and analyses any possible future situation created by increasing the irrigation water supply [46]. Traditionally, urban planners have used the worst-case scenario for creating water distribution systems to improve the reliability of their plans [20]. However, various possible water situation scenarios can

be established using the water evolution and planning model (WEAP) to support the water management policy [47]. It is necessary to observe the parameters for setting these scenarios to obtain precise results [21].
The similarities and differences between the results of various scenarios dealing with urban growth simulation from different viewpoints could support decision-makers in selecting the most suitable solutions [48]. In addition, scenarios based on spatial analysis offer scientific support for environmental development [13]. Therefore, developing scenarios using simulation and optimization modelling can help in the long-term urban planning and management of water resources [49].

3.2 Simulation and optimization models

Simulation of land use land cover changes (LUCCs) in urban areas and their surroundings has been a highly useful tool for supporting sustainable urban planning [41]. Although scholars have recognized that the functionalities of spatial modelling and optimization techniques are important in composing conversion scenarios and optimizing intelligent city operations, such functionalities are regularly omitted from application software notions [35]. If these kinds of technique can be operated in real time, common traditional methods may be abandoned [50]. It has proved that land-use simulation and optimization models support the accuracy of the water-simulation models by defining water consumption for each type of land use and adding detailed information [51].

One of the most common simulation models of land use and cover is the cellular automata (CA) model, which contributes to the generation of a decision support system tool used as a specialized knowledge-based tool [52]. Additionally, the CA model based in Metronamica software can aid in improving planning and management strategies related to spatial analysis with a long-term perspective [12]. Likewise, the spatial simulation model of a Future Land Use Simulation (FLUS) model has been applied into a graphical user interface (GUI) software (GeoSOS-FLUS) utilized by Li, Cheng and Han (2020), it is an integration of two techniques for simulating (LUCC) [33]. The first was CA simulation, which can indicate the built-up status in the case of sprawl at the expense of other land-use classes for subsequent years [53]. The other technique was the Markov Chain, which can optimize several efficient environmental planning and management policies [38]. While the combined cellular automata and artificial neural network (CA–ANN) model is the most appropriate and effective technique for simulating difficult (LUCCs) classes for study [53], the integration of criteria analytical hierarchy process (AHP) modelling and CA and Markov Chain (CA–Markov) can be applied to simulate the LULC dynamics and develop a scenario-based LULC prediction for sustainable urban growth [32]. Therefore, optimization and simulation models should be developed to achieve high resolution utilizing spatially implied or outright models such as CA to ensure optimal land use in the planning phase and also in intervention plans [30].

WEAP is a system for modelling and simulation that can offer certain advantages for evaluating water systems. This system is modelled as a collection of water demand, supply and transmission objects [54]. In addition, WEAP contains algorithms that utilize climate time-series data and simulates the rainfall runoff of basins and sub-basins [55]. Moreover, it can simulate fine details such as river runoff, water intake points and water transfer distances. Furthermore, compared with measurable general equanimity models, WEAP models are user friendly and have easier operation systems [56]. This offers an integrated approach for deploying a water-balance database and a scenario-generation tool to evaluate water management policies and stakeholder processes [57]. Another integrated model is river basin planning and management (RIBASIM), which supports water planning to allocate scarce water at the river basin level and performs efficient simulations for analysing water supply and demand based on different possible scenarios in order to achieve sustainable water management [58]. Additionally, it enables a manual optimization of the systems by changing the source of the water supply [59]. (RIBASIM) is often used as a robust means of implementing the water-accounting process in any case study

[60]. Although there have been many different water simulation and optimization models, techniques that combine water quality and quantity are rare [25].

Other models have been applied by many scholars. Genetic algorithm-based flexibility optimization (GAFO) was developed by Tsegaye, Gallagher and Missimer (2020) in Visual C++ programming language and linked with EPANET system software for the design of water distribution systems that are more adaptable and to recognize uncertainties [20]. Similarly, Jha, Peralta and Sahoo (2020) integrated the groundwater flow simulation model (GFSM) with optimization models to develop favourable exploration-scale water management policies [49]. Moreover, Handayanto et al. (2018) used NARXNET and the land change modeller (LCM) for simulating LULC change, while a combination of genetic algorithm (GA), Particle Swarm Optimization (PSO) and a local search was applied to achieve the optimum land use [61]. Additionally, Elliot et al. (2019) built a combined model that includes the multi-objective integer linear programming (MILP) model along with (LUCCs) implementation scores for enhancing the collection of locally supplied urban ecosystem services (UES) [62]. In future models, more and better local factors than are used in the abovementioned models, such as population distribution dynamic and accessibility, should be incorporated to support the decision-making operation regarding land-use allocation [12,63].

Finally, advancements in remote sensing (RS), GIS technology and spatial models, and also available open-source data, have formed powerful tools for exploring detailed features of the earth and for estimating future LULC change [53]. A geospatial analysis model that takes advantage of the integration of GIS and RS can provide a cost-effective method of creating evidence and help in the design of solution-orientated support systems [1]. GIS is a powerful tool for simulation and optimization in order to support sustainable development decisions in urban areas [64]. Therefore, the integration of RS techniques and GIS should be used to support the water resource modelling software by providing precise geospatial data [47].

Consequently, scholars should develop urban sustainable progress scenarios and improve the management of massive data sets to connect various observation scales in order to enhance land-use policy at a global level [65]. Moreover, future studies should quantify the economic costs of these optimizations and land-use and cover transformations [62]. In addition, the quality and the quantity of water should be integrated into a comprehensive intergenerational (cross-generational) resource management methodology [25]. Likewise, optimization models should be enhanced with local factors such as population and accessibility in order to improve the decision-making to achieve sustainable development [12,63]. To improve the optimization model, some open-source software can be used, such as GeoSOS for ArcGIS, which provides the complete functions for optimizing, simulating and visualizing the terrestrial model and dynamic process. This is a user-friendly system for running a CA simulation process [66].

4. Parameters

4.1 Urban growth and land use and cover change

Geospatial analysis models have contributed significantly to understanding the urbanization level that has damaged the environment and abused natural resources [52]. Although world leaders and international organizations on multiple occasions have been anxious to challenge tremendous urban sprawl growth combined with accelerated urbanization [1], the fast urbanization process has taken place across the earth at an extraordinary level, and its severe consequences on the environment and societies are evident [31].

Simulation models showed that the scale of urban development areas will swell under the status quo scenario for subsequent years, while urban sprawl will expand under an economic-centric scenario [41]. In addition, the accelerated urbanization scenario would lead to diverse problems, such as exhausting land resources, damaging ecosystem services and degrading sustainable development in most parts of the world [43]. However, the accelerated population growth, the expansion of infrastructure and the development of rural areas have increased in built-up areas worryingly; consequently, various sustainability projects have been obstructed [16].

Moreover, the total effect of driving factors, climate change, fast urban sprawl and high-density populations have increased the danger of water shortage and reduced agricultural production [23]. Meanwhile, environmental conditions have been significantly affected by these factors; for example, water quality degradation, change in domestic microclimatic circumstances and heat island impacts. Furthermore, water deficit and climate change have strongly affected rural–urban migration [1]. Therefore, monitoring the changes in classes of (LULC) at the expense of water bodies has been crucial for controlling natural resources and delivering fair sustainability [40].

Therefore, planners and scholars should analyse ecological sustainability performance for orientating sustainable urban designs for developing creative accomplishments [14]. In addition, they should also improve techniques for controlling land-use planning and ensuring the security of natural spaces in a sustainable framework [51]. BY improving land-use processes, the world could improve flexibility to manage and control the COVID 19 pandemic [67].

4.1.1 Urban growth and the COVID-19 pandemic

The furious spread of the coronavirus pandemic has obliged the international community to seriously think about how people behave, either in urban areas or in the country [68]. COVID-19 has highlighted the sensitive relationship between the pillars of sustainability: environmental, social and economic factors. Each one depends on the other [69]. Therefore, its rapid spread worldwide has drawn attention to interdisciplinary research in urban design and public health [70].

The most significant factor that has bred favourable conditions for the COVID-19 pandemic has been mismanaged urban growth, which has caused the loss of biodiversity in the ecosystems. Poor urban Planning has caused the demolition of wildlife communities, the increase of contacts of humans with wildlife, and alteration of the niches that host viruses, which have increased the chances of viruses contacting humans [71]. In addition, the pandemic was extremely severe in megacities, where rapid urban growth has led to serious issues of accessibility to public facilities and limited provision of medical services [72]. Consequently, decision-makers should consider the initial assumptions of urban planning, which proposed that people should move to rural areas to avert the disasters of the megacity [73].

Although rules of social distancing have affected people's access to their rights in enjoying affordable, open, green spaces during this phenomenon [74], the lockdown of towns has noticeably increased remote business meetings, which were seldom used previously. This could advantageously decrease the demand for mobility and thus reduce atmospheric emissions; therefore, planners could exploit this advantage in future urban planning [75].

Consequently, the COVID-19 crisis could supposedly change the concept of urban densification as an alternative solution for the rapid urban sprawl [73]. The high-density population has been the biggest obstacle that has faced the epidemic control measures [45]. In addition, it increases air pollution, which in turn extensively increases pandemic spread [76]. Although a polycentric urban scenario could have various consequences on socio-economic growth and environmental methods at different scales, it may be more suitable for controlling the isolation and quarantine in this pandemic [77]. Therefore, in response to periodic epidemics, it is recommended that planners return urban design to a healthy city model that is capable of accommodating different healthy activities in order to manage the crisis [70,78].

4.1.2 Land use and cover change

Although optimal land use has been a significant obligation in the field of regional and urban planning due to land being a non-renewable resource [15], land-use and cover analysis indicators collected by spatial analysis modelling have demonstrated that substantial green areas have been converted into built-up areas [40]. The building areas were extended at the cost of the other use classes to facilitate the dynamic economy [43].

Previous studies indicated that poor land use has continued worldwide. For example, Gong and Liu (2020) stated that the results of implementing scenarios of "no land-use policy" and "land-use policies" were highly counteractive. While urbanization was dominant in the first, urban built-up areas, forests and water bodies were prevalent in the second scenario [28]. Likewise, Ruben et al. (2020) observed that, under the Government Designated Scenario, green areas and water bodies have increased, while under (BAUS), built-up regions have increased at the expense of the green areas [40]. Furthermore, Li, Cheng and Han (2020) showed that, under the rapid urban development scenario, built-up areas would expand at the expense of green and water spaces during the period from 2015 to 2030, while forests would grow under the scenario of ecological protection during the same period [79]. Similarly, Yatoo et al. (2020) indicated that the built-up areas have increased at the expense of water bodies, open spaces, agricultural land and urban vegetation [53]. Therefore, models of spatial analysis of LULC have confirmed that accelerated urbanization has continued to be a significant challenge for regional and global sustainability [51,80].

Unlike rapid urban development, governance scenarios with precise control inside urban areas have led to the largest dispersion average; as a result, more sustainable development could be achieved in the study area [12]. Furthermore, the balanced economic scenarios that consider the sustainability goals have shown better results in terms of achieving the optimal land-use and cover patterns [48]

4.2 Water supply and demand

The drought crisis has been the primary reason for wars and conflict between riparian countries due to the lack of regional laws or local agreements about sharing water resources [46]. Water shortage plays a deciding role, because the quantity of water is not enough to meet all water uses [81]. Therefore, the sustainability of water resource systems requires increased consideration of the negative impacts of population growth and climate change, and it needs additional coordination of international and local priorities [19].

The high population growth and gas emission levels have been the factors most directly affecting natural resources and the climate; in addition, socio-economic developments have threatened potential water demand increases [52, 82]. Moreover, urban densification has put pressure on water resources and has also damaged the water distribution system, which forms approximately 80–85% of a water supply system [20,44]. Consequently, the increase in water demand ratio has been for the residential sector, which forms approximately 41% of a whole city's water demand [26].

Sustainable management has been required to avoid the drought hazard using optimal solutions [38]. Decision-makers should seriously discuss the options available for developing wastewater reclamation, considering environmental and financial matters [23]. Therefore, the sustainable urban planning model could efficiently alleviate the overall impacts of regional urban dynamics on water supplies [42].

4.3 Factors of sustainability

Due to continued uncontrolled and random urban growth, which has damaged environmental spaces and land-use sustainability systems, the quality and quantity of natural resources have severely degraded [38]. While urban development seeks economic land revenue, sustainable urban planning attempts to secure existing natural resources and create incremental value for environmental products [17].

The degree of sustainability is associated with the place's condition, natural features and socio-economic development [83]. The most comprehensive and combined measurement for this degree is the compound index that considers the balance between economic growth, urban environment and social consistency [65]. Furthermore, the primary means of ensuring this balance is a water resource management strategy for the long term [46]. Therefore, a comprehensive understanding of all economic, social and environmental issues is the key to ensuring sustainable water [21].

4.3.1 Environmental factors

As a sustainability management system is a cornerstone of environmental protection, a deep understanding of the socio-economic implications for all aspects of ecological sustainability requires further assessments in an incorporated framework of spatial modelling [14,23]. However, enough awareness of environmental risks could be achieved by simulating and optimizing modelling in urban areas to avoid adverse sprawl effects and other sources of environmental degradation [61]. Therefore, the broad and long-term vision of the urban area is necessary to help in drawing up sustainable spatial planning policies to refine environmental risk assessment [29].

Sustainable planning is critical in considering the inter-regional exchange amidst the urban development and eco-environmental protection scenarios [83]. In addition, the land-use situation under the environmental protection scenario was found to be more contributory than the urban development scenario for preserving and recovering natural areas and achieving sustainable development of ecosystem services [43]. Therefore, strict environmental restrictions should be imposed to protect natural resources, reduce water pollution and ensure sustainable land use [25,41].

5. Summary of the literature

The urbanization phenomenon has seriously impacted the earth's sustainability, and its impact on the environment and society is apparent. In recent years, this problem has prompted scholars and researchers worldwide to warn authorities about the consequences of such threats, and many models and techniques have been used to estimate the dimensions of these threats under different scenarios.

In previous studies, three main scenarios were commonly used. The first, BAUS, assumes that nothing will change in terms of human activities and circumstances. Under this scenario, most of the results showed that climatic change, urbanization and rapid population growth were the main factors driving the consumption of natural resources to the point of exhaustion. In addition, these factors have led to an unprecedented increase in water demand. As a result, sustainable management of drought risk is currently necessary. The second scenario was rapid urbanization. Under this scenario, urbanization would continuously threaten resource sustainability because the natural resources would be exhausted too quickly. In contrast, the third, the sustainable development scenario, is an ambitious strategy that relies on land-use optimization and assumes that land is a scarce, non-renewable resource.

Further studies should be conducted to improve the optimization model in order to obtain high geographical accuracy using spatially implied or outright models, such as the CA model, to specify the best sites for land-use change [30]. The CA model contributes to building a decision support system tool used as a specialized knowledge-based tool [52]. Additionally, integration of AHP modelling and CA–Markov can be applied to simulate the LULC dynamics and develop a scenario-based LULC prediction for sustainable urban growth [32]. However, the combined CA–ANN model is the most appropriate and effective technique for simulating difficult LULC classes for study [53].

Although the use of CA software, such as Metronamica and SLEUTH, as experimental and management tools for simulating land-use changes over time has been widely documented, there are few available applications in the open-source community with full functions. However, open-source software can be used to improve the optimization model, such as GeoSOS for ArcGIS, which provides the complete functionality for optimizing, simulating and visualizing the terrestrial model and dynamic process. It is a user-friendly system for running a CA simulation process [66].

WEAP is a system for modelling and simulation that can offer certain advantages for evaluating water systems. This system is modelled as a collection of water demand, supply and transmission objects [54]. WEAP contains algorithms that utilize climate time-series data and simulates rainfall runoff of basins and sub-basins [55]. Another integrated model, RIBASIM, performs efficient simulations to analyse water supply and demand based on different possible scenarios in order to achieve sustainable water management [58].

Furthermore, recent advancements in RS, GIS technology and spatial models and available open-source data form powerful tools for exploring detailed features of the earth and estimating future LULC change [53,84]. Moreover, a geospatial analysis model that takes advantage of integrating GIS and RS can provide a cost-effective method of creating evidence and help in designing solution-orientated support systems [1].

Accordingly, a hybrid model can be further improved by using a Cellular automata (CA) model in combination with WEAP and the integration of GIS and RS, as well as Analytic Hierarchy Process (AHP) method. It is a tool that is used for supporting real-time decisions (supported decision-making [SDM]), which allows urban planners to optimize, simulate and visualize spatial models and land-use change and water supply and demand dynamics. Table 1 includes examples of models and scenarios that have been commonly used in previous research.

Table 1. Examples of models and scenarios used in previous studies

Study	Models	Scenarios
[13]	• Future urban regional environment (FUTURE) • Integrated valuation of environmental services and trade-offs (InVEST)	• Status quo (SQ) • Urban planning development (UPD)
[36]	• The land-use evolution and impact assessment (LEAM)	• Reference scenario (RS) • Agricultural preservation (AP)
[85]	• Inquired land assignment (ILAM)	• Sustainable optimum land use allocation • Optimum urban development land use allocation • Optimum urban land uses allocation
[17]	• Cellular automata (CA) and gap rent theory	• Natural development (ND) • Government designated development (GO) • Geological protection (GP)
[32]	• Cellular automata (CA), Markov chain (Markov) and multi-criteria analytical hierarchy (AHP)	• Ecologically sensitive (ESS) • Business as usual (BAUS)
[43]	• The integrated valuation of ecosystem services and trade-offs tool (InVEST) and land use and its effects at small region extent (CLUE-S)	• Reference scenario (RS) • Rapid urbanization (RU) • Ecological security (ES) • Cultivated land protection (CLP)
[40]	• Cellular automata (CA) and Markov chain (Markov)	• Business as usual (BAUS) • Governance (Gov)
[39]	• Future land use simulation (FLUS) and Markov	• Ecological protection (EP) • Natural Growth (NG)
[33]	• Markov chain model and cellular automata (GeoSOS) and Future land use simulation (FLUS) • Integrated valuation of ecosystem service and trade-offs (InVEST)	• Business as usual (BAU) • Ecological protection (ELP) • Rapid urban development (RUD)
[47]	• Water evolution and planning (WEAP)	• Reference scenario (RS) • Future scenario • Scenario combinations under the normal population growth rate using RCP 4.5 future climate data
[58]	• River basin planning and management (RIBASIM) and the genetic algorithm (GA) optimization model	• Various scenarios

6. Conclusion

The onset of COVID-19 sounded the alarm, signalling the urgent need for all countries to commit to sustainable development and improve priorities for managing global challenges like urbanization, climate change and the provision of clean water. Moreover, this pandemic could change many concepts used as alternatives in solving urban planning problems. While urban densification will increase air pollution, polycentric urban methods could be improved to control it more effectively. As a consequence of this shift in priorities, simulation and optimization models need to be improved to enable the prediction of future urban areas with high geographic accuracy in order to specify the best locations for land-use and fair water allocation. Therefore, an improved hybrid model could be devised by joining the cellular automata model (CA), water evolution and planning model (WEAP) coupled with GIS, RS and Analytic Hierarchy Process (AHP) method. This could optimize, simulate and visualize the dynamic processes of land-use change as well as water supply and demands to overcome critical conditions.

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