A critical review on scale concept in GIS-based watershed management studies

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Abstract Watershed management is critical in achieving sustainable development for water resources. Geographic information system (GIS) provides efficient functions to store, retrieve, analyze, and display spatial data. Therefore, GIS is used to develop watersheds' decision support systems (DSS) to find useful ways of solving waterbodies' problems. Studies on watershed problems need considering both biophysical conditions and information on human–environment relationships, which points to the need to deal with different geographical fields. Definitions of scale in each field and making clear connections among them is essential for having comprehensive and practical water management plans. These scales are spatial, social, and political scale. However, in studies on developing a DSS for watershed management, there is a gap in defining social and political scales and aligning them with spatial scale, which can be a barrier to have concrete and integrated watershed GIS-based DSS's. This study reviews papers in dominating fields of GIS-based DSS's for watershed management and provides proof that studies have focused only on spatial scales, while social and political scales are considerably neglected. This paper aims to point to this problem by reviewing relevant papers, elaborating some critical issues arisen from this neglect, and suggesting some future directions.

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1 Introduction

The water supply, which is water for households and businesses, livestock, crop irrigation, and rural industry, is the part of freshwater that is the focus of hydrological studies since human activities have been posing threats to both the quality and the quantity of their sources such as lakes and rivers. The overuse of freshwater such as excessive demand and inefficient water use has caused decrease in the quantity of water supply sources, and the pollution from point and non-point sources has caused the degradation of the quality of water supply sources. Therefore, there is a need for comprehensive, multi-source, and integrated plans for mitigating water pollution and providing a balance between demands and needs through watershed management [1]. Every single point on the land surface belongs to at least one watershed, which is also called catchment, drainage basin, or basin. Watershed is a part of the land in which the land's receiving precipitation or streams flow to the same outlet due to the topography of the watershed. Due to the fact that the watershed boundaries can be measured using widely available topographic data, and also because in each watershed all the streams flow to the same outlet in which the amount of available water from receiving precipitations can be measured, watershed has become the land units for water supply management [2].

Watershed management is a coordinating framework for environmental management; watershed management is about using of soil, water and vegetation in a way that not only conserves the natural resources but also maximizes the productivity of the lands by focusing on the hydrological linkage between the shared and individually-organized areas [3]. Since a watershed is part of the land that is used for agriculture, manufacturing, and other human

activities, watershed management is important not only from an economic point of view because of optimizing environmental services for human uses but also from a political perspective because of simplifying resource management for policymakers [4]; Therefore, watershed can be described as a hydrologic unit, a physical-biological unit, a socio-economic and socio-political unit used for implementing resource management activities [5]. As a result, in watershed management for planning and implementing a set of actions to preserve natural, human, and other resources, considering social, political, economic, and institutional factors within the watershed is crucial [6]. Therefore, it is essential to work with social, economic, and political concepts along with data providing necessary information for modeling watersheds hydrological behavior [7]; Which means we need an integrated and collaborative watershed management, and for achieving it, we need to model both the hydrological behavior of watersheds and the human–environmental interactions.

Water quality and the quantity problems in watersheds are embedded in space and time. In terms of modeling the hydrological behavior of watersheds, in watershed management, geographic information systems (GIS) has an important role, especially in water quality modeling and in visualizing impacts of implementing management scenarios. Sophisticated spatial analyses in GIS and its ability to work with accurate digital data, are two valuable features for deriving drainage networks and flow paths in watershed management systems. Besides, GIS has high interoperable software environment, and it can be used as a web-based platform for real-time analyses that can bring communication between different organizations [8]. One of the important aspect that should be considered in the geographical problems, such as watershed problems, is spatial scale definition. For example, for watershed management, questions such as (1) at which scale decisions can be made? (2) which scale is appropriate for watershed management? and (3) how we can deal with multiple scale considerations? Should be answered in finding a potential and applicable solution for water quality and the quantity problems. The spatial scale is a fundamental concept in geography, and it creates a link between an object and its representation in the modeling environment. Therefore, it provides key information for geographical models and policy makers [9]. In addition, specifically in the watershed management field, proposing appropriate spatial scales is essential for having comprehensive watershed models.

Along with hydrological models representing watersheds' behavior, we also need to have models representing human–environmental interactions. Although GIS is an inseparable component in the watershed management field, it cannot fulfill all the needs in the watershed management and planning domain such as dealing with both hydrological models and human-environmental related models. Therefore, with GIS, spatial and non-spatial data, computer-based biophysical models and knowledge-based (expert) systems are needed, which all can be handled by a watershed management decision support system (DSS). GIS-based decision support systems aiming at making comprehensive decisions for spatial problems, are powerful systems that we need in the watershed management field [10]. Decisions in watershed management decision support systems can be made by utilizing GIS models such as GIS-based hydrological models and models representing the interactions between human and environment along with using objectives, preferences, and constraints introduced by different organizations and policymakers. Backing to modeling the human-environmental interactions in watershed managements, aside from the spatial scale, ecological, social and political scales also needed to be defined explicitly to make connections between the ecological, social and political domains with the environment, which is the spatial domain [11]. The main issue is the fact that modeling the interactions between human communities and watersheds is complex and dynamic and it is affected by the scale of the examination. The equitizing of socio-economic and political boundaries with the boundary of the studied watershed is the other issue that must be considered [12]. Although there is a huge stress on clear and explicit definitions of spatial scale, ecological, social, and political scales and making connections among these definitions, most studies have failed to have such definitions. Due to either neglecting social and political scale definitions or not having a clear definition for the spatial scale of the study areas, we see that GIS-based decision support systems proposed in studied to help decision-makers in the field of watershed management either fail to be implemented or fail to achieve comprehensive decisions to conserve watersheds from the mentioned associated problems. The objective of this review study is reviewing papers in dominating fields of GIS-based decision support systems for watershed management research and providing proof that most of these papers have focused only on physical geography scales, which are spatial and temporal scales, and human geography scales such as social and political scales are considerably neglected. While there is a huge need to define social and political scales and aligning them with spatial scale to have an integrated decision support system, which can be implemented to solve the aforementioned water supply problems, working on this side of the problem is procrastinated so far that can be a huge barrier to have a concrete, efficient and practical GIS-based DSS for watershed management. This paper aims to pointing to this problem by reviewing relevant papers, elaborating some critical issues arisen from this neglect, and suggesting some future directions.

2 Geographical conceptualization of scale

The concept of scale helps us to have vivid geographical imaginations, which empower us to understand the spatial aspects of the world around. Since geography has two broad subfields, which are human and physical geography, and in each subfield, there are many other fields of interest such as political, social or GIS interests, there is not an agreement on what *geographical scale* means. Therefore, multiple definitions of scale are introduced in different geographical subfields. However, Howitt (1998) stated that in geography, the scale has referred as either *size, level or relation*. Scale as the size is mostly used in physical geography, while scale as level and relation are dominant ones in human geography [13]. Since the focus of this paper is on GIS-based decision support systems for watershed management, scale definition in geographic information science (GIS) and in social and political geography are explained.

2.1 Scale from the perspective of a physical geographer with GIS interest

The accurate definition of scale is GIS is fundamental since all the transformations, analyses, and manipulations in GIS are scale specific, but what should be considered in the scale definition in GIS is the semantic of scale to users of GIS. Based on working with either analog data or digital data, there are three definitions for scale in GIS. Analog data is used for creating maps on paper sheets, and in this case, scale means the ratio between a distance on a map and the corresponding distance on the ground; This ratio is for showing the amount of positional accuracy on maps. However, rapid advancement in geomatics technology and increase in the use of computers as the main tools in scientific studies lead to the emergence of digital datasets in GIS, which can be analyzed, manipulated, and visualized in computers. Scale in digital GIS can be either the extent of a study area, mainly the extent in space or time, or the data resolution, the degree of detail in the spatial and the temporal dimensions [14]. But the question is which definition is used in which situation? For answering this question, we should know that for space representation of geographical reality in digital GIS, object and field conceptualizations can be used. Object conceptualization, which is also called discrete object conceptualization, is used for representing discrete objects such as buildings and trees. These objects can be shown as points, lines, areas, or volumes depending on their size and the purposes of the study. Field conceptualization is used for representing continuous phenomena such as topography [15]. Depending on the nature of data, the available software and various available types of

analyses and models, both conceptualizations can be represented either as vector or raster datasets. In vector and raster datasets, most of the time, scale as the extent of the research area is an implicit definition, and the focus is mostly on defining the scale as the resolution. However, for raster datasets, the definition of scale as a resolution is implicit as well since it is defined as the size of the raster cells, which are almost always squared in the two-dimensional case. Regarding vector datasets, in point datasets, distance between two points is used for defining the resolution but the problem is deciding about which concept of distance (minimum, mean, maximum, or nearest neighbor distance) should be used. For line and polygon datasets, we can specify a rule that if there are a great number of areas and volumes, and the boundaries are detailed, then we have a fine resolution in those datasets; otherwise the resolution is coarse [14]. Generally, in vector representations resolution is almost always poorly defined. There are two serious problems in scale definitions in GIS. These problems are (1) coarsening (or fining) spatial resolution affect the results of spatial analysis (aggregation of the small areas into larger ones results in a stronger correlation between the variables), and (2) assigning the behavior of a system at coarse scale to fine scale is misleading [16].

2.2 Scale from the perspective of human geographers with social or political interests

Recently, human geographers have profoundly theorized scale since they realized that scale is a foundational element of geographic theory. In these theories, the scale is defined, produced, and transformed by different actors and processes that have different meanings in different time and space [17]. The simplest definition of scale in human geography is the *Hierarchical Scale*. The hierarchical scale is a qualitative/subjective scale that is the level of the representation of social, physical, and political practices. The hierarchical scale is a deliberate classification of the phenomenon that has a vertical scope, and it is important to the social geographers since they need to analyze specific types of socio-spatial activities [18]. The problems with this definition of scale are (1) there are nonhierarchical interactions within multilevel networks of public, private and civil society actors in environmental management programs, (2) there are nonlinear and dependent interactions between different scales [19], and (3) there is a small number of presupposed levels. For example, by using only a "*national*" term to refer to the scale of a place, we are not considering the spatial size, population, economic production, military expenditure, etc. There are relations between geopolitics, territory, structure, culture, history, economy, environment, and society that are not considered in scale as a level definition [20]. Therefore, we need

another definition for scale that is *Scale as Relation* that acts like a network stretching across hierarchical space. Using this definition for complex geographical areas is useful since there are relational and dialectical webs in these areas that are essential for examining special sorts of geographical totalities [13]. Overall, when human geographers are working with scale, the focus of their research should be on scalar practices of social actors instead of on scale as an analytical category and they need to pay attention to the power of asymmetries for understanding nets of relations within and between scales [21]. The last definition of scale that can be applied to social and economic processes is the operational scale. The operational scale is the spatial and temporal scales at which geographical processes happen and itis based on this belief that actual entity independent of the way of observing it [19]. This definition is used rarely in both human and physical geography.

2.3 What are the geographical definitions of scale in the watershed management studies?

Scale in watersheds means either scale as a *hierarchy* or scale as a *magnitude*. When referring to scale as a hierarchy, each watershed is considered in hierarchical relationships with the other watersheds. For example, micro-watersheds are within large or macro-watersheds. On the other hand, when referring to scale as a magnitude, scale means the size of watersheds, the number of hectares that a watershed covers, or from a socioeconomic perspective, the number of people living in it [22] In scientific articles, scale usually refers to a hierarchy, therefore, terms like watershed scale and sub-watershed scale are abundant in these papers. Choosing an appropriate scale depends upon the situation and the objectives, but as a rule of thumb, working on large scales needs improved institutional arrangements and improved technologies. On the other hand, some hydro-logical problems can be addressed while working on large scales such as macro-scale not on small sales [23]. Something obvious about studies in watershed management is that in these papers there is a lack of any definition for social and political scales, and the only scale definition that can be found is the spatial scale. Mentioned studies have been done on three spatial scales, which are (1) watershed scale, (2) sub-watershed scale, and (3) agricultural-field scale. Most of the papers have been focused on the physical geography scales and human geography scales in watershed management are neglected.

3 GIS-based decision support systems in watershed management

In this section, some papers in dominating fields of watershed management research are reviewed. As mentioned before, spatial, and temporal scales are the most attractive scales for researchers in watershed management studies. In the next subsections, watershed management studies in the watershed, sub-watershed, and agricultural field scales are reviewed.

3.1 GIS-based DSS in watershed management: watershed scale

Zhang et al. [24] worked on one of the serious research gaps in watershed management studies, which is the insufficiency of using non-distributed models and desktop-based DSS's in watershed management. The authors proposed a web-based quasi-real-time DSS using (1) pre-generated maps and (2) parallel processing in the simulation stage of the hydrological model by deploying a Hadoop cluster. Scaling up is a feature of their proposed DSS that provides this opportunity to be able to work with any size of watersheds. Although the proposed system is able to technologically process and analyze data from each size of the watershed, there is not mentioned that if there is any policy/rule about how social and political data (human-environment related modeling) can be merged with the spatial data at any size of watershed. The other question is that how a watershed as the scale is defined? how big is it? By one step further, Werts et al. [25] combined the current WebGIS technologies with social media to provide an integrated framework for soil and water conservation programs. For increasing the participation of clients in this WebGIS application, the authors used Microsoft Silverlight that brings the application graphical rendering and processing to the clients' computer. They also enabled commenting on VGI submissions to increase the credibility of the data as well as public understanding and retention of the knowledge. Study in the field of integrating VG information with web-GIS application for decision making in environmental fields is important due to the reduction of government funds to collect data, the burden of data collection and environmental monitoring issues. Besides, conditions in agricultural fields are constantly changing which brings a need for a constantly updating sensor network that is too expensive. Developers should use more volunteering data that are provided by the farmers. Although the proposed system is able to use VG information to get around the data collection/data management challenges, the question is that what about the social and the political data? How are they gathering and at which

scale? Sieker et al. [26] used the concept of the decision matrix in their proposed DSS; the decision matrix is a structured decision space with columns, management objectives, and rows, scenarios of conceivable measures. In their proposed DSS, models such as water and subsurface flow model are implemented to assess the impact of analysis on system dynamics. This DSS can be used by a large group of stakeholders who want to work together on big projects in the watershed management field. But there is not mentioned how the human-environment related models should be developed and how they should get to merge with hydrological models? By focusing on surface water quality management, Sun et al. [27] proposed three metamodels to support decision-making for near-term nutrient load prediction, online sensitivity analysis, and long-term load reduction planning. Three metamodels are developed using the ANN model that works with the output and input of the SWAT model to forecast pollutant loadings, PCM to assess the sensitivity of parameter values, and the uncertainty analysis. A model which is called PLOAD model is also used for checking the impact of land-use changes on long-term pollutant loading. In watershed management, there is a need to work with large sets of parameters containing spatial, economic, political parameters that makes the models so complex; considering it, the strength of this paper is using hierarchical watershed modeling that can be useful for DSS's with different groups of users with different levels of knowledge; so, using the idea of hierarchical watershed modeling is the way of avoiding development of complex models, since for each group of users only some parameters will be used for modelling. But the question is at each level of this hierarchical watershed modeling which spatial, social, and political scales should be used?

Focusing on increasing spatial and temporal resolution by using remote sensing datasets coupled with the geographical information system (GIS), Choi et al. [28] developed a user-interactive DSS to improve the accuracy of soil erosion estimation in hydrological models. In watershed management, local administrators and people collaborate in taking decisions; So, the idea of developing a user-interactive DSS is the strength of this study. Also, the novelty of this study is proposing the engineering measures module that considers some influential factors such as population and political pressures on soil erosion. But, there is a lake of clarification about which kind of datasets in which scales can be used. Sengupta et al. [29] proposed a spatial decision support system (SDSS) that can link the impacts of unconstrained soil loss and soil loss constrained scenarios in an agricultural watershed to the changes in the economy and non-point source pollution. The spatial scale of this study is agricultural watersheds; however, the economic scale is farmers' income. So, there is a scale

mismatch between spatial scale, which is agricultural field here, and economic scale, and the authors did not talk about it in their study. The weaknesses of this study are, not considering the errors and uncertainties of geographic data and models possess error and uncertainty, and also not considering all costs and benefits. Ochola and Kerkides [30] developed a DSS to improve water resource quality. The strength of this work is using both biophysical and socioeconomic factors in developing the proposed DSS; They use a farming systems research (FSR) approach for this goal. The reason for this integration is the fact that sustainable water and land use are functions of various economic, environmental, ecological, social, and physical goals and objectives and the proposed SDSS can connect water and land use practices to hazard management strategies. Although the authors used both biophysical and socioeconomic factors, they have not talked about the scale of integration and the way they have been able to address the problem of social scale mismatch to spatial scale. As we can see in most studies the watershed management field, the area of concentration is the technological part of DSS's. However, some authors mentioned spatial and temporal scales in their study but other scales such as economic, political, and social scale have been considerably neglected.

3.2 GIS-based DSS in watershed management-sub-watershed scale

By focusing on the soil erosion and runoff problems in watersheds, papers focusing on sub-watershed scale mainly are about prioritizing sub-watersheds considering how serious these problems are in each of the sub-watersheds. One of the popular GIS methods used in this regard is the analytic hierarchy process (AHP). Chowdary et al. [31] utilized an AHP based Sediment Yield Index model along with remote sensing and GIS techniques to extract AHP input parameters from thematic maps and to visualize the model outputs. Implementing AHPSYI using GIS frameworks is helpful when decision-makers want to use many large multi-disciplinary datasets for finding out the raking of the sub-watersheds. In this paper, it is mentioned that by using continuous flows of satellite data, the priority status of sub-watersheds can be updated easily and on a short-time basis. However, the authors only used geospatial datasets, and other necessary datasets (social and political information) for watershed management were ignored. The scale of satellite data, which is the spatial scale, is not properly referred to as well. Patel et al. [32] proposed a new method in which the morphometric-based compound factors with thematic maps are integrated using the GIS weighted overlay techniques. The strength of their work was using an Analytical Hierarchical Principle (AHP)

based multi-criteria evaluation (MCE) decision matrix that supports consistency of the weight, and it avoids misjudgments in the weighing process. Rahaman et al. [33] worked on natural drainage system analysis in the prioritization of sub-watersheds. They proposed a novel method by investigating the fuzzy analytical hierarchy process (FAHP) to avoid using complex information related to morphological characteristics. Their work has higher accuracy in the identification and prioritization of sub-watersheds in comparison with the other studies. Vulević and Dragović [34] implemented the Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) in ArcGIS to rank the nine sub-watersheds in the Topciderska river watershed, Serbia. Their results show a complete ranking of sub-watersheds that are vulnerable, and the decision-makers can use them to decide where to implement soil erosion measure. Jaiswal et al. [35] used the SAHP tool for nine erosion hazard parameters (EHPs). Saaty's AHP (SAHP) tool is designed for defining the unstructured problem, developing AHP hierarchy, pairwise comparison, computation of relative weights, consistency check and obtaining an overall rating for the desired results. This tool is one of the well-known MCDA tools for finding the prior alternatives using the users' preferences. The authors also used remote sensing data, topographic information, and field knowledge to define EHPs. The strength of this paper is using the SAHP tool, which is a suitable tool for complex decisions, for providing a comprehensive and rational framework for structuring a decision problem. As mentioned frequently in the previous sections, in collaborative and integrated watershed management, there is a need to work with different social and political groups and with different geospatial data. However, in all the above-referred papers, the only focus was on spatial data, and although each paper has achievements in prioritizing the sub-watersheds, the prioritizations have been done based on only spatial data and hydrological behavior and social and political preferences have been ignored. In addition, in terms of GIS concepts, the weaknesses of AHP in the watershed management field are (1) the sensitivity of results to the available information, criteria, thresholds for criteria, and the preference of each criterion (2) utilizing the AHP method for large datasets is challenging. There are a few studies focused on the methods other on AHP. Strager et al. [36] discussed the watershed characterization and management system (WCMS), which is a geographically based decision support system. The WCMS uses an overland flow model, a flow estimation technique for all streams, instream water quality, a loading model for pollutant levels, and a watershed ranking model for prioritizing sub-watersheds. The main strength of using WCMS in watershed management is the unique capability of this system to provide information to

prioritize areas that need more detailed levels of data acquisition and modeling efforts. Besides, WCMS can use the unique spatially explicit methodology to model pollutants, and it can also use geographic data within a multiple-criteria decision-making framework. The aim of Dymond et al. [37] research is integrating discipline-specific (hydrologic, economic, and fish health) models with different spatial and temporal resolutions in the context of a web-enabled spatial decision support system that is named WebL2W. This proposed system is for managing the effects of urban and suburban development with regards to water resources. The objective of this integration was to adapt the land-use change evaluation methods and discipline-specific models into a decision-making tool along with the domain researchers. The interesting aspect of this paper is that the assessment model in each discipline was developed, calibrated, and validated outside the SDSS using techniques common in the vertical areas of hydrology, economics, and fish health. However, on which scales these calibration and validation has been done is not mentioned.

3.3 GIS-based DSS in watershed management: agricultural-field scale

Agricultural lands are the main contributors to watersheds non-point source (NPS) pollution since agricultural runoff causes significant water quality problems in rivers and lakes. In this regard, the impacts of adopting the best management practices (BMP) scenarios in the watershed-scale have been studied a lot because of the power of watershed-scale models in management plan development. But the problem is the fact that implementing BMPs in large scales such as watersheds is impossible; BMPs should be implemented in individual fields because of the nature of these programs. Therefore, figuring out the true cost and effectiveness of the BMPs at the agricultural field and watershed scales is essential to provide helpful information for decision-makers [38]. Agricultural-field scale is a local scale, although the clear definition of it is not provided in the literature. This unclarity in definition of spatial scale is one of the problems I have mentioned in the introduction section. In this regard, a few studies have been conducted on agricultural- field scale. Srinivas et al. [39] proposed a novel field-scale Decision Support Framework (DSF) capable of addressing the agricultural conservation practices based on hydro-conditioned DEM, rigorous terrain analysis and physiographic, economic and ecologic benefits, and evaluation of farmer's willingness to adopt those practices. The authors integrated Agricultural Conservation Planning Framework (ACPF), Prioritize Target and Measure Application (PTMApp) and Hydrological Simulation Program Fortran-Scenario Application Manager

(HSPFSAM) to develop the integrated framework for Plum Creek watershed in Minnesota. The strength of this framework is its ability to recognize the strong features of models to integrate them to accomplish major watershed objectives. Besides, this framework is good to add any criteria for practice placements, which makes it generally applicable to any watershed using the required input data. Getahun and Keefer [40] worked on finding the optimal nutrient loss reduction strategies at the field level in watersheds. The main aim of this study is to find the BMPs for which there is a reasonable tradeoff between the cost of implementation and the amount of water quality improvement. In this regard, the authors integrated the SWAT model with the Archived Micro Genetic Algorithm 2 (AMGA2) that is an optimization algorithm to propose an integrated modeling framework. Besides, the authors utilized the historical land management conditions in models to make these models able to consider the changes in the simulation process. The Conservation Reserve Program (CRP) is one of the programs introduced in the U.S. Department of Agriculture (USDA) to encourage farmers to communicate with each other and the decision-makers regarding soil, water, and related natural resource issues on their lands in an environmentally sustainable manner. Using this program, Rao et al. [41] designed and developed a prototype web-GIS Decision Support System. In this DSS, an image classification tool and a hydrologic-crop management model have been combined within ArcIMS to be used as an effective tool for managing and evaluating the CRP. This system will enable USDA to do decision-making because of maximizing the benefits from the CRP program by enrolling lands that require conservation.

4 Discussion and conclusion

As mentioned before, watershed management is a collaborative work of public and private organizations to figure out the most serious freshwater quality and quantity degradation triggers. Therefore, not only physical and biological factors but also political and socio-economic factors should be considered to achieve comprehensive and integrated decisions in watershed management decision support systems. The participation of different social, political and economic communities will bring the sustainability of watershed management plans, while different organizations and institutions with various interests work together to achieve a same aim [3]. The various interests and goals will lead to some contradictions and conflicts among organizations who are seeking watershed management plans. The most critical contradiction will be the different definitions of the "Scale" concept in these scientific fields. As mentioned before, to have successful

watershed management plans, political and social scales should be considered along with the physical scales. But the fact is that watersheds delineate physical boundaries, not political and social boundaries. In addition, the existing administrative hierarchical, physical, and social boundaries defined at various social, political and economic communities are different from each other most of the time [42]. Therefore, the problem will appear as a mismatch between these scales, which means the boundaries of governing organizations are different with each other and also with the boundaries of environmental systems, and this issue leads to a failed or inefficient watershed management decision support system. Consequently, considering social and political scales in watershed management is essential in order to set the interest and factors clearly to reach comprehensive and effective decisions.

In most watershed problems such as nutrient runoff, quantifying the dynamics of the processes (parameterization problem in hydrological models) is a challenge in which "Spatial Scale" plays an important role. In addition, spatial scale is a critical component in soil erosion studies because it determines the data availability, data quality, the way the model should be developed, and value of the analysis outputs to the policymakers [43].Therefore, model developers need to not only consider the matching issue between the social and political scales with physical scale, but also, they need to choose an appropriate physical scale for their studies. Selecting the appropriate physical scale for watershed management plans, depends on the problems at hand. For example, controlling nutrient can be addressed well at the sub-watershed level, while the other problems may be addressed at the watershed level [4].

By doing the literature review in the field of GIS-based decision support systems for watershed management, by focusing on the scale concept, some critical issues have been arisen, Given the importance of spatial scale in watershed management studies, very few scientific papers have addressed the issue of scale as a crucial component in the development of watershed management DSS's. In most studies in Geospatial Information System (GIS) domain, most researchers have focused on the use of modern GIS technologies in order to improve either the processing speed or the accuracy of the outputs of their proposed DSS. In a few papers, the authors explicitly pointed to the scale; in these studies, the researchers have attempted to use remote sensing (RS) high-resolution satellite datasets in order to improve the accuracy of the hydrological models. In addition, although it is repeatedly emphasized on the importance of considering different spatial, political, and social scales in developing watershed management DSS's, these scales are as forgotten components of most studies. Ignoring these scales in developing decision support systems arises the question which is "Can these systems really

be helpful for decision-makers to increase the sustainability of watersheds?" or "Should these systems should remain as "proposed" systems, not as "implemented" ones forever?" Another problem has been seen in the most articles was that the size of the study area was ambiguous. For example, Ahmad and Goparaju [44] worked on finding the spatial distribution pattern of geospatial data, at the watershed level. They stated that studies should focus on finding solutions to improve the land soil at the watershed level by improving freshwater availability to meet sustainable development goals. But they have not refered to the scale of watersheds; So, the question is "all watersheds or watersheds within specific spatial scales?" In such studies, the focus is entirely and explicitly on the concept of scale as the extent study area. The spatial scales of these studies are either watershed, sub-watershed or agricultural-field. The problem is that there is no clear emphasis on how much big these under study watersheds, sub-watersheds, or agricultural fields are. For water resource planning and data management, there are six levels for watersheds based on the size of watershed which are Region, Subregion, Basin, Sub-basin, Watershed, and Sub-watershed. The problem is that a watershed may be as small as a parking lot or as large as f thousands of square kilometers, but the extent of watersheds which are referred in papers are not clear. Also, the term sub-watershed is used informally to describe much smaller watersheds in most of papers; those with a few hectares or those with a few hundred hectares [2]. But how big are they exactly?

By considering the mentioned points, in order to not only propose but also develop an integrated and collaborative decision support system for real watershed management, the future studies need to (1) explicitly define the spatial scales, and (2) social and political scales alongside the spatial scale also are needed to be explicitly defined. This system then certainly can help decision-makers to move toward sustainable environment and watersheds, which is one of the aim of geography science.

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