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Gaps in the Accounting of Stakeholder Integrations in HydroGIS Tools to Face the Challenge of Sustainable Urban Flood Management

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Abstract: The maturity of science had resulted in sophisticated urban flood management hydro-GIS tools. However, persistent and increasing floods show that, thus far, no sustainable solution has been identified. A closer look reveals a shortfall in incorporating stakeholder requirements into these tools and how this should be done.

The objective of the present work is to evaluate the gaps in the integration of stakeholder requirements in HydroGIS tools for urban flood management and make necessary recommendations.

Expert discussion and systematic literature surveys were performed to capture the components and integration of activities in the ongoing decision-making systems using HydroGIS tools. A literature weighting scheme was developed to quantitatively assess the current level of stakeholder involvement and the associated gaps which demand urgent attention.

Development of the associated system revealed the main system components that need consideration as decision-makers, recipients, hydro, GIS, and HydroGIS models. The weights obtained indicated that the integration of hydro and GIS with the HydroGIS model deserve top priority.

The concerns of the HydroGIS model component are, therefore, vital for sustainable urban flood management as the component focally facilitates the optimisation of scientific and management concerns in decision making.

Keywords: HydroGIS tools, Sustainable Urban Flood Management, Recipients, Stakeholders

1. Introduction

1.1 Background

Due to the devastating repercussions, urban flood management has received decision-maker attention [1]–[3]. Flood management is commonly done by using hydrological models, and they manipulate the spatial data by combining Geographic Information Systems (GIS) [4], [5]. HydroGIS refers to a combination of hydrology and GIS components, while HydroGIS modelling tools are designed to perform hydrologic process computations using spatial information management capacity of GIS [6], [7]. Today, HydroGIS has become a popular tool for flood management, especially in urban areas. Hydrology has been practised over a long time, and continuous research has now reached maturity [8]. GIS came into play over fifty years ago. With the boost of technological advances, GIS is now used to improve hydrological data management with better efficiency, accuracy, and user-friendliness. Therefore, combined HydroGIS models are becoming popular tools [9]-[21].

Most environmental management decisions are influenced by dynamic stakeholders, rigid scientific assessments, and sensitive economic impacts [22]. Incorporation of stakeholders in decision making has been discussed since the 1960s [23], and by the 21st Century, water professionals understood the importance of incorporating the general public, who was a missing component in water decision making [24]–[26]. The flood management decisions should be carefully incorporated with the stakeholder concerns to reach a practical and sustainable solution. Therefore, HydroGIS tool must be constructed to facilitate stakeholder needs to make and carry out sustainable flood management decisions [27].

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Nevertheless, HydroGIS's prime task is to perform accurate hydrological and GIS calculations, which require considerable processing time and effort. Then those stakeholder requirements place additional pressure on the resource requirement. As a result, HydroGIS tools face a challenge because of the need for efficient and effective tools [28].

Literature has several models and frameworks, such as Bhatt et al. [29] and Alcaraz et al. [13], that have attempted to develop suitable HydroGIS tools. However, the lack of examples and documentation makes it difficult to ensure whether the stakeholder requirements have been satisfactorily met. Literature also shows that, when tools are developed, the attention is either on hydrology, GIS, or stakeholders, but not all components in a holistic manner. It is also noted that many had identified different stakeholders, their roles, and a multitude of concerns [30]–[34].

Therefore, it is necessary to understand stakeholder concerns and integrate them into HydroGIS tools to develop a practically successful HydroGIS tool.

1.2 Objective

The objective of the present work is to find the status of stakeholder integration in HydroGIS models and recommend options for the systematic development of urban flood management tools.

2. Method and Materials

2.1 Identification of Components of HydroGIS Tool Framework

Four (04) approaches can be observed when integrating hydrological models and GIS models. This integration refers to the execution of process steps and data exchange between the hydrology model and the GIS model [31], [35], [36]. Reviewing those integrations could have conceptualised and identified associated specific stakeholder groups with their possible roles, as shown in Table 1.

The importance of public participation in water decisions has been discussed since the 1960s, and has become a world accepted practice by 2000 [23]–[26]; yet, the general public (recipients) is missing in the possible stakeholders (Table 1).

Therefore, 11 selected guidelines and HydroGIS tools ([4], [16], [44], [25], [37]–[43]) were evaluated to capture all possible stakeholder involvements, as shown in Table 2. It presents the extracted information corresponding to the role of GIS, hydrology, recipient stakeholders (users/public), and the decision-makers concerning either a tool or guideline. Table 2 provides a picture of the Integrations and their frequency of occurrence while providing a guideline to identify components in a HydroGIS model development framework for urban flood management. Accordingly, there are five main components: (1) *HydroGIS Model*, which carries out the integrated activities to develop flood management model. The

Table 1 - Review for Identifying HydroGIS Tools Users

Hydro GIS Integration Approach	Execution of		Author's Review		
	Process steps	**Data exchange**	**Knowledge required**	**Possible stakeholders**	**Roles of stakeholders**
Loose coupling	Stakeholders carry out the process using different software	Stakeholders share the data files among different software	Spatial Data formats, input preparation, and output interpretation	Modeller/ Hydrology Decision-makers	Modeller models process steps and data (metadata). Decision-maker flow the process by manipulating the data (actual data)
Tight coupling	Customised software codes carry out the process sequence	Software codes pass the data in between software	Software coding knowledge, and understand the architecture of both software	Mainly Software developer. Others are Modeller and Decision-makers	Modeller models process steps and data (metadata) to the software developer. Software Developers automate the process. Decision-makers use the automated tool.
Embedding GIS in hydro model	Hydrological software carry out all the processes	Data passed as Parameters within the modules in the software	In-depth knowledge in GIS function automation		
Embedding hydro model in GIS	GIS Software carry out all the process		In-depth knowledge in Hydrology model automation		

HydroGIS modellers encapsulate the hydro and GIS models to perform the particular task; (2) *Hydro Model* which is created or selected to the specific situation. The Hydrology modellers perform the activity; (3) *GIS model* which is created by GIS modellers to provide required inputs and display outputs of the hydro model; (4) The decision-makers who make the flood management decisions finally; and (5) The recipient stakeholders who are the prime target of flood management service delivery.

When considering the frequencies of components' appearance in the 11 works of literature, nine had considered decision-makers while eight considered GIS modellers. As well, seven had considered hydrology modeller when six had considered HydroGIS modeller. The lowest consideration is to pay recipients, which is 5 out of 11.

2.2 Confirmation of Components

An online expert review was conducted with local and international professionals to confirm the identified components [45]. The experts with substantial experience were selected from hydrology, GIS, water management, and public administration areas. They were invited to comment on the sufficiency of the components to the proposed model using a five-point Likert scale (5-Strongly agree to 1-Strongly disagree) and express the elaborations to be highlighted. Various studies have suggested utilising 5 to 20 varied numbers of experts for successful evaluation [46], [47]. Nevertheless, the present work considered nine experts are sufficient since a substantial accuracy can be achieved with nine samples in HydroGIS research [48]. All experts agreed with the findings but elaborated on whom to be included in each component. Table 3 shows the summary result of the expert discussion.

2.3 Assessment of Integrations

During HydroGIS tool development, the key is to find integration between each stakeholder group responsible for each component's activities. Evaluation of the integration between components would enable the assessment of current guidelines available for satisfactory HydroGIS tool development. A critical review of the existing literature was performed for this evaluation. Various types of scientific documents on HydroGIS systems were assessed by considering (1) the scientific value of the publication; (2) the depth of scientific investigation corresponding to each integration; and (3) the description of the influence of integration in publication.

Table 3 - Summary of Online Discussion

Expert #	Experience (Years)	Acceptance (5-Strongly agree to 1-Strongly disagree)
Elaborated on		
1	15	Agreed (4)
Considered the recipients as vital in flood management and suggested three components: (1) a Social Science method to handle stakeholders; (2) Web-based tools for collaborating and educating the stakeholders; and (3) Hydrology model		
2	12	Highly Agreed (5)
Considered that hydrology and GIS are the essential components in flood risk management.		
3	45	Agreed (4)
Commented that it is difficult to state what to include in the model; yet, it is necessary to consider the stakeholders and elements in the Flood managements phases, such as (1) Planning and forecasting, (2) Early warning and (3) Rescue. Highlighted the attention to additional stakeholders such as decision-implementors (Drainage constructors to drainage cleaners).		
4	15	Highly Agreed (5)
Shared local experience highlights 14 different stakeholders and their role.		
5	35	Agreed (4)
Highlighted the trans-boundary decision-makers such as countries and flood management agencies.		
6	10	Agreed (4)
Suggested to consider three main models, i.e., (1)prediction model, (2)protection model, and (3) damage assessment model.		
7	30	Agreed (4)
Pursued on individual stakeholders such as Water Resources Department of the State, Ministry of Water Resources, prominent academic institutions of the locality, disaster management cell, local administration, active NGOs working in the related field and renowned hydrologists.		
8	42	Agreed (4)
Stated that the Government and the people in upstream and downstream are a specific component.		
9	10	Agreed (4)
Suggested to incorporate the following to the components: (1) Residents in flood-prone areas; (2) Government; (3) Commercial building owners in flood-prone areas; (4) Insurance providers; and (5) Researchers.		
Average	**23.8**	**Above Average (4.2)**

In the absence of a clear methodology to evaluate each of the above, the present work incorporated qualitative, judgmental specific Likert-scale based conceptualisation.

2.3.1 Scientific Value of Publication

The scientific value was assessed by considering the degree of review of contents in each publication. Assigned weight for each type was rationalised by using a small group discussion and a questionnaire survey. Thirty-four university academics participated in the survey, and Table 4 describes the types and weights found in the study.

Table 4 - Literature Weights according to the Type

Literature Type	W.*	Rational
Specific Guideline/ Standards	3.13	Established reviewed documents for new technology considered as appropriate for practice
Book/ Chapter	4.56	Established reviewed knowledge of seasoned knowledge and practice
Indexed Journal	4.68	A thoroughly reviewed knowledge
Peer-Reviewed Journal	3.71	A well-reviewed knowledge
Conference Proceedings	2.49	Ideas for discussion in scientific forums which require critical review
Thesis	3.62	Similar work evaluated at an institutional level and requiring further review
Monograph	2.35	The concept which requires further review
Web Document	1.65	General views and ideas that may have value

* Article Weight

2.3.2 Depth of Scientific Investigation

The depth of scientific investigation (conclusiveness) is the detail to which research has analysed and concluded a particular Integration. A 5-point Likert-scale was developed, the same as the previous (Table 5).

2.3.3 Influence of Integration in Publication

The third and critical influence identification criteria were assessed by the explicitness of the results point given in each document (influence). Again, a 5-class Likert-scale was used for this assessment (Table 6).

Table 5 - Classification of the Conclusiveness of an Integration

Class	C.*	Description
Very High** (VH)	5	Publication comprehensively analyses the integrations in an identified system.
High (H)	4	A clear and specific conclusion of integration is presented.
Medium (M)	3	An implicit result of integration is presented with analysis and conclusion.
Low (L)	2	Indicates a relevant result within the result section or in discussion but not conclude.
Very Low (VL)	1	Only an indication reflects the value of integration either in the introduction or in the literature review.

* Conclusiveness

Table 6 - Classification of the Description of the Influence of Integration

Class	I.*	Description
Very High** (VH)	5	Use of explicit terminology such as "Very much, much, highly, must-have, important, sine-quo-none" to describe the integration.
High (H)	4	Qualitative descriptions in between moderate and extremely high groups.
Medium (M)	3	Use of explicit terminology such as "Moderate, also important."
Low (L)	2	Qualitative description in between moderate and very low groups.
Very Low (VL)	1	Use of terminology such as "Interesting, should consider, supportive factor, at least consider."

* Influence

2.4 Evaluation of Literature

Five possible integrations were discovered among the five main components identified earlier. Next, 32 works of literature were evaluated to find the values for conclusiveness (Table 5) and influence (Table 6) of each integration. With the use of publications' Article weight (Table 4), conclusiveness and influence values, a Reclassification Matrix (Table 7) was developed using the equal weight method. The status of each integration was reclassified into a 1-5 scale by using such a matrix (Table 8).

Table 7 - Reclassification Matrix

Article weight	Reclassification Value for (Conclusiveness x Influence)÷ 5											
	0.2	0.4	0.6	0.8	1.0	1.6	1.8	2.0	2.4	3	4	5
1.65	1	1	1	1	1	2	2	2	2	2	4	4
3.13	2	2	2	2	2	3	3	3	4	4	4	5
4.56	3	3	3	3	3	4	4	4	4	4	5	5
4.68	3	3	3	3	3	4	4	4	4	4	5	5

Those reclassification values were multiplied to compute the overall levels corresponding to the investigation depth of each integration (Level of the Depth of Investigation); Table 9 shows the details.

3. Results and Discussion

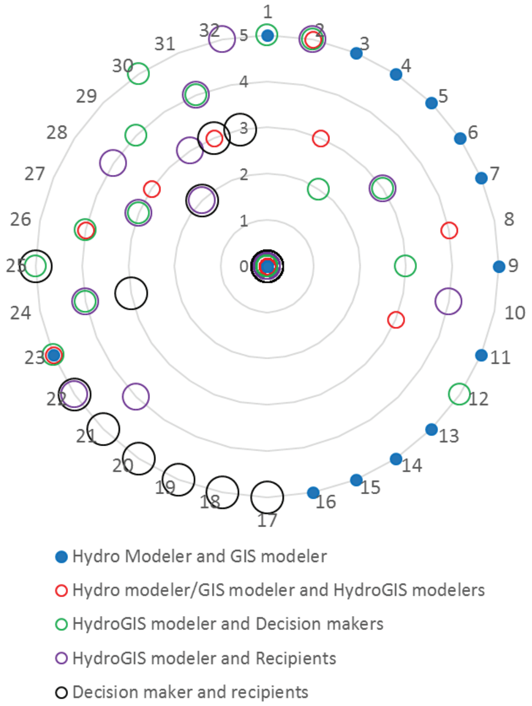
Table 10 presents the Depths of Investigation of individual integrations. The same information is illustrated in Figure 1. Both show that the scientific communication between the hydro modeller and GIS modeller has been extensively studied.

The interaction between the management components and scientific components, denoted through the communication between HydroGIS modeller - decision-maker – recipients, has an average depth of interest. Few researchers have conducted in-depth studies on internal integrations that appear in scientific modelling (between hydro-GIS-HydroGIS models).

Table 10 - Depth of Investigation of Each Integration

Integration of Components	No of documents based on Investigation depth of scale (1-5)				
	1	2	3	4	5
Hydro modeller and GIS modeller				1	12
Hydro modeller/GIS modeller and HydroGIS modellers			4	2	2
HydroGIS modeller and Decision-makers	1		3	4	6
HydroGIS modeller and Recipients		1	3	5	3
Decision-maker and recipients		1	3		7

Figure 2 presents the average depth of investigations and the number of integrations in each document. There is a moderate negative correlation (-0.51) between the count of integrations in the document over the depth of integrations' investigation. It further shows that only one (01) paper had discussed four (04) Integrations while five (05) documents had discussed three (03) Integrations in a single document. Both results denote the absence of research in all five integrations and less attention paid to the integration of multiple components.



*Depth of investigation is increased from centroid(0) to perimeter(5)

Figure 1 - Depth of Investigation in Documents Corresponding to each Integration

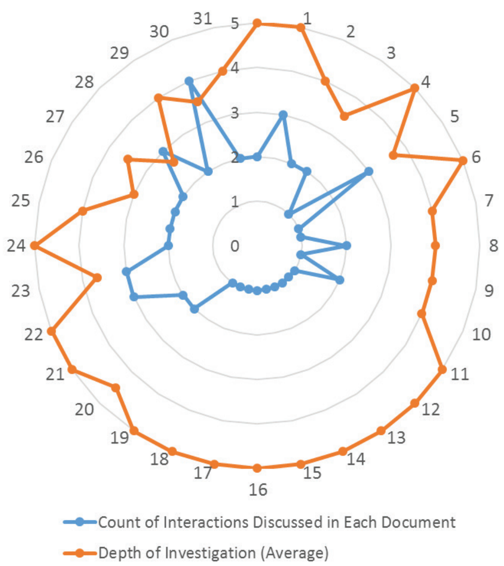


Figure 2 - Average Depth of Investigation and Number of Integrations in each Document

Accordingly, recognition of the status of integrations in the HydroGIS tool development revealed very low coverage values that reflect the need for a significant effort for improved tool development (Figure 3).

The relative comparison implies that the transfer of HydroGIS requirements to the hydrologic and GIS model Integration is at a very low volume (0.94 out of 5), and the HydroGIS is lying in between management and scientific components. This indicates that the possibility of impractical flood management decision-making due to ineffective communication facilitates the systems to optimise scientific model requirements with stakeholder needs.

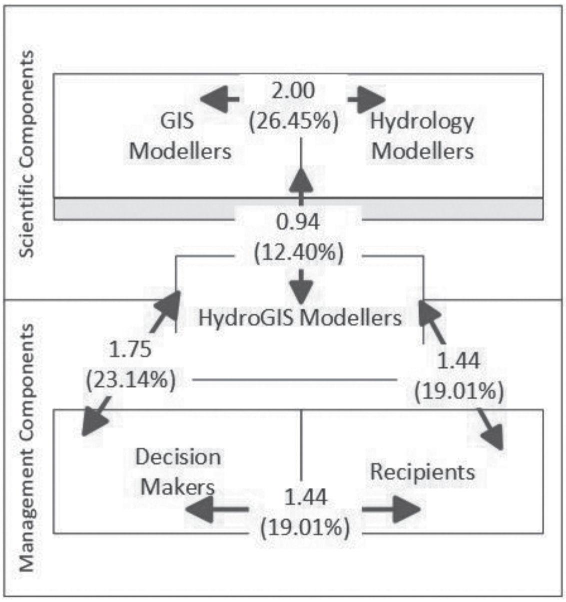


Figure 3 - The Average Depth of Investigation in Each Integration and its Comparison Level as a Percentage

4. Conclusion

Evaluation of the standard-setting in the HydroGIS model development for urban flood management enabled to identify the framework for stakeholder Integrations.

The rationalised qualitative assessment in the present work reveals that the current status of incorporating the stakeholder concerns is at a low level in all integrations.

The percentage values computed for the relative coverage signifies a gap in transferring of the decision-makers and recipients' concerns to hydro modellers and GIS modellers through HydroGIS modellers.

The HydroGIS modellers' concerns, which are optimising the scientific needs with management requirements, are vital as they are the focal facilitator of communication between scientific components and management components of the urban flood management system to develop sustainable decisions.

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Table 2 – Review of Availed Guidelines and HydroGIS Tools Against the Stakeholder Involvement

Literature / Framework	Description	GIS Modeller	Hydrology Modeller	HydroGIS modeller	Recipients	Decision-makers
Municipal ICT capacity and its Impact on the Climate-Change Affected Urban Poor [38]	A proposed ICT framework for climate resilience	Maps are created for disaster decision-making	**No** description available	**No** description available	Participate only, no involvement in decision making	The controllers of the process
Urban flood management in a changing climate [4]	A practitioner's guideline/ tool to manage urban flood in a multi-stakeholder approach	The GIS-based analysis is highlighted, but roles were not described	The requirement of the entire water cycle analysis is highlighted, but roles were not described	The importance of flood modelling is highlighted, but roles were not described	Recipient involvement is considered as specially important but only provide an operationalisation guideline	Guide to decide on an integrated approach, but no detailed description provided
Directive 2000/60/EC of the European Parliament and the council [25]	The EU framework for water policy to be applied by the Member States to manage data	**No** guideline	**No** guideline, but discussed the water resource planning	The importance of water resource modelling is described, but roles were not described	Recipients are stressed to make integrated water management decisions when the watershed excessed the individual territory	Stressed to detailed management plan with the member states and its participants
AkvaGIS [39]	AkvaGIS: A plug into GIS-based software. It manages the hydro-related analysis on the GIS platform	A model was selected to utilise in the tool.	A model was selected to utilise in the tool.	The selected models are integrated perfectly to achieve the purpose	Provide outputs to make decisions without incorporating stakeholders' views	Decision-makers can use the tool
Modelling decentralised systems for urban drainage and flood mitigation [40]	Use of Kalypso Hydrology software module to modelling sustainable drainage system to mitigate urban flood	A model was selected to utilise in the tool	A model was selected to utilise in the tool	The selected models are integrated perfectly to achieve the purpose.	Provide outputs to make decisions without incorporating stakeholders' views	Decision-makers can use the tool
Integrated Hydrologic Modelling and GIS in Water Resources Mgt [41]	Application of GIS for hydrologic modelling in water resource management	Develop dynamic GIS models	Select and automate hydro models	The selected models are integrated perfectly to achieve the purpose	Does not discuss the influence of stakeholders	Use the tool in management decisions
A Review on Hydrological Models [19]	Analysis of hydro models for application of complex scenarios	**No** description of GIS modellers' activities	Review the options available to hydrology modellers	**No** description	Does not discuss the influence of stakeholders	Can select the best model to make decisions
Integrating GIS with hydrological modelling - applicability and limitations [42]	Analysis of GIS capabilities in hydrological modelling	Develop dynamic GIS models in hydro modelling	Highlights the requirement of distributed data analyses requirements	The selected models are integrated perfectly to achieve the purpose	**No** discussion about how to incorporate stakeholder requirements	No discussion available
Integration of GIS in Environmental Modelling and Hydrological Analysis [43]	Analysis of 51 research papers about the integration of GIS in water resource modelling	Develop a better interface to Hydro model	Discuss the utilisation of GIS and its data on water resource modelling	The role is to develop a better interface between hydro and GIS models	The stakeholder influences on integration were not discussed	No discussion present
Watershed management within the Havel River Basin [44]	Discussed the applicability of the European Water Framework Directive (WFD) in land use development and stakeholder involvement in watershed management	Identify, Integrate, and Analyse layers	Role of the hydrology modeller not described	Integrate the land-use scenarios with stakeholder requirements, but no optimisations of requirements over models	Provide opinions in the decision-making process	Integrate stakeholder requirements and present outputs to stakeholders when decision-making

Harmonised principles for public participation [37]	A detailed study about the stakeholders in the integrated water resource modelling	**No** discussion about GIS models or modellers' behaviour with stakeholders	Develop water resource management process	Develop entire processes but no discussion about GIS	Provide opinions in the decision-making process	Managing the involvement of stakeholders

Table 8 - Reclassification of the Weights of the Integrations

Srl	Publication's Author and Year	Validation of the Literature (1)		Integration Type																			
				Hydro Modeller and GIS Modeller				Hydro modeller/GIS Modeller and HydroGIS Modellers				HydroGIS Modeller and Decision-makers				HydroGIS Modeller and Recipients				Decision-Maker and Recipients			
		Type	Weight	Conclusiveness	Magnitude	CxM*	Reclass 1	Conclusiveness	Magnitude	CxM*	Reclass 2	Conclusiveness	Magnitude	CxM*	Reclass 3	Conclusiveness	Magnitude	CxM*	Reclass 4	Conclusiveness	Magnitude	CxM*	Reclass 5
1	Jern (2005) [49]	Book	4.56	VH	VH	5	5.00					VH	VH	5	5.00								
2	Parker et al. (2002) [50]	ID Jour	4.68					VH	H	4	5.00	VH	H	4	5.00	VH	H	4	5.00				
3	Alcaraz, Vázquez-Suñé, Velasco, & Criollo (2017) [13]	ID Jour	4.68	VH	VH	5	5.00	VL	VL	0.2	3.00												
4	Alsabhan (2010) [51]	Web	1.65	VH	VH	5	4.00					VH	VL	1	1.00								
5	Waleed & Steve (2011) [52]	ID Jour	4.68	VH	VH	5	5.00																
6	Al-Sabhan, Mulligan, & Blackburn (2003) [53]	ID Jour	4.68	VH	VH	5	5.00					M	VL	0.6	3.00	M	VL	0.6	3.00				
7	Bhatt, Kumar, & Duffy (2014) [29]	ID Jour	4.68	VH	VH	5	5.00																
8	David et al. (2013) [54]	ID Jour	4.68					H	H	3.2	4.00												
9	Andreadis et al. (2017) [55]	ID Jour	4.68	VH	VH	5	5.00					VH	VL	1	3.00								
10	Cázares-rodríguez, Vivoni, & Mascaro (2017) [56]	ID Jour	4.68													VH	L	2	4.00				
11	Sanzana et al. (2017) [57]	ID Jour	4.68	VH	VH	5	5.00	VH	VL	1	3.00												
12	Leskens, Brugnach, Hoekstra, & Schuurmans (2014) [58]	ID Jour	4.68									VH	VH	5	5.00								
13	Goodchild, Haining, Wise, & Others (1992) [59]	ID Jour	4.68	VH	VH	5	5.00																

Srl	Publication's Author and Year	Validation of the Literature (1)		Integration Type																			
				Hydro Modeller and GIS Modeller				Hydro modeller/GIS Modeller and HydroGIS Modellers				HydroGIS Modeller and Decision-makers				HydroGIS Modeller and Recipients				Decision-Maker and Recipients			
		Type	Weight	Conclusiveness	Magnitude	CxM*	Reclass 1	Conclusiveness	Magnitude	CxM*	Reclass 2	Conclusiveness	Magnitude	CxM*	Reclass 3	Conclusiveness	Magnitude	CxM*	Reclass 4	Conclusiveness	Magnitude	CxM*	Reclass 5
14	Stuart & Stocks (1993) [60]	ID Jour	4.68	VH	VH	5	5.00																
15	Sui & Maggio (1999) [35]	ID Jour	4.68	VH	VH	5	5.00																
16	Huang & Jiang (2002) [31]	ID Jour	4.68	VH	VH	5	5.00																
17	Arnstein (1969) [23]	Book	4.56																	VH	VH	5	5.00
18	European Water Framework Directive (2000) [25]	GU / STD	3.13																	VH	VH	5	5.00
19	ACC/ISGWR (1992) [24]	GU / STD	3.13																	VH	VH	5	5.00
20	The Hague Ministerial Declaration (2000) [26]	GU / STD	3.13																	VH	VH	5	5.00
21	Mostert (2003) [61]	ID Jour	4.68													H	L	1.6	4.00	VH	VH	5	5.00
22	Henriksen et al.(2009) [37]	ID Jour	4.68													VH	VH	5	5.00	VH	VH	5	5.00
23	Comair et al. (2014) [30]	ID Jour	4.68	VH	VH	5	5.00	VH	VH	5	5.00	VH	VH	5	5.00								
24	Zhang et al. (2011) [62]	ID Jour	4.68									M	M	1.8	4.00	M	M	1.8	4.00	L	VL	0.4	3.00
25	Jessel & Jacobs (2005) [44]	ID Jour	4.68									VH	VH	5	5.00					VH	VH	5	5.00
26	Welsh et al. (2013) [63]	ID Jour	4.68					VH	L	2	4.00	H	L	1.6	4.00								
27	Fatichi et al. (2016) [64]	ID Jour	4.68									H	VL	0.8	3.00	M	VL	0.6	3.00				
28	Voinov et al. (2016) [33]	ID Jour	4.68					M	VL	0.6	3.00					H	H	3.2	4.00				
29	Jha, Bloch, & Lamond (2012) [65]	GU / STD	3.13									H	H	3.2	4.00	H	VL	0.8	2.00	H	VL	0.8	2.00
30	Assaf et al. (2008) [28]	ID Jour	4.68									VH	VH	5	5.00	M	VL	0.6	3.00				
31	Maskrey, Mount, Thorne, & Dryden (2016) [66]	ID Jour	4.68					H	VL	0.8	3.00	H	M	2.4	4.00	H	M	2.4	4.00	H	VL	0.8	3.00
32	Evers et al. (2012) [67]	ID Jour	4.68													VH	VH	5	5.00	H	VL	0.8	3.00

CxM* : Value in Table 5 corresponding to Conclusiveness column classification is multiplied by Value in Table 6 corresponding to Magnitude column classification

Table 9 - Average Levels of the Depth of Investigations in each Literature

#	Reference in List	Scale of Publication Type	Integration Type					Count of Integrations Discussed in Each Document	Depth of Investigation (Average)
			Hydro Modeller and GIS Modeller	Hydro Modeller/GIS Modeller and HydroGIS Modellers	HydroGIS Modeller and Decision-Makers	HydroGIS Modeller and Recipients	Decision-Maker and Recipients		
1	Jern (2005) [49]	4.56	5.00		5.00			2	5.00
2	Parker et al. (2002) [50]	4.68		5.00	5.00	5.00		3	5.00
3	Alcaraz, Vázquez-Suñé, Velasco, & Criollo (2017) [13]	4.68	5.00	3.00				2	4.00
4	Alsabhan (2010) [51]	1.65	4.00		1.00			2	2.50
5	Waleed & Steve (2011) [52]	4.68	5.00					1	5.00
6	Al-Sabhan, Mulligan, & Blackburn (2003) [53]	4.68	5.00		3.00	3.00		3	3.67
7	Bhatt, Kumar, & Duffy (2014) [29]	4.68	5.00					1	5.00
8	David et al. (2013) [54]	4.68		4.00				1	4.00
9	Andreadis et al. (2017) [55]	4.68	5.00		3.00			2	4.00
10	Cázares-rodríguez, Vivoni, & Mascaro (2017) [56]	4.68				4.00		1	4.00
11	Sanzana et al. (2017) [57]	4.68	5.00	3.00				2	4.00
12	Leskens, Brugnach, Hoekstra, & Schuurmans (2014) [58]	4.68			5.00			1	5.00
13	Goodchild, Haining, Wise, & Others (1992) [59]	4.68	5.00					1	5.00
14	Stuart & Stocks (1993) [60]	4.68	5.00					1	5.00
15	Sui & Maggio (1999) [35]	4.68	5.00					1	5.00
16	Huang & Jiang (2002) [31]	4.68	5.00					1	5.00
17	Arnstein (1969) [23]	4.56					5.00	1	5.00
18	European Water Framework Directive (2000) [25]	3.13					5.00	1	5.00
19	ACC/ISGWR (1992) [24]	3.13					5.00	1	5.00
20	The Hague Ministerial Declaration (2000) [26]	3.13					5.00	1	5.00
21	Mostert (2003) [61]	4.68				4.00	5.00	2	4.50
22	Henriksen et al. (2009) [37]	4.68				5.00	5.00	2	5.00
23	Comair et al. (2014) [30]	4.68	5.00	5.00	5.00			3	5.00

#	Reference in List	Scale of Publication Type	Integration Type					Count of Integrations Discussed in Each Document	Depth of Investigation (Average)
			Hydro Modeller and GIS Modeller	Hydro Modeller/GIS Modeller and HydroGIS Modellers	HydroGIS Modeller and Decision-Makers	HydroGIS Modeller and Recipients	Decision-Maker and Recipients		
24	Zhang et al. (2011) [62]	4.68			4.00	4.00	3.00	3	3.67
25	Jessel & Jacobs (2005) [44]	4.68			5.00		5.00	2	5.00
26	Welsh et al. (2013) [63]	4.68		4.00	4.00			2	4.00
27	Fatichi et al. (2016) [64]	4.68			3.00	3.00		2	3.00
28	Voinov et al. (2016) [33]	4.68		3.00		4.00		2	3.50
29	Jha, Bloch, & Lamond (2012) [65]	3.13			4.00	2.00	2.00	3	2.67
30	Assaf et al. (2008) [28]	4.68			5.00	3.00		2	4.00
31	Maskrey, Mount, Thorne, & Dryden (2016) [66]	4.68		3.00	4.00	4.00	3.00	4	3.50
32	Evers et al. (2012) [67]	4.68				5.00	3.00	2	4.00
Weight Total (W_tot)			64	30	56	46	46	Total of Levels of the Depth of investigations	
Level of the Depth of Investigation (Scale of 5-1) (W_tot÷32) = x			2.00	0.94	1.75	1.44	1.44	7.56 = Tot_x	
Comparative Level of the Depth of Investigation (%) ([W_tot÷32] ÷ Tot_x) * 100			26.45	12.40	23.14	19.01	19.01	~100.00	