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RESEARCH

Harmonising Stakeholders' Perspectives: a Watershed Project Desirability Index

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Abstract

Any watershed project is a multi-stakeholder endeavour incorporating diverse socio-hydrological dimensions of a region. The project's worth is correlated with the stakeholders' willingness to continue. Identifying the most desirable watershed parameters is challenging for watershed managers. This research aims to explore critical parameters and construct a watershed project desirability indexing framework to examine the congruence of stakeholders' perceptions on a hypothetical watershed parameter list. It contains 31 critical operational areas (or sub-domains) in eight domains incorporating different management mechanisms and socio-economic and environmental activities covering diverse watershed inventories based on watershed management protocols, including the Integrated Watershed Management Programme (IWMP), Integrated Water Resource Management Programme (IWRM), World Bank directives and government guidelines, and relevant literature. Stakeholders' agreeability was recorded from two stratified stakeholder groups at the Satpokholi watershed project in the Brahmaputra Valley, India, using a structured questionnaire based on a 5-point Likert Scale. Subsequently, the degree of alignment of the perception of stakeholder groups regarding the sub-domains and domains and the relative desirability are evaluated by applying statistical and mathematical operations. Results reveal that this watershed project desirability indexing (WPDI) would help identify the congruency of views regarding adopted watershed domains and sub-domains. Applying the same WPDI, stakeholders' desirability in two other adjacent watershed projects (Kaldia and Turkunijan) was evaluated. Findings were validated by a series of expert interviews, which shows the potential of this WPDI to assess different watershed projects operating in an analogous environment. This indexing method might be modified to manage and reengineer multi-stakeholder projects where incongruent perceptions exist.

Keywords Watershed indexing · Stakeholders' desirability · Congruent perceptions

Introduction

Synchronising the project parameters with stakeholders' prerequisites is challenging for watershed managers. The problem intensifies as the participants' interests change for various reasons, like socio-political, behavioural, and institutional change. Watershed policymakers must identify the most adaptive domains and sub-domains based on commonly accepted IWRM principles in congruence with regional settings. Misalignment of perception between stakeholder groups leads to project failure. Therefore, checking the stakeholders' desirability regarding the project parameters is essential for proper planning, intervention, and restructuring.

Integrated Water Resource Management (IWRM) and Integrated Watershed Management Programmes (IWMP) have evolved into widely accepted policy initiatives for water

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management. Although it has been around 70 years since it was rediscovered in the 1990s, its definition is still relatively amorphous. Sometimes, IWRM is considered a 'nirvana' concept, which defines ambitious objectives in an ideal world that cannot be met in the real world [1]. Experts argue that IWRM is exceedingly difficult to make operational [2] due to the complexities in standardising IWRM parameters regarding appropriateness, promotion, development, and monitoring. IWMP adopts two major IWRM concepts: the social, economic, and environmental issues of the watershed zone are the focus area [3], and the active involvement of community members and organisational representatives is indispensable to tackling inequities [4]. Based on survey data from 118 watershed initiatives, Kenny commented that collaboration, consensus, and stakeholders' participation are the most frequently cited keys to success [3]. With a similar perspective, watershed practitioners in many countries form community-based organisations (CBOs) to maximise participation, alertness, and willingness to continue.

Therefore, a significant problem in watershed management is the identification of project parameters with high stakeholder agreeability. This is imperative because, as conceived in IWRM and IWMP principles, any alternative decision should attract the participant CBOs [5]. However, the core of the difficulty lies in the abstractness of IWRM protocols, which makes 'IWRM an end in itself' [6]. Critically reevaluating IWRM, Biswas found that there are 35 sets of issues that different authors suggest should be integrated under IWRM. However, achieving integration for these issues is not feasible [2]. In this context, to address current and future challenges, the UN and OECD emphasise the need for clear public policies with measurable objectives, assigned responsibilities, and regular monitoring and evaluation [7]. FAO recommended conducting a multidisciplinary assessment of the watershed situation and trends to understand the main issues at stake, establish a baseline, and adapt solutions to the local context [8].

In this scenario, watershed managers must dynamically scrutinise the most desirable objectives for better trade-offs.

Research and case studies were conducted to investigate the key parameters contributing to sustainable watershed programmes and methods to compare the degree of alignment of stakeholders' perceptions or indexing project desirability.

Globally, water managers and policymakers have tried to identify key performance indicators based on commonly accepted principles and in unity with regional settings. Heathcote [9] suggested formal watershed modelling based on standard watershed inventories, like (a) use impairment and water conflicts; (b) hydrology, biology, and water quality; (c) population and land use; and (d) facilities and infrastructure. Reviewing a good number of literature sources, Hooper B. identified (i) 34 attributes of best practices, (ii) 15 river basin management problems, (iii) 115 universal performance indicators of IWRM in ten categories, and (iv) 20 IWRM benchmarks for the River Basin Commission in eight categories [10]. The planning body of the Government of India (NITI Aayog) has proposed a Composite Water Management Index as a helpful tool to assess and improve the performance of water resources management. It suggested a set of 28 key performance indicators (KPIs), expecting the index to generate better outcomes by meeting the citizens' expectations [11]. Besides identifying challenging hydrological parameters, studying their interdependencies is valuable for sustainable watershed modelling [12]. Factors like urbanisation and population growth influence the mismatch of watershed service delivery's demand and supply side [12, 13]. Many researchers have documented critical assessments of the spatial variability of watershed parameters essential for modelling ecosystem services [14, 15].

Thus several authors have studied the forces affecting water management to suggest various key watershed parameters, and there is a remarkable consensus amongst them [16, 17].

Although prescribing 'keys to success' parameters is valuable, it is somewhat limiting if the real goal is to enhance community participation in watershed programmes. In most watershed projects, success is commonly assessed in top-down methods [18, 19] rather than bottom-up reporting and stakeholders' feedback. Instead, ascertaining the degree of fulfilment of the project targets earmarked by the planning agency from the stakeholders' perspective will give a closer picture of the success or failure scenario. Success can be assessed meaningfully by what happens on the ground and from the standpoint of improved socio-economic and environmental indicators based on community information [3, 20]. Policy and process effectiveness are valid success criteria rather than counting several constructions in the watershed zone.

J. Gallego-Ayala and D. Juizo [21] attempted to evaluate river basin organisation and differentiated the relative importance of various indicators. Lemos et al. emphasised the development of metrics for adaptive capacity and water security as support for decision-making. Still, they contested in terms of (a) which indicators should be included and at what scale, (b) how to measure them, (c) how they provide feedback on each other and affect established institutions such as law and regulation, (d) how actionable they are, and (e) how well they represent the dynamic, non-stationary, and complex systems they seek to represent [16]. In a study to identify the factors influencing the success of public-private partnerships, Ng S T et al. [22] applied Spearman's rank correlation coefficient to calculate the aggregability of the stakeholders' groups.

However, little study has examined stakeholders' desirability about planned watershed indicators or assessed the degree of perception alignment amongst stakeholder groups. Therefore, it is imperative to explore how the disparity of perception can be measured for harmonising community participation.

Given that, this study focuses on these questions: Can there be some methods to select the most desirable watershed parameters from the stakeholders' perspective? Furthermore, can this methodology be used to construct a framework for determining the watershed project desirability index (WPDI), which is applicable as a decision-making tool in measuring watershed project effectiveness?

A comprehensive desirability study of a sustainable watershed project should begin with the most common parameters and management actions braced by socio-economic, environmental, and developmental dynamism as the effectiveness of an IWMP is reflected by the overall outcome in the watershed eco-system encompassing human, social, and economic aspects [20, 22]. Then, based on the acceptability of the actors, a decision-processing indexing system might be formulated. So, the following steps are used to pick the watershed performance parameters most desirable by the stakeholders' group.

Firstly, a hypothetical, standard list of 227 critical parameters or indicators is developed by reviewing social science theories, research papers, IWRM books, OECD, and the World Bank guidelines for adaptive watershed management [8–15, 20, 22–31]. Focusing on different perspectives of socio-hydrology, watershed management mechanisms, and possible economic and environmental impacts, the listed 227 parameters (Annexure 1: Indicators) are categorised into 31 sub-areas (Sub-domains) and eight operational areas (Domains) (Table 1).

Table 1 List of hypothetical domains and sub-domains for a watershed project

Domains	Sub-domains	Sub-domain code
1. Land use and morphology	Open space management	L1
	Plotted land management	L2
	Physical land-water interactions	L3
2. Water and uses	Water quantity management	W1
	Water supply management	W2
	Flood management	W3
	Hydro-electric power	W4
	Navigation facility	W5
	Mining	W6
	Water-based recreation	W7
	Water quality control—physical	W8
	Water quality control—biological	W9
	Water quality control—chemical	W10
	Water treatment	W11
3. Production and economic activities	Crop management	P1
	Economic audit	P2
	Livestock management	P3
	Population migration control	P4
	Critical planning (or budgeting) for production areas	P5
4. Forest and natural landscapes	Status assessment and planning	F1
5. Energy	Energy alternatives and conservation	E1
6. Socio-cultural actions	Impact on education	S1
	Social impact	S2
	Community inclusion	S3
7. Environmental activities	Environmental impact assessment	V1
	Conservation and awareness	V2
8. Development and management	Goal conformity	D1
	Role articulation	D2
	Dynamic assessment	D3
	Common-law causes of action	D4
	Monitoring and evaluation	D5

Secondly, an opinion survey was conducted with participants from two broad groups of stakeholders from the Satpokholi IWMP project in the Brahmaputra valley, Assam (India), to identify the most desirable watershed domains and sub-domains. A structured questionnaire based on a 5-point Likert Scale was used to collect their opinions on the hypothetical list. Then, applying relevant statistical analyses on the collected primary data, domains and sub-domains' desirability and the degree of alignment of perceptions of the involved groups are tested. Finally, a watershed project desirability index (WPDI) was developed.

The validity of the WPDI is tested in two other watersheds in Brahmaputra Valley. Results show that this indexing method is appropriate for identifying a watershed project's most desirable watershed objectives and determining the desirability index of any operating project to enhance sustainability. Additionally, managers can compare the effectiveness of different functional watershed projects in an analogous environment by applying the indexing process.

This study strives to answer a pertinent question for watershed project managers: How can we quantitatively examine the stakeholders' willingness to continue in the project? Subsequently, an indexing framework is developed to evaluate the alignment of stakeholders' perspectives regarding different project domains and sub-domains. The framework includes the most common watershed variables valid in a regional context. Therefore, it can be applied to similar projects in a homogeneous setting. Unlike the usually adopted top-down evaluation method, this study offers a participatory method using community information. The framework can potentially be used in IWMP projects, ex-ante or ex-post.

Materials and Methods

Figure 1 summarises the research procedures and methods in this study.

Data Collection

With the hypothetical list, a pilot study was conducted before moving to the data collection stage. Three experts with at least 5-years of experience in carrying out watershed projects representing the public sector, two experts from watershed monitoring agencies, and four beneficiaries were randomly selected from the general community to pilot the questionnaire.

A structured questionnaire protocol was designed for field surveys based on identified parameters. The study area, Satpokholi IWMP (3B1C8) project, is situated in the Brahmaputra valley in the Kamrup district of Assam (India). After an initial study of the project area and preliminary communication with the stakeholders, it was observed that there are noticeable differences in perception between the local stakeholders and the project experts. Subsequently, respondent stakeholders were classified into two groups using a stratified sampling approach (Table 2).

A total of 190 respondents took part out of 351 questionnaires administered, representing a response rate of 54.13%. The response rate of Group 1 is 58.3%, while that of Group 2 is 51.95%. Table 3 shows the breakdown of the survey sample.

Respondents were briefly introduced to the watershed concept and research objectives before distributing questionnaires. They rated the degree of importance of the identified

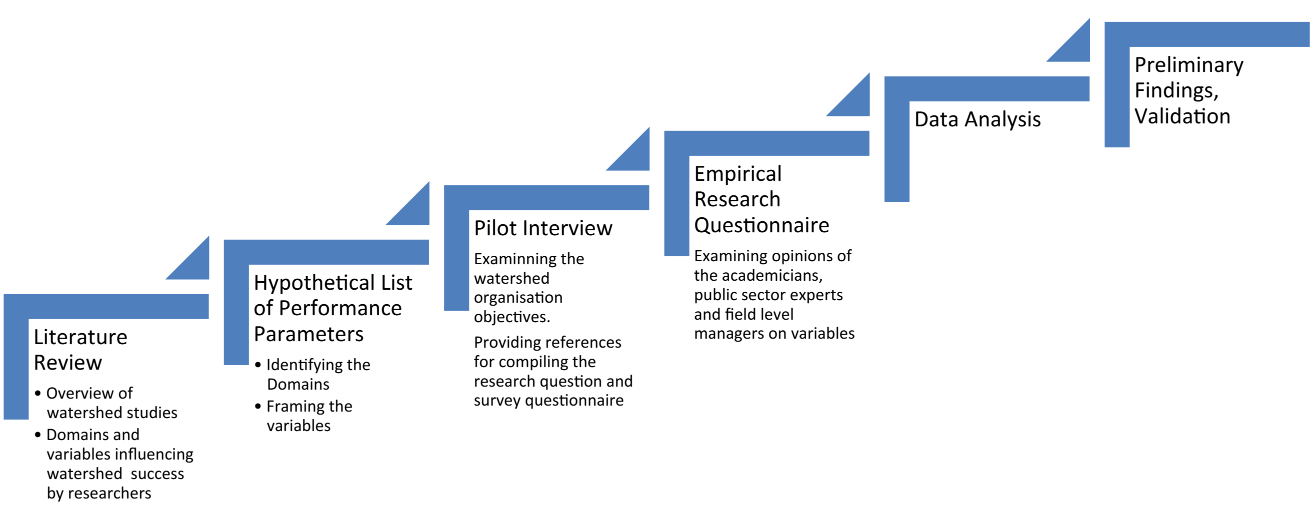

Fig. 1 The research framework

Table 2 Groups of survey respondents

Groups	Roles
Group 1	The watershed planners, academicians, consultants, and water resource and IWMP officers in the public sector
Group 2	The IWMP CBO members, community beneficiaries, and volunteers at the field level

Table 3 The response rate of the questionnaire survey

	Questionnaire administered		Valid questionnaire response received		Response rate %	
	Group 1	Group 2	Group 1	Group 2	Group 1	Group 2
Sent by hand/post	120	231	70	120	58.3	51.95
Grand total	351		190		54.13	
Sector-wise percentage	34.19	65.81	36.84	63.15	19.94	34.19

parameters according to their desirability using a 5-point Likert scale.

Data Analysis Framework

The 5-point Likert scale rating was converted to an ordinal score for numerical analysis: strongly agree = 5, agree = 4, neutral = 3, disagree = 2, strongly disagree = 1. Then, each group's mean score given to each parameter is calculated and summed up to obtain the mean score of each sub-domain. After that, the group-wise relative rankings of sub-domains and domains are determined in descending order of importance. A descriptive analysis was conducted to establish the relative significance of the parameters. Finally, the average rankings of the two surveyed groups are calculated to obtain the sub-domain and domain mean rank. This method facilitates cross-comparison of the relative significance of the domains and sub-domains across the respondents.

Spearman's rank correlation coefficient (Spearman's rho, ρ) reflects the level of agreements perceived by the groups on their rankings of domains and sub-domains (Eq. 1) [32].

$$\rho = 1 - \frac{6\sum d^2}{N\left(N^2 - 1\right)} \tag{1}$$

Here, d represents the difference in rank of the two groups for the same variable, and N denotes the number of pairs of variables ranked. The coefficient ranges between −1 and +1. A value of +1 represents a perfect positive linear correlation. In contrast, negative values indicate a negative linear correlation, meaning that the low ranking on one is associated with a high order on the other. If the correlation is close to zero, it implies that no linear relationship exists between the two variables. Thus, if rho is significant under the correlation test, one can reject the null hypothesis that there is no significant correlation between the two groups on the rankings. Generally, a rho value above or below 0.6 is standard. However, since watershed management includes macro-level accuracy, we have chosen this level to be 0.3 (in both +ve and −ve directions).

Testing the Desirability of Parameters

The terms, calculations, and arbitrary conditions for data analysis are shown in Table 4.

Determining Sub-domains' Desirability

The following methods are used to obtain the desirability of sub-domains.

Method-1 for Calculating Validity Index (VI) by Sub-domains Desirability with Threshold Mean Rank (TMR)

The average score of both groups to each sub-domain is calculated from the primary data. Then, the average scores of each group are ranked in ascending order (from low to high value). After that, the mean of the inter-group rank value for each sub-domain is calculated. The mean rank value will indicate the comparative desirability of sub-domains. It will be the researcher's prejudice to assign an MR value level as threshold mean rank (TMR), below which value he will consider the sub-domain desirable. A manager can choose the TMR for the project under study. For example, if a watershed manager decides on sub-domains whose mean ranks are 85% of the maximum mean rank and the maximum MR is MRmax, then TMR= MRmax× 85%. The sub-domains having MR value below TMR are desirable.

This method is helpful as a validity test for the hypothetical parameters list. For example, a manager can find the validity index as VI = Numbers of desired sub-domains by TMR/numbers of sub-domains. The watershed manager's prerogative will be to put an arbitrary value (say

Table 4 Terms, definitions, calculations, and conditions employed in this study

Terms	Definitions	Calculations	Arbitrary conditions for desirability check (assigned)
Domain	Watershed Project Operational Area		
Sub-domain	Watershed project sub-areas under the domains		
Desirability	The degree of appeal about a watershed domain about a domain or sub-domain		
Rank values (R1 for Group 1 and R2 for Group 2)	Rank values based on the average score obtained by each domain and sub-domain	Calculated in ascending order for the set of domains and sub-domains	
Mean rank (MR)	Mean of inter-group rank value for each domain and sub-domain	MR = (R1 + R2)/2 (rank by Gr1plus rank by Gr2 divided by number of respondent groups)	
Threshold mean rank (TMR)	MR value limit to depict stakeholders' desirability about sub-domains	TMR = maximum MR × (arbitrary percentage set by manager)	A sub-domain is desirable if its MR is below 85% of the maximum rank value (i.e. if MR < 24.23) and if MRI > 0.041; otherwise not desirable
Mean rank inverse (MRI)	Multiplicative reciprocal of MR value	MRI = 1/MR	
Rho	Spearman's rho value	By standard method	A parameter is desirable if rho > 0.3; otherwise, it is not desirable
Threshold rho (TR)	Arbitrarily chosen rho value limit to depict stakeholders' desirability about sub-domains		
Validity Index (VI)	Validity of hypothetical list of parameters for the project.	VI = numbers of desired sub-domains by TMR/numbers of sub-domains listed.	VI < 60% is not acceptable.
Effective rank (ER)	Product of rho and MRI for each sub-domain	ER = rho × MRI	The ranking of the desired domain is in ascending order. Thus, the top-order sub-domain has a high rank.
Watershed Project Desirability Index (WPDI)	Product of the number of desirable sub-domains and summation of their ER (rho × MRI)	= n × [Σ(rho × MRI)] here *n* denotes the number of sub-domains scoring above threshold rho and MRI values. (see example: sub-domains in the HR-HM quadrant of Fig. 4)	It determines the total desirability of a watershed project.
Congruency of inter-group perception on sub-domains (CIP_{SD}) and domains (CIP_D)	Rho squared expressed in percentage	= ρ^2× 100%, where ρ is Spearman's rank correlation coefficient	If $\rho > 0$, the CIP value indicates an alignment of perception; if $\rho < 0$, it shows nonalignment. The maximum value of CIP_{SD} is 1, and acceptable CIP_{SD} >9% (assigned, with acceptable $\rho > 0.3$)

The table defines the self-developed terms used in this study and their calculation methods for the developed WPDI framework. For this framework, arbitrary conditions and limiting values are assigned, as shown in the rightmost column. Policymakers and watershed managers can set suitable limiting values while using the framework in their projects

k) for desirable VI when VI<k is unacceptable. In this study, the k value is assumed to be 0.6.

Method-2 for Calculating Sub-domains Desirability by Threshold Mean Rank (TMR) and Threshold Rho (TR) Values

Method-2 is an improvement over Method-1. In Method-2, the effect of congruency of inter-group agreement about each sub-domain is incorporated to make the desirability check more meaningful.

Spearman's rho (ρ) or rank correlation coefficient indicates an alignment of inter-group agreement about a set of variables (parameters). Rho values may range from + 1 to − 1. +1 indicates a perfect association of ranks, 0 means no association, and − 1 indicates a perfect negative association of ranks. The positive rho values indicate the favourable alignment of inter-group perception about a parameter set. Hence, one of the criteria for choosing desirable sub-domains can be filtering out the sub-domains with negative rhos. Thus, rhos are calculated on the stakeholders' groups' mean rank of each sub-domain parameter. However, sub-domain selection will be based on specific arbitrary desirability conditions or threshold rho values determined by the respective watershed manager. In this study, the threshold value is 0.3, which means a sub-domain is desirable if rho > 0.3; otherwise, it is not desirable.

The steps carried out for Method-2 are as follows:

a) Calculating the inverse of mean rank (MRI) for all sub-domains (having an acceptable mean rank level). Since the assumed TMR = 24.23, the threshold MRI would equal 1/24.23 (or 0.041). Thus, the sub-domains with MRI values above 0.041 are considered desirable, otherwise undesirable.
b) Choosing an arbitrary threshold rho level (in this study, it is 0.3). Sub-domains with rho values above 0.3 are desirable; otherwise, they are undesirable.
c) Constructing a decision matrix with the rationale presented in Table 5. This matrix is similar to the Importance-performance analysis (IPA) methodology, also known as quadrant analysis [33]. IPA is a helpful and straightforward technique for identifying attributes of a product or service that most need improvement or candidates for possible cost-saving conditions without significant detriment to overall quality. Practitioners apply IPA to analyse two dimensions of service attributes: performance level (satisfaction) and customer importance. Analyses of these attributes are then integrated into a matrix that helps a manager identify primary drivers of customer satisfaction and set improvement priorities based on these findings [34]. IPA combines measurements of importance and satisfaction levels in a two-dimensional graph. Graphic IPA is divided into four quadrants based on the results of the importance-performance measurement. This method depicts essential attributes along the *X*-axis and performance attributes along the *Y*-axis [35]. We have presented the rho value along the *X*-axis and the MRI value on the *Y*-axis.

Developing Watershed Project Desirability Index (WPDI)

The rho × MRI value of a sub-domain is the product of the rho and the MRI value of the sub-domain. In rho × MRI value, the rho value acts as a weightage that evolves from inter-group congruency of stakeholders' opinions. So, sub-domain desirability is a function of congruency and mean rank. Method-2 is an improvement on Method-1, where desirability is only calculated as a function of mean rank. Therefore, a sub-domain rho × MRI value can also be termed an effective rank (ER). Subsequently, after getting

Table 5 Decision matrix

Criteria/quadrant	Rho value	MRI	Decision	Rationale
HR-HM* Quadrant	High	High	Desirable	Stakeholders agree with a *desirable* mean rank
HR-LM* Quadrant	High	Low	Undesirable	Stakeholders agree with an *undesirable* mean rank
LR-HM* Quadrant	Low	High	Doubtful (equally probable) (necessitates further inter-group consultation)	Stakeholders are not in *agreement* with a *desirable* mean rank.
LR-LM* Quadrant	Low	Low	Doubtful (equally probable) (necessitates further inter-group consultation)	Stakeholders are not in *agreement* with *undesirable* mean rank.

HR-HM represents high rho with a high mean rank, HR-LM represents high rho with a low mean rank, LR-HM represents low rho with a high mean rank, and LR-LM represents low rho with a low mean rank. Figure 4 depicts the decision graphic the rho × MRI score of each desirable sub-domain with high rho and high MRI (those appearing in the HR-HM quadrant), the desirability index of the watershed project can be calculated by the following formula,

$$\text{Watershed Project Desirability Index (WPDI)} = n \times [\Sigma (\text{rho} \times \text{MRI})]$$

where n number of desirable sub-domain above an arbitrary threshold level (sub-domains falling on the HR-HM quadrant of Fig. 2) and [Σ (rho × MRI)] = the sum of the product of rho and MRI of each desirable sub-domain.

In this index development, a question may arise about why we should have defined effective rank as (rho + MRI) using an 'OR' logic. If we use 'OR' logic, the rho value or the MRI alone can unilaterally influence the result. So, the result might be biased towards the enormous value. However, we require a method where rho and MRI are equally effective. Thus, we use 'AND logic' to define effective rank by rho × MRI, where both scores influence the result simultaneously. As such, a high score of one cannot compensate for the low score of the other, and there is no trade-off on the lower score.

Congruency of Inter-group Perception on Sub-domains (CIP_{SD})

Salkind suggested two methods for determining inter-group rank agreement [36]: (a) by eyeballing the ρ value and (b) by squaring the ρ value to reflect percentage agreement. Thus, when $\rho > 0$, the ρ^2 value gives a percentage alignment of inter-group perception, and when $\rho < 0$, the ρ^2 value gives a percentage nonalignment of inter-group perception. Accordingly, CIP_{SD} is defined as $CIP_{SD} = \rho^2 \times 100\%$.

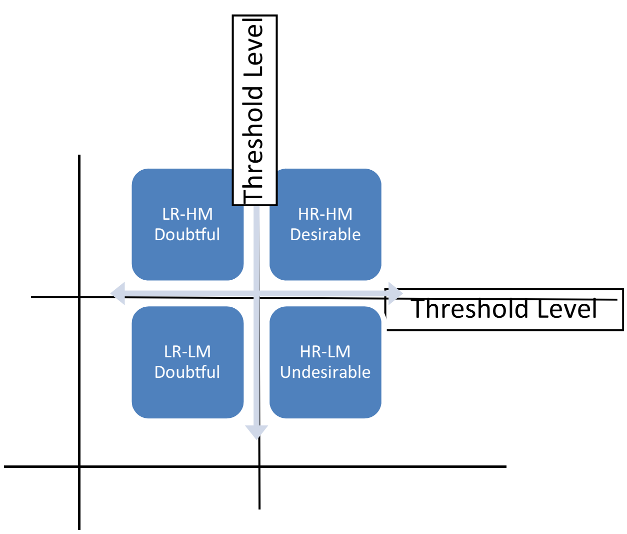

Fig. 2 Decision graphic

Determining Domains' Desirability

The following methods are used to obtain the desirability of each domain.

Domain Desirability by Domain MR

The average score given by both groups to each domain is calculated from the primary data. Then, the average scores of each group are ranked in ascending order (from low to high value). After that, the means of rank given to each domain is calculated. The MR score will indicate the comparative desirability of domains. In finding domain desirability, no threshold value is used.

Congruency of Inter-group Perception on Domains (CIP_D)

Congruency of inter-group perception on domains (CIP_D) is calculated by Spearman's rho (ρ_d) or rank correlation coefficient for the domains. The CIP_D is defined as $CIP_D = \rho_d^2 \times 100\%$.

Validation of Results

Based on the WPDI framework and methodology, separate questionnaire surveys are carried out in two other watershed projects (Kaldia and Turkunijan). The results are validated by inviting six experts representing the participant groups for a focused group discussion.

Results and Discussion

Sub-domains Desirability

Calculating Validity Index (VI) by Sub-domains Desirability with Threshold Mean Rank (TMR) (Method-1)

Applying the methods in the Satpokholi IWMP project, the sub-domains' ranks given by two stakeholders' groups and inter-group mean ranks are calculated (Table 6). The mean ranks of the sub-domains in ascending order are shown in Fig. 3.

As per the threshold MR value assigned in this study, sub-domains with the top 85% of MR value (i.e. MR below 24.23) can be considered desirable, filtering out

Table 6 Sub-domain group rank and mean rank

Domains	Sub-domains with code	Sub-domain rank Gr1	Sub-domain rank Gr2	Mean rank	Desirability by threshold MR*	Rhos	Congruency by threshold rho*	Overall sub-domain rho on rank equivalent (ρ)
1. Land use and morphology	L1 Open space management	24	10	17	D	0.716	C	0.117
	L2 Plotted land management	15	14	14.5	D	−0.487	NC	
	L3 Physical land-water interactions and prevention of extreme situations	10	6	8	D	0.184	NC	
2. Water and uses	W1 Water quantity	7	1	4	D	−0.66	NC	
	W2 Water supply	23	5	14	D	0.099	NC	
	W3 Flood management	1	2	1.5	D	−0.3	NC	
	W4 Hydroelectric power	28	25	26.5	UD	0.5	C	
	W5 Navigation	25	26	25.5	UD	1	C	
	W6 Mining	30	24	27	UD	1	C	
	W7 Water-based recreation	21	20	20.5	D	−0.187	NC	
	W8 Water quality—physical	1	29	15	D	−0.054	NC	
	W9 Water quality—biological	1	27	14	D	0	NC	
	W10 Water quality—chemical	15	31	23	D	0.395	C	
	W11 Water treatment	1	28	14.5	D	0.5	C	
3. Production and economic activities	P1 Crop production	9	9	9	D	0.252	NC	
	P2 Economic audit	1	3	2	D	−0.333	NC	
	P3 Livestock	12	8	10	D	−0.15	NC	
	P4 Population migration	31	7	19	D	−0.25	NC	
	P5 Critical planning (or budgeting) for production areas	19	16	17.5	D	0.57	C	
4. Forest and natural landscapes	F1 Status assessment	22	19	20.5	D	0.805	C	
5. Energy	E1 Awareness	25	23	24	D	0.632	C	
6. Socio-cultural actions	S1 Impact on education	29	13	21	D	0.5	C	
	S2 Status of community actions	11	15	13	D	−0.232	NC	
	S3 Community engagement assessment	20	4	12	D	0.359	C	
7. Environmental activities	V1 Impact assessment	13	17	15	D	0.084	NC	
	V2 Awareness programme	1	21	11	D	−0.411	NC	

Table 6 (continued)

Domains	Sub-domains with code	Sub-domain rank Gr1	Sub-domain rank Gr2	Mean rank	Desirability by threshold MR*	Rhos	Congruency by threshold rho*	Overall sub-domain rho on rank equivalent (ρ)
8. Development and management	D1 Goal conformity	14	18	16	D	−0.2	NC	
	D2 Role articulation	7	12	9.5	D	−0.046	NC	
	D3 Dynamic assessment	18	22	20	D	−0.618	NC	
	D4 Common law causes of action	27	30	28.5	UD	0.82	C	
	D5 Monitoring	17	11	14	D	0.114	NC	
Total sub-domains	31							
Total desirable sub-domains by threshold mean rank	27							
Validity Index	= (27/31) ×100%=87.1							
Total sub-domains with aligned opinions (with +ve rho)	18							
Total sub-domains with nonaligned opinions (with ve rho)	13							
Total congruent sub-domains above threshold rhos	12							
CIP_{SD}	$=(\rho^2)\times$ 100%=1.37							

**D*, *UD*, *C*, and *NC* denote desirable, undesirable, congruent, and non-congruent, respectively

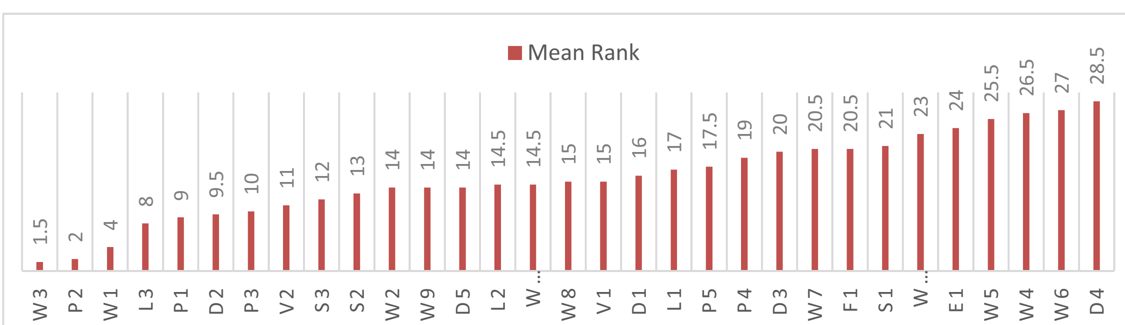

Fig. 3 Mean ranks value of sub-domains

the undesirable sub-domains (W4, W5, W6, and D4) (Fig. 3). The sub-domain W3 scores the lowest MR value (1.5), denoting W3 as the most desirable sub-domain by mean rank. On the other hand, the sub-domain D4 scores the uppermost MR (28.5), indicating D4 to be the least desirable sub-domain by mean rank. Noticeably, 27 sub-domains out of 31 have MR values below the threshold, giving a good validity index (87.1). This indicates that the hypothetical parameter list is acceptable for the project under study.

Calculating Sub-domains Desirability by Threshold Mean Rank (TMR) and Threshold Rho (TR) Values (Method 2)

The Spearman's rho value is calculated over the mean rank of both groups to test the alignment of the perception of the stakeholders' groups ($\rho = 0.117$) (Table 6). This positive value indicates a positive alignment of inter-group perception regarding the sub-domains. Nevertheless, the rho value is much lower than the acceptable rho limit or threshold rho value (0.3) assigned for this study. The feeble agreement of perception is also reflected by the congruency index CIP_{SD} (1.37%), which is below the acceptable value (9%) (Tables 4 and 6).

It is seen that, out of 27 desirable sub-domains, only 18 sub-domains show a positive inter-group alignment of perception (66.7%). Again, out of 27, only 12 have positive alignment levels above the threshold (44%). In other words, these 12 sub-domains are more desirable as they have both acceptable mean rank and favourable alignment.

Calculating Watershed Project Desirability Index (WPDI)

For all sub-domains with rho > 0, MRI and rho × MRI are obtained using the method described above. The results are presented in Table 7; Fig. 4.

Eight sub-domains are in the HR-HM quadrant, as their MRI value and rho value are above the threshold MRI value (0.041) and the threshold rho value (0.3). Therefore, they are in the desirable category. Four sub-domains are in the HR-LM quadrant as they have MRI < threshold MRI, and rho > threshold rho. Here, the high rho value shows that stakeholders agree about their MRI. So, these sub-domains are rejectable. There are five sub-domains in the LR-HM quadrant. They have high MRI, but stakeholders' agreement about their MRI is low. Therefore, no decision can be taken

Table 7 Decision table showing desirable sub-domains (coloured rows)

Sub-domains Code	Mean Rank	Rho	MRI	Rho × MRI	Quadrants	Decision
V1	15	0.084	0.067	0.006	LR-HM	Doubtful
W2	14	0.099	0.071	0.007	LR-HM	Doubtful
D5	14	0.114	0.071	0.008	LR-HM	Doubtful
L3	8	0.184	0.125	0.023	LR-HM	Doubtful
P1	9	0.252	0.111	0.028	LR-HM	Doubtful
S3	12	0.359	0.083	0.030	HR-HM	Desirable
W10	23	0.395	0.043	0.017	HR-HM	Desirable
W4	26.5	0.500	0.038	0.019	HR-LM	Rejectable
W11	14.5	0.500	0.069	0.034	HR-HM	Desirable
S1	21	0.500	0.048	0.024	HR-HM	Desirable
P5	17.5	0.570	0.057	0.033	HR-HM	Desirable
E1	24	0.632	0.042	0.026	HR-HM	Desirable
L1	17	0.716	0.059	0.042	HR-HM	Desirable
F1	20.5	0.805	0.049	0.039	HR-HM	Desirable
D4	28.5	0.820	0.035	0.029	HR-LM	Rejectable
W5	25.5	1.000	0.039	0.039	HR-LM	Rejectable
W6	27	1.000	0.037	0.037	HR-LM	Rejectable
Total sub-domains with MRI > 0.04	13					
Total sub-domains with rho > 0.3	12					
Total + ve rho sub-domains	17					
Total desirable sub-domains (n) (number of sub-domains in the HR-HM quadrant of Fig. 4)	8					
Total doubtful sub-domains	5					
Total rejectable sub-domains	4					
Threshold MR	24.23					
Threshold MRI	0.041					
Threshold rho	0.3					
Total rho × MRI for all desirable sub-domains	0.246					
Watershed Project Desirability Index (WPDI)	1.966					

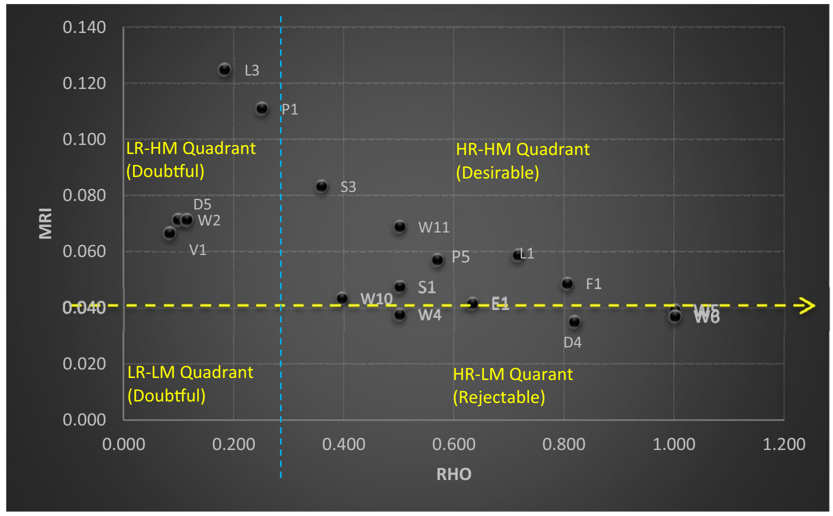

Fig. 4 Rho Vs. MRI plot. Note: The horizontal dashed line shows a threshold MRI value (0.041), and the horizontal dashed line indicates a threshold rho value (0.300)

about them. Consequently, they are in the doubtful category. It is seen that there is no sub-domain in the LR-LM quadrant. Even if there were one, stakeholders' opinions about its low MRI would be weak (as their rho < threshold rho). So, it would be in the doubtful category.

The eight sub-domains (E1, F1, L1, P5, S1, S3, W10, W11) in the HR-HM quadrant will be the most acceptable for calculating the watershed index (Fig. 4). Then, using the method described in the 'Developing Watershed Project Desirability Index (WPDI)' section, WPDI of the project under study is estimated.

Here, for the watershed project under investigation, $n = 8$ and Σ (rho $\times$ MRI) = 0.246; therefore, the Watershed Project Desirability Index (WPDI) = 8 $\times$ 0.246 = 1.966.

Domains' Desirability

Desirable Domains by Mean Rank

The rank given to each domain by the two stakeholders' groups and the mean rank scored by each domain are shown in Table 8.

Domain 1 (land use and morphology) (MR value 2 and inter-group rank difference 0) is the most desirable. Most of the action of water in a basin is conspicuous on the surface morphology of the area. Land use is primarily dependent on water flow behaviour. Hence, the choice of domain 1 as the most desirable domain is also the most realistic. Moreover, the inter-group rank difference of value zero indicates complete congruence of perception regarding the desirability of this domain. On the other hand, domain 5 (energy) is the least desirable (MR value of 7.5) for both stakeholder groups. This score is also realistic since most watershed areas under this study do not have any alternative energy generation or allied hydropower activities. The inter-group rank difference is highest for domain 3 (production and economic activities) and domain 6 (socio-cultural actions), which indicates that the stakeholders' perceptions regarding these domains are the most incongruent. The incongruency of opinions in the case of domain 7 (environmental activities) is also significant.

Going more profoundly through the results, essential interpretations can be drawn regarding the perception of the stakeholders' groups. For example, domain 3 has the first

Table 8 Group-wise domain rank, mean rank, and rho

Domains	Domain ranking Gr1	Domain ranking Gr2	Inter-group rank difference	Mean rank	Rho on rank equivalent	CIP_D
Domain 1: Land use and morphology	2	2	0	2	−0.024	0.06%
Domain 7: Environmental activities	1	5	−4	3		
Domain 3: Production and economic activities	6	1	5	3.5		
Domain 4: Forest and natural landscapes	5	4	1	4.5		
Domain 8: Development and management	3	6	−3	4.5		
Domain 2: Water and uses	4	7	−3	5.5		
Domain 6: Socio-cultural actions	8	3	5	5.5		
Domain 5: Energy	7	8	−1	7.5		

rank amongst Group 2 stakeholders (consisting of the field-level watershed managers and watershed participants from the community). Still, its rank from the Group 1 stakeholders (consisting of water resource planners, academicians, consultants, and water management officers in the public sector) is 6. Such diversity of opinions regarding a critical watershed domain calls for urgent action from the watershed planners. The case for domain 6 and domain 7 is similar. Domain7 ranks 1 from Group 1, but its rank from Group 2 is 5. This indicates that Group 2 (the community group) has a lesser appeal for environmental activities, unlike the preference given by Group 1. Domain 6 has the last ranking (8) from the Group 1 stakeholders, whereas its rank from Group 2 is 3. It infers that watershed management programs prioritise including actions towards the local socio-cultural development for enhancing community participation. Thus, the disparity reflected by the result can provide valuable input from field-level stakeholders to develop effective interventions.

Congruency of Inter-group Perception on Domains (CIP_D)

Spearman's rho is calculated over the mean rank of both groups to test the alignment of the stakeholders' group's perception of the domains. The obtained rho (−0.024) value is weak, negative, and below the acceptable level of 0.3 (arbitrarily chosen for this study). Thus, it indicates a very feeble alignment of perceptions of both groups regarding the domains. Similarly, the CIP_D (0.06%) reflects the weak agreement.

Finally, the results show that the indexing method presented in this study can be applied to identify the desirable watershed objectives from the stakeholders' perspectives. The sub-domain desirability and WPDI rest on two primary threshold conditions that policymakers or water managers can arbitrarily assign: the rho value and the mean rank's threshold value. The choice of using Spearman's rho value serves two essential purposes. Firstly, rho values enable us to measure stakeholders' perceptions, and secondly, they act as weightage factors with mean rank values in determining the final desirability decision.

Here, threshold rho and mean rank are assumed as 0.3 and 24.23 (85% of the hypothetical watershed performance parameters list), respectively. Watershed managers of different projects can use one hypothetical master list for every watershed project operating in an analogous hydro-sociological region or modify it as required. Then, before the final WPDI calculation, the project managers can check the validity of the master list for each project by calculating the validity index (VI).

Results Obtained from Kaldia and Turkunijan IWMP

The same WPDI framework and methodology were applied in the other two IWMP projects (Kaldia IWMP and Turkunijan IWMP, Brahmaputra Valley, Assam, India), having analogous hydro-sociological settings. Before obtaining the key indices, the validity of the framework is tested. The summarised results are shown in Fig. 5.

The results and indices values are cross-referenced with the local stakeholders of each project. There is broad consensus on the results. The developed framework's validity indices (VIs) are above 87% for all projects. It corroborates one of the study objectives: an adaptable framework can be designed to measure watershed project desirability for watershed projects operating in a homologous regional setting.

From the results, three other valuable indices are derived, and they provide quantitative values about the complex qualitative attributes like stakeholders' perception of the planned project parameters, which are often very difficult to measure. Fulfilling the research aim, the indices will deliver vital insights into the effectiveness of the operating

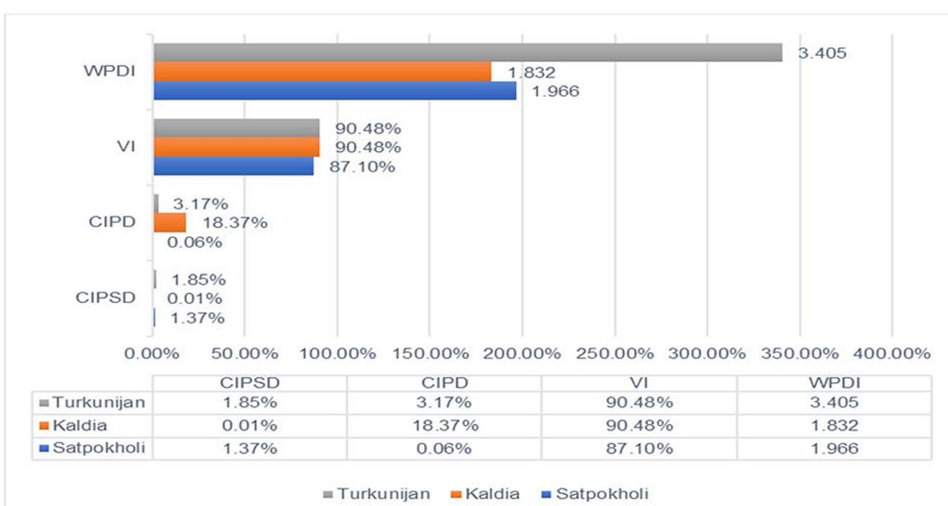

Fig. 5 Different indices of all three IWMPs

watershed projects to enhance community participation and design new interventions for project reengineering. A deeper introspection into the congruency of perception about sub-domains and parameters will enable watershed managers to assess and filter out the parameters with low congruency periodically.

Moreover, the WPDI framework is resilient enough to incorporate arbitrary threshold limits (for rho and MR values) in determining congruency as watershed managers decide. Policymakers and watershed managers can shorten the list of desirable parameters and make the obtained indices more stringent by increasing the threshold values with procedures mentioned in the 'Material and methods' section.

Comparing the functionality and effectiveness of different watershed projects operating in a region has been challenging for policymakers. In the present framework, many parameters are relatively universal; therefore, this evaluation methodology would apply to other IWMP projects with suitable modifications, if necessary. Thus, the project indexing method may greatly help the managers as a performance measuring and comparing tool. This study has evaluated three sets of different indices (WPDI, CIP_D, and CIP_{SD}) for Kaldia, Satpokholi, and Turkunijan IWMP, and policymakers can compare those values for introducing interventions. Here, the WPDI of Turkunijan IWMP has the highest value (3.405), indicating the best stakeholders' desirability amongst the studied projects. On the other hand, the lowest stakeholder desirability (1.382) is seen in the Kaldia project. In the case of Kaldia, higher congruency of perception on domains (CIP_D =18.37%) but very low congruency of perception on sub-domains (CIP_{SD}=0.01%) are observed. It indicates a higher disparity amongst the stakeholders' group in selecting the sub-domains. With deeper introspection, the concerned watershed manager might modify the parameters or initiate stakeholders' consultation to eliminate possible misconceptions. This way, watershed project planning could be made less abstract and more strategic for direct impact and clearly defined project goals, preferably with community involvement. This is crucial because local participation is proposed to achieve various goals, including sharpening poverty targeting, improving service delivery, expanding livelihood opportunities, and strengthening demand for good governance [37].

The methods proposed in this study would be helpful in alternative planning and decision-making in both project feasibility and operation stages. Applying ex-ante, the technique would help better collaborative planning, while using ex-post it would facilitate dynamic policy review for better sustainability, which had been a significant objective in watershed programmes [3, 8, 17, 20, 38].

Another advantage of this indexing method is that, unlike many top-down evaluation strategies, it is based on a participatory approach, which would generate active participation of the general community and reduce future conflicts.

Conclusion

By design, watershed programmes are best carried out by stakeholders' participation. Policymakers and watershed managers strive for ways to potentially reduce incoherent stakeholders' perceptions and conflicting demands when they exist. Moreover, any project's continuous evaluation and performance analysis are essential for suitable intervention and reengineering. Supplementing this objective, this study has proposed a methodology to explore the watershed parameters most desirable by the stakeholders' groups in IWMP projects.

Pursuing a vital watershed management question, 'How can local people get involved in the complexities of planning, designing and managing the water resource issues?', this study examines stakeholders' desirability about the planned watershed parameters. It develops an indexing method for harmonising community participation.

As the first step of the indexing methodology, an exhaustive parameters list covering watershed inventories that may be valid for a broad spectrum of watershed projects was constructed. The parameters, including the watershed project-level information and infrastructural inputs, are extracted from IWMP protocols, the documents of the State Level Nodal Agency, Assam, Department of Land Reform and NITI Aayog, (India) and empirical studies of IWMP projects in Brahmaputra Valley, Assam (India). Then, suitable statistical methods are fitted to develop a hypothetical framework. Subsequently, the framework was applied in selected IWMP projects via a questionnaire survey to glean community information and stakeholders' perceptions of the theoretical watershed parameters.

The framework has the potential to filter the parameters by cross-examining two vital attributes: rank and stakeholders' aggregability. The findings show that in every project, some parameters have acceptable rank but unacceptable aggregability. Very few parameters have both acceptable rank and aggregability. Only these parameters are used for estimating the watershed project desirability index (WPDI), which has made the indexing method robust and unique. The WPDI of Satpokholi, Kaldia, and Turkunijan IWMP projects are 1.966, 1.831, and 3.406, respectively, The framework substantially reveals critical misalignments of stakeholders' perceptions regarding the planned parameters of the studied watershed projects. The degree of misalignment could also be quantified to present a measurable state of affairs in watershed projects. The congruency of inter-group perceptions regarding the sub-domains for Satpokholi, Kaldia, and Turkunijan projects are 1.37%, 0.01%, and 1.85%, respectively.

The findings also reveal that the framework will be a worthy tool to compare the effectiveness of different watershed projects regarding community participation in project planning. As the methodology is based on a participatory approach, the indexing procedure helps promote an enabling environment to improve social learning and understanding of the water system, encouraging the exchange of knowledge and best management practices.

Although on-the-ground achievements are the proper lens for justly evaluating success, a limitation may crop up relating to scale issues—spatial and temporal. Therefore, this study allows managers to compare the effectiveness of different watershed projects operating in analogous socio-hydrological environments. Regarding the generalisation of the framework, a critical point of concern is the degree of transferability of the findings to evaluate the effectiveness of any IWMP projects. Although many variables are relatively universal in this framework, making assumptions about which cases offer similar contexts is often challenging. Therefore, the appropriate way to deal with the transferability of findings is to initiate a large number of case studies in the future to obtain statistically significant analyses.

Besides contributing to watershed management, the developed methodology might be valuable in exploring specific aspects of the problem diagnosis and goal articulations in socio-economic endeavours where stakeholders' perceptions are diverse. Thus, researchers and policymakers might apply a similar approach in other developmental programs like public health, public-private partnerships, and rural and urban development.

Annexure 1: Indicators

Table 9 Some critical watershed domains, sub-domains and indicators with code

Domains	Sub-domains	Operational areas/ variables/indicators
Domain1: Land use/morphology	Open space management	P1-L1-a: Open space- Non-agricultural
		P2-L1-b: Open space- Agricultural
		P3-L1-c: Open space- Agricultural cropland
		P4-L1-d: Open space- Agricultural rangeland
		P5-L1-e: Open space- Parkland
		P6-L1-f: Open space- Forested
		P7-L1-g: Open space- Undeveloped/ idle land
	Plotted land management	P8-L2-a: Residential land
		P9-L2-b: Commercial land
		P10-L2-c: Industrial land
		P11-L2-d: Townhouses
		P12-L2-e: Roads and highways
	Physical land-water interactions and prevention of extreme situations	P13-L3-a: Soil erosion
		P14-L3-b: Landslides
		P15-L3-c: Siltation of reservoirs
		P16-L3-d: Siltation of cropping field
		P17-L3-e: Stormwater management
		P18-L3-f: Drainage system
		P19-L3-g: Flood occurrence
		P20-L3-h: Flood damage
		P21-L3-i: Drought management
		P22-L3-j: Loss of soil fertility
		P23-L3-k: Soil moisture content
		P24-L3-l: Sediment production
		P25-L3-m: Land pollution
		P26-L3-n: Soil feature degradation

Table 9 (continued)

Domains	Sub-domains	Operational areas/ variables/indicators
Domain2: Water quality & quantity/use	Water quantity	P27-W1-a: Stream flow
		P28-W1-b: Ground water level
		P29-W1-c: Water logging
		P30-W1-d: Spread of water bodies (Ponds/ wells/ springs)
		P31-W1-e: Rejuvenation of water bodies (New)
		P32-W1-f: Water harvesting
	Water supply	P33-W2-a: Potable water supply- Public
		P34-W2-b: Potable water supply- Private
		P35-W2-c: Industrial water supply
		P36-W2-d: Agricultural water supply- Irrigation
		P37-W2-e: Agricultural water supply- Livestock
		P38-W2-f: Agricultural water supply- Aquaculture
	Flood management	P39-W3-a: Flood control- Dams
		P40-W3-b: Flood control- Levee
		P41-W3-c: Flood control- Reservoirs
		P42-W3-d: Flood control- Channel protection
	Hydroelectric power	P43-W4-a: Hydroelectric power- Impoundment
		P44-W4-b: Hydroelectric power- Dam
		P45-W4-c Hydroelectric power- Pumping
	Navigation	P46-W5-a: Navigation- Recreational
		P47-W5-b: Navigation- Commercial shipping
		P48-W5-c: Navigation- Commercial
	Mining	P49-W6-a: Mining- Quarrying
		P50-W6-b: Mining- Ore milling & crushing
	Water based recreation	P51-W7-a: Water-based recreation- Fishing
		P52-W7-b: Water-based recreation- Swimming
		P53-W7-c: Water-based recreation- Boating
		P54-W7-d: Water-based recreation- Picnicking
		P55-W7-e: Water-based recreation- Nature aesthetics
		P56-W7-f: Water-based recreation- Bird watching
		P57-W7-g: Water-based recreation- Golf course
	Water quality -physical	P58-W8-a: Water quality- Physical (Overall)
		P59-W8-b: Water quality- Clarity
		P60-W8-c: Water quality- Suspended sediment
		P61-W8-d: Water quality- Conductivity
		P62-W8-e: Water quality- Hardness
		P63-W8-f: Water quality- Temperature
		P64-W8-g: Water quality-Aesthetics
	Water quality -biological	P65-W9-a: Water quality- Biological- Bacteria
		P66-W9-b: Water quality- Biological- Parasites
	Water quality -chemical	P67-W10-a: Water quality- Chemical- Dissolved oxygen
		P68-W10-b: Water quality- Chemical- Nutrients

Table 9 (continued)

Domains	Sub-domains	Operational areas/ variables/indicators
		P69-W10-c: Water quality- Chemical- Metals/ Salts
		P70-W10-d: Water quality- Chemical- Trace elements (DDT/ Chlorine etc)
		P71-W10-e: Water quality- Chemical
	Water treatment	P72-W11-a: Water treatment- Filtration
		P73-W11-b: Water treatment- Chemicals tested (Iron/ Arsenic/ Fluoride)
		P74-W11-c: Water treatment- Testing Facility
Domain3: Production or economic activities	Crop production	P75-P1-a: Level of production
		P76-P1-b: Fallow & wasteland brought under cultivation
		P77-P1-c: Area under irrigation
		P78-P1-d: Area under micro-irrigation
		P79-P1-e: Area under HYV cropping
		P80-PI-f: Market support/ Eco centres
		P81-P1-g: Cooperative activities
		P82-P1-h: Price support
		P83-P1-i: Off farm facilities
		P84-P1-j: Export/ import facility
		P85-P1-k: Use of new technology
		P86-P1-l: Local innovations
		P87-P1-m: Cropping pattern
		P88-P1-n: Cash crop production
		P89-P1-o: Vegetable production
		P90-P1-p: Cropping intensity/ land productivity
		P91-P1-q: Crop selection for maximum nutritional uptake
		P92-P1-r: Crop failure protection
	Economic audit	P93-P2-a: Number of families with positive income
		P94-P2-b: Average employment days
		P95-P2-c: Maximising combined income
		P96-P2-d: Households with stable income
		P97-P2-e: Maintenance of financial disciplines
		P98-P2-f: Employment opportunity
		P99-P2-g: Self-employment opportunity
		P100-P2-h: Unproductive employment
	Livestock	P101-P3-a: Livestock production
		P102-P3-b: Number of livestock owners adopting artificial insemination
		P103-P3-c: Adoption of apiculture
		P104-P3-d: Adoption of pisciculture
		P105-P3-e: Adoption of milk production

Table 9 (continued)

Domains	Sub-domains	Operational areas/ variables/indicators
	Population migration	P106-P4-a: Population migration- Inward
		P107-P4-b: Population migration- Outward
		P108-P4-c: Distress migration
	Critical planning (or budgeting) for production areas	P109-P5-a: Critical area planning -Agricultural
		P110-P5-b: Critical area planning -Livestock
		P111-P5-c: Critical area planning -Aquaculture
		P112-P5-d: Critical area planning -Industry
		P113-P5-e: Area under cultivated fodder
		P114-P5-f: Strip cropping/ terracing
		P115-P5-g: Cover cropping
		P116-P5-h: Range management
		P117-P5-i: Integrated pest control
Domain4: Forest or natural landscapes	Status assessment/action	P118-F1-a: Soil damage by deforestation
		P119-F1-b: Forest destruction
		P120-F1-c: Temperature rise due to deforestation
		P121-F1-d: Green house gas emission
		P122-F1-e: Cutting of unripe trees
		P123-F1-f: Forest fire occurrences
		P124-F1-g: Loss of flora and fauna
		P125-F1-h: Number of families engaged in agroforestry
		P126-F1-i: Number of rich species- flora
		P127-F1-j: Number of rich species- fauna
		P128-F1-k: Area under grassland
		P129-F1-l: Number of types of animals
		P130-F1-m: Number of types of plants
Domain5: Energy	Status assessment/awareness	P131-E1-a: Energy/fuel waste
		P132-E1-b: Loss of power generation
		P133-E1-c: Use of alternative/ new energy source
		P-134-E1-d: Energy conservation efforts
Domain6: Socio-cultural actions	Impact on education	P135-S1-a: Literacy
		P136-S1-b: School dropout
		P137-S1-c: Girl's education
	Status of community actions	P138-S2-a: Poverty alleviation
		P139-S2-b: Disorganised labour force
		P140-S2-c: Child marriage
		P141-S2-d: Gender equality
		P142-S2-e: Women's empowerment
		P143-S2-f: Youth empowerment
		P144-S2-g: Socio-cultural cohesion
		P145-S2-h: Unscientific behaviour/ loss of civility
		P146-S2-i: Lack of cooperation
		P147-S2-j: Labour problem
		P148-S2-k: S10-Defined property rights
		P149-S2-l: Alienation
		P150-S2-m: Equitable resource distribution
		P151-S2-n: Institutional anarchy
		P152-S2-o: Number of social audit

Table 9 (continued)

Domains	Sub-domains	Operational areas/ variables/indicators
		P153-S2-p: Number of community assets created
		P154-S2-q: Number of private assets created
	Community engagement assessment	P155-S3-a: Number of CBOs linked
		P156-S3-b: Number of SHGs linked
		P157-S3-c: Number of WTCGs linked
		P158-S3-d: Number of Gram Sabhas linked
		P159-S3-e: Protection of valued features
		P160-S3-f: Community action
		P161-S3-g: Human environment interdependence
		P162-S3-h: Joint (public & private) management
		P163-S3-i: Community management
Domain7: Environmental activities	Impact assessment	P164-V1-a: Protection of aquatic and wetland habitat
		P165-V1-b: Ecological balance
		P166-V1-c: Precipitation measurement
		P167-V1-d: Meteorological measurement
		P168-V1-e: Web-based weather service
		P169-V1-f: Ambient solar radiation
		P170-V1-g: Pollution control
		P171-V1-h: Excessive use of surface water
		P172-V1-i: Excessive use of groundwater
		P173-V1-j: Eco Park development
		P174-V1-k: Waterborne commerce
		P175-V1-l: Temperature rise
		P176-V1-m: Greenhouse gas emission
		P177-V1-n: No of types of animal species
		P178-V1-o: No of types of plant species
		P179-V1-p: No of individuals of each species
		P180-V1-q: Biota health
		P181-V1-r: Species diversity
		P182-V1-s: Natural landscape
		P183-V1-t: Effect on current use of land & resources
		P184-V1-u: Effect on rare & endangered species
		P185-V1-v: Effect on human health
		P186-V1-w: Scope for future use of resources
		P187-V1-x: Identifying unforeseen effects
	Awareness programme	P188-V2-a: Crop/plant selection for minimum pesticides
		P189-V2-b: Appropriate pesticide/ herbicide use
		P190-V2-c: Use of drip irrigation
		P191-V2-d: Recycle/reuse of irrigation water
		P192-V2-e: Appropriate manuring
		P193-V2-f: Anti-litter ordinance
		P194-V2-g: Farmers awareness about climate change

Table 9 (continued)

Domains	Sub-domains	Operational areas/ variables/indicators
Domain8: Development and management	Goal conformity	P195-D1-a: National perspective conforming
		P196-D1-b: Regional perspective conforming
		P197-D1-c: Local perspective conforming
		P198-D1-d: Participatory evaluation
	Role articulation	P199-D2-a: Roles of project managers- Service continuity
		P200-D2-b: Anticipation of future problems
		P201-D2-c: Roles of project managers- Skills
		P202-D2-d: Roles of project managers- Service performance
		P203-D2-e: Roles of stakeholders
		P204-D2-f: Training of stakeholders- CBO
		P205-D2-g: Training of stakeholders- farmers
		P206-D2-h: Exposure visit of stakeholders- CBO
		P207-D2-i: Exposure visit of stakeholders- farmers
	Dynamic assessment	P208-D3-a: Level of regulations/ authority sharing
		P209-D3-b: Scope of review/ redirection
		P210-D3-c: Provision of sustainability audit
		P211-D3-d: Interactions with stakeholders
		P212-D3-e: Fairness and equity in service delivery
		P213-D3-f: Number of sustained watershed organisations
		P214-D3-g: Number of micro-enterprises
	Statute/law	P215-D4-a: Conflict management
		P216-D4-b: Nuisance reduction- Private
		P217-D4-c: Nuisance reduction- Public
		P218-D4-d: Regulating water rights/ riparian rights
		P219-D4-e: Regulating strict liability
		P220-D4-f: Regulating trespass
		P221-D4-g: Regulating negligence
	Monitoring	P222-D5-a: Compliance with legal obligations
		P223-D5-b: Effectiveness of mitigation measures
		P224-D5-c: New unusual effects
		P225-D5-d: High-valued sites
		P226-D5-e: Repetitive monitoring
		P227-D5-f: Third-party audit

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Data Availability The datasets generated during and analysed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics Approval This is an observational study and does not include any personal data from individual survey respondents. Hence, no ethical approval is required.

Informed Consent was obtained from all individual participants included in the study. Verbal informed consent was brought before the interviews.

Competing Interests The authors declare no competing interests.

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