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A planning-oriented sustainability assessment framework for peri-urban water management in developing countries

Markus Starkl [a,*], *Norbert Brunner* [b], *Eduardo López* [c], *José Luis Martínez-Ruiz* [c]

[a] *University of Natural Resources and Life Sciences (BOKU), Vienna 1180, Austria*
[b] *Centre for Environmental Management and Decision Support (CEMDS), Vienna 1180, Austria*
[c] *Mexican Institute of Water Technology (IMTA), Cuernavaca 62550, Mexico*

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ABSTRACT

DPSIR and the three-pillar model are well-established frameworks for sustainability assessment. This paper proposes a *planning-oriented sustainability assessment framework* (POSAF). It is informed by those frameworks but differs insofar as it puts more emphasis on a constructivist conception which recognises that sustainability needs to be defined anew for each planning problem. In finding such a consensus definition, POSAF uses participatory scenario analysis and participatory planning, technical feasibility study, participatory assessment, analysis of trade-offs and social networks in an unusual combination and for goals that differ from the original conceptions of these methods. POSAF was applied in a peri-urban area of Mexico City for the design of improved water service provision, integrating solid waste management. It supported consensus amongst users about the importance of environmental issues, informed planners about the values of stakeholders and users, detected local differences, and identified possible conflicts at an early stage of decision-making.

1. Introduction

1.1. Concepts of sustainability assessment

There is an abundance of sustainability assessment methods. They tend to differ in the tools applied, but most use just two well-established frameworks, namely the PSR (OECD) and DPSIR (EEA) framework of drivers, pressures, states, impacts, and responses and the three-pillar model of social, economic, and environmental dimensions, possibly expanded by institutions or culture as a fourth pillar. (A framework defines views on the factors and interactions which matter for sustainability.) Wallis et al. (2011) surveyed 54 approaches and most are based on these frameworks or combinations thereof. Their common ground is the (positivist) assumption that there are scientific models which correctly describe sustainability.

In the planning of water infrastructure it does not suffice to feed local data into sustainability theories and compute the

* *Corresponding author*. Competence Centre for Decision-Aid in Environmental Management, University of Natural Resources and Life Sciences (BOKU), DIB, Gregor Mendel Strasse 33, Vienna 1180, Austria. Tel.: +43 1476545057.
E-mail addresses: markus.starkl@boku.ac.at (M. Starkl), office@cemds.org (N. Brunner), edumixtli@yahoo.com.mx (E. López), jlmartin@tlaloc.imta.mx, demeparis@yahoo.fr (J.L. Martínez-Ruiz).

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most sustainable solution, because, 'there are no indicator sets [...] backed by compelling theory, rigorous data collection and analysis' (Parris and Kates, 2003). Instead, in planning bottom–up sustainability assessments have been developed, as in the Strategic Choice Approach (Friend and Hickling, 2005; Lennartsson et al. 2009), CLUES (Lüthi et al. 2011), and Lundie et al. (2006), where stakeholders help in determining importance of criteria. Simon et al. (2004) ask stakeholders to identify antagonisms locally and overcome them by piecemeal improvements. Common to bottom–up approaches is the identification of the problem and the actors concerned, the factors that affect the problem (c.f. DPSIR), the aspects to consider (c.f. the three-pillar model), and finally the development of alternatives and their assessment, with various degrees of stakeholder participation. Because of the fragmentation of stakeholders (Lienert et al. 2013) such participation is difficult to implement, and in practice experts often decide what is best for users. Such planning is doomed to fail, however (Starkl et al. 2013b).

To overcome this difficulty, the paper presents a *planning-oriented sustainability assessment framework* (POSAF). POSAF aims at making stakeholder participation in sustainability assessment more consequential by using a *constructivist conception* (Roy, 2010). It does not presuppose a 'true' theory of sustainability, but instead limits itself to providing tools for communication between those concerned with planning and by supporting their reflection on problems commonly related to sustainability. Thus, POSAF focuses on the process by which stakeholders of planned water systems define their own common ad hoc notion of sustainability. In particular, POSAF addresses the potential problem of societal conflicts owed to the fragmentation of stakeholders, and introduces social network analysis and other tools from social sciences to sustainability assessment. This paper illustrates the application of POSAF and these tools.

1.2. *Water management applications for POSAF*

Peri-urban water management in developing countries is an issue of serious concern and lacks sustainable solutions. Centralised metropolitan systems often serve only a small urban core (Marshall et al. 2009) and their expansion lags behind the pace of urban growth (Peter-Varbanets et al. 2009). Environmental pollution may destroy the natural landscapes that still surround cities (Torres, 2011), weakening important ecosystem services such as improvement of water quality or protection from flooding (Butterworth et al. 2007). For instance, downstream of the capital city Delhi the water quality of the Yamuna River is amongst the worst in India (Kazmi et al. 2013). The situation is further complicated by the existence of various institutions with no clear responsibilities and inadequate financial resources to provide sustainable solutions. It can be concluded that peri-urban water management in developing countries faces multiple conflicts, including those between stakeholders (Douglas, 2006).

The authors tested elements of POSAF in China, Indonesia, and Nepal. On the basis of those experiences POSAF was developed and tested in Argentina and Mexico, whereby a complete demonstration was conducted for Mexico (see Section 3). Currently, POSAF is tested in India and preliminary results have also informed this paper. Overall, POSAF encompasses the following four steps (Fig. 1):

- Participatory scenario analysis and participatory planning. These are well-established methods, but applied in a novel context as tools to raise the awareness and interest of stakeholders, which in developed countries is a precondition for bottom–up approaches (Letsela et al. 2010), and engage them in a dialogue about water planning. In Mexico, users together with institutional stakeholders first created *development scenarios* which they could understand and evaluate. A development scenario is a vision of how the case study area could develop in future. It is not restricted to aspects of water management but includes all aspects of urban planning, allowing different sectors to be integrated in sustainability considerations.
- Technical feasibility study: In Mexico, this was supported by defining *concept scenarios*. This is a set of concrete water technologies suitable for the overall goals of the development scenario. For instance, if the development scenario is increasing urbanisation then a centralised water system may be most suitable. A technical feasibility study, conducted by experts, refines this and identifies feasible technical concepts that would best support the goals of each development scenario.
- Participatory assessment: this encompasses established methods for environmental, economic, social and institutional assessment. In Mexico, participation was ensured in two ways. First, stakeholders were involved in defining the criteria to be used for comparison of the concept scenarios and their technologies. Second, social assessment with the future users of the system determined the acceptance of the proposed technologies by users, and institutional assessment investigated the compatibility of the proposed technologies with the existing institutional system to highlight the changes which would be required.
- Analysis of trade-offs and social network analysis: this new step in sustainability assessment supports the consensus-finding of stakeholders. In optimal cases individual preferences do not differ substantially between stakeholders and consensus criteria weights may be input into multi-criteria decision aid and a high level of aggregation is possible (Brunner and Starkl, 2004). Multi-criteria decision aid is often applied in such way in environmental assessment (Halog and Manik, 2011; Wallis et al. 2011). Where there are multiple conflicts of interests, however generally there are

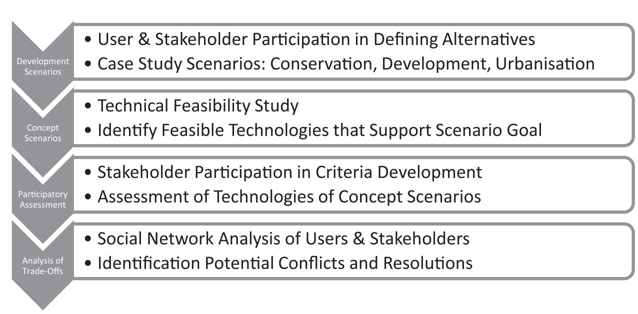

Fig. 1 – Components of the sustainability assessment framework.

no consensus weights. In Mexico, POSAF applied tools to delimitate and resolve conflict potential, such as social network analysis of stakeholders (also applied by Luzi et al. 2008). POSAF used this information to identify the relevant political factions for the negotiation of compromise solutions. The goal is to enable stakeholders of the future planning process to resolve conflicts themselves.

1.3. *Goal*

The first goal of this paper is the presentation of POSAF. As shown above, the first three steps are based on established methodologies used in an unusual combination and hence they are only summarised in this paper. The focus rests on step 4, which includes the novel concepts highlighted above. The second goal of this paper is the demonstration of step 4 in the concrete setting of water management in a peri-urban area of Mexico City. Essentially, the paper asks if step 4 facilitates consensus-finding amongst stakeholders with different views on solutions to water-related problems.

2. Methods

Generally, POSAF is methodologically pluralistic. The following methods serve the demonstration of POSAF step 4; this does not preclude the application of other or simpler methods in another context.

Step 4 started with focus group meetings to inform stakeholders and future users about the outcomes of steps 1–3. Then household interviews and questionnaires about the relevant criteria (of step 3) were evaluated by means of multi-criteria decision aid to define individual criteria weights for each respondent.

For multi-criteria decision aid the *analytical hierarchy process* (AHP) was applied (commercially available as Expert Choice software). It was used for two reasons (Saaty, 2010). First, other than for discrete choice models (e.g. willingness to pay; Greene, 2008) the focus is on individuals. AHP translates individual qualitative assessments into individual quantitative criteria weights. (Starting from pair-wise comparisons, e.g. less/more important is recorded by an entry of 0.5 or 2.0. For four criteria groups, these comparisons define a 4×4 matrix. The eigenvector to the largest real eigenvalue, EV, of this matrix is computed and defines criteria weights.) Second, AHP classifies responses by their consistency ratio $CR = (EV - 4)/2.7$; responses are consistent if $CR \leq 10\%$. Only consistent responses are considered fully informative and not inherently contradictory.

AHP is often used to obtain criteria weights for decision-making (e.g. Gomez-Limon and Atance, 2004; Halog and Manik, 2011; Wallis et al. 2011). POSAF, however, uses the weights for integrative assessment only if there is a consensus of users and/or stakeholders on appropriate weights.

To identify consensus, POSAF processed weights using statistics; computations were done with XL Stat (Addinsoft). Contingency tables (assessment of significance by chi-squared test) on the basis of the ranks, the characteristics of the respondents and their opinions about the scenarios were constructed. In order to take care of the ordinal scale of the criteria ranks contingency tables on the basis of high (rank 1 or 2) and low (rank 3 or 4) preferences were also assessed. The Mann–Whitney test was used to see if a group had stochastically higher preferences. Pearson correlation matrices (*T*-test for significance) were used to prepare pattern recognition.

Pattern recognition was based on a notion of nearness of respondents, defined in terms of highly correlated responses; meaning the correlation coefficients between the respective vectors of weights and CR exceeded 0.9. *Agglomerative hierarchical clustering* (AHC) then identified clusters of stakeholders. AHC iteratively joins the nearest clusters (nearness in terms of high correlations of cluster elements) and stops when the correlation coefficients are below 0.9 or the number of clusters is below a given threshold (Chipman and Tibshirani, 2006). The AHC method was also used for this purpose in Gomez-Limon and Atance (2004).

In order to communicate the results to stakeholders more easily, alternative characterisations of clusters were derived by *chi-squared automatic interaction detection* (CHAID) classification trees. This method successively partitions data, resulting in a tree structure defined by successive queries (Hand et al. 2001). Queries are chosen to maximise information content (i.e. the partition minimises the expected Shannon entropy or a similar measure of information entropy).

Clusters were visualised and analysed by social network analysis (UCINET 6 by Analytictech). The paper hypothesises that high correlation coefficients were 'emotionally supported' in the sense that respondents shared similar ideas about the importance of criteria and expressed these preferences in similar ways (measured by CR), which eased their communication so respondents with highly correlated responses were linked. Amongst considered measures for the roles of actors within the network was eigenvector centrality. (Starting from the adjacency matrix of the network it weighs nodes analogously to AHP from the eigenvector to the largest eigenvalue.)

3. Results: demonstration for the case study of Mexico City

3.1. *Problems in the case study area*

In order to prove the concept of step 4, POSAF was tested in a concrete setting of a peri-urban area of Mexico City, namely Xochmilco, one of the 16 delegations of *Mexico City* with approximately 415.000 inhabitants (INEGI, 2010). The problems observed there can be observed in many growing cities of developing countries and therefore this case study area is well-suited for testing POSAF.

Xochimilco is located south of the city. It is famous for its *chinampas* (traditional agriculture on artificial islands; see Martínez-Ruiz, 2004), which make it a well-known tourism destination and a region of intense agriculture. The considered case study villages were La Conchita and San Martin, respectively representing the low land and the hilly areas of Xochimilco.

Agricultural land is lost because of a change in traditional practices (a global problem: Ovalle et al., 2006) and *chinampas* are increasingly replaced by greenhouses. Further, there is competing land use because of urbanisation and irregular settlements (Wigle, 2010). Water pollution owed to agrochemicals and pollution from uncollected waste cause serious problems. As regards water supply illegal connection or water from tanker trucks is common. There are no sewers and wastewater is illegally discharged into irrigation channels. Of strategic importance for the metropolitan area would be the recharge of overexploited aquifers to secure water provision (Nanninga et al. 2012). Nevertheless, currently the city is 'exporting' untreated wastewater to water bodies outside the city via a deep drainage system (Biswas, 2006).

There is therefore an obvious conflict between urbanisation and protection of the natural landscape and its ecosystem services. This is reflected in the different interests of stakeholders (Table 1). Another challenge for participative approaches is the often precarious social situation of the users. Users in irregular settlements may not be prepared to take part in the planning or in the cost-sharing, as exposure of their illegal status carries the risk of expulsion. Such difficulties are observed worldwide (Katukiza et al. 2010).

3.2. Summary of steps 1–3

Detailed results of steps 1–3 are available in open-access publications (Nanninga et al. 2012; Starkl et al. 2013a). In step 1, a baseline study identified institutional stakeholders. Amongst selection criteria were their ties to the case study area and their interest in pre-defined topics (Table 1): water and wastewater management, waste management and recycling (compost, biogas). Users were approached for qualitative participation (method explained in Robson, 2011), focus groups (Aubel, 1994) and household interviews. Based on this participation, three scenarios for the future development were identified:

- *Conservation* of the local identity aims at preventing external influences (pressures for urbanisation) and securing continued cultivation of the *chinampas*.
- Economic *development* aims at community development in the hills and the generation of higher incomes from agriculture in the *chinampa* areas. Development of tourism was initially considered, but was not a viable option for the case study villages.
- *Urbanisation* was added by the project team as a default scenario, which assumes that the current trends of the integration into Mexico City will continue.

In step 2, the development scenarios were linked with concrete technologies and transformed into concept scenarios (details: Nanninga et al. 2012). In summary, conservation was supported by a set of individual, mainly on-site solutions. Typical wastewater technologies were eco-san for black-water, bio-filters for grey-water and constructed wetlands at household level. Development was supported by decentralised and reuse-oriented systems for agriculture, such as a decentralised compact wastewater-treatment plant for several households (Biostar). Urbanisation utilised mainly centralised solutions for service delivery, such as the connection to a centralised waste-water treatment system. Fig. 2 maps the planned location of technologies.

In step 3, representatives of institutional stakeholders discussed the selection of relevant criteria for assessment in terms of economic costs and benefits, environment and health, user issues (e.g. acceptance), and institutional issues (e.g. need for capacity building). Subsequently experts

Table 1 – Institutional stakeholders.

Stakeholder	Function	Interests	Characteristics
Delegación Xochimilco	Administration of local resources	Develop conservation programmes, execute programmes of the Federal District and own programmes	Strategic decision-maker on development
Sistema de Aguas de la Ciudad de México	Control & manage centralised systems of water & drainage of Mexico City	Implement specific laws and programmes (e.g. Urban Development Programme, Law of Solid Waste)	Decision-maker on water & sanitation for all of Mexico City
Comisión de Recursos Naturales de la Secretaria del Medio Ambiente	Manage all projects related to natural resources	Promote understanding that peri-urban area has unique environmental characteristics, crucial for the city's development	Resolve problems of urbanisation & irregular settlements, promote soil conservation, biodiversity
Freshwater Action Network SARAR Transformación	Consultancy & awareness-raising for possible solutions	Propose appropriate technologies (e.g. sustainable sanitation) & better use of environmental resources	Interest in social & environmental issues & technical, organisational & social aspects
Universidad Nacional Autónoma de México Universidad Autónoma Metropolitana Unidad Xochimilco	Input expertise in environmental issues & knowledge of the social, political, economic and cultural situation	Help in finding solutions that promote ecological recovery of Xochimilco, make best use of resources	Interest in environmental and social science aspects
Asociación Nacional de Empresas de Agua y Saneamiento de México A.C.	Provision of water supply and sanitation services	Find economically viable forms of water service provision	Interest in more centralised systems, if managed by them

Source: adapted from Nanninga et al. (2012)

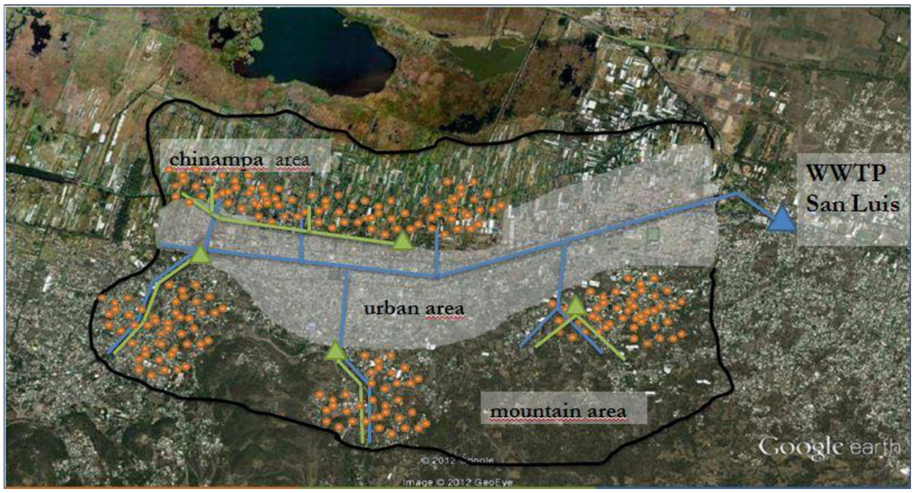

Fig. 2 – Map of case study area and location of technologies. Colour code: orange on-site (conservation scenario), green decentralised (development), blue centralised (urbanisation). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

assessed expected impact in terms of all criteria supported by any stakeholder (details: Starkl et al. 2013a). Table 2 summarises the integrated assessments of the above mentioned technologies.

3.3. *Application of step 4*

Based on the impact assessment, feedback on possible trade-offs between the criteria was obtained from a policy workshop (11 returned questionnaires) and from 20 household interviews in the two case study villages. As the purpose of this analysis was not actual decision-making but demonstration of POSAF, this sample size was sufficient, as 10–30 respondents are generally acceptable in social sciences (Isaac and Michael, 1995). Additional information came from stakeholder workshops on participatory criteria development (step 3).

Respondents were informed about the results of the previous steps, whereby technical options were explained in the context of the scenarios and how technologies contribute to them. The questionnaires for stakeholders and users first asked about the respondents' background, their opinion about the scenarios and then key questions about the relative importance of four criteria groups: environment and health, costs and economy, user issues, and institutional issues.

In view of the responses (the paper records findings significant at the 95% level) no scenario could be removed from future planning.

Users were split by location and gender; those in La Conchita (*chinampas*) preferred conservation or development, the others urbanisation. Amongst consistent responses, women supported conservation or development but men were split. These responses could also be explained in terms of preferences for criteria. Sixteen of 20 user responses were consistent and they showed a clear preference for environment and lowest weights for institutional issues. The perception about costs decided, however, which scenario was preferred: Users in La Conchita ranked costs low, those in San Martin high, and users preferring urbanisation had a high preference for costs, the others a low one. Indeed (step 3), in terms of net present value projected overall costs of centralised systems were the lowest. The reason is the low valuation of natural resources: for example, as water is provided free (standpipes, tankers) or is stolen (illegal connections), reuse of treated wastewater does not save costs.

Table 2 – Comparison by ranking of typical waste-water technologies (summary assessments).

Criteria group	Criteria	Eco-san (black-water) + bio-filter (grey-water)	Constructed wetland (on-site)	Biostar	Centralised waste-water treatment
Environment	Removal efficiency	na	2	2	1
	Water conservation	1	1	1	4
	Energy	1	1	3	3
	Recycling (nutrients)	1	2	2	2
	Health	4	1	1	1
Costs & benefits		2	4	3	1
User issues	User opinion	2	3	4	1
	Impact on users	4	3	2	1
Institutional issues		3	2	3	1

Amongst 11 institutional stakeholders, eight responses were consistent, environment, costs and user issues ranked highest, and stakeholders preferred conservation but did not consider it as the most realistic option. Preferences were less distinct, however: users' weights for environment were stochastically higher than stakeholders' weights.

Linking highly correlated responses defined a social network (Fig. 3), within which pattern recognition (AHC) identified the four clusters below (colours in Fig. 3), defined by a high correlation coefficient with their centres (Table 3); ambiguities were decided by the higher correlation coefficient. Considering only consistent responses (24) a CHAID classification tree (Fig. 4) characterised clusters in terms of weights for user issues and the environment.

- SC0: the centre put almost equal weight on the criteria environment, costs and user issues (Table 3), whereas in comparison with other clusters SC0 put low weights on environment (Fig. 4). Six stakeholders clustered in SC0, only two were in other clusters, and three were idiosyncratic and not classified. This clearly distinguished stakeholders from users.
- UC1: in comparison with other clusters, user issues had a low weight (Fig. 4) and the centre put high weight on environment and costs (Table 3).
- UC2: in comparison with other clusters, user issues had a high weight (Fig. 4) and the centre put high weight also on environment (Table 3).
- UC3: in comparison with other clusters, environment had a high weight (Fig. 4) and the centre put ca. 50% weight on environment (Table 3). In terms of eigenvector centrality of the social network, there was a concentration of central respondents in UC3, indicating a special role of UC3 (close similarity of preferences within UC3). Amongst users women were mainly in UC3 and men (especially those of San Martin) in other clusters.

In the light of Fig. 3, further agglomerations were considered: (1) UC1 + UC3, amongst them 13 users with very high weight on the environment, and (2) SC0 + UC2, amongst them seven users with comparatively less weight on the environment. Agglomerations beyond these larger clusters would be no longer meaningful, however, as the removal of just one respondent (U14) would remove all high correlations between the larger clusters.

In view of this 13:7 split of users, POSAF did not identify a societal consensus, but rather a potential conflict in future decision making between two strong groups. Interviews revealed strategies to resolve this potential conflict in future decision making: Many users expected that government would pay for water infrastructure, whence costs would not concern them. (This explains why the high emphasis of UC2 members on user issues and their low emphasis on costs, expressed by the centre, did not contradict each other.) This led to the recommendation that future planning needs clear political decisions about cost sharing for infrastructure and about costs for the consumption of natural resources:

- If new infrastructure requires substantial contributions by users, but consumption of natural resources remains highly subsidised, then SC0 + UC2 may become dominant and urbanisation may be preferred for its lower costs.
- If infrastructure is provided at low costs but subsidies for natural resource consumption are reduced, then the cost advantage of centralised systems may vanish and preferences of UC1 + UC3 may become dominant, whence on-site or communal scale technologies may be chosen for their environmental benefits.

It may be for such policy constraints that despite a high valuation for the environment cost-dominated planning is still widespread (Brunner and Starkl, 2012).

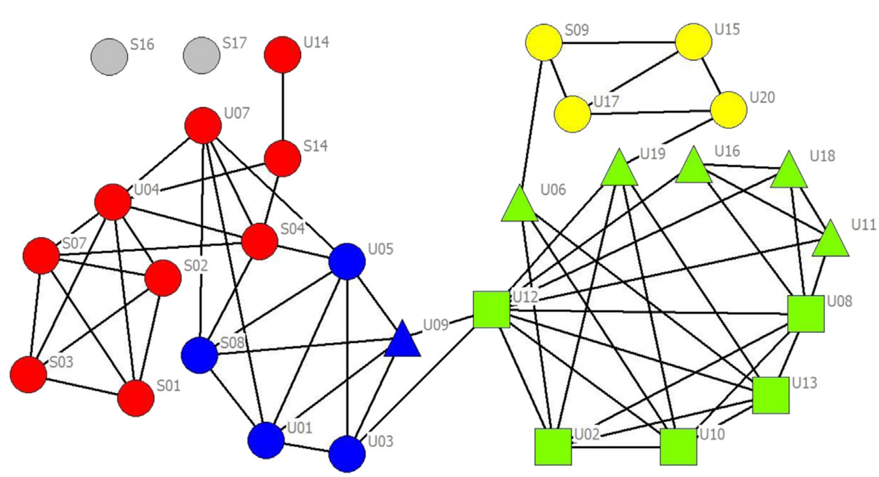

Fig. 3 – Clustering of Mexican responses by high correlation coefficients. Explanation. Nodes represent respondents (labels: Table 3), colour clusters (SC0 = red, UC1 = yellow, UC2 = blue, UC3 = green, exceptions = grey), shapes eigenvector centrality (circle = below one-third of the maximum observed centrality, triangle = medium, square = above two-thirds of the maximum observed centrality), and lines connect respondents with correlation coefficients > 0.9 (computed for the vectors of criteria weights plus CR).

Table 3 – Preferences of institutional stakeholders and users.

ID	Cluster	G	Pref.	CR	Criteria weights (AHP)				Stakeholder
					Environ.	Costs	Users	Inst.	From
S01	SC0	–	C	0%	25%	25%	25%	25%	Academia
S02	SC0	–	U	0%	25%	25%	25%	25%	Local Government
S03	SC0	–	–	0%	25%	25%	25%	25%	Other/Anonymous
S04	SC0	–	C	0%	29%	29%	29%	14%	NGO
S07	SC0	–	D	2%	25%	25%	30%	21%	NGO
S08	UC2	–	D	2%	31%	22%	37%	9%	National Government
S09	UC1	–	C	2%	42%	35%	15%	9%	Other/Anonymous
S14	SC0	–	–	5%	24%	34%	24%	17%	National Government
S16	–	–	U	17%	27%	35%	18%	20%	National Government
S17	–	–	C	50%	34%	22%	24%	20%	National Government
S18	–	–	C	–	–	–	–	–	National Government
U01	UC2	M	C, D	0%	36%	18%	36%	9%	La Conchita
U02	UC3	F	C, D, U	2%	51%	21%	18%	10%	San Martin
U03	UC2	M	C, D	2%	42%	9%	35%	15%	La Conchita
U04	SC0	M	U	2%	25%	29%	29%	18%	San Martin
U05	UC2	M	U	2%	33%	20%	33%	14%	San Martin
U06	UC3	F	C, D	2%	40%	24%	20%	17%	La Conchita
U07	SC0	M	U	2%	33%	28%	28%	12%	San Martin
U08	UC3	F	C, D	7%	56%	8%	23%	13%	La Conchita
U09	UC2	F	C, D	7%	37%	19%	32%	12%	La Conchita
U10	UC3	F	C, D, U	7%	46%	22%	19%	14%	San Martin
U11	UC3	F	C, D	7%	50%	9%	20%	21%	La Conchita
U12	UC3	M	C, D	7%	49%	15%	26%	11%	La Conchita
U13	UC3	M	U	7%	49%	23%	20%	7%	San Martin
U14	SC0	M	C, D	9%	29%	29%	21%	22%	La Conchita
U15	UC1	M	C, D, U	9%	39%	39%	15%	7%	San Martin
U16	UC3	F	C, D, U	9%	55%	7%	19%	19%	La Conchita
U17	UC1	M	C, D, U	17%	37%	35%	21%	7%	San Martin
U18	UC3	M	C, D	17%	51%	11%	24%	14%	La Conchita
U19	UC3	F	C, D, U	17%	45%	24%	22%	10%	San Martin
U20	UC1	F	C, D	21%	38%	32%	21%	9%	San Martin
SC0	SC0	–	–	2%	27%	28%	26%	20%	Cluster Centre (computed)
UC1	UC1	–	–	13%	37%	35%	18%	10%	Cluster Centre (computed)
UC2	UC2	–	–	3%	36%	18%	35%	12%	Cluster Centre (computed)
UC3	UC3	–	–	8%	49%	16%	21%	14%	Cluster Centre (computed)

Explanation. ID = identifier: Sx (institutional stakeholder representative, missing numbers: foreign stakeholders not discussed here), Ux (user), SCx, UCx (computed class centre); G = gender, Pref = highly preferred scenario: C (conservation), D (development), U (urbanisation); CR = consistency ratio; – (no answer or not applicable).

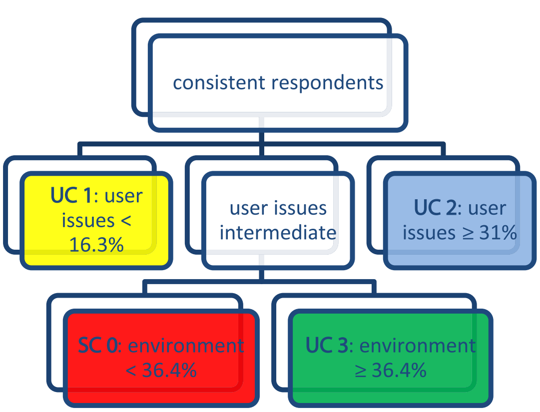

Fig. 4 – Classification tree for clustering consistent responses. Explanation. Colours for clusters are as in Fig. 3; thresholds were determined with XL-Stat. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

4. Discussion

POSAF enabled a dialogue between future decision makers, institutional stakeholders and users, which was meaningful, as information flow was bidirectional and information was also well-received and utilised to form or modify preferences.

In one direction of the information flow, stakeholders with environmental interests could inform users repeatedly about environmental issues. Presenting technical issues in the context of scenarios was a successful vehicle for awareness-raising and easing communication, also with irregular settlers. POSAF demonstrated that users were highly aware of the environmental problems and thus POSAF supported a consensus that *new technology should not be implemented without considering its expected environmental impact*. Thereby institutional stakeholders did not talk users into such preferences, as actually their own preferences were remote from users' preferences.

In the converse direction, information flow ensured that future decision-makers became aware of the concerns of users, which is a precondition for successful planning (Starkl et al. 2013b). In Xochimilco each relevant group defined criteria important to them. This means that if a technology is unacceptable with respect to any of these criteria, then POSAF is able to recognise this. Of course, such technology should not be implemented, as important societal interests could be violated. In particular, POSAF was capable to detect *the relative importance of criteria in the local context*, uncovering differences between two villages about urbanisation. In classical planning conflicts result when local differences are ignored (Starkl et al. 2009). Instead, solutions need to be adapted to the different needs of the small villages involved.

There are three possible outcomes of POSAF analysis.

- The criteria weights may define a cluster that encompasses all stakeholders and users. In this case, POSAF may be followed by a classical technocratic top–down approach: a planner bases decisions on the criteria weights of the cluster centre, using multi-criteria decision aid to identify an optimal system and adding a sensitivity analysis to take care of inaccuracies and uncertainties. In such a situation, unconventional on-site technologies that require cooperation of users also have a chance of being accepted.
- As in the case study there may be a potential conflict between two or more large clusters. Then political resolution of the conflict is needed and local users and interested stakeholders themselves have to find a consensus about their finally preferred solution. POSAF may aid them in obtaining and processing the necessary information. (In the case study this was information about future cost-sharing that indicated which system would be acceptable; Section 3.3.) If this process leads to consensus, planning may continue as in the first step. If the political process is bogged down, planning continues with the step below.
- Preferences of users and stakeholders may be scattered in many small incompatible clusters. In this case political resolution may be futile and if a prolongation of the status quo is unacceptable, a classical technocratic and top–down approach may be appropriate. Decision-makers, however, need to consider the information from POSAF about user preferences to avoid technologies that over-task them, are not accepted and are therefore not used properly.

Although POSAF is supported by partial implementation experiences in six countries, several issues remain to be resolved. POSAF was applied only on the communal scale and involved only a few case studies. It needs still to be tested, in each country where it is applied, whether its application to different sectors, for different levels of government or under different cultures of stakeholder interaction (e.g. India: caste problem), requires modifications to the framework. An interesting observation in all case studies (Argentina, China, India, Indonesia, Mexico and Nepal) was the peculiar pattern of responses by politicians, such as unwillingness to compare criteria, indifference or high levels of inconsistency. This might derive from their wish to reconcile conflicting interests. How should POSAF deal with such responses? Ignoring them would exclude politicians from stakeholder analysis, although their responses may follow a certain pattern. The authors addressed this issue by first analysing all responses (Table 3 and Fig. 3) and then analysing consistent responses in a separate step (Fig. 4). POSAF is designed to uncover such peculiarities and inform decision-makers about consequences. If they still disregard the importance of, e.g., health, POSAF accepts this as their informed decision about sustainability.

5. Conclusion

Sustainability assessment requires the consideration of complex interactions between environmental and social systems, whence planning, even if transparent, participative and democratic, may in the end be driven by (sometimes self-appointed) experts. Those concerned may at best view such approaches as paternalistic. POSAF addresses this point and offers a complementary framework to the well-established ones:

- POSAF helps local stakeholders and users to arrive at informed opinions about their requirements and demands, in some cases also including sustainability aspects, when facing local problems. It motivates them to ask salient questions (relevant to them and their problem), and development and concept scenarios support them in understanding complex issues.
- This lets them communicate on an equal footing with experts and therefore supports them in finding a credible basis (that may come from expert advice) for their decisions.
- The additional procedure of the analysis of their preferences and of possible conflicts is a prerequisite for resolving conflicts by consensus and thereby arriving at legitimate decisions (that give fair consideration to divergent views, whence consensus is made possible).

POSAF is a complete framework for the assessment of sustainability and therefore encompasses a wide variety of tools: user & stakeholder participation in defining alternatives, technical feasibility study, participatory assessment of technologies (environmental, economic, social aspects), and participatory identification of the preferred option and final decision making. However, depending on the local context and situation, certain tools of POSAF may need more consideration than others. For instance, POSAF may include supporting measures such as awareness raising, capacity building or institutional strengthening, tailor made to the specific situation in a case study. Therefore POSAF has to be seen as a flexible framework that can be adapted to specific requirements of a case study.

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