

Article

Gender and Cross-Scale Differences in the Perception of Social-Ecological Systems

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Abstract: The sound management of Social-Ecological Systems (SESs) requires a deep knowledge of the system and its dynamics, but effective strategies also need to include the perceptions of the local actors. These perceptions are specific and might differ for different actors. In this research, we analyzed the gender and across scales differences in the perception of a SES and unveiled the potential reasons that shape the different actors' understanding. Using structural analysis tools, we analyzed the perceptions of local women, local men, and external stakeholders on the most relevant variables shaping the actual and future sustainable management of a SES. The research was developed in Santiago Comaltepec, an Indigenous community located in the Sierra de Oaxaca (Mexico) that manage their forest under community-based strategies. The gender differences in perception showed the inequalities in agency, voice, and power between women and men. The comparison of the perceptions between community members and external stakeholders showed greater similarities, but still reflected power differences and differences in knowledge and cultural representations. We concluded that sound and resilient SES management need to recognize the gendered and across scales diversity in perception, knowledge, and practices and create bridges and synergies among knowledge systems to shape desirable trajectories.

Keywords: community-based natural resource management; structural analysis; knowledge systems; Mexico

1. Introduction

Social-ecological systems (SESs) are complex adaptive systems in which different subsystems (either ecological or social) interact in a strong linked performance [1]. They can be described as sets of actors (representing not only individuals, but also historical processes, economic forces, and institutional perspectives) [2] who share a space or structure (a geographical space, an ecosystem, a social network, a market, etc.) [3], are interdependent, and their relations cannot be linearly described [4].

In Indigenous communities whose livelihoods directly depends on natural resources, the social and ecological subsystems are highly dependent [5]. These communities hold traditional ecological knowledge and practices adapted to the ecological systems in which they live [4] and are essential players in the sustainable management of SESs around the world [6–8]. The lands of indigenous people represent approximately 40% of all terrestrial protected areas and ecologically intact landscapes [9]. They often manage their natural resources through community-based natural resource management (CBNRM) strategies.

CBNRM concept has evolved over the past two decades as an alternative approach to top-down strategies in the management of natural resources and several definitions can be found in the

literature [10]. For this research, we assumed the definition proposed by Fabricius and defined CBNRM as the collective use and management of natural resources by a group of people with a self-defined identity, using collectively agreed strategies and assets [11]. These strategies aim to reconcile natural resource conservation objectives and local development efforts [12], emphasizing the role played by local communities in the environmental conservation and the sustainable development of natural resources [13]. Garnett et al. highlighted the contribution of the Indigenous People's lands to the Sustainable Development Goals [9].

CBNRM strategies strongly encourage stakeholder involvement and participation in the environmental decision-making. However, they are organized on multilevel governance systems [14] in which some decisions are taken by local actors [15]; while others depend on external institutions. Consequently, sustainable management requires high levels of mutual understanding and collaboration between local and external actors [16].

Social-ecological system dynamics and evolution are characterized by complexity and uncertainty but are also highly influenced by the decisions of the actors that interact with the natural resources. Sound management requires combining different knowledge systems (e.g., local and scientific) of the SES and its dynamics, and often strong investments in governance structures and capacity building [17].

Perception has been identified as a variable that influence people's actions, adaptive strategies [18], and policymaking. Effective strategies need to address and incorporate local representations. However, research has only recently become engaged with individual concerns around attitudes and psychologies, including peoples' perceptions, interests, and values [19]. SES perception describes how a person perceives the SES through the brain and their sense ability to process and store information [20]. These perceptions are culturally and socially contextual [21]; hence they have to be analyzed for every specific SES and they might differ for different types of actors. To analyze the motivational mechanisms and the cognitive processes and perceptions that form the behavior of the different actors, it is necessary to understand alternative forms of thinking and action. Sound decision-making requests engagement with the diversity of voices and knowledge systems of the different stakeholders [22].

The objective of this research is to identify and analyze the gender and across scale differences in the perception of a SES and to unravel the potential reasons that support this different understanding. In an Indigenous community with community-based forestry management in the Sierra of Oaxaca (Mexico), we analyzed the perceptions of three different types of actors with a strong influence on the SES performance: local stakeholders, differentiating between women and men perceptions, and external stakeholders from different political-institutional backgrounds. Our aim was to discriminate between the perceptions of local women, local men, and external stakeholders identifying how their different sets of motivations and perspectives draw a different understanding of the SES functioning.

Gender analysis in the field of SESs and CBNRM still remains understudied [22], even if in the last years different authors have significantly contributed to bridge this knowledge gap. Gender and socio-ecological resilience have been analyzed by several authors in developing and post-industrial settings [19,22,23]. Gendered opportunities for participation and social learning in collaborative forest governance were explored in Canada and Uganda [24]. Other researchers emphasized the relevance of gender analysis for adaptive capacity, focusing the analysis on climate change [25] and the capacity to innovate SESs [26].

Different authors have highlighted the relevance of gender analysis of SES, SES resilience, and CBNRM and asked to enrich knowledge developing gendered research and generating gendered evidence base that inform policies for the sustainable management of natural resources [19,22,23,25,27]. Understanding the complexities of gender and across scales relations can help to better inform local and higher levels of policy making and secure the relevance of gender research to those primarily focused on understanding SES management [19].

We also examined the distinctive perceptions across scales due to the role of external agents in CBNRM. We assumed that local and external stakeholder perceive the SES from different geographic (local vs. regional or national) and political-institutional scales [28]. Focusing attention on the perceptions of socially differentiated groups can bring substantial knowledge into collaborative resource management, foster the adoption of strategies and actions, and improve the collective understanding of the SES conditions [24]. The different perceptions might inform the knowledge of the social mechanisms and norms and the behavior patterns at community level.

We only present evidences from a case study and do not aim to make generalizations but to contribute to the emerging literature on gender analysis of SES perceptions [22], examining the differences in knowledge systems, agency, and power relations across scales. To unveil perceptions we used structural analysis tools [29].

The use of structural analysis tools helped to structure the discussions around the dynamics of the system. The participatory reflection process and the request of consensus foster the sharing of visions among the participants, lay the foundations for a more comprehensive understanding of the SES as a whole, and reinforce the skills for natural resource management [30]. In this research, the inclusion of the local community and the external stakeholders in the analysis of the problems and the discussion of potential solutions, aimed at contributing to cross-fertilization and empowerment [31], and to build capacities that strengthen the multilevel governance of the SESs.

2. Case Study Description

The SES analyzed in this research is Santiago Comaltepec, a Chinantec community located in the Sierra de Juárez (Oaxaca), in the Mesoamerican bio-cultural corridor, one of the most diverse regions in Mexico.

The community has 1115 inhabitants [32] located in three settlements along the territory: Santiago Comaltepec (the main village), La Esperanza, and San Martín de Soyolapam. The altitude gradient ranges from more than 3000 masl in Santiago Comaltepec to around 200 masl in Soyolapam creating a rich variety of landscapes, forest systems, and livelihood options. Santiago Comaltepec's Human Development Index is 06773, ranking in the 803th position out of 2419 municipalities, thus ranking above average in Mexico [33]. The main village has primary and secondary schools and some health facilities. The offer of health and education facilities is much more limited in the two small villages. In relation with other infrastructure, all the houses have access to electricity, even if the service can be very deficient. Piped water is available to 85% of households and there are sewage infrastructures, but not sewage treatment. A paved road connects with Oaxaca city, facilitating the relationships and the commercial flows of the community. However, the two small villages also have lower provision of access and infrastructure [34].

The community has communal property rights over 18,366 ha of land and forest entitled in 1953 by the Mexican Government and ratified and certified in 2008 by PROCEDE (the Program for the Certification of Ejido Rights and House Plot Ownership). However, in 1956 the Government gave a 25-year concession to exploit the forest resources of the Sierra de Juárez to a paper mill that systematically overexploited and destroyed many forests. The natural capital destruction profoundly affected the communities in the area. When the Government intended to renovate the concession for another 25 years, different communities joined forces to fight this decision. After a hard struggle, in 1984 the communities succeeded, and the concession was not renewed. These events intensely marked the community and to a certain extent explain the existing aversion to new investments and activities.

Afterwards, the community recuperated the rights to manage their natural resources and initiated the implementation of CBNRM strategies, creating the governance institutions and taking decisions to recover the good environmental status of the forest. Subsequently, most of the territory (10,300 ha) is allocated to forest protection and only 1726 ha are used for forest production. Their forest management

and conservation practices are internationally acknowledged [35]. The remaining land is used for agriculture and agro-forestry (6108 ha) and for forest restoration and urban use.

Forest resources are managed using customary practices (*usos y costumbres* by its Spanish name) based on a complex governance system (Figure 1). Local rules are embedded in state and federal laws, but the administrative management of the territory is organized through a direct democracy model where members of the community are in charge of administrative roles, natural resource management, and police functions. The community's maximum authority is the General Assembly of Commoners that decides the SES management rules. Every family has a representative, usually the husband; indeed before 2010 women were not accepted as commoners. This situation has changed now, but they still lack voice in this arena. This Assembly elects the Communal Property Commissioner, the executive body in charge of implementing the decisions, the Overseeing Elder Council, and the Surveillance Committee. These bodies check the actions of the Commissioner, the compliance of the General Assembly's decisions and the commoners' activities such as assembly attendance, participation in *tequios* (organized work for a collective benefit), commissions, household labor, subsistence agriculture, and monitoring activities. Finally, there are different commissions in charge of the administrative and management functions in the territory. The Assembly decisions tend to be very conservative and aim to avoid changes; risk aversion and blocking new activities characterize the decision-making. The system is not fair for women and young people preventing them having a voice and or responsibility in decision-making.

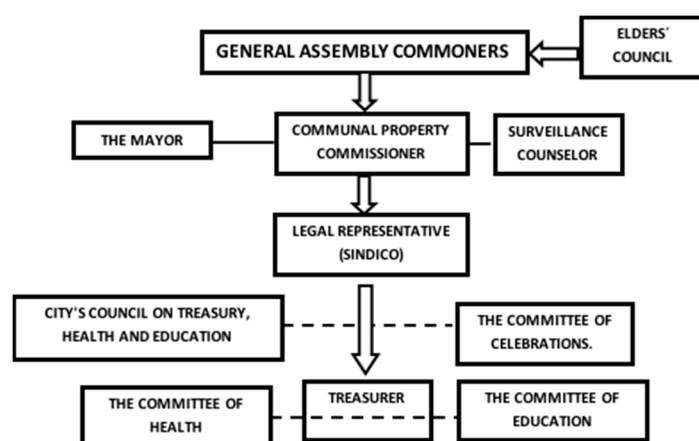


Figure 1. Governance system.

The community is small, close-knit, and rather homogeneous in economic and social terms. The SES main activities are linked to forest production and subsistence agriculture and every commoner has access to these resources for family needs, but not for commercial purposes; hence there are not important economic status or revenue differences among them. The management functions are developed under a nonpaid system that obliges to every commoner to dedicate between 6 and 9 years (in periods of 1–2 years) of his working life to work for the community under a pro-bono system. In return, the inhabitants have collective rights over the land and natural resources and do not pay taxes (or pay symbolic ones) to the Mexican government. These yearlong duties are called cargos. In the last years there is a timid shift to remunerate cargos, but the amount devoted is insufficient to satisfy families' needs. Women do not participate in these collective activities and their role is mainly relegated to the household sphere, even if more recently some of them are in charge of commissions, like those of education and health.

To manage the forest, since 1994 the community elaborates Land Use Plans and Forest Management Programs that request the approval of the Mexican environmental authorities every ten years. These plans are developed by UZACHI, a technical organization hosted by four Indigenous

communities that provides technical assistance in forest management and timber trade. The community harvests an average of 2500 cubic meters of round wood per year (mainly pine wood) which is well below the natural growth rate. This wood is certified as Smart and Sustainable Wood by the Forest Stewardship Council, even if it cannot be marketed as such due to its low production volume. However, for the community it is important to maintain this sustainability label to verify the sustainable management of their forest. The community owns a sawmill to process the logs and buys and markets wood produced by other nearby communities, and some other community enterprises linked to ecotourism. These enterprises provide some jobs and income to the inhabitants directly working in it. However, the economic benefits of the activities are not distributed among the commoners; but invested in the community's infrastructure and projects or in forest maintenance, limiting individual or household revenues. These decisions constrain the community welfare levels and consumption capacity and foster migration.

Migration is one of the main drivers in the community situation and evolution. Around 50–60% of the total population have emigrated at least once and nearly all the families receive remittances. Short-time migration (1–3 years) was a usual practice, however, the stricter USA migration laws are forcing more permanent migrations or definitively blocking this strategy. Several reasons, like the lack of economic opportunities and jobs for qualified people and the rigid community rules that block individual actions, create this constant draining of people and are a main vulnerability of the SES.

3. Materials and Methods

This research was part of the investigations developed in the action research project COMET-LA (Community-based management of environmental challenges in Latin America: <http://www.comet-la.eu>) aiming to identify sustainable governance models in the community-based management of natural resources. In this project, we performed a comprehensive characterization of the SES following the extended version of the SES framework [36] proposed by Delgado-Serrano and Ramos [37]. Next, we developed a structural analysis exercise, and afterwards, we built scenarios. We used the structural analysis to identify the key variables in explaining the dynamics of the SES and to explore the roles these variables play. Structural analysis tools enable structuring the factors that describe a system and extracting the roles (actual and future) played by the key variables and drivers in the evolution of the system. The method is developed through participatory workshops where experts (people with a deep knowledge of the system under analysis) select the main variables describing this system and how they influence each other [30]. The influence/dependence relationships classify the variables in clusters that delimitate the role played by them within the system, according to participants' perceptions [38]. The method can run many variables and identify them according to their capacity to drive changes, show possible trends and evolution, identify loops of variables, and describe the strength of the relationships and influences. Structural analysis tools allow identifying how the relevant variables in a system interact. By using these techniques, the effects of different management actions addressing one or several variables within the SES can be analyzed, and its implications for the system evaluated [30]. The structural analysis exercise was systematized in four phases and developed through participatory workshops.

The participants in the workshops were selected using stakeholder mapping techniques [39]. As the structural analysis was developed after nearly two years of research, researchers had already built trust relationships with community members and had a thorough understanding of them. Participatory and ethnographic observation, interviews, and life story research methods were used during this time. This knowledge permitted inviting to participate to female and male community members with a deep knowledge of the SES and select them according to their willingness to participate. To select the external stakeholders, we identified governmental and non-governmental organizations working or with influence in the SES and asked to participate to people with a good knowledge of the system (see Appendix A for a description of the participants).

Initially, we planned to compare the perceptions of local inhabitants and external stakeholders in order to share and discuss both visions and to foster the processes of cross-fertilization and capacity building. However, after developing the first phase of the research (listing the main variables in the system), the local women demanded to host separate workshops to facilitate confidence and free discussions without the participation of the community males. Thanks to this decision we can compare the results in three types of stakeholders, which is one of the objectives of this research.

3.1. Listing the Variables

This phase consists of compiling a list of the most relevant variables in a system. The participants were asked to select the variables that they perceived as the most relevant for the actual and future sustainable management of the SES. To help in the selection, the participants received, in advance, the characterization of the SES that had been built in earlier stages of the research (it can be consulted in a past paper [40]). This information aimed to prompt reflections by providing participants with a broad overview of the SES, but they were free to choose the variables. Facilitators (one of them speaking the indigenous language) conducted the debate and helped the participants to focus on the research question. The participants openly expressed their opinions and facilitators made an effort to encourage inclusive and gender participation.

We initiated the process with local stakeholders and a total of 14 women and nine men participated in the first workshop. After thorough discussion, a final list of variables was decided by consensus; each variable was clearly defined and characterized, in order to be distinctly understood by all the participants (Appendix B). After, we hosted a workshop with 22 external stakeholders (16 males and 6 females). We selected them in order to represent different sectors with influence in the SES like government institutions with influence in the territory: SEMARNAT (natural resources), CONAFOR (forestry), CONANP (protected areas), CDI (Indigenous people), and SEDESOL (social affairs); researchers and academics from different universities and research institutes; NGOs, Civil Society Organizations, and members of UZACHI (see Appendix A). All of them have worked in the area and had a sound knowledge of the SES. They were provided with the SES characterization and with the list of variables selected by the local inhabitants. Both documents were discussed, and the externals agreed that the variables in the list were the most relevant, but they added a new one, "the monitoring and sanctioning rights". Local stakeholders were consulted about the pertinence of including this variable in their initial list and agreed to incorporate it for the second phase of the research.

3.2. Describing the Relationships between Variables

In this phase, a cross-impact analysis was performed. Cross-impact probability methods define simple and conditional probabilities of hypotheses and/or events, as well as probabilities of combinations of events, taking into account interactions or impacts between events and/or hypotheses and reducing uncertainty in future decisions. We used this analysis to assess the influences between variables (from 0, no influence; to 3, strong influence) using MICMAC software. The strength of the influences of every variable needs to be decided by consensus. The results were represented in an $n \times n$ matrix, which is known as the matrix of direct influences. The sign (positive/negative) of the influences is not introduced in the matrix, because this would make the next analysis impossible. In this phase, it is very important to clearly identify the real direct influences (e.g., do not introduce indirect influences through other variables) and to distinguish which of the two analyzed variables influences the other. In this phase, three workshops were hosted (with local women, local men, and external stakeholders, respectively), and three different matrices constructed, being the base of the analysis in the differences in perception presented in this study (the matrices can be consulted in Appendix C).

3.3. Identifying the Roles Played by the Variables

After completing the matrices, the overall direct influence and dependence of every variable was calculated. The direct influence of any given variable k (I_k) is the sum of the values of row k in the matrix, as is the direct dependence of variable k (D_k) the sum of the values in column k :

$$I_k = \sum_{j=1}^n m_{kj} (k = 1, 2, \dots, n) \quad (1)$$

$$D_k = \sum_{i=1}^n m_{ik} (k = 1, 2, \dots, n) \quad (2)$$

Both values for each variable were calculated and served as a base to plot the direct influence/dependence maps using MICMAC software (<http://www.lapropective.fr/methodes-de-prospective/les-outils-versioncloud/1-micmac.html>) [29]. The position of the variables in every cluster indicates the different functions the variables play in the system.

We used the classification proposed by Delgado-Serrano et al.: input variables exert a strong influence, but they are hardly influenced, they describe the system and condition of its dynamics; stake variables are both highly influential and dependent, but they are also the most unstable because any influence on them can cascade throughout the rest of the system and derive unexpected or unwanted consequences; regulator variables have both moderate dependence and moderate influence on the system, however they are among the most relevant variables in the system evolution since they can act as levers of change, by both receiving influences and influencing other variables; autonomous variables have low potential to generate changes and output variables have low influence but are very influenced by others; thus, they are descriptive indicators of the system's evolution [41] (Figure 2).

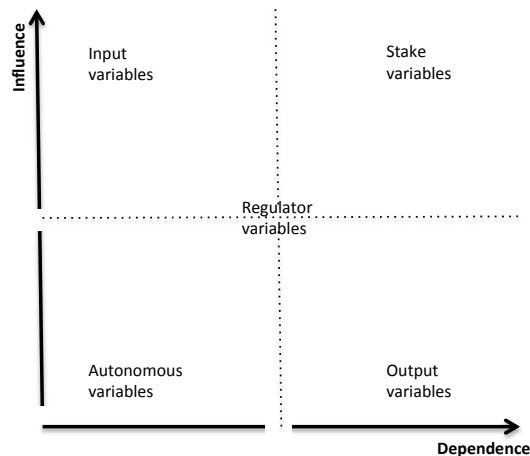


Figure 2. Clustering of variables according to their influence and dependence based on a past paper [41].

The map shows the participants' perceptions of the system and what they consider to be constraints (variables that cannot be influenced), opportunities (variables with medium influence and dependence capacity), and potentialities (variables with high influence and dependence capacity) for change [30].

3.4. Validating and Interpreting the Results

The maps of direct influence/dependence were discussed and validated in two workshops; one with the community people and another with the external stakeholders. To the validation workshops were invited all the community members and other external stakeholders and researchers with the objective of disseminating the results to a broader audience and strengthening the capacity building

and cross-fertilization. Participants reviewed the variables that had been identified and prioritized, discussed the roles played by the different variables in the provided visualizations, and gave feedback on the results. Special attention was paid to analyze and discuss counterintuitive outcomes with the participants. The workgroup's final remarks were considered in the analysis of the information.

4. Results

Table 1 presents the final list of variables and the total direct influence and dependence of everyone. The variables predominating in the list are those related to the natural resources governance system (governance institutions, property right system, collective-choice rules, exclusion and extraction rights, monitoring and sanctioning rights, and nonpaid collective activities), followed by those linked to socio-economic attributes (economic activities, livelihoods, importance of resources, economic value, and migration trends), and policy settings (political stability and environmental regulation). We found a predominance of internal variables (e.g., those that can be controlled by the community). The good status of conservation of the natural resources [35,42] and the links with nature of the community might explain the lack of ecological variables in this selection. The same exercise was developed in other SES leading to rather different results [30].

Table 1. List of variables and total influence (TI) and dependence (TD) values for every group.

Variables	TI Females	TD Females	TI Males	TD Males	TI Externals	TD Externals
Economic activities	13	26	15	38	12	37
Livelihoods	10	28	17	31	20	29
Nonpaid activities	24	21	18	18	26	17
Migration trends	17	21	11	19	10	14
Political stability	31	32	19	33	17	21
Environmental regulation	30	13	19	8	19	10
Governance institutions	32	24	37	12	29	15
Property rights system	26	11	29	7	22	8
Collective-choice rules	30	14	27	17	22	10
Monitoring and sanctioning rights ¹	17	30	22	23	17	24
Exclusion and extraction rights	17	28	23	19	13	23
Economic value	16	11	24	23	9	26
Importance of resources	21	25	22	25	14	17
History of use	33	24	34	26	28	0
Health infrastructures	12	21	7	25	3	10

¹ Variable included by the external stakeholders.

4.1. The Vision of Women

Figure 3 shows the influence/dependence map derived from the matrix of direct influences elaborated by the local women.

Women identify as input variables, two variables related with the SES governance system (the property right system and the collective-choice rules) and one linked to the political settings, the environmental regulation established by the government.

The autonomous variables for them are the economic value derived from the SES; hence for them this variable cannot be changed (they do not foresee options to increase this value) neither does it have the capacity to influence other variables.

They identify three variables as stake, namely the political stability, the history of use, and the governance institutions. According to this perception the actions of the local inhabitants can shift these variables, but at the same time the direction of the resulting actions cannot be controlled by them due to potential cascade effects.

As regulators, they locate the nonpaid activities, the migration trends, and the importance of resources. These three variables are highly related since the lack of economic opportunities and jobs and the heavy duties linked to the commoners' nonpaid work are drivers of the migration trends. This women's perception envisages that if other decisions over these variables were taken, the SES could evolve differently.

Finally, for women, the output variables are livelihoods, economic activities, exclusion and extraction rights, monitoring and sanctioning rights, and health infrastructures, meaning that these variables are the results of the decisions taken over other variables.

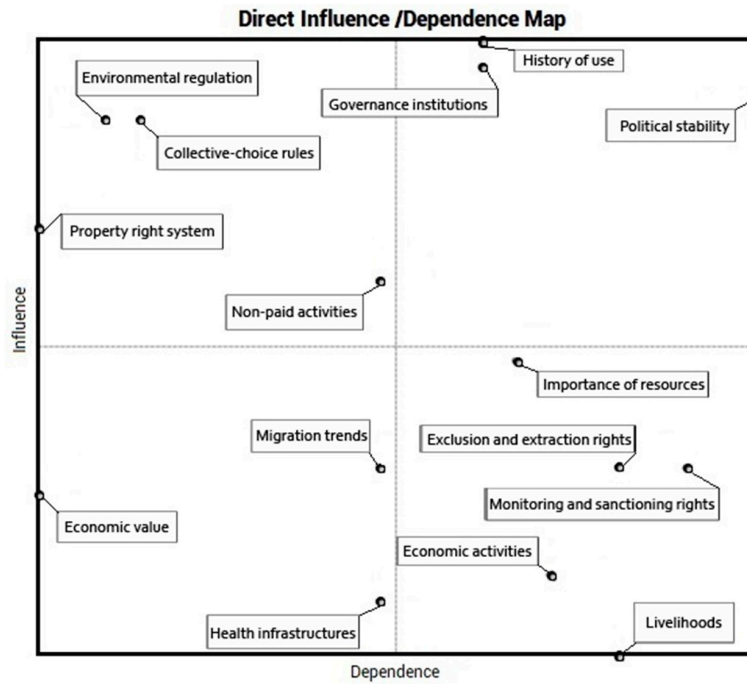


Figure 3. Women’s map of direct influence/dependence.

4.2. The Vision of Men

Figure 4 shows the influence/dependence map derived from the matrix of direct influences elaborated by the local men.

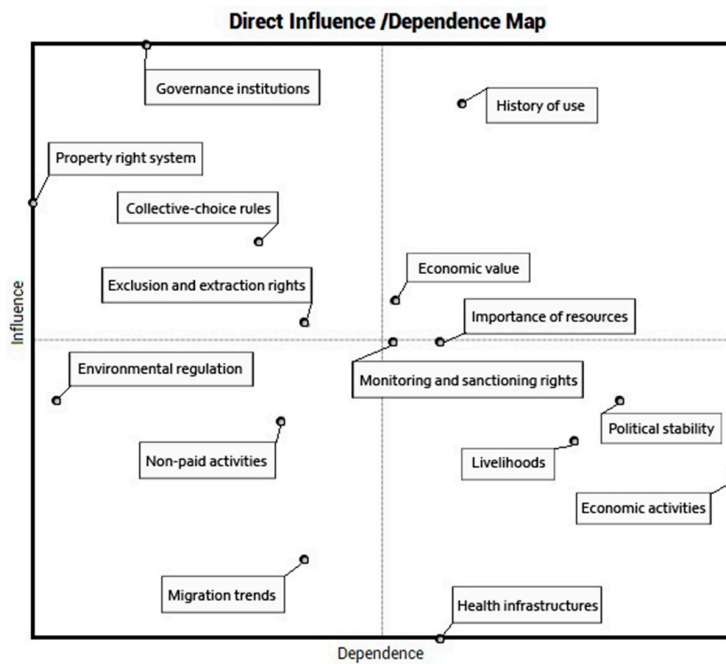


Figure 4. Men’s map of direct influence/dependence.

For men, the input variables are two variables related with the SES governance system (i.e., the property rights system and the governance institutions). This output reveals that commoners do not foresee such changes despite the General Assembly of Commoners having the right to change both.

The variable selected as autonomous is environmental regulation. This positioning reflects the need of approval by the environmental authorities of the forest management plans elaborated by the community, but also the male perception that they will keep managing the SES according to their sustainable customary practices, no matter if the governmental regulations change. The migration trends' variable is located in an intermediate position between autonomous and regulator; hence men consider that other variables influence this one, but they can do little to modify these trends.

As a stake variable, they only mention the history of use. Hence, for male community members this variable explains much of the actual situation of the SES, being very influential, and at the same time, it is dependent of many other variables.

Men identify a high number of variables as regulators, indicating they recognize their capacity to influence these variables and trigger changes in the SES. These variables are related to the internal governance system (exclusion and extraction rights, monitoring and sanctioning rights) that is decided by the Assembly of Commoners; and to economic factors over which to some extent, they also have a decision capacity (economic value, collective-choice rules, nonpaid collective activities, and importance of resource).

Finally, as output variables they position the political stability, the livelihoods, the economic activities, and the health infrastructures.

4.3. The Vision of External Stakeholders

Figure 5 shows the influence/dependence map derived from the matrix of direct influences elaborated by the external stakeholders.

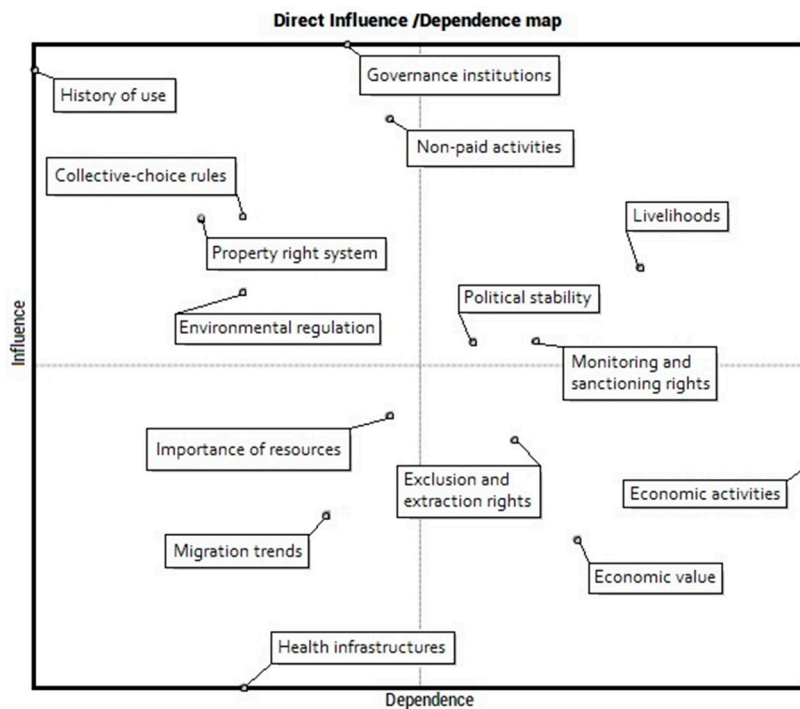


Figure 5. External stakeholder’s map of direct influence/dependence.

The map drew by external stakeholders presents differences from the previous ones, with a higher concentration of variables in the upper left part and the center of the figure and no variable depicted as

stake. As input variables, they include the history of use, the environmental regulation, the property right system, the governance institutions, the collective-choice rules, and the nonpaid activities. The inclusion of the last two variables in this cluster can be considered as counter-intuitive as these variables are locally controlled. However, the external stakeholders reflected in this perception the well-established trend towards immobility existing in the community, the tight decision methods and the risk aversion of most commoners.

Health infrastructures are identified as an autonomous variable. Economic variables (the economic value and economic activities) are considered as outputs of the system. Therefore, these participants reflect in their perceptions that the decisions taken, and the actions implemented by the community members shape the economic performance of the SES.

All the remaining variables (migration trends, importance of resources, political stability, livelihoods, exclusion and extraction rights, and monitoring and sanctioning rights) are identified as regulators. Hence, for the external stakeholders, local people might have a significant capacity to influence the SES with their decisions and as such of regulating the SES evolution. For these participants, the dynamics of the system will strongly depend on the choices and actions taken by the community members in relation to their livelihoods, how and under what rules they manage their resources, and how all these variables will foster or hinder migration. They identified opportunities to develop individual entrepreneurial activities in the community if the Assembly would be less restrictive and permit them.

Table 2 summarizes the role played by every variable according to the perceptions of the different groups analyzed.

Table 2. Variable clustering according to the different perceptions ¹.

Variable	Women	Men	External
Economic activities	Output	Output	Output
Livelihoods	Output	Output	Regulator
Nonpaid activities	Regulator	Regulator	Input
Migration trends	Regulator	Auton./Regulator	Regulator
Political stability	Stake	Output	Regulator
Environmental regulation	Input	Autonomous	Input
Governance institutions	Stake	Input	Input
Property right system	Input	Input	Input
Collective-choice rules	Input	Regulator	Input
Monitoring and sanctioning rights	Output	Regulator	Regulator
Exclusion and extraction rights	Output	Regulator	Regulator
Economic value	Autonomous	Regulator	Output
Importance of resources	Regulator	Regulator	Regulator
History of use	Stake	Stake	Input
Health infrastructures	Output	Output	Autonomous

¹ Input variables, strong influence and low dependence; stake variables, high influence and dependence; regulator variables, moderate dependence and influence; autonomous variables, low influence and dependence; and output variables, low influence and high dependence.

5. Discussion

In the following sections, we focus the discussion on how the differences in perception between local women and men reflect the disparities in power, voice, and agency. We emphasize the fact that women asked for a ‘gender space’ [24] for discussion, because they felt that by continuing the workshop dynamics together with men they would have fewer opportunities to contribute to discussions. As Kawarazuka et al. mentioned, participatory processes should not neglect the way in which power relations may shape the production of knowledge [19].

Next, we assess how the differences in knowledge and understanding across scales, and how the barriers perceived by every type of stakeholder shape a different vision of the SES and its

management [28]. Between women and men, we do not perform any other intersectional analyses since race, economic status, and other parameters are very similar [43].

It is worth mentioning that the three collectives agreed in the selection of variables and present important similarities in their perceptions. However, our analysis was focused on identifying the variables that positioned differently in the clusters drawn by the participants in the influence/dependence maps.

5.1. Gender Differences

The comparison between the local women and men perceptions shows important differences in the role assigned to nearly half of the variables. These variables are linked to the community-based governance system (governance institutions, monitoring and sanctioning rights, and extraction and exclusion rights), the political settings (political stability and environmental regulation), and the socioeconomic attributes (economic value and livelihoods).

Women allocate a stronger capacity to influence the SES to the governance institutions. They position it as a stake variable that can both influence and be influenced by other variables. However, for men it is an input variable with low dependence capacity. These different perceptions reflect the differences in power relations, agency [44], and gender asymmetries [24]. Women believe that men have the power to take decisions that change the governance system, but men are conscious of their aversion to decide this type of change and based on this long-term experience, they do not consider that this variable can be influenced.

For the case of monitoring and sanctioning rights and extraction and exclusion rights, women identify a higher capacity of being influenced than men. Both variables are considered as output by women and as regulator by men. Men allocation reveals their understanding of the importance of holding these rights, in order to preserve the sustainable management, they do in the SES. Women perception recognizes that only the voices that are represented have the power to drive rules and their evolution [45]. Different authors have also reported the gendered dimensions of resource-based livelihoods [19,23,25], and more specifically, how forest resource management have marked gender behavioral patterns that reproduce social inequalities between men and women [25,46].

The political stability has a high influence and dependence capacity for women (stake variable), while for men it is an output, e.g., they do not foresee having capacity of influence. The relevance of this variable can be explained by the actual instability existing in Mexico and the fear in the community that the Mexican government could change the legal framework regulating the collective property rights of Indigenous communities, opening the options to privatize these lands and resources as it already did with ejidal property rights [47].

Concerning the socioeconomic variables, economic value is a regulator variable for men and can act as a lever of the system. However, for women it is autonomous, and has very little influence and dependence capacity. This counter-intuitive result might be explained by the male predominance in the economic decisions at community and household levels. The livelihoods variable is considered by women as a variable with null capacity of influence, while men allocate a higher influence capacity to this variable, even if they still locate it in the output cluster. The restrictions that social norms and labor division impose on women reduce their perceptions in their ability to influence socio-economic variables [26]. Their perceptions highlight their invisibility and lack of voice in the decision-making processes [44]. Men's perception that both variables can be influenced is a recognition that the decisions over the natural resources taken in the Assembly (where often new economics activities or investments are blocked) determine, at least in part, the economic value of the resource and the livelihoods opportunities of the community.

The differences in perception highlighted by these results reveal the existing disadvantages of women in terms of voice, agency and power in the SES management, and even at household level [48,49]. The constraints women face in taking decisions in the management of natural resources and in their capacity to influence the governance systems [23] are reflected in the cluster positioning

allocated to the variables linked with these aspects. These perceptions unpack how people occupying different gender positions perceive their (lack of) capacity to negotiate around the management of the natural resources.

Women perceptions reflect how the customary management system tends to discriminate them in decision making and how they are less likely to participate in community-based management activities [50]. The community governance institutions, especially the informal ones, are gendered, and traditionally the customary norms over communal property rights or resource management and even intra-household relationships have discriminated women [22]. Women's perceptions reflect how the gender identities are coproduced through power relations and shaped in everyday life and practices [26,43]. In our case study, we did not appreciate any shift from traditional management to new management institutions involving women, what difficult women empowerment and changes in behavioral patterns. As outlined in previous works [24,25], forest-based communities tend to have a marked gender labor differentiation. However, women also recognized that a different division of labor that allows them to participate in the collective activities probably might equate to a heavier labor burden. Cohen et al. found similar results [26].

Recent social-ecological research warns about the need to seek alternative forms of thinking about, and action toward SES management [22,51]. Women participation in SES management is restricted by social/cultural norms and power imbalances [52]. The existing social norms to manage the SES are based on unequal exchange, making women more vulnerable, increasing gender asymmetries. Women have fewer opportunities to contribute their knowledge to decision-making and governance processes [24]. Not taking into account gendered needs, perceptions, and knowledge may undermine the resilience of the SES [23]. Indeed, SESs are shaped by internal changes; gendered diversity in knowledge and practices and in access to resources and decision-making are critical aspects to cope with sound and resilient SES management [53]. The lack of gender awareness and the underestimation of women's roles and contribution in SES management compromise future sustainability. Side-lining women's knowledge and needs might be a significant barrier to sustainable SES management [23].

5.2. Cross-Scale Differences

The analysis of the perceptions of the three groups underlines differences in only three variables linked to socioeconomic factors, namely economic value, livelihoods, and history of use. The economic value is the variable where bigger differences are perceived. For the external stakeholders is an output of the system and as such, the result of the performance of other variables; for men this variable is a regulator and for women is autonomous. These perceptions reflect that community males are aware of their options to take different decisions over the economic activities that represent a source of income, but that external stakeholders have little confidence on the willingness of the Assembly to take such decisions [23].

However, for the other two variables, both local women and men coincide in their perceptions; e.g., the history of use is a stake variable for them. External stakeholders assign a high influence to this variable, but they consider that it will not be changed by the community. Similarly, both local groups consider livelihoods as an output variable with low influence capacity, but external stakeholders locate it in the regulator cluster and thus, with higher influence capacity. The latter envisage opportunities to improve the livelihoods of the community if different decisions on the management of natural resources are taken.

Making separate analysis between local men and external stakeholder the main difference is in the nonpaid activities variable that, for the locals, is an autonomous variable with limited influence and dependence capacity, although external stakeholders believe that this variable is not static, but highly influence the system and has a considerable capacity to be influenced by other variables.

The results of comparing the views of women and local stakeholders displays differences in the consideration of two variables, monitoring and sanctioning rights and political stability. For women, the first one is an output variable, with limited influence capacity, but for external stakeholders is

a regulator that can activate changes in the system. This disparity reflects how women perceive their lack of power and participation in the customary management of the SES [22], but for external stakeholders this situation can and should be changed. Gender relations are neither deterministic or static, but socially constructed, and as such, they can be continuously contested and (re)defined [54].

Finally, the political stability has strong influence and dependence capacity for women, while for external stakeholders is a regulator that can act as a lever of the system. The differences in knowledge systems influence the latter perception. They do not consider it as a stake variable, but as one that, to a certain level, can be controlled.

The results show important similarities in the perception of the SES but also underline the diversity and multiple ways of shaping this understanding. They highlight how the 'situated knowledge' is mediated by gender, scale, and cultural contexts [22]. The relations of power between these socially differentiated groups, their cultural representations, and their agency capacity reflect different pictures in the perception on the capacity of the variables of influencing or being influenced in the SES management and evolution. Understanding the differences in power and cultural approaches across scales is essential to the development and functioning of a SES [22].

This diversity of approaches enriches the knowledge of the SES and can be a starting point for further knowledge generation [51]. Indigenous communities manage SESs drawing on their cultural, political, and philosophical traditions [9]; external views, when not imposed, may encourage thinking across traditional disciplinary boundaries and develop new conceptual approaches and empirical insights to work interculturally in SES management [55]. Linking diverse knowledge system can improve SES management by taking advantages of emerging opportunities and buffering negative impacts. This approach might lead to the generation of new understandings of the SES dynamics, to change mental models, and to widen perceptions among all knowledge holders [51]. Nurturing a diversity of sources of perceptions and insights might drive social learning processes that benefit sustainable SES management and contribute to Sustainable Development Goals.

5.3. Limits of the Method Used

The main limitations of structural analysis arise from its qualitative nature and the fact that results depend on the perceptions of the participants in the exercise, hence they are subjective. In our research we did a careful selection of participants based on their knowledge of SES and their willingness to participate in the exercise. However, we did not aim to display a correct representation of the SES, but to investigate how the participants perceive it and to foster a discussion process that promotes a thorough understanding of the different perceptions, and how the main variables selected could act as drivers, constraints, or opportunities for sustainable management. An extensive discussion of the limits of structural analysis can be found in a past paper [30].

Another concern is linked to the need of working with a single list of variables. In this research, we provided the external stakeholders with the list initially selected by the local inhabitants, but we emphasized that they were free to choose the most representative variables in the SES performance according to their views. They agree with all the variables, but introduced a new one leading to a round of interactions with local people to reach a consensus for its inclusion. We are rather sure that external participants were not greatly influenced by the initial list, but in other researches the situation can be quite different.

6. Conclusions

Structural analysis results are based on how participants perceived the system. Understanding perceptions is essential to identify the problems that people observe and to design strategies to tackle them. The evolution of a system is highly influenced by the decisions of local actors, and to include their vision is essential in any sustainable strategy. Our results provide insightful information that can be used to design effective planning and management actions.

The analysis presented the diversity of perceptions of the multiple actors about the variables that can drive the SES. We found that perceptions were shaped by different factors, in particular, gender, social norms, decision-making capacity, willingness to bear risks, power structures, coping capacity, and differences in knowledge across scales.

The gender context shaped the different perceptions of women and men and unpacked the power relations and the situated sensitivities. These perceptions were largely shaped by the roles, responsibilities, and entitlements held by each of them. Women felt largely excluded from the institutions and the rules that define the management of SESs and revealed a passive role in the evolution of the SES. Gender blindness is problematic and excluding women and women's knowledge from decision-making bodies might create problems for the future sustainability and negatively affect the resilience of the system [23]. Bringing critical gender analysis to SES management might generate an integrated knowledge that enhances the sustainability and contributes to several Sustainable Development Goals such as 5, 10, 13, and 15. Further efforts are necessary to make gender aspects relevant to decision makers.

The analysis across scales showed that understanding the diverse perspectives of different groups of interest in a SES can support multilevel governance processes. Bridging cross-scale interactions might support the incorporation of multiple knowledge systems across scales [28] to cope with changes and foster sustainable management. Gendered and alternative knowledge can be very relevant for sustainable SES management in multi-level governance contexts but it is necessary to bridge this different knowledge to generate suitable solutions and to develop mechanisms for legitimate, transparent, and constructive ways of creating synergies [51] among knowledge holders. Cross-fertilization among the perceptions of the different type of stakeholders may drive desirable trajectories into the future.

Further research is needed to mainstream the gender analysis of SES and natural resource management perception. We contributed with a single case study, but investigations and meta-analysis covering a wider variety of case studies and making possible generalizations and theory building are necessary.

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Appendix A. Participants in the Workshops

Table A1. List of community members participating in the research.

	Sex	Role in the Community
Participant 1	M	Communal Property Commissioner
Participant 2	M	Treasurer
Participant 3	M	Communal Property Secretary
Participant 4	M	Major

Table A1. Cont.

	Sex	Role in the Community
Participant 5	M	Municipal authority
Participant 6	M	Long standing council member
Participant 7	M	Comaltepec's farmer
Participant 8	M	Representative of livestock breeders
Participant 9	M	Communal Enterprises General Coordinator
Participant 10	F	Representative of social affair commission
Participant 11	F	Community member
Participant 12	F	Community member
Participant 13	F	Representative of social affair commission
Participant 14	F	Community member
Participant 15	F	Community member
Participant 16	F	Community member
Participant 17	F	Community member
Participant 18	F	Representative of forestry commission
Participant 19	F	Community member
Participant 20	F	Community member
Participant 21	F	Community member
Participant 22	F	Community member
Participant 23	F	Community member

Table A2. List of external stakeholders participating in the research.

	Sex	Organization
Participant 1	M	Project Manager ERA A.C. and Rain Forest Alliance
Participant 2	M	University Professor (UNSIJ)
Participant 3	F	University Professor (CIIDIR UPN)
Participant 4	M	Researcher CIESAS campus Oaxaca
Participant 5	M	Representative of CONAFOR
Participant 6	M	Representative of SEMARNAT, Oaxaca
Participant 7	M	Representative of CONANP
Participant 8	F	Representative of CONANP
Participant 9	M	Representative of SEDESOL
Participant 10	F	Representative of Estate Institute of Ecology
Participant 11	M	Representative of CDI, Guelatao Coordination Center
Participant 12	M	President of the Managing Board UZACHI
Participant 13	M	Forest Management Director UZACHI
Participant 14	M	Manager of Protected Areas UZACHI
Participant 15	F	Manager of organization and capacity building UZACHI
Participant 16	M	President of NGO Servicios Ambientales de Oaxaca
Participant 17	F	University Professor (UNSIJ)
Participant 18	M	Treasurer UZACHI
Participant 19	F	Representative of ERA A.C.
Participant 20	M	Representative of CDI, Guelatao Coordination Center
Participant 21	M	Secretary of the Managing Board UZACHI
Participant 22	M	Representative of SEDESOL

Appendix B. Description of the Variables Selected by the Stakeholders

Economic activities: Economic activities are those that represent a source of income for the community members.

Livelihoods: *Livelihoods* are the day-to-day activities performed by all inhabitants for the subsistence of the families and the community regardless of whether or not they generate monetary income.

Non-paid activities: *Non-paid activities* are those held by the commoners without payment and on mandatory basis to support the CBNRM. These activities strengthen the community ties. Some of

the most important activities in this category are the services to the community performing long-term administrative and management activities (*cargos* and commissions), the short-term unpaid labour for the community (*tequios*), domestic labour, and monitoring activities.

Migration trends: *Migration trends* refer to the migration patterns, the changes happened over the years, as well as to the reasons for these changes. This variable also includes identifying who migrates, why and where to. In the case study, migration started in the eighties and nineties and there has been a stable trend since then, showing some declining tendency in the last few years due to USA migratory policies.

Political stability: *Political stability* is related to the political situation at the regional, national and local levels, whether stability or conflict (either current or potential) prevails and to the influence of the policy decisions in the SES. It also refers to the degree of compliance with the rules due to the knowledge that community members have of them and to the community's enforcing power. The variable also includes aspects such as trust, reciprocity and predictability of the behaviour among commoners and the trust in the authorities' performance.

Environmental regulation: *Environmental regulation* includes the environmental laws affecting the management of the resources at the regional, national and local levels; for instance, the (lack of) autonomy of the community to perform or block activities related to the natural resource management due to national environmental laws.

Monitoring and sanctioning rights: The *Monitoring and sanctioning rights* refer to the rights of commoners to monitor the correct use of the natural resources and verify the compliance of the established rules. When the compliance with the rules is not effective or the resources are used inappropriately, they have the authority to impose sanctions to the commoners (monetary, community labour, imprisonment). For non-commoners, they have the right to communicate the non-compliance to the regional authorities.

Governance Institutions: *Governance institutions* refers to the multilevel institutions operating in the SES, its performance and its structure; for instance, the Commoners' Assembly, the Citizens Assembly, the municipal authorities, the Communal Property Commissioner, and the Surveillance Council.

Property Right System: The *Property Right System* describes the formal property rights regarding the resource system and the common pool resources.

Collective-choice rules: The *Collective-choice rules* consist on the rules for the collective action and the community-based management of resources.

Exclusion and extraction rights: This variable refers to the rights to define who and under what conditions have access to the resources and to its management. The Assembly of Commoners defines who can use the resources and how and arbitrates in the decision-making process related to *exclusion and extraction rights*.

Economic value: *Economic value* refers to the market price of the natural resources, for instance, timber and non-timber forest resource prices.

Importance of resources: This variable is related to how important the resources are for the lives and economy of the commoners and how much they depend on such resources.

History of use: This variable gathers the history of the community over the use of land and the management of natural resource. It also includes how the interactions among the resource units have changed over the years.

Health infrastructures: *Health infrastructure* describes the infrastructure and services that improve health conditions in the community.

Appendix C. Matrixes of Direct Influence Dependence

Table A3. Women’s Matrix of Direct Influence Dependence.

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	Total Influence
V1	0	1	0	2	2	0	2	0	0	0	0	2	2	0	2	13
V2	0	0	0	3	2	0	0	0	0	0	0	0	2	1	2	10
V3	3	2	0	2	3	0	3	0	0	3	2	0	0	3	3	24
V4	2	2	2	0	1	0	3	0	0	0	3	0	2	0	2	17
V5	3	2	3	2	0	2	3	3	3	3	3	0	0	2	2	31
V6	3	3	3	3	3	0	0	2	0	3	3	2	3	0	2	30
V7	0	2	3	2	3	3	0	3	3	3	3	0	1	3	3	32
V8	3	2	0	1	3	0	3	0	3	2	3	0	3	3	0	26
V9	3	2	3	2	3	0	3	0	0	3	3	1	2	3	2	30
V10	1	2	3	0	3	0	0	0	0	0	0	3	2	3	0	17
V11	2	3	3	0	3	0	0	0	0	3	0	0	0	3	0	17
V12	3	2	0	3	1	0	0	0	0	2	2	0	3	0	0	16
V13	0	2	0	0	0	3	2	0	3	3	3	1	0	3	1	21
V14	3	2	0	1	3	3	3	3	2	3	3	2	3	0	2	33
V15	0	1	1	0	2	2	2	0	2	0	2	0	2	0	0	12
Total dependence	26	28	21	21	32	13	24	11	14	30	28	11	25	24	21	329

Table A4. Men’s Matrix of Direct Influence Dependence.

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	Total Influence
V1	0	3	1	2	3	0	0	0	3	0	0	0	0	0	3	15
V2	3	0	0	3	2	0	0	0	0	1	0	3	2	0	3	17
V3	2	2	0	1	2	0	1	0	0	0	3	2	1	3	1	18
V4	3	2	0	0	1	0	0	0	1	0	0	0	3	0	1	11
V5	2	1	2	1	0	0	0	1	3	2	0	2	2	2	1	19
V6	3	3	0	0	0	0	0	0	2	0	3	2	3	0	3	19
V7	3	2	3	3	3	2	0	2	3	3	3	2	2	3	3	37
V8	3	2	2	0	3	2	3	0	2	3	3	2	1	3	0	29
V9	3	2	3	1	3	1	3	0	0	3	2	1	2	3	0	27
V10	2	3	1	0	3	0	0	0	0	0	2	3	2	3	3	22
V11	3	2	3	1	3	0	0	1	1	2	0	2	2	3	0	23
V12	3	3	0	3	3	0	0	0	0	3	0	0	3	3	3	24
V13	3	2	0	2	2	0	2	0	0	3	0	3	0	3	2	22
V14	3	3	3	2	3	1	3	3	2	3	3	1	2	0	2	34
V15	2	1	0	0	2	2	0	0	0	0	0	0	0	0	0	7
Total dependence	38	31	18	19	33	8	12	7	17	23	19	23	25	26	25	324

Table A5. External Stakeholder’s Matrix of Direct Influence Dependence.

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	Total Influence
V1	0	3	0	1	1	0	0	0	0	1	0	3	2	0	1	12
V2	3	0	2	3	3	0	0	0	1	2	1	2	3	0	0	20
V3	3	2	0	3	2	0	3	0	0	3	3	3	2	0	2	26
V4	1	2	2	0	2	0	0	0	0	0	0	0	2	0	1	10
V5	3	0	3	0	0	1	3	0	0	2	2	3	0	0	0	17
V6	3	2	0	0	0	0	2	0	0	2	2	3	3	0	2	19
V7	3	1	3	2	3	1	0	2	3	3	3	2	1	0	2	29
V8	3	3	3	1	0	2	1	0	3	2	3	1	0	0	0	22
V9	3	3	1	0	3	1	0	0	0	3	3	1	3	0	1	22
V10	3	2	0	0	0	3	3	3	0	0	0	3	0	0	0	17
V11	3	2	0	0	0	0	0	0	0	3	0	3	1	0	1	13
V12	3	2	0	2	2	0	0	0	0	0	0	0	0	0	0	9
V13	3	3	0	1	2	0	0	0	0	0	3	2	0	0	0	14
V14	3	2	3	1	3	1	3	3	3	3	3	0	0	0	0	28
V15	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	3
Total dependence	37	29	17	14	21	10	15	8	10	24	23	26	17	0	10	261

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