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# Water-related challenges in nexus governance for sustainable development: Insights from the city of Arequipa, Peru

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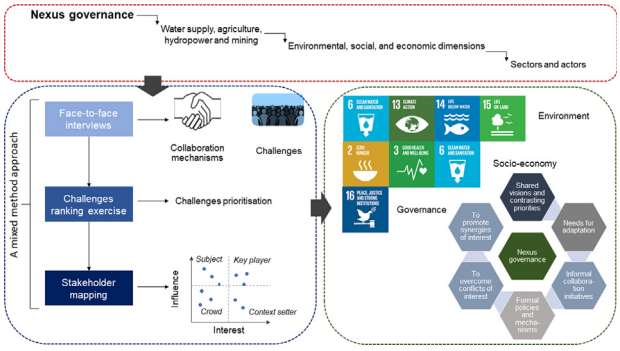
## HIGHLIGHTS

- A novel mixed methods approach to explore nexus governance challenges in Arequipa
- Formal and informal mechanisms support successful cross-sectoral collaborations.
- Complementary and contradictory priorities were evident across sectors and actors.
- Adaptation needed to overcome weather, urban growth or increased demands.
- Enhancing stakeholder awareness and governance are key for a shared vision.

## GRAPHICAL ABSTRACT

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## ABSTRACT

Peru has one of the fastest-growing economies in Latin America, but there are concerns regarding how long this can be sustained. Negative environmental impacts are increasing due to the pressures of a growing urban population and competition for natural resources. This study explores stakeholder perceptions linked to nexus governance in the context of integrated management of natural resources, particularly water, and the environmental, socio-economic and governance challenges constraining the achievement of UN Sustainable Development Goals (SDGs). Our analysis focused on the urban and rural areas associated with the city of Arequipa, an economically dynamic region subject to extreme levels of water stress. Face-to-face interviews with key informants were conducted to identify mechanisms that have enhanced successful multi-sectoral collaboration, and to assess challenges in promoting sustainable economic development. A workshop prioritised the identified challenges and an online survey was then used to assess stakeholder interest in and influence over nexus governance of water with other natural resources. Stakeholder mapping revealed a complex network of actors involved in nexus governance, where successful collaboration could be promoted through formal and informal mechanisms, including exemplar policies and initiatives across sectors and actors. Shared visions between stakeholders were identified as well as contradictory priorities relating to the sustainable management of natural resources. A key finding that emerged was the need to promote adaptation in water and land management (SDG 6) due to perceived impacts of extreme climate events (SDG 13), urban population growth (SDG 11), and increased sectoral water demands.

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This situation in combination with poor governance and lack of planning has exposed the vulnerability of Arequipa water supply system to future shocks. Urgent action will be needed to raise stakeholder awareness, strengthen governance and enforcement, and agree on a collective vision for integrated land and water planning if the SDGs are to be achieved.



## 1. Introduction

Economic development coupled with appropriate management of natural resources is required to achieve sustainable outcomes, such as those in the 2030 Agenda for Sustainable Development (UN, 2015). This Agenda represents 'a shared blueprint for peace and prosperity for people and the planet' which is defined in 17 Sustainable Development Goals (SDGs) (UN, 2020). Understanding the inter-dependencies between the SDGs is crucial for achieving long-lasting sustainable development (ICSU, 2017) since they cannot be achieved in isolation (Pradhan et al., 2017). In this respect, promoting an integrated perspective of natural resources, including water (Requejo-Castro et al., 2020), land, energy (Engström et al., 2019) and minerals (Bleischwitz, 2019) is vital for sustainable development (Pahl-Wostl, 2017).

Peru is one of the fastest-growing economies in Latin America (World Bank, 2019). Since the beginning of the 21st century, it has experienced rapid growth in the export of high-value horticultural products, and is currently the world's leading exporter of asparagus (FAO, 2019). In 2017, mining contributed around 10% of the national GDP and is the main pillar of Peruvian exports with ca. 62% of total export revenue earnings (Ministerio de Energia y Minas, 2017). While these generate positive impacts on economic growth and employment (Schuster and Maertens, 2017), the growing demands for water and land due to agro-export production (Hepworth et al., 2010) and mining (Bebbington and Bury, 2009) are unsustainable. Indeed, the use of scarce water resources to support agro-export production (Schwarz and Mathijs, 2017) and mining (Pérez-Rincón et al., 2019) along the Pacific coast has triggered major debate regarding environmental sustainability. This is a part of the country where 63% of the population resides, and yet it only contains 1.8% of the nation's freshwater resources (ANA, 2015).

Over the last two decades, the country has experienced remarkable socio-economic progress and poverty reduction, but Peru still needs to overcome a number of negative development 'traps' derived from institutional weaknesses and a lack of environmental sustainability (OECD, 2019). Urbanisation (e.g., Lima-Callao urban sprawl) has highlighted shortcomings in drinking water and sanitation provision, as well as increasing concerns from air pollution, urban transport and the treatment and disposal of waste. In contrast, in rural areas major challenges still exist relating to poverty alleviation and equitable access to land and water resources (OECD, 2017). The city of Arequipa (Lat 16°23′S; Lon 71°32′W, altitude 2300 m) is an exemplar of water-related management conflicts across agriculture, hydropower and mining sectors. A recent ethnographic study identified common and private interests in the implementation of the 2009 Water Law (Perú, 2009), including material and organisational infrastructure on the one hand and ideologies and values on the other (Andersen, 2019). Concerns have also arisen due to the role of the large mining company - Cerro Verde - in financing water-related infrastructure, as this may hinder equal representation of interests and views in formed alliances (Filippi et al., 2014). However, other studies have illustrated potential positive outcomes that the mining sector can play in helping to achieve sustainable development in resource-rich countries by delivering business benefits while also addressing social issues (Fraser, 2017). These studies highlight the range of perspectives and priorities in the management of water resources, but there is still a knowledge gap to better understand the broader management of water and other natural resources, and its environmental and socio-economic implications and relevance to SDGs, and the role that stakeholders can play in supporting or hindering such initiatives. This study attempts to address that knowledge gap.

The scientific literature on sustainable development often refers to integrated natural resources management (INRM) and integrated water resources management (IWRM) with INRM highlighting the importance of embedding and reconciling different interests across different user groups to sustainably manage natural resources (Frost et al., 2006). This approach has been developed for complex natural resource management situations, where populations are highly dependent on local resources for their livelihoods (German et al., 2012). In contrast, IWRM has focused on coordinated development and management of water challenges, but with the inclusion of land and related resources (GWP, 2000). The water-energy-food nexus agenda builds on these approaches (Liu et al., 2017; Wichelns, 2017) by adding the need to clearly identify governance and policy as being integral pillars of the process (Roidt and Avellán, 2019).

There is a growing evidence base on nexus research (Albrecht et al., 2018) with new concepts emerging to address people and resource inter-dependencies and the need for sustainable governance and management of natural resources (Pahl-Wostl, 2017). A nexus approach could be seen as an analytical tool, a governance framework and/or an emerging discourse (Keskinen et al., 2016) to span empirical, pragmatic and normative levels, based on the aspirations of transdisciplinarity (Max-Neef, 2005). In this study, we embrace the description of a nexus approach to governance that links water management to natural resources in environmental, social, and economic dimensions across sectors (Pahl-Wostl, 2017) and actors (White et al., 2017) and term this 'nexus governance' (Stein and Jaspersen, 2018).

Supporting research through engagement and collaboration across stakeholders is essential to address global sustainability challenges (Irwin et al., 2018). Since nexus governance requires a balance between different policy goals and stakeholder interests (Kovacic, 2020), the challenges and opportunities associated with nexus governance in natural resources can draw on approaches and tools associated with stakeholder analysis (Reed et al., 2009). This has become increasingly popular in research, policy and decision-making (Cvitanovic et al., 2016), with its origins in business management (Friedman and Samantha, 2006), policy, and development (Brugha and Varvasovszky, 2000). An important aspect of stakeholder analysis lies in differentiating between and classifying stakeholders. Such categorisations allow researchers to group stakeholders according to similar characteristics so that those of strategic importance can be identified. This can then help to determine how stakeholders might be engaged (Reed et al., 2009) to implement policy changes or to support informed decision-making for sustainable development and natural resources management.

This study aimed to explore how nexus governance for integrated management of water and other natural resources can be achieved to support sustainable development in the urban-rural area surrounding the city of Arequipa (Fig. 1). Three objectives were identified: (i) to map stakeholder interest in and influence over the management of water and other natural resources; (ii) to identify the mechanisms and initiatives that support successful collaboration and promote synergies between users, regulators and managers of water supply and sanitation services, as well as with the agricultural, hydropower and mining sectors; and, (iii) to explore the environmental, socio-economic and governance challenges across sectors and actors to determine the implications for achieving impacted SDGs. This study provides new insights and directly contributes to contemporary debates relating to the

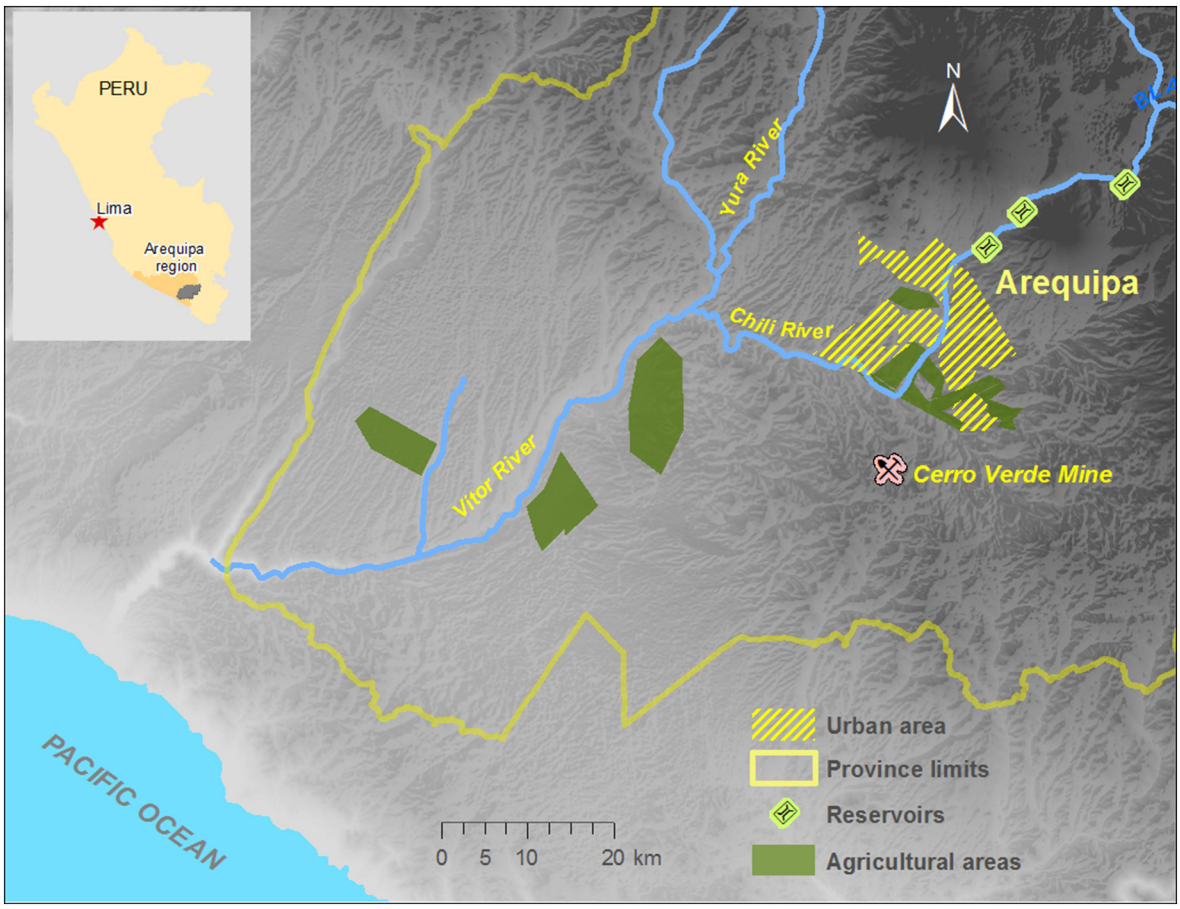


**Fig. 1.** Location of the case study.

water-energy-food nexus governance for sustainable development. The most prescient issues facing transformational management of water and natural resources were analysed using a novel mixed-methods approach, paying special attention to the most relevant and impacted SDGs. We are not aware of any equivalent studies reported in the scientific literature. The study also provides a critical discourse on developmental policies linked to water resources management, land planning, agricultural production and adaptation of communities to extreme climate events. Considering there are many other urban areas both in Peru and globally, especially in the developing world, that face similar migratory (Inostroza, 2016), climatic pressures (Hunt et al., 2017), increasing water scarcity (Li et al., 2015; Vázquez-Rowe et al., 2017a), and weak governance (Bell, 2015), the new insights presented here have high relevance to other locations facing complex nexus-governance challenges.

## 2. Material and methods

### 2.1. Case study: urban-rural span in Arequipa city

Arequipa is the second largest city in Peru with a population of ca. 1,008,000 and is one of the fastest growing regions in Peru (INEI, 2018). Although it is an Andean city, it is associated with the rapid economic growth that has occurred along the coastline and is part of the key economic corridor that connects the Andean highlands with the coast (Benavides and Cárdenas, 1999). Poor urban development and planning has led to informal settlements and marginal contributions to improving living conditions (Pineda-Zumaran, 2016). The case study area is located in the Quilca-Chili river basin, which originates in the western highlands of the central Andean cordillera and drains into the Pacific Ocean. This was the first pilot for a river basin council implemented through the 2009 Water Law (Perú, 2009). It is one of the most regulated river basins in Peru, with seven dams in the highlands (>6000 m above sea level) (Andersen, 2018) supplying the city with water. Current water supplies are threatened by accelerated warming in the highlands (Vicente-Serrano et al., 2018), the retreat of glaciers (Veettil and Kamp, 2019) and desertification in the upper basin due to over-grazing and deforestation (Filippi et al., 2014); which is seriously jeopardising downstream water supplies for irrigation, hydropower and urban domestic water supply (Buytaert et al., 2017).

### 2.2. Methodological approach

#### 2.2.1. Study design

A mixed-methods approach was used to identify and explore the challenges in Arequipa associated with promoting sustainable economic development in nexus governance for the following sectors: water and sanitation services, agriculture, hydropower, and mining. A combination of face-to-face semi-structured interviews, ranking exercises, and a stakeholder mapping exercise were used between May and October 2019. The face-to-face interviews were used to collect narrative data to identify existing governance mechanisms and potential synergies and conflicts between the different sectors that might emerge in the pursuit of integrated approaches to management of water and natural resources. The ranking exercise was used in a stakeholder workshop to build on the findings from the interviews and to identify shared stakeholder objectives as well as potential conflicts of interest. Lastly, an online survey evaluated respondents' views on the differing levels of

interest and influence stakeholders had for effective management of water and natural resources, using a scoring approach.

*2.2.2. Sampling size and approach*

A total of 16 face-to-face interviews were carried out involving 25 participants (three interviews had more than one participant). A purposive sampling approach (Bryman, 2016) was used to ensure access to a range of individuals with expertise in the three topics addressed in the interviews (Section 2.2.3), so that the perspectives of the key informants from the different sectors could be researched. Purposive sampling is a form of non-probability sampling which intentionally select participants because of their ability to elucidate on a specific theme, concept or phenomenon (Robinson, 2014). In purposive sampling, sample composition is therefore more important than sample size, particularly when the objective is to undertake in-depth qualitative interviews with key experts and stakeholders, as was the case here. Participants included representatives from national, regional and provincial level government, water regulation agencies, water supply services, the mining and agricultural sectors, universities and civil society (Table 1). These interviews helped to identify 48 organisations with a stake in nexus governance of water and natural resources. These were later used as the basis for the stakeholder mapping exercise (Section 2.2.5).

The workshop comprised of 30 participants, including stakeholders (19), project partners from Peru and the UK (5), note takers (4) and support staff (2). Seven participants had previously taken part in the face-to-face interviews and six new participants represented organisations already interviewed during the face-to-face interviews. The remaining stakeholder participants (6) were identified through the face-to-face interviews and represented five new organisations (Table 1). The online survey made use of a classification exercise (Section 2.2.5) and was completed in October 2019 by 16 key informants including representatives from local authorities, water utility services, water user associations, the agricultural and mining sectors, and NGOs.

*2.2.3. Face-to-face interviews*

In May 2019, face-to-face semi-structured interviews were conducted in Arequipa to identify existing governance mechanisms and potential synergies and conflicts between sectors for integrated management of water and natural resources. An initial critical review of existing scientific and grey literature including academic journals and government reports helped frame the main issues to be addressed in the face-to-face interviews. Three main issues were identified as fundamental: (i) the mechanisms that support successful collaboration between users, regulators and managers of water supply and sanitation services, as well as with economic sectors related to agriculture, hydropower and mining; (ii) the role of existing collaborative initiatives in creating and/or promoting synergies across sectors and actors; and, (iii) the major environmental, socio-economic and governance challenges across sectors and actors to promote sustainable economic development in Arequipa. The questionnaire used for the interviews can be found in the Supplementary material. The interviews lasted between 20 and 90 min and were recorded to support later transcribing of notes.

Following common practice in grounded theory (Bryant, 2014), a coding process of the transcribed interviews led to the inductive identification of key themes linked to the three critical issues identified during the literature review and described above. Increased understanding of the different themes across the interviews led to frequent checks, reorganisation of the themes and identification of affected SDGs. The final themes were used as the basis of the ranking exercise in the stakeholder workshop.

*2.2.4. Stakeholder workshop*

The stakeholder workshop was organised in May 2019 at the Universidad Nacional de San Agustin de Arequipa to review and discuss the key findings emerging from the interviews, and to prioritise the challenges relating to integrated management of water resources and other natural resources across environmental, economic, social and governance domains. During the workshop, participants were asked to rank the challenges identified in the interviews. Each participant was given six sticky dots per 'challenge' (i.e., environmental, economic, social and governance) and asked to select the most pressing issues that needed to be addressed from their own organisational perspective. In the second part of the workshop, the issues that received the highest number of votes were then discussed in groups divided across four themes (environmental, economic, social and governance). A facilitator was appointed for each theme, and the participants, who were randomly allocated to a group, then rotated every 15 min between each theme table. The main ideas discussed by the participants were gathered by the facilitators to derive a final ranking of preferences (percentage of total votes per challenge).

*2.2.5. Stakeholder mapping*

A stakeholder mapping exercise was conducted via a standard $2 \times 2$ matrix, representing 'interest' and 'influence' dimensions (Bourne and Walker, 2005) to classify stakeholders as either *key players*, *context setters*, *subject* or *crowd* (Eden and Ackermann, 1998; Reed et al., 2009). The mapping exercise was undertaken with respect to a key desired outcome which was defined as "Who has interest in and influence over nexus governance of water and other natural resources in support of sustainable development in Arequipa province". An online survey was designed in Qualtrics (2019) to classify the 48 organisations involved as *key players*, *context setters*, *subject* or *crowd*, in of the nexus governance of water and natural resources. With respect to the desired outcome for the mapping exercise, participants were asked to assess each stakeholder's interest and influence using a ranking scale (1: No influence/interest, 2: Some influence/interest, 3: Influential/Interested, 4: Very influential/interested, 5: Extremely influential/interested). The Supplementary material includes the list of stakeholders in the analysis.

In Eden and Ackermann's (1998) scheme, *Key players* are the most supportive and influential stakeholders for achieving the desired outcome because of their high interest in achieving that outcome and their high influence, which allows them to act on that high interest. *Context setters* have low interest in achieving the desired outcome, but at the same time, have high influence over it, and therefore represent an obstacle or risk to achieving the desired outcome. *Subject* are stakeholders with a high interest in the desired outcome, but with low influence overachieving it. To help achieve the desired outcome, they can increase their influence by uniting among themselves or with more influential *key players*. The *crowd* can generally be ignored since they tend to be peripheral to the process, as they have low interest and low influence in achieving the desired outcome. Notwithstanding this, it should be noted that circumstances do change over time, so it is important to monitor the *crowd* and indeed all stakeholder groups for any shifts in interest and influence.

## 3. Results

*3.1. Complex nexus governance and stakeholder roles*

The stakeholders identified during the face-to-face interviews and workshop and classified during the online survey were used to map them into a stakeholder grid to group them into *key players*, *context setters*, *subject*, and *crowd* (Fig. 2). *Key players*, who had both interest in and influence overachieving nexus governance of natural resources, included public institutions with a direct responsibility for the regulation and management of water (National Water Authority – ANA), the natural environment (Ministry of the Environment – MINAM), and regional government. *Context setters*, a risk to nexus governance, were mainly represented by public institutions from the energy and mining sectors (Ministry of Mining and Energy - MINEM), Cerro Verde Mining Company and municipalities. This appeared to be related to an extractive use of water and natural resources by the energy and mining sectors,

**Table 1**
Individual stakeholder organisations that participated in the interviews and workshop.

| Stakeholder type | Name of the organisation | Sectors[a] | | | | | Number of individuals interviewed | Number of workshop participants | Total participants |
|---|---|---|---|---|---|---|---|---|---|
| | | W | A | H | M | E | | | |
| Government | National Water Authority (ANA) | √ | √ | | | | 1 | 1[b] | 1 |
| | AgroRural | | √ | | | | – | 1 | 1 |
| | Regional Energy and Mining Department | | | | √ | | 1 | – | 1 |
| | Regional Environmental Authority (ARMA) | | | | | √ | 1 | – | 1 |
| | Environmental Department of Arequipa Province | | | | | √ | 1 | 1 | 2 |
| | Autonomous Authority of Majes (AUTODEMA) | | | √ | | | – | 1 | 1 |
| | Water Administrative Authority (AAA) Caplina-Ocoña | √ | √ | | | | 1 | – | 1 |
| | Water Local Authority (ALA) Chili[1] | √ | √ | | | | 1 | – | 1 |
| Public services | National Superintendence of Sanitation Services (SUNASS) | √ | | | | | – | 1 | 1 |
| | SEDAPAR – Arequipa Potable Water and Sewerage Service | √ | | | | | 1 | 1 | 2 |
| Private sector | Agro-export company | | √ | | | | 1 | – | 1 |
| | Cerro Verde Mining Company | | | | √ | | 2 | 2 | 4 |
| University & Research | Universidad Nacional de San Agustín de Arequipa | √ | √ | √ | √ | √ | 5 | 3[b] + 1 | 6 |
| | Universidad Católica de San Pablo | √ | | | | √ | – | 1 | 1 |
| | National Institute of Agricultural Research (INIA) | | √ | | | | – | 1 | 1 |
| Civil society | Water users Chili Regulado | √ | √ | | | | 6 | 1[b] + 1 | 7 |
| | Water users la Joya Antigua | √ | √ | | | | 1 | 1 | 2 |
| | Peasant communities | √ | √ | | √ | √ | 1 | – | 1 |
| | Asociación Civil Labor | √ | √ | | √ | √ | 1 | 1[b] | 1 |
| | AEDES (Asociación Especializada para el Desarrollo Sostenible) | √ | √ | | | √ | 1 | 1[b] | 1 |
| Total | | | | | | | 25 | 7[b] + 12 | 38 |

[a] W: water; A: agriculture; H: hydropower; M: mining; E: environment.
[b] Indicate the same person of the organisation participated in the interview and workshop.

and municipalities may have had less interest since they do not have direct jurisdiction over the management of water and natural resources. Interestingly, the mining sector, represented by Cerro Verde Mining Company, appeared to have a higher interest in a nexus approach to governance than MINEM and the municipalities, possibly due to its role as both a water user and a water provider in water supply services. *Subject*, with high interest in nexus governance of natural resources, but low influence in achieving it, were mostly represented by public institutions in the environmental sector (Forest and Wildlife Service – SERFOR, National Service of Natural Protected Areas - SERNANP, Regional Environmental Authority - ARMA), as well as peasant communities and NGOs. Peasant communities depend directly on water and land resources for their livelihoods, and due to their lack of influence over regulations and management decisions, are subject to the decisions made by *key players* and *context setters*. The *crowd* were those considered by the participants, to have little interest or influence and mostly comprised of those who were not responsible for the management or direct use of any particular natural resource (National Superintendence of Labour Inspection - SUNAFIL, National Police of Peru - PNP). However, the stakeholder mapping showed that some stakeholders were close to the boundary areas of the mapping grid (Fig. 2), so the location of those stakeholders needs to be interpreted with care. For instance, the Arequipa Potable Water and Sewerage Service (SEDAPAR) could have been considered to be a *context setter* rather than *key player*, if a slightly lower interest in nexus governance had been assigned to it by the participants of the online survey.

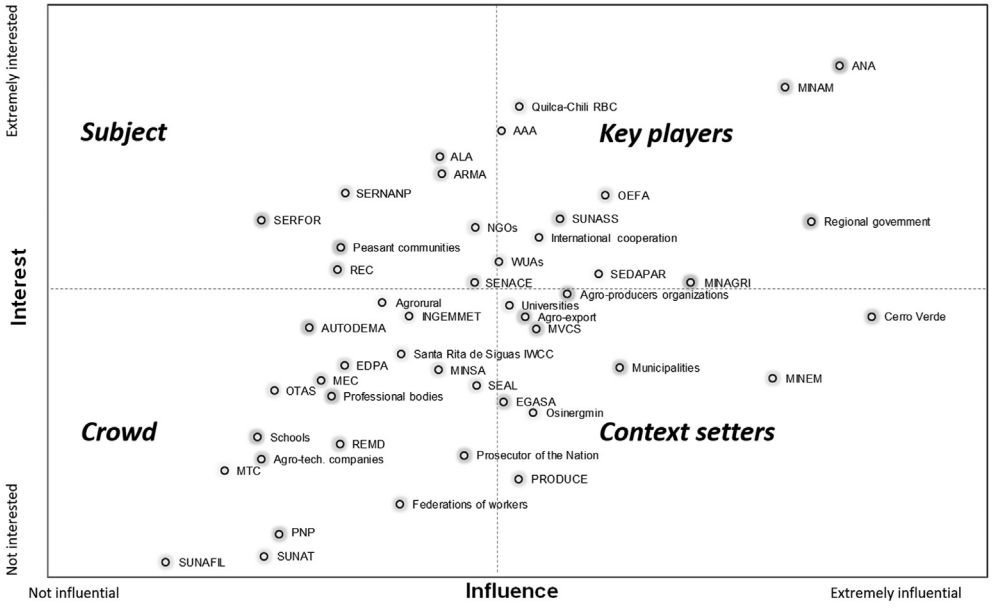


**Fig. 2.** Mapping stakeholder interest in and influence over integrated management of natural resources in support of sustainable development. The full list of acronyms is given in the Supplementary material.

### 3.2. Mechanisms to support successful collaboration in nexus governance

During the interviews a series of mechanisms, including policies and collaboration initiatives, were identified as examples of nexus governance across economic sectors and actors. The new Water Law of 2009 (Perú, 2009) established a model for water resource management with multi-sectoral engagement and a participatory approach at the river basin level. The Water Law established river basin councils as instruments for water governance to coordinate and arrange all sectors involved in water management as well as users. The Technical Water Secretary represents ANA (National Water Agency) in the river basin councils, whereas the presidency is represented by the regional government, as a way to link land development with water resources management. Nevertheless, as one participant from ANA emphasised, the selected regional government representative needs to have the power to make decisions regarding how to implement and financially fund river basin management plants, as there is currently a lack of coordination.

The interviews also highlighted the dependence of ANA on the Ministry of Agriculture and Irrigation (MINAGRI), as the latter ultimately strongly influences how financial resources are allocated. For instance, the agrarian system has funded programmes for agricultural development, but there is no budget provision for water resources planning. Since there is no national funding for the river basin management plans, these have to be financed through local and regional governments, but they have their own interests and priorities for allocating limited funds.

The interviewees from the Regional Environmental Authority, ANA and Environmental Department of Arequipa Province also indicated that the local and regional coordination committees allow participation across actors. For instance, the Regional Environmental Commission is represented by 19 members including provincial and local authorities, as well as affected private institutions. The Commission performs joint work through a specialised technical group dealing with growing environmental challenges, for example, river contamination. At the provincial level, a local environmental management system, sets guidelines on how to perform environmental management at district jurisdictional levels. This includes an environmental agenda to improve environmental quality, including stakeholders such as: ANA, SEDAPAR (Arequipa Potable Water and Sewerage Service), and SUNASS (National Superintendence of Sanitation Services) representing the water sector. For energy, PRODUCE (Ministry of Production), SEAL (company supplying electricity) and EGASA (company generating electricity) are included. At the provincial level, the Municipal Environmental Commission promotes environmental quality in the province of Arequipa and is led by the districts in collaboration with regional authorities, ANA and universities, among others. Nevertheless, as shown in Fig. 2, the Municipal Environmental Commission was considered to be in the *crowd* category in the stakeholder mapping exercise, which highlighted the weak role that it was considered to have in bringing about real change in natural resources management within Arequipa.

### 3.3. Collaborative initiatives to promote synergies in nexus governance

During the stakeholder interviews, synergies in existing initiatives were identified in terms of how actions by one sector could be directly beneficial to others. The current law for the retribution mechanisms for ecosystem services of water resources (Peru, 2014) was mentioned. This mechanism aims to protect, recover and promote the sustainable functioning of ecosystem services, such as water regulation, maintenance of biodiversity, carbon sequestration and storage, and regulation of natural risks. The payments for ecosystem services will be collected by the water sanitation company (SEDAPAR) with funds paid through water user tariffs. This initiative has the potential to promote watershed conservation in the upper mountainous reaches of the basin, where most peasant communities are located, in order to benefit downstream urban users and other economic activities such as agriculture and mining. ANA also highlighted a water fund that has been created in collaboration with Cerro Verde Mining Company, SEDAPAR and farmers for reforestation, conservation and water regulation services in the upper part of the catchment. They created this mechanism as an alternative to the proposed retribution for ecosystem services as it provided more flexibility on funding than a mandatory regular payment, which has not been particularly supported by the mining sector. Another initiative by ANA was the regulation for water re-use (ANA, 2013) that allows the private sector, including energy and mining activities, to use recycled wastewater at no cost, on condition that the wastewater resource is treated appropriately. It is a measure that promotes recycling of the wastewater resource which also benefits the environment (Vázquez-Rowe et al., 2017b).

### 3.4. Environmental, economic, social and governance challenges in Arequipa

A wide range of environmental, economic, social and governance challenges relating to the management of water and other natural resources to promote sustainable development in Arequipa were also identified in the interviews. The environmental challenges that were most frequently mentioned (>10% of interviews) referred to SDG 6 (clean water and sanitation) and SDG 11 (sustainable cities and communities) (Fig. 3). Those challenges included air and water pollution, water availability and access, as well as the conservation of the *campiña* (traditional peri-urban farmland) and green areas of the city. High levels of air pollution in the city were mainly attributed to the transport system, which still relies heavily on an obsolete vehicle fleet (Verán-Leigh et al., 2019), although concerns regarding air pollution related to mining were also identified. In line with this, participants mentioned the need for conservation of natural areas as a way to control air pollution and preserve natural vegetation cover so as to promote shaded areas, since Arequipa has one of the highest levels of solar radiation in South America. Arequipa is also one of the fastest growing cities in Peru, and new areas are being developed for human settlements in the city periphery, where potable water supplies and wastewater treatment services have yet to be planned. In the rural areas there is still a lack of sufficient water and sanitation services (INEI, 2019).

Regarding economic challenges, the most frequently cited issues in the interviews related to SDG 4 (quality education), SDG 8 (decent work and economic growth) and SDG 10 (reduced inequalities) (>10% of interviews) (Fig. 3). There were reported to be unequal opportunities in terms of market access for small-scale farmers who were interviewed from the *campiña* as well as those living in peasant communities in the highlands. Interviewees highlighted that farmers experienced barriers to national market access and international trade, for certain products, such as vegetables from the *campiña* and alpaca fibre from the highlands. This emphasised the need to improve technical training, extension and guidance for small-scale farming communities.

From a social perspective, SDG 4 (quality education), SDG 11 (sustainable cities and communities) and SDG 16 (peace, justice and strong institutions) stand out (>15% of the interviews) (Fig. 4). The migratory pressures arising from urban population growth at the expense of rural depopulation was identified. Expectations generated in the city regarding increased well-being and financial opportunities were not met in many cases because natural resources were over-exploited, as shown by the approval of new water licences that were not included in basin management plans. Weak environmental education and the lack of dialogue on improving management of natural resources for sustainable economic development were identified as key constraints. Regarding governance challenges, these mostly referred to SDG 6 (clean water and sanitation) and SDG 16 (peace, justice and strong institutions) (Fig. 4). Concerns regarding the absence of a political vision for integrated land and water planning were most frequently mentioned (>20% of interviews), followed by weak representation in the Quilca-

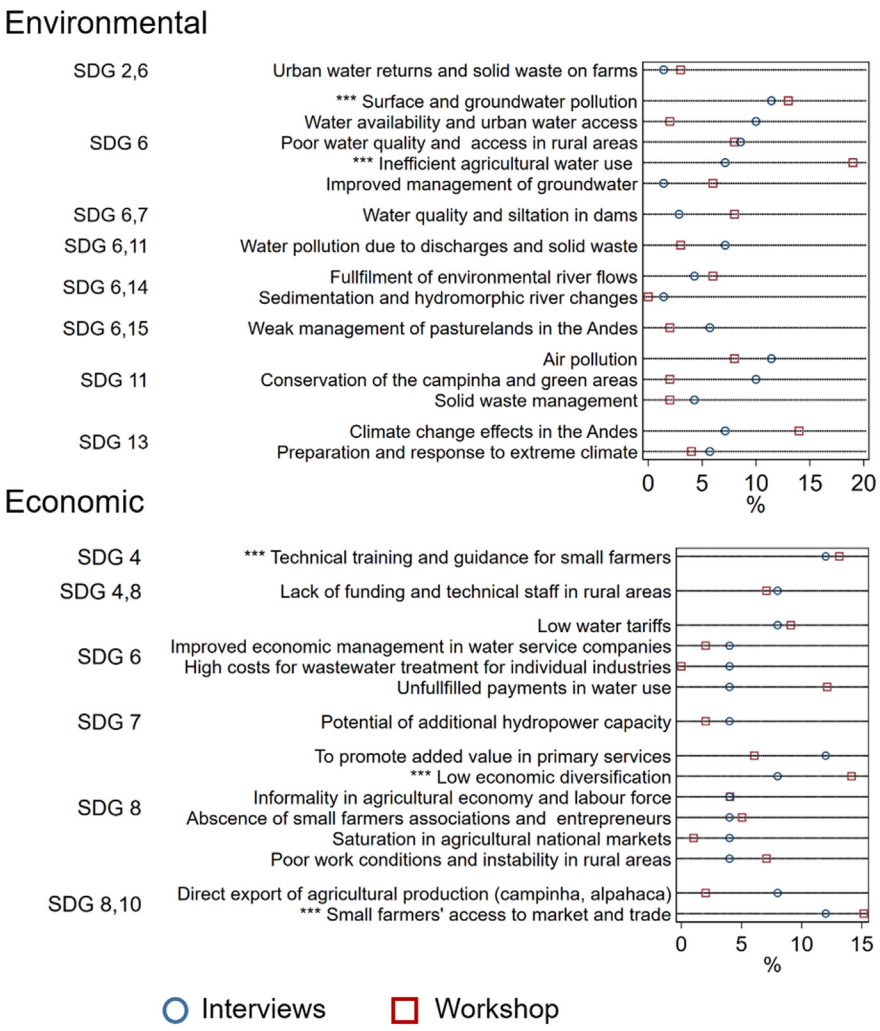


**Fig. 3.** Ranking (%) of environmental and economic challenges identified during the interviews (blue circle) and workshop (red square) relating to the management of water, agriculture, hydropower and mining systems in the urban-rural territory of Arequipa city. *** indicates the most voted challenges during the workshop. Sustainable Development Goals (SDGs) are indicated as follow: SDG 2 (zero hunger); SDG 4 (quality education): SDG 6 (clean water and sanitation); SDG 7 (affordable and clean energy); SDG 8 (decent work and economic growth); SDG 10 (reduced inequalities); SDG 11 (sustainable cities and communities); SDG 13 (climate action). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Chili river basin council, and then the need to comply with rules and identify common interests.

The challenges identified during the face-to-face interviews were voted on during the stakeholder workshop (shown as red square markers in Figs. 3 and 4) to rank their importance. At the workshop, additional environment challenges relating to inefficient agricultural water use (SDG 6) and the effects of climate change in the Andean highlands (SDG 13: climate action) were mentioned (Fig. 3). The greater emphasis assigned to these challenges during the workshop may be explained by the attendance of more participants with experience in agricultural water management and how this is affected by climate change. In comparison to the interviews, topics that decreased in priority were the conservation of the peri-urban *campiña* and green areas within the city, and water availability and urban water access. The topics most frequently mentioned as economic challenges in the interviews were also highly ranked in the workshop, except for the "low value-added in primary services (farming, mining, and agricultural business activities)". For the social challenges, there was consistency between the interviews and workshop preferences. At the workshop, weak civic culture (i.e., citizens ask for rights, but do not commit with obligations) (SDG 16) was also stressed as a social challenge. For governance, low citizen participation and leadership, lack of agrarian policies and weak implementation of regional development programmes (SDG 16) were also identified as pressing issues (Fig. 4).

In the second part of the workshop, participants discussed those challenges that had been ranked through votes as the most important in groups. These are identified by the three asterisks in Figs. 3 and 4. This activity provided an opportunity to investigate key topics in more detail, and to include challenges that were not previously identified in the interviews. A new list was generated, and participants were again asked to vote for their preferred option (Figs. 5 and 6). The results showed that there was a widespread desire to better understand and promote adaptation in water and land management (SDG 6) due to the perceived impact of extreme climatic events (including droughts and floods) (SDG 13) (Fig. 5) and contrasting migratory dynamics (SDG 11) of urban growth and rural depopulation (Fig. 6). Differences in water productivity was seen as a useful metric for measuring the value of water and a fair approach to allocating water under drought conditions (SDG 6, 13) (Fig. 5). Nevertheless, there was still the challenge to decide how to compare different metric of water productivity and decide water allocation across sectors. Something ANA is currently working on to develop a protocol in water management under drought conditions.

Understanding the reasons for land planning failures was also identified as a key step to overcoming barriers linked to the implementation

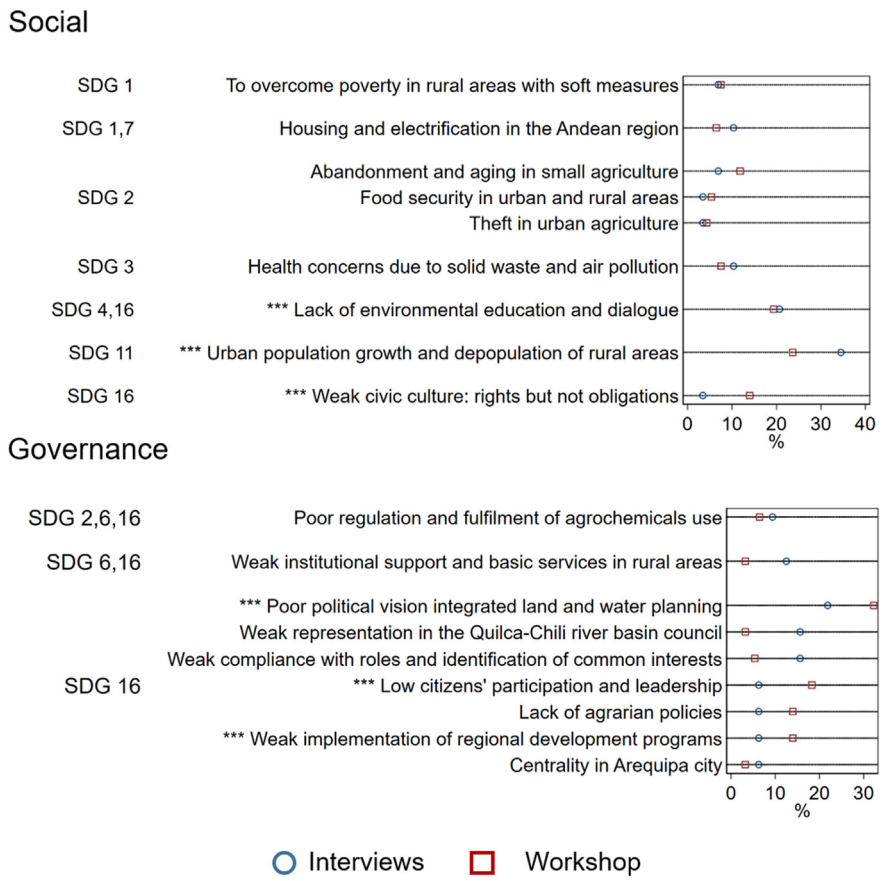


**Fig. 4.** Ranking (%) of social and governance challenges identified during the interviews (blue circle) and workshop (red square) relating to the management of water, agriculture, hydropower and mining systems in the urban-rural territory of Arequipa city. *** indicates the most voted challenges during the workshop. Sustainable Development Goals (SDGs) are indicated as follow: SDG 1 (no poverty); SDG 2 (zero hunger); SDG 3 (good health and wellbeing); SDG 4 (quality education): SDG 6 (clean water and sanitation); SDG 7 (affordable and clean energy); SDG 11 (sustainable cities and communities); SDG 16 (peace, justice and strong institutions). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

of a future integrated land and water planning vision (SDG 16). In this context, the challenges to be tackled include improvements in education (SDG 4), strengthening governance, and the promotion of spaces for more collaborative dialogue between different institutions and actors in the Arequipa region (SDG 16) (Fig. 6).

## 4. Discussion

### *4.1. Stakeholder mapping as a tool to support nexus governance*

In Arequipa, there is a complex network of actors that are involved in multi-sectoral nexus governance, where successful collaborations could be enhanced through both formal and informal mechanisms. The stakeholder mapping exercise helped to identify the individual actors' interest in and influence over nexus governance of water and other natural resources. We discuss below what stakeholders supported and/or opposed in nexus governance in Arequipa as well as the collaboration mechanisms available to generate synergies to improve the management of water and other natural resources and to overcome existing conflicts in interest.

It is important to note that the approach used in this study has some limitations. The purposive sampling method employed to select participants is a subjective sampling technique and, hence, some bias is expected and should be recognized. Our sample size was also relatively small, because our engagement with participants aimed to develop an in-depth and detailed understanding of the opportunities and challenges in nexus governance as experienced by stakeholders and key experts who could represent their respective sectors. However, this was the most appropriate approach for the type of insights we sought to gain from this study. Participant selection was based on identifying those actors that would best enable us to answer the research questions, but the aim was not to make generalizations as the sample was not representative of the population. The objective was to reveal the underlying narratives and themes through discussion. Thus, the identification of the participants in the face-to-face interviews ensured we had access to a range of individuals with the expertise and experience to be able to engage in detailed discussions around the three topics that were identified in our literature review as key to developing a nexus approach to resource governance. This is accepted practice in qualitative social science.

#### *4.1.1. Synergies of interest to improve nexus governance*

In the stakeholder mapping, the National Water Agency (ANA) followed by the Ministry of the Environment (MINAM) showed the highest interest and influence in achieving nexus governance. The regional government may have been considered by participants to be less influential then ANA and MINAM due to Peru's efforts to recentralize land use planning and lack of sectoral integration (Gustafsson and Scurrah, 2019). Local government and research organisations developing new initiatives for nexus governance of natural resources need to engage with ANA and MINAM because their interests appear to be aligned. The Forest and Wildlife Service (SERFOR), National Service of Natural Protected Areas (SERNANP) and peasant communities, classified as *subject*, will become influential if they are able to

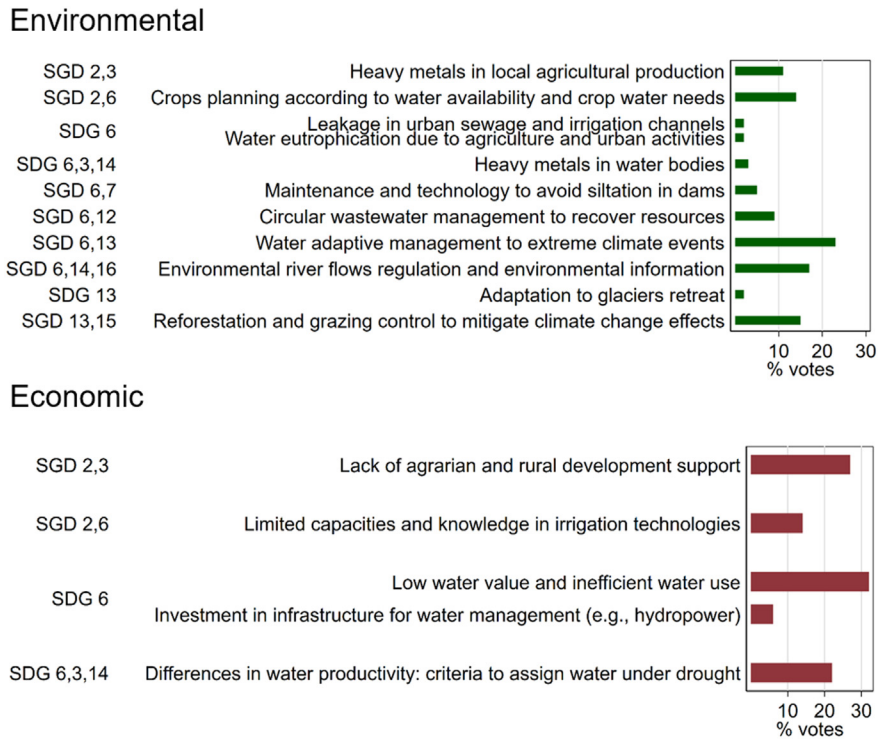


**Fig. 5.** Final ranking of preferences in environmental and economic challenges expressed as a percentage of total votes per thematic challenge. Sustainable Development Goals (SDGs) are indicated as follows: SDG 2 (zero hunger); SDG 3 (good health and wellbeing); SDG 4 (quality education): SDG 6 (clean water and sanitation); SDG 7 (affordable and clean energy); SDG 10 (reduced inequalities); SDG 11 (sustainable cities and communities); SDG 12 (responsible consumption and production); SDG 13 (climate action); SDG 16 (peace, justice and strong institutions).

form alliances (Reed et al., 2009) with other *subject* stakeholders and/or with *key players*. The achievement of the desired outcome should act as a natural synergy and rallying call as they all have high interest in nexus governance. For example, highlands in Peru are currently threatened by global climate change, leading to water resource insecurity across a range of socio-environmental systems (Mark et al., 2018). But current collaborative mechanisms such as the water fund developed by ANA, Cerro Verde Mining Company, and SEDAPAR (Arequipa Potable Water and Sewerage Service) to support reforestation and conservation of water by farmers in the highlands should contribute to reduce water vulnerability of peasant communities in the upper part of the catchment and benefit downstream water users in Arequipa. Further private-public partnerships between local authorities and the agricultural (Rankin et al., 2016) and mining (Oxford Business Group, 2017) sectors

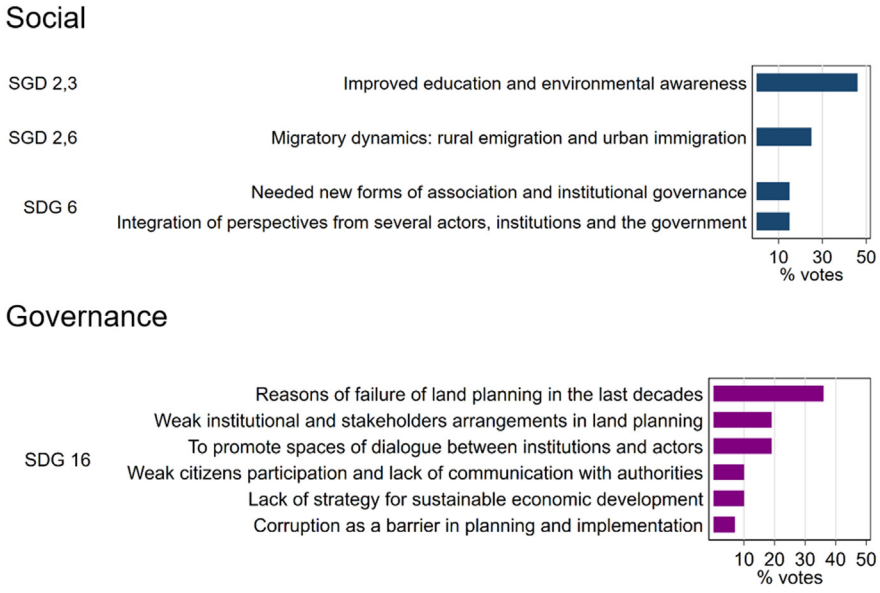


**Fig. 6.** Final ranking of preferences in social and governance challenges expressed as a percentage of total votes per thematic challenge. Sustainable Development Goals (SDGs) are indicated as follows: SDG 2 (zero hunger); SDG 3 (good health and wellbeing); SDG 6 (clean water and sanitation); SDG 16 (peace, justice and strong institutions).

could have the potential to complement and generate synergies for the benefit of the population in rural areas and counteract the growing migration to Arequipa city with its related environmental and social pressures.

The Water Footprint initiative of ANA, named *Certificado Azul*, can complement these mechanisms. This initiative allows interested parties to calculate the water footprint of a product or system using either the Water Footprint Framework method (Hoekstra et al., 2011) or the ISO 14046 life-cycle based (ISO, 2014). After doing this, the interested party can then design and implement a water use reduction scheme, which is verified by a third party, and receive the *Certificado Azul* ecolabel (ANA, 2020). These metrics, which are being increasingly used in Peru (Vázquez-Rowe et al., 2017a) for monitoring and reducing water use and impacts on water scarcity would help to achieve SDG 6.4 (Vanham et al., 2018).

An example of a coherent policy that creates socio-economic and environmental benefits from interdependent land, water and energy systems is the recent water re-use initiative. A water re-use license is required when the destination of treated wastewater is not the same as that for which it was authorized (ANA, 2013). The largest volume of authorized water re-use given by ANA between 2009 and 2017 was granted to the Cerro Verde Mining Company in Arequipa (31.5 $hm^3$) (Aquino Espinoza, 2017), identified as a *context setter* in this study. Despite varied perceptions of the societal benefits of water re-use in Arequipa (OCMAL, 2013), the water quality in the Quilca-Chili river basin has improved since the implementation of the wastewater treatment plant in 2016 (Valverde, 2018). Water re-use has a promising future in Peru and linking with universities could provide the evidence required to develop socio-technological transitions for innovations that support sustainable development (Geels, 2019).

#### 4.1.2. Overcoming conflicts of interest to improve nexus governance

The Ministry of Energy and Mining (MINEM) was identified as the second most influential actor within the *context setters*. For this type of stakeholder, new initiatives must focus on increasing their interest in nexus governance across natural resources in order to become *key players* or to find ways to reduce their influence if their interests continue to conflict with nexus approaches. The former could be achieved by identifying shared interests with *key players* (Humphreys et al., 2007) such as MINAM. For instance, current mining activities generate large amount of sludge from the treatment of drainage-impacted waters that could have an added value if they were used for fertiliser production (Rakotonimaro et al., 2017). This provides a valuable opportunity for MINEM to promote circular economy thinking in mining activities that would gain wider interest from other sectors such as agriculture and the environment, and to align with current circular economy activities relating to innovation and technology transfer in Peru (PRODUCE, 2019), including the construction sector (Mesta et al., 2019) and solid waste management (Margallo et al., 2019).

Contrasting positions can also emerge between *key players* and *context setters*. For instance, the opposition between MINEM and MINAM regarding ecological and economic zoning in land use planning (Gustafsson and Scurrah, 2019). If increasing MINEM's interest cannot be achieved, then reducing their influence in natural resources management would be the alternative. The creation of MINAM and the new Water Law occurred in 2009, so MINEM still holds significant power, since the mining sector is very influential due to its large tax payments and high export earnings. The question then arises as to how to balance the trade-offs between mining activities, which are the main economic contributor in the region, while increasing water efficiency and meeting water and air environmental standards. As a result, initiatives that aim to promote nexus governance will need to generate a shared understanding across stakeholders by embedding politics and decision-making for mutual gain (Salmoral et al., 2019).

### 4.2. Nexus governance as an enabler to promote sustainable development in Arequipa

Major income and welfare inequalities have been reduced in Peru through national policies and programmes for water and electricity provision, education and nutrition, but essential public services are very inadequate given growing demand (Fernández Maldonado, 2018). Participant insights, from both the interviews and workshop, emphasised pressing issues in Arequipa related particularly to SDG 6 (clean water and sanitation), SDG 11 (sustainable cities and communities), SDG 13 (climate action) and SDG 16 (peace, justice and strong institutions). The migration dynamics with a growing urban population (at the expenses of depopulated rural areas) are putting available land and water resources under pressure in the arid climate of Arequipa and its periphery. The increase in urban population and weak governance of local and regional governments has led to chaotic land planning and a vulnerable water supply and wastewater treatment systems, which, in many cases, is compounded by the over-burdened municipal solid waste disposal network. This has resulted in substantial releases of waste into water bodies. The predominant importance of water in our study is consistent with Dodds and Bartram (2016) who stated that a nexus concept was largely water-driven due to the transversal role of water as an economic and socio-ecological good across many sectors.

The challenges identified in this study were largely focused on water use and supply and highlighted the need for an adaptive water management system, resilient to climate change and socio-economic pressures. In this context, water regulation, governance and enforcement have been included, from an adaptation to climate change perspective (SIWI, 2017), in the Peruvian Nationally-Determined Contributions (NDCs) to comply with the Paris Agreement (Gobierno del Perú, 2018). Moreover, within the international agenda the SDGs have emphasised the need to achieve clean water and sanitation for all (SDG6), where the SDGs can be seen as a network of targets (Le Blanc, 2015). The interlinkages between indicators relating to SDG6 and other SGDs have been studied in detail, where the direct links relate to health, gender, energy, economic growth, inequality, sustainable cities and communities, sustainable consumption and production, and terrestrial ecosystems (Requejo-Castro et al., 2020). The identification of these linkages is needed in order to achieve synergies between goals (e.g., health and access to water and sanitation), as well as trade-offs that might arise (e.g., between access to water and sanitation and responsible consumption and production) (Pradhan et al., 2017).

This study has identified the most relevant SDGs related to challenges in nexus governance for integrated management of water resources with other natural resources, which can help to inform policies in water resources management, land planning, agricultural production, and adaptation to extreme climate events. Nevertheless, achieving SDGs in one location should not put at risk the achievement of SDGs elsewhere (spatial dimension) or for future generations (temporal dimension) (Pahl-Wostl et al., 2018). In this context, the future development in Arequipa city will largely depend on how well rural areas are able to overcome poverty, reduce migration to the cities, and adapt to the pressures from a changing climate. A nexus approach to natural resources management can thereby support improved integrated planning, decision-making and governance (Liu et al., 2018). However, this should not be a substitute for other forms of effective planning or regulatory frameworks (Larcom and van Gevelt, 2017) but should rather to provide a focus for integration across sectors (Pahl-Wostl, 2017) and actors (White et al., 2017).

### 4.3. Potential for water and environmental policies to act as enablers for nexus governance

The 2009 Water Law (Perú, 2009) was passed in response to pressures from climatic change, urban population growth, larger agricultural

water demand, and the increasing importance of the mining industry (Del Castillo, 2011). It was inspired by the concept of integrated water resource management and aimed to include all sectors of society making use of water (Paerregaard et al., 2016). However, since this vision was introduced by the law in 2009, it has not been fully implemented as yet. Although the Water Law promotes land development through water resource management plans executed by river basin councils, there is no national funding allocated for such management plans (Del Castillo, 2011).

The regional government has the necessary mechanisms to contribute to territorial development (Zucchetti and Freundt, 2019), but as in other regions in Peru, vertical coordination across administrative scales remains absent. Regional development, and urban and local plans are formulated independently, without embedding plans from higher or lower planning levels due to the absence of integrated land development (Fernández-Maldonado, 2019). With three levels of government that focus on land development (i.e., national, regional and municipal), water resources management is not currently supported or planned for by either the local or regional government, as they have their own and sometimes competing interests. Given the lack of appropriate funding and the lack of sufficient power given to ANA to secure and enforce the law (Kopecká, 2019), the implementation of economic instruments such as water tariffs (Ioris, 2016) and the monitoring and control of water rights is still weak (Oré and Muñoz, 2018).

The financial support for water resources management does not currently match the expected multi-sectoral approach of the Water Law. Financial support to ANA comes from MINAGRI, leading to a larger agricultural focus and weak financial support for water resources management. This institutional arrangement has also affected participation in the river basin councils giving them an agricultural bias. Although the Water Law stated that the river basin councils should establish stakeholder participation (Perú, 2009) when the regulation was approved (Ministerio de Agricultura, 2010), MINAGRI was responsible for the engagement process in the river basin council. As a result, a multi-sectorial approach was not considered at the beginning of the engagement process. Until recently water users in the river basin council were categorised as agricultural or non-agricultural users. Not until more recently passed legislation (Perú, 2018) have representatives of the wider population been considered. Nevertheless, ecosystem services are still not explicitly considered by the river basin councils.

In basins with significant proportions of highland territory, the inclusion of ecosystems services will be key as highland areas are the main water sources for downstream urban users, especially in the Pacific Ocean basin. There is the example of the law for the retribution mechanisms for ecosystem services in water resources (MRSE) (Peru, 2014). The MRSE was designed to include economic activities that are linked to water and ecosystem services, such as water supply, electricity, and mining. In other coastal cities in Peru such as Lima (Bleeker and Vos, 2019) and Piura (Ostovar, 2019), this payment for ecosystem services has been implemented to promote watershed conservation. A total of 15 cities in Peru have already approved a water tariff for financing ecosystem services, collected by the water utility companies (Zucchetti and Freundt, 2019). However, to date only the water supply services have issued a specific directive (SUNASS, 2017) to incorporate MRSE in the running of water utility companies and the water tariffs to be recognized by SUNASS (National Superintendence of Sanitation Services). Specific directives will be developed for other sectors such as hydropower, mining and agriculture, but implementation will depend on the degree of support from the organisations involved.

## 5. Conclusions

The study identified both shared visions between stakeholders as well as contradictory perspectives and priorities relating to the sustainable use and management of water and other natural resources within an urban-rural area. One of the key innovations arising from the research is mapping environmental, economic, social and governance challenges identified from the key informant interviews and stakeholder workshop. The management of water for agriculture, hydropower and mining against relevant SDGs has highlighted where progress was being made, or conversely where there were ongoing barriers to achieving SDG goals in Arequipa. These are highly valuable outcomes for both policy makers and planners involved in implementing IWRM and INRM principles.

In Arequipa, a complex nexus governance network of actors is involved in the management of water with other natural resources. Given the widespread acceptance of the need for better understanding and promotion of integrated water and land planning, successful collaborations could be enhanced through formal and informal mechanisms. Exploiting existing mechanisms (e.g., river basin councils, retribution for ecosystem services) and initiatives (e.g., water fund) will add momentum and enhance shared interests among the actors involved. In future initiatives for sustainable development, it will be key to engage those actors with high influence and interest in nexus governance. Further private-public partnerships between local authorities, water supply services, and the agricultural and mining sectors will be needed to generate synergies for the benefit of the population in rural areas and counteract the effects of migration and its related environmental and social pressures in Arequipa. Stakeholder mapping exercises as in our study will also support the sustainable management of natural resources in developing contexts where there are conflicting interests and hence economic development could be compromised.

Our research has also highlighted the need to assess and adapt to the impacts of extreme climatic phenomena and the pressures linked to increasing water demands. Although the focus has been set on the city of Arequipa, many fast-growing cities along the hyper-arid coasts of Chile and Peru are experiencing similar challenges due to urban population growth, agricultural irrigation expansion and mining activities. Therefore, the mixed-methods approach developed in the current study could be easily replicable to these cities, as well as others located in geographical areas that suffer from similar water-related challenges. In the agricultural sector in Arequipa, small-scale farmers are required to reduce water pollution, improve their technical capabilities and gain better access to markets, while in the mining sector the main environmental challenges were attributed to water and air pollution. Addressing sustainable development challenges and hence meeting the SDGs should go hand in hand with improvements in education, strengthening nexus governance and promoting spaces for dialogue and collaboration. Finally, raising stakeholder awareness regarding sustainable management of water supply and sanitation services and the economic sectors associated with agriculture, energy and mining will help ensure long-term activities contribute to sustainable economic development and welfare.

## CRediT authorship contribution statement

**Gloria Salmoral:** Conceptualization, Methodology, Investigation, Formal analysis, Writing - original draft, Writing - review & editing, Funding acquisition. **Eduardo Zegarra:** Conceptualization, Investigation, Writing - review & editing, Funding acquisition. **Ian Vázquez-Rowe:** Conceptualization, Investigation, Writing - review & editing, Funding acquisition. **Fernando González:** Conceptualization, Investigation, Writing - review & editing, Funding acquisition. **Laureano del Castillo:** Conceptualization, Investigation, Writing - review & editing, Funding acquisition. **Giuliana Rondón Saravia:** Investigation, Writing - review & editing. **Anil Graves:** Conceptualization, Methodology, Writing - review & editing. **Dolores Rey:** Supervision, Writing - review & editing. **Jerry W. Knox:** Conceptualization, Methodology, Writing - original draft, Writing - review & editing, Supervision, Funding acquisition.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.scitotenv.2020.141114.

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