Cocreation for Climate Change—Needs for Actions to Vitalize Drivers and Diminish Barriers

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ABSTRACT: This study determines the conditions and provides a recommendation for fostering cocreation for climate change adaptation and mitigation (CCA&M). In postulating that insufficient cocreation by stakeholders in the quadruple helix model is an important factor contributing to the low effectiveness of climate actions in the regions, we have focused our research on identifying real stakeholder engagement in climate action and identifying the needs, barriers, and drivers for strengthening the cocreation process. We identified the needs for action highlighted by stakeholders as having an impact on reducing barriers and stimulating drivers. We treated the identified needs for action as deep leverage points (intent and design) focused on three realms—knowledge, values, and institutions—in which engagement and cocreation can be strengthened and have the potential to increase the effectiveness of climate action taken by stakeholders within our quadruple helix. We recommend knowledge-based cocreation, which puts the importance of climate action in the value system and leads to paradigm reevaluation. The implementation of the identified needs for action requires the support of institutions, whereby they develop standards of cooperation and mechanisms for their implementation as a sustainable framework for stakeholder cooperation. The research has proved how the quadruple helix operates for climate action in the Poznań Agglomeration. We believe that this case study can be a reference point for regions at a similar level of development, and the methods used and results obtained can be applied in similar real contexts to foster local stakeholders in climate action.

SIGNIFICANCE STATEMENT: This study aims to understand the condition of cocreation and engagement between stakeholders included in the quadruple helix model responding to climate change challenges. We identified needs for climate actions in the Poznań Agglomeration and operationalized them as leverage points, which can strengthen engagement and cocreation and contribute to increasing the effectiveness of climate action taken by stakeholders. We show a wide range of possible climate actions, but at the same time we highlight the barriers that, in the Poznań Agglomeration case, mainly result from poor cooperation between stakeholders and insufficient use of social capital. Cities with similar problems could make use of our results and consider both weak points and recommended solutions in planning strategies for climate change adaptation and mitigation.

KEYWORDS: Adaptation; Climate services; Decision support; Policy; Societal impacts

1. Introduction

The important role of humanity as a driver of climate change is increasingly well documented, especially thanks to the Intergovernmental Panel for Climate Change, which is already preparing the Sixth Assessment Report (https://www.ipcc.ch/report/sixth-assessment-report-working-group-i/). The inhabitants of large cities and urbanized regions are particularly vulnerable to the effects of climate change, for which the most important effects of the rapid rise in temperature include an increasing frequency and violence of extreme weather events, population health problems, increasing energy consumption, and difficulties in water availability (Hunt and Watkiss 2011; IPCC 2014).

In recent years, various initiatives have been taken in urbanized areas to adapt to climate change (Aylett 2014; Reckien et al. 2018; Heikkinen et al. 2020). Planning the structure of the city to support its resilience focuses on nature-based solutions (Kabisch et al. 2017). The nature-based-solutions approach in cities includes management, conservation, and restoration of ecosystems, which deliver services that can help to reduce climate change exposures (Colls and Ash 2009; Munang et al. 2013). This is based, particularly, on the design and improvement of green and blue infrastructures (Müller et al. 2014; Bowler et al. 2010). These climate change adaptation and mitigation (CCA&M) initiatives also find a positive social resonance, as they concern actions at local and regional dimensions. Despite the effects of climate change being globally observable, these are individual to localities, because the causes are generated on the local level. Thus, climate change is simply a quintessential multilevel governance problem (Lee and Koski 2015). Local actions occur in regional, national, and international government arrangements for mitigation (Allen et al. 2009; Sharpe et al. 2016) and adaptation efforts (Amundsen et al. 2010; Van Well and Scherbenske 2014). Lee and Koski (2015) consider political and economic conditions at the local level as the optimal scale in pushing climate actions and that local policy makers have been key players in multilevel

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governance. The majority of studies show that climate change is perceptible at the local scale and has impacts on the increase of social awareness (Reyes-García et al. 2016). According to Torabi et al. (2016), awareness occurs not only when the society learns through social networks, but also from a personal experience of extreme and unpredictable phenomena (Chingala et al. 2017). The growing perceiving of climate change is also increasingly leading the local society to participate in creating targeted adaptation strategies that provide tangible benefits to residents, addressing important regional goals (Picketts et al. 2013). In the last decade, the role of regional and local government has been changing. It shares responsibilities with local actors such as academia and education, business, and civil society organizations (CSO) (Ricart et al. 2019). The growing importance of the social component is documented by business initiatives such as corporate social responsibility (CSR) or cooperation between business, government, and/or CSO in cross-sector social partnerships (CSSP) (Barnett 2019; Googins and Rochlin 2000). However, joint actions for adaptation to climate change and mitigation have been either stillborn or limited, due to different factors that include political weakness in the decision-making processes at the local level, conflicting interests of socioeconomic and environmentally opposed priorities, rejection of alternative societal points of view, and inefficiency of existing policies or the roles of scientists and experts, as well as absence of public supporters (Adger et al. 2009; Withmarsh 2011).

The relationships between stakeholders in the cocreation process should be based on possessing equal rights and positions (Chaudhary et al. 2018). However, the rule is that there are differences between the possibilities and the strength of influence of individual stakeholders (Hein et al. 2017; Wang et al. 2020) These include decision-making authority (local government), financing options (business), the possibility and effectiveness of influencing public opinion [nongovernmental organizations (NGOs), CSOs], or credibility in formulating arguments (science). Ackermann and Eden (2011) argue that those stakeholders who can contribute the most to achieve strategic goals should be prioritized. Moreover, individual stakeholders may have competing interests. These facts prove that in the cocreation process, more careful attention needs to be paid to social inequality and power asymmetries (Barnaud et al. 2018).

Taking these conditions into account, this paper argues that insufficient cooperation between various stakeholders in the area of cocreation or codesign of solutions adjusted to the local circumstances is one of the important factors influencing the low effectiveness of activities on behalf of CCA&M.

Bai et al. (2018) presented a set of research priorities for cities worldwide related to climate change. They point out that researchers, policy makers, practitioners, and other city stakeholders need to strengthen partnerships and produce knowledge together. It is not only a matter of controlling the actions of local and regional authorities, but also of involving various social groups in the cocreation of effective solutions (Kuenkel 2019; Lam et al. 2019). The process of implementing complex climate actions needs to take place with the active involvement of a wide range of stakeholders. However, this requires cooperation in taking action at different levels by different stakeholder groups in a so-called network environment. This approach corresponds to the quadruple helix concept, developed by Arnkil et al. (2010) and Carayannis and Rakhmatullin (2014; Carayannis et al. 2015), which emphasizes cross integration of different knowledge modes. These include academia and education, business, local government, and CSOs as sources of specific types of knowledge that intertwine to create new, innovative solutions.

In this paper, we aim to advance the theory and practice of cocreation and solutions responding to climate change challenges. The research procedure (Fig. 1) included recognition of barriers, drivers, and needs for action in terms of cooperation between academia and education, business, and local government as well as civil society in the cocreation of innovative solutions for climate action.

We paid special attention to recognizing needs for action to improve cocreation by eliminating barriers and stimulating drivers.

We treated the identified needs for action as leverage points (Meadows 1999; Abson et al. 2017) to increase the effectiveness of climate actions. The concept allows for the identification of places in a system where a small shift can lead to fundamental changes in the system as a whole and thus help to overcome barriers and to identify the subsystems, issues, areas, times, places, and sectors for effective interventions (Meadows 1999).

The objectives of the investigation included the following:

1) determination of the role, competence, and scope of activity of individual stakeholders in cooperation with CCA&M;
2) identification of needs for action, barriers, and drivers for climate action, as perceived by different stakeholders;
3) systematization of the necessary actions in the system of three realms of leverage points (knowledge, values, institutions) where engagement and cocreation could be strengthened and have a chance to increase the effectiveness of climate action taken by stakeholders;
4) formulation of recommendations to create a favorable milieu for the efficient cocreation of effective CCA&M solutions.

We conducted a research study for the Poznań Agglomeration. The Poznań Agglomeration is located in the western part of Poland in the center of Wielkopolska voivodeship (analogous to a province). It comprises Poznań and the 17 neighboring communes. The agglomeration covers an area of 2162 km^2 and has over 1 million inhabitants. It is one of the most important economic and academic centers in the country, characterized by a buoyant and developed labor market, diversified economic structure, established transportation network, and a high level of attractiveness for tourism (Parysek and Mierzejewska 2006; Churski et al. 2020). Thanks to the diversified structure of the social and environmental system, the Poznań Agglomeration is an interesting area for the analysis of the functioning of the stakeholder network in the context of cooperation with CCA&M. Even the expected economic difficulties caused by the COVID-19 pandemic should be relatively mild here because of the varied economic structure.

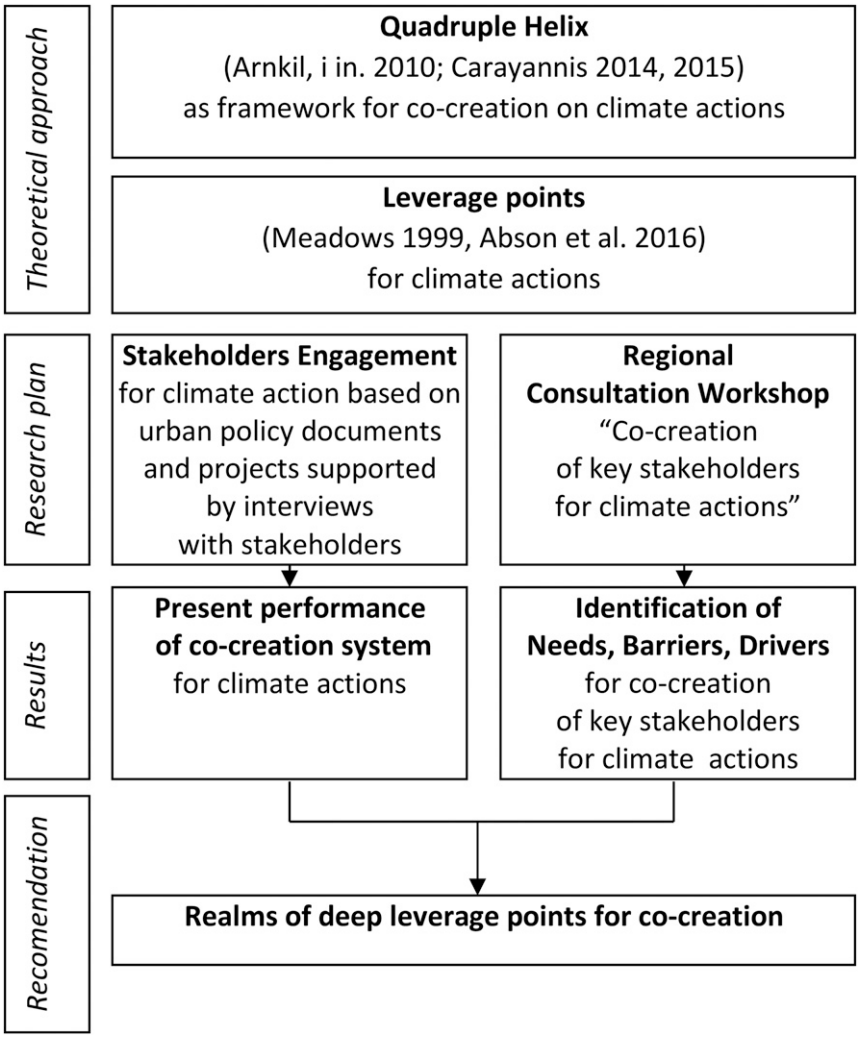

FIG. 1. The investigation procedure.

These conditions create a specific background for the helix functioning of the various stakeholder groups whose climate action could be developed jointly in a cocreation process.

The Poznań Agglomeration faces contemporary urban challenges such as suburbanization and urban pressure on green infrastructure on the one hand and depopulation of the core city on the other (Kaczmarek 2017; Zwierzchowska et al. 2019). The most pressing problems for the Poznań Agglomeration, intensified by climate change, are related to water management—the need for a systematic and complex approach to rainwater and meltwater management (countering the effect of droughts and floods; e.g., Jawgiel 2017); thermal conditions—higher frequency of heat waves and the impact of urban heat island in Poznań (e.g., Majkowska et al. 2017); air quality—threats exceeding the permissible concentrations of PM_{10} and $PM_{2.5}$ and their harmful effects on the health of the residents; and spatial planning—supporting investments in nature protection and green infrastructure to increase regulatory ecosystem services (e.g., Zwierzchowska et al. 2019). Climate change increases the frequency and intensity of extreme weather events as well as modifies the availability of natural resources in urban areas in Poland (Kundzewicz and Kowalczak 2008). Without proper action, the current problems will worsen in the future, impacting the quality of life in the region. To meet these challenges, the local authorities initiated the process of preparing a plan for adaptation to climate change for the Poznań Agglomeration in a similar way as has already been achieved in the City of Poznań (see Poznań City Council 2019a).

A chance for better-tailored and, therefore, more effective actions in the region, tackling current challenges, and supporting climate change adaptation and mitigation is driving a dialogue and cooperation between different actors, such as the inhabitants, policy makers, infrastructure managers, social organizations, and entrepreneurs (see Churski et al. 2020).

The results presented in this paper are the effect of peripheral research related to the Horizon 2020 project Territorial Responsible Research and Innovation Fostering Innovative

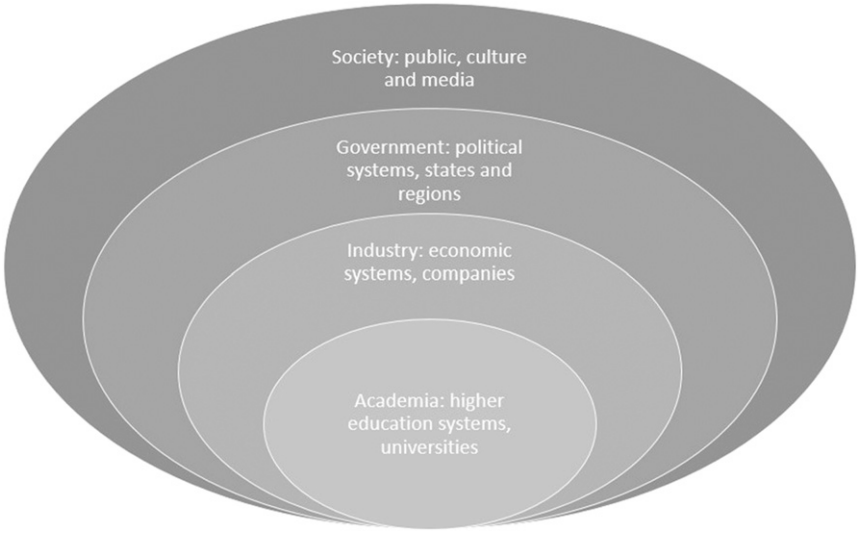

FIG. 2. Subsystems of quadruple helix model [source: Carayannis et al. (2019)].

Climate Action (TeRRIFICA), that includes an innovative approach through the establishment, reinforcement, and development of multistakeholder partnerships (https://terrifica.eu).

2. Theoretical assumptions

a. The cocreation processes for climate actions within innovation systems

The processes of cocreation related to climate change mitigation and adaptation is considered, within this study, as a form of creative activity taking place in the regional innovation system. It refers to a high degree of stakeholder involvement in the process of producing knowledge and defining and implementing activities, solutions, or projects related to climate change. In this approach, the knowledge and expertise of stakeholders (including the tacit ones) is treated as being equal to scientific knowledge. We believe that innovation is a key means to reaching environmental objectives and realizing and supporting regional actions and adaptation plans with regard to climate change.

Cocreation on mitigation and adaptation to climate change relies, to the greatest extent, on the active role of the citizens and civil society organizations in the innovation process. This has a direct impact on innovation systems that have become nonlinear, network based, and deeply rooted in a regional context (McAdam et al. 2015). Sources of innovation are no longer restricted to interactions within university–industry–government in the traditional triple helix model of innovation (Etzkovitz and Leydesdorff 1997). They have become more heterogeneous and socially distributed.

Under these conditions, investigating the cocreation process within the regional innovation system for the Poznań Agglomeration requires a broader view of new ways in which different elements of the system interact and collaborate, with the aim of managing climate change challenges; we use the concept of the quadruple helix (Carayannis and Rakhmatullin 2014; Carayannis et al. 2015). It expands the triple helix by adding the following new dimension. This fourth dimension is civil society (Arnkil et al. 2010), which is understood as ''nongovernmental organizations, as well as more or less formal associations and communities of interest and practice including engaging citizens as lead users, codevelopers and cocreators of innovative and entrepreneurial initiatives'' (Carayannis et al. 2019).

This concept allows the integration of a bottom-up approach in the system (complementing the top-down policies and practices) and forms a more inclusive, democratic system based on dialogue and reflecting the values of society (Cavallini 2016). A new approach is necessary to solve problems in which social and technological progress coevolve in order to generate social and public value (OECD 2011). It also helps universities to create new alliances and networks and to achieve more ambitious social transformation goals (Vallaeys 2013).

In this study, we analyzed the cocreation process related to climate change adaptation and mitigation, using the quadruple helix model approach (Fig. 2). The model helps to define the main actors of the system (in the Poznań Agglomeration) to describe the interactions and relations between them, as well as the process of creation, distribution, and exchange of knowledge. They are representatives of academia and education (institutions of higher learning, including universities, but also including research centers), business [companies, small and medium enterprises (SMEs)], local government (policy makers on various levels), and civil society (CSOs, the public, culture, and media).

The interaction between stakeholders is multilateral and depends on many factors that are locally embedded, such as regional climate strategies, funding programs, legal regulations, social capital, existing conflicts, strengths of regional networks, innovation, culture, and so on.

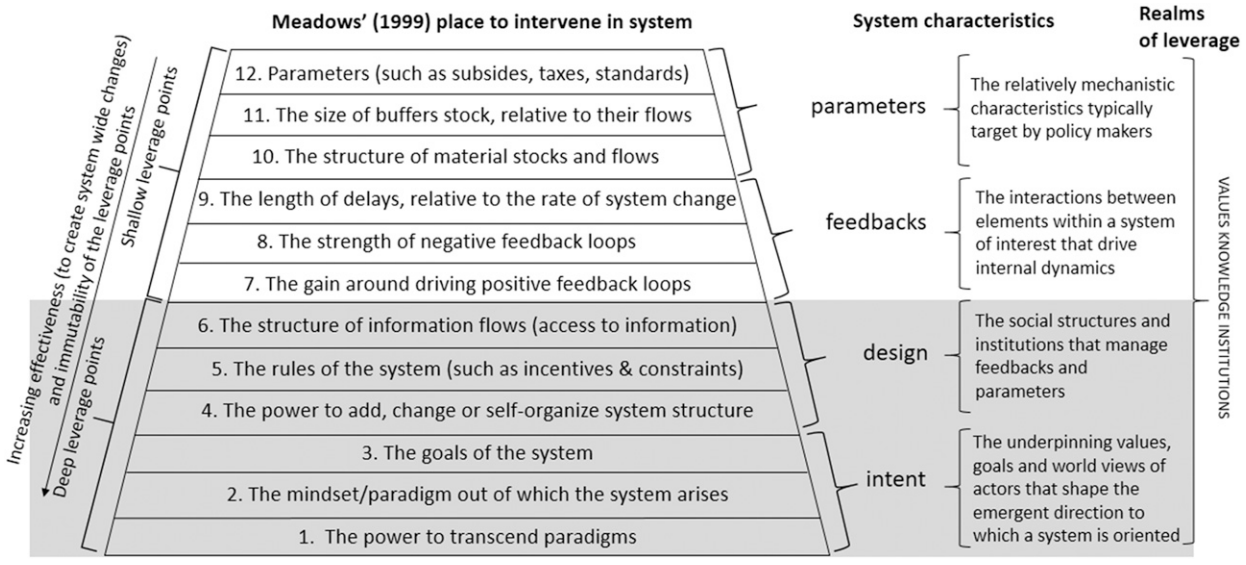

FIG. 3. Usage of the leverage-points concept in our research (gray field) [source: Abson et al. (2017)].

b. Leverage-points approach to fostering cocreation processes for climate actions

In our research, we argue that a leverage-points perspective deserves greater attention because, as stated by Fischer and Riechers (2019), it holds substantial promise to inspire new directions in sustainability science and practice.

The idea of leverage points is not unique to systems analysis (Forrester 1969, 1971). Leverage points are places in a system where relatively minor interventions can lead to relatively major changes in certain outcomes (Meadows 1999). On the basis of years of experience, D. Meadows—one of the world's pioneers in research on coupled human–environment systems (Meadows et al. 1972)—postulated a hierarchy of "places to intervene" in complex systems (Meadows 1999). The essence of the proposed systematization of "places to intervene" comes down to distinguishing the so-called leverage points where interventions are easy—however, their potential for transformational changes is not big (they are referred to as "shallow" leverage points)—and leverage points where interventions are difficult but have a high potential for transformational change (they are referred to as "deep" leverage points). Recently, the 12-leverage-points structure, postulated by Meadows, has been subject to modification. Abson et al. (2017) simplified this classification into four "leverage areas" related to changes in parameters, changes in feedback, changes in system design, and changes in the intent encapsulated by the system parameters. These may be considered as modifiable, mechanistic features such as taxes, incentives, and standards, or physical elements of a regional system such as stock levels or material flow rates. The feedback includes interactions between elements in a regional system that can amplify or limit its internal dynamics. They also provide information to evaluate interventions by assessing their effectiveness and efficiency. The design is related to the information flow structures in the regional system, which, on the one hand, are based on the principles defined by the authorities and, on the other hand, on the ability of society to self-organize. Finally, the intent includes norms, values, and objectives that constitute the basis for the activity of individual stakeholders of the system and the basis for building the paradigm of its function. The last two groups—design and intent—as deep leverage points are of particular importance in identifying the necessary actions and areas in which cooperation and cocreation could be strengthened (Abson et al. 2017) and would have the chance to increase the effectiveness of climate actions taken by stakeholders. They should be used to organize the necessary actions needed to improve the level of cocreation. Within the scope of deep levers that may lead to transformational change, we attach particular importance to knowledge, values, and institutions (Fig. 3) of which the great potential results from strong interactions between them (Abson et al. 2017; Fischer and Riechers 2019; Lam et al. 2019).

Knowledge should be identified with the processes of its creation and usage in the process of regional system transformation. Values include attitudes, norms, and behaviors of people in relation to the elements of regional systems and the process of their transformation. Institutions create formal and informal conditions for the process of system transformation, which are determined, on the one hand, by the quality of the functioning administration and, on the other hand, are shaped by social competences and skills in the field of interpersonal cooperation. We argue that investigating interactions between these three realms of deep leverage points for identifying the drivers and barriers to effective cocreation, mitigation, and adaptation to climate change is a crucial issue.

3. Investigation methods

The empirical part of the study was focused on the analysis of climate action from the perspective of real stakeholder

involvement and on what needs, barriers, and drivers they identify to strengthen cocreation (see Fig. 1).

The first step was understanding the current state of the stakeholders' (academia and education, business, local government, and civil society) engagement and cocreation for climate change adaptation and mitigation in the Poznań Agglomeration through the desk study. For this analysis we worked from relevant policy papers as well as from on projects and ventures that the stakeholders performed or collaborated on (Churski et al. 2020).

Three local policy papers were taken into consideration: The Urban Climate Adaptation Plan (UCAP; Poznań City Council 2019a), Strategy for Rainwater and Meltwater Management (SRMM; Poznań City Council 2019b), and Low Carbon Economy Plan (LCEP; Poznań City Council 2014). The analysis also took into account the projects and undertakings that were carried out by academia and education, business, local government, and CSOs. The subject of the study was to determine the scope and manner of taking into account individual stakeholders as well as interrelations between them. Structured interviews with representatives of the stakeholders supplemented the abovementioned analysis. That has helped to identify good practices as well as occurring conflicts that influence the stakeholders' engagement and cocreation process.

In the second step, during a half-day regional consultation workshop, we empirically investigated how stakeholders representing elements of the quadruple helix model perceived the conditions for cocreation of innovation for climate actions in the analyzed regional system.

The 30 participants included representatives of science and education (university, science foundation, schools, research laboratory), business (five sectors), government (city, agglomeration, and region authorities), and civil society (members of four NGOs and three CSOs). The workshop was conducted in the world café scheme—an effective format to encourage large groups of people to share their knowledge on selected topics.

The organizers formulated three questions and divided the participants into three groups. During the 20-min rounds of conversation, participants considered the following questions:

1) What knowledge about climate change is needed to strengthen cooperation and cocreation for climate protection?
2) What motivation (values) can encourage actors to take action for climate change adaptation and mitigation?
3) What institutional changes are needed to strengthen the climate actions?

Facilitators working with the groups wrote down and ordered the obtained answers. They then presented them during a plenary session. There was then the possibility for an additional plenary discussion summarizing the results obtained.

The workshop participants, using their knowledge specific to each stakeholder group, created an extensive list of factors that referred to the process of climate change adaptation and mitigation from various perspectives. These included both the possibilities of implementing solutions and actions for climate change adaptation and mitigation as well as the conditions for their cocreation by different stakeholders. In relation to the thesis adopted in the study, the analysis of the identified factors was focused on the conditions of the cocreation process.

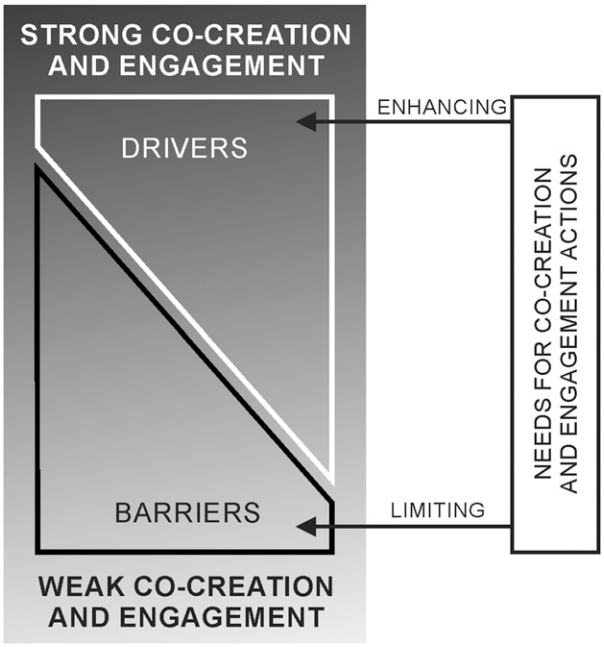

FIG. 4. Relations between needs, drivers, and barriers for cocreation and engagement.

The panel of facilitators and other experts from Adam Mickiewicz University in Poznań analyzed all the factors identified during the workshop and chose those that were directly relevant to the cocreation process. The obtained set of factors was divided into three groups: 1) barriers—what disturbs the cocreation, 2) drivers—what facilitates the cocreation, and 3) needs for action—limiting barriers and enhancing drivers.

We have assumed (Fig. 4) that the intensity and quality of cocreation depends on the size of the barriers on the one hand and on the stimulating role of drivers on the other. The result of the workshop was the identification of needs for action in connection with both factors determining stakeholders' engagement and cocreation.

The panel of experts analyzed the relationship between individual needs for action and single barriers, and drivers. Using this procedure, the impact of subsequent needs for action (N1, N2, . . . , N8) on individual barriers (B1, B2, . . . , B9) and drivers (D1, D2, . . . , D6) was determined. This recognition made it possible to differentiate the needs for action according to the range of links with the barriers and drivers and according to the stakeholder groups that identified the individual factors.

The authors' team, which belongs to the scientific community, did not duplicate their position with the stakeholders' role during the investigation. As facilitators of the workshop, they strictly limited their activity to gathering, summing up, and, in

the next stage, to analyzing knowledge about the cocreation process provided by stakeholders.

4. Results—Needs for action versus barriers and drivers in cocreation process

a. Stakeholders' engagement in the practices relevant to climate actions

The three policy documents considered (see section 4a) provide a framework for the involvement of individual stakeholders in CCA&M projects, and show the importance attributed to cocreation.

UCAP (Poznań City Council 2019a) for the City of Poznań until 2030 contains general declarations of participation of various stakeholders in the creation and implementation of detailed solutions. The document explicitly emphasizes the importance of collaboration with CSOs, the scientific community, and entrepreneurs. However, these declarations are not reflected in the attitude of local governments, which put neither CCA&M issues nor partnerships with stakeholders at the center of their interests.

SRMM (Poznań City Council 2019b) for the City of Poznań is a policy paper that proposes nature-based solutions in urban water management. It takes into account changes in the seasonal distribution of precipitations, including higher frequency of heavy rains. The participation of stakeholders in creating the strategy was marginal. The role assigned to stakeholders is to participate in the dialogue on implementation and dissemination of the content.

LCEP (Poznań City Council 2014) is aimed at reducing the demand for coal as a fuel and increasing the thermal modernization of buildings. Both of these main directions of intervention influence the reduction of greenhouse gas emissions. This policy paper acknowledges a need to consult stakeholders on how to implement the provisions of the document and promotes their participation in dissemination of good practices.

The projects analyzed by scientists and schools, representing academia and education, illustrate three different areas of relationship with other stakeholders. The Climate Change Impact Assessment for Selected Sectors in Poland project (CHASE-PL; http://www.chase-pl.pl/) is aimed at acquiring new knowledge and transferring it to policy makers and the general public, who are not assigned an active role.

The project Coproduction with Nature for City Transitioning, Innovation and Governance (Connecting Nature; https://connectingnature.eu/) has a different character. Its aim is to implement nature-based projects in urban settings through cooperation between local authorities, communities, industry partners, NGOs, and academics. Herein, cocreation of new solutions with the participation of all stakeholders is at the center of the activities.

The Educational Anti-Smog Network (ESA; https://esa.nask.pl) is a purely educational project focused on raising awareness of the harmfulness of particulate matter from coal combustion. This is closely related to the implementation of the low-carbon economy. It concerns raising the competences of teachers and influencing the general public through students.

Business-initiated and business-funded projects include nature conservation, ecological education, creation of green spaces in the city, and promotion of cycling. Civil society is the main partner for business by being involved in the implementation of actions for climate change. It can be said that that business strengthens CSOs by funding their activities, and this dependence hinders partnership between them. On the other hand, business benefits from this collaboration because the social partners supported and promoted the actions taken by business (e.g., by sharing their communications channels, social media), reaching a broad spectrum of society from their areas of activity and taking responsibility for the completion of certain tasks in the projects. This proves that business–civil society cocreation could support the building of the general public's environmental awareness through CSR.

Examples of projects implemented by the local government include the implementation of the waste management system, planting trees in the most built up district, and development of a new joint route for pedestrians and cyclists. All these projects show the dominance of a top-down approach enriched with consultations with business or social partners, which may lead to some modifications of the adopted solutions. There is no place here for partnership cocreation of the best solutions.

A synthetic approach to the roles played by individual stakeholders in relation to climate actions is presented in Table 1. It shows the lack of formal standards as to their involvement.

One of the main findings of the study is a lack of, or low level of, the involvement of citizens in the cocreation of climate actions for the Poznań Agglomeration. Some mechanisms exist (public consultations or formal meetings), but they are mostly routine or limited to a small number of citizens. The scope of this process is too narrow and does not reflect the intellectual and social capital of the citizens as well as various organizations, which is understood to be a network of relations between various actors, leading to a trust-based and long-term cooperation with mutual benefits. The communication between the stakeholders usually happens through the media (local television stations, press releases, social media) as well as during public meetings, educational events, and festivals. We have also identified the existing conflicts within policy-making institutions (on the level of views, values, coordination, communication, bureaucracy). They mostly refer to the national versus regional competencies and have a large impact on the governance process of the climate actions in the region. The tensions between economic interests and general interests in climate actions (conflicts: money vs environmental protection) are present in the region, especially between entrepreneurs and the local public. The conflicts arise from different grounds (politics, competencies, financial resources), but they are often related to values and particular needs. The need of people to be closer to nature is one of them, and this affects the relationship, especially with policy makers. Different visions and interests on climate change actions also affect the cocreation process.

Engaging multiple stakeholders needs a benefits-based policy. People usually get involved when they feel that their opinions and ideas really do matter and can change the reality by solving a given well-specified problem. Another important

TABLE 1. The main roles of stakeholders (quadruple helix approach) in climate actions (source: authors' own study of policy documents and projects).

Relevant stakeholders	Main roles
Academia and education	Generate, cocreate, and transfer knowledge
	Educate climate change experts
	Support development of innovation activities for CCA&M of citizens, business, and policy makers
	Share research findings
	Provide data for decision-making
	Collaborate in awareness-raising activities
	Collaborate in policy development
Business (large companies and SMEs)	Develop proposals to obtain funding
	Provide funding for climate action events and campaigns
	Introduce good environmental practices
	Develop eco-innovations
	Facilitate knowledge transfer
	Collaborate in awareness-raising activities
Local government	Develop and approve adequate legislation and policies
	Publish and share national and regional climate data
	Coordinate intersectoral collaboration
	Identify climate priorities
	Develop support policy and financial tools
	Provide funding for CCA&M
	Support the development of innovations
	Organize and facilitate the dialogue process
CSOs	Implement CCA&M projects and/or support projects at community level
	Develop and implement awareness campaigns on climate change
	Organize educational events and festivals
	Participate at the consultations
	Introduce and promote good environmental activities
	Promote dialogue culture and networking
	Propose innovations in climate actions that are needed and relevant for the society
	Participate in citizens' panels and open debates

aspect is the lack of awareness regarding the distribution of tasks and responsibilities in the area of climate action between different institutions in the region. The cocreation process needs a clear governance structure. Making the society more sensitive on public problems (including the climate change issues) is a long-term process, which demands accurate means and strategies. With these basic findings, it can be stressed that there is a strong need to foster the cocreation process in the Poznań Agglomeration in climate change adaptation and mitigation activities.

b. Identification of barriers, drivers, and needs for actions

Aggregation of the opinions of representatives of the local cocreation system, gathered during the Regional Consultation Workshop, led to the identification of three sets of key elements influencing the level of cocreation and engagement (Fig. 5): drivers, barriers, and needs for action.

In the approach used, the most important are the needs for cocreation and engagement actions, the satisfaction of which should, on the one hand, reduce the negative impact of barriers and, on the other, strengthen the positive effects associated with the impact of drivers. The identified needs have been additionally grouped according to the adopted realms of cocreation process (Fig. 5) including knowledge, values, and institutions.

There is a visible diversity of analyzed needs, in terms of the scope of their impact, resulting from the number of barriers and drivers affected and in terms of the level of perception (identification) of a given need by representatives of four local stakeholder groups (Fig. 6). Of eight needs, four (N1, N2, N5, and N7) were identified by each stakeholder group. The need to develop a culture of dialogue (N4), on the other hand, has only been recognized by CSOs. On the whole, the above considerations led to the identification of common fields of action to strengthen cocreation and climate action.

The characteristics of the identified needs for the engagement of key stakeholders in climate actions was carried out in the realms of cocreation process: knowledge, values, and institutions. Later in this article, we suggest analyzing the text together with Figs. 5 and 6 for a better understanding of described relationships between identified needs, drivers, and barriers.

The realm of knowledge group included two needs for developing instruments that effectively raise the level of public knowledge on issues related to climate change (Figs. 5 and 6).

Strengthening cocreation and stakeholder involvement in climate action is largely conditioned by the *elaboration of new curricula for schools and higher education curricula focused on the challenges of climate change* (N1), as indicated by representatives of all stakeholder groups forming the local cocreation

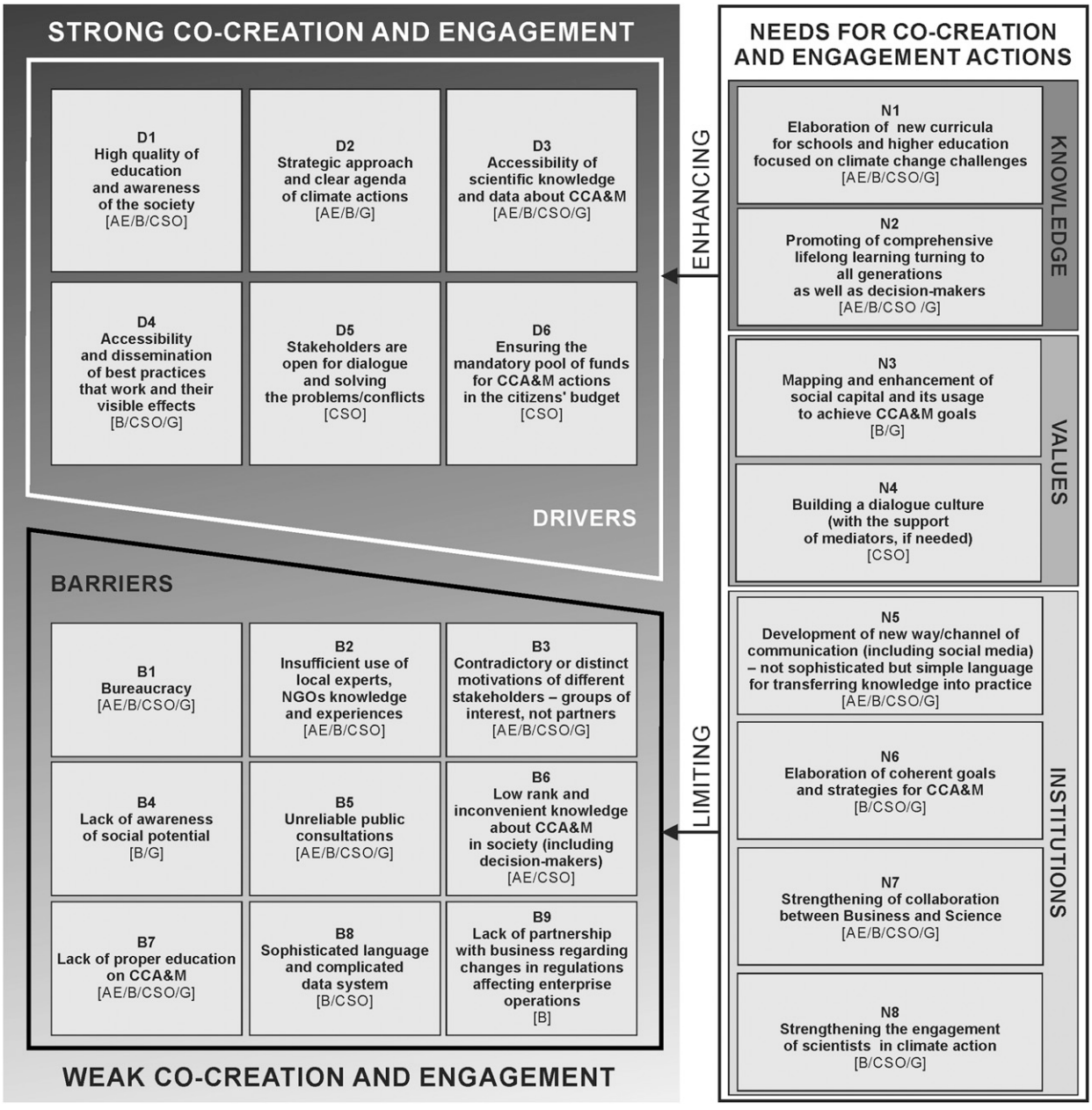

FIG. 5. Barriers, drivers, and needs for key stakeholders' engagement in climate actions. The information in square brackets shows the abbreviations of the sectors of the quadruple helix, whose representatives formulated a given need: academia and education (AE), business (B), government (G), and civil society organizations (CSO).

system. Innovative educational programs would make it possible to significantly increase the use of expert knowledge and experience of nongovernmental organizations (B2), reduce the knowledge deficit related to climate change among the local community (B6), and eliminate the barrier related to the lack of adequate education for adaptation and mitigation to climate change (B7). On the other hand, the development of new educational programs would significantly improve the quality of education and the level of environmental awareness of the public (D1), as well as improving the conditions for introducing new strategic approaches and developing comprehensible action programs (D2). Appropriate changes in educational programs should also lead to a readiness to engage in social dialogue among future generations (D5).

The second of the needs assigned to the sphere of knowledge is the *promotion of comprehensive lifelong learning aimed at generations, with emphasis on decision-makers* (N2), which was indicated by representatives of all sectors. Similar to the need of N1, it postulates a profound reform of the education system by adopting the principle of lifelong learning for all citizens.

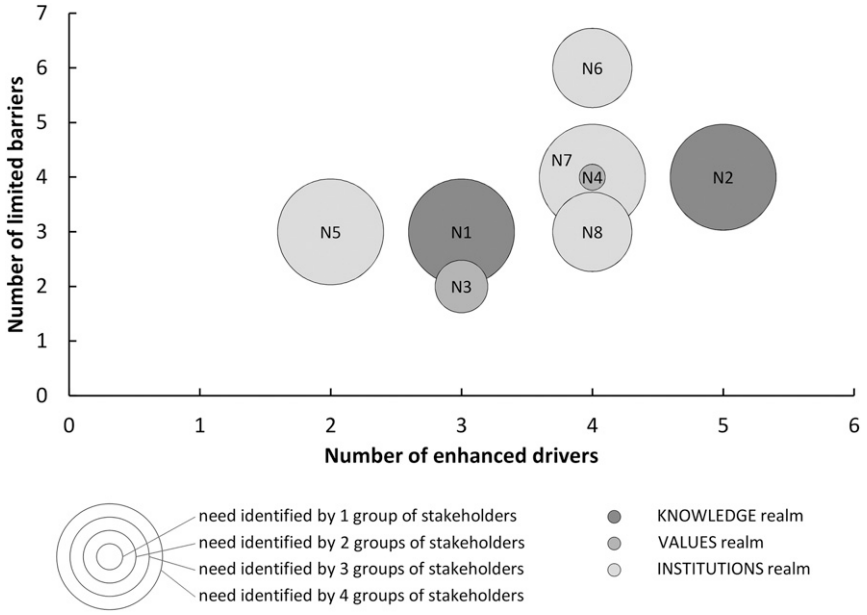

FIG. 6. Relations between the needs, barriers, and drivers for key stakeholders' engagement in climate actions.

In this context, this action can contribute to better use, not only of scientific knowledge but also of citizens' knowledge, based on a participatory approach and development, mainly by NGOs as well as other representatives of civil society and local experts (weakening barrier B2). Introducing and consolidating the lifelong learning principle into the education system can make an important contribution to improve the quality of education, stimulated by growing expectations from an increasingly conscious society (D1), as well as to increasing the availability of data, scientific knowledge (D3), and good practice on cocreation and social participation (D4, D5). Addressing this need should have positive effects on society (B6) and raise awareness of social capital (B4). Weakening the latter barrier is particularly important to increase the activity and cooperation of different social groups in the decision-making process.

Two of eight identified needs (N3, N4) concerned building a culture of dialogue between key actors of the local cocreation system and strengthening the level of social capital, which determines the involvement of the local community in activities for the benefit of CCA&M, belong to the realm of values (Figs. 5 and 6).

The need of *mapping and enhancement of social capital and its usage to achieve CCA&M goals* (N3) was indicated by representatives of business and local authorities. On the one hand, it provides opportunities to involve local experts adequately in current needs and conditions (D2); on the other hand, it strengthens dialogue and stimulates openness of stakeholders to solve problems (D5). Mapping of social capital makes it possible to collect information on existing solutions and practices, their levels of effectiveness, and scalability (D4). As a result, decision-makers and/or leaders obtain valuable information that increases their awareness of the social capital they possess and its usefulness (B4). The participants in the workshop stressed that knowledge of social capital provides a chance to strengthen social consultations, the potential of which is currently underused (B5).

The second need within the framework of the realm of values—*building a dialogue culture (with the support of mediators, if needed)* (N4)—was strongly emphasized by the representatives of CSOs whose experience in this area was rather negative. In the examples cited, the stakeholders' specific interests were too important to build consensus in the spirit of social dialogue (B3). Building a constructive dialogue and instilling its principles from an early age provides an opportunity to make better use of the knowledge and experience of civil society (B2) and the potential inherent in the social capital of the particular region (B4). Shaping a culture of dialogue and the ability to reach a common understanding strengthens other factors that foster cocreation, including quality of education and social awareness (D1), application of a strategic approach to climate action (D2), accessibility and dissemination of good practices in climate cooperation (D4), and openness of stakeholders to dialogue and cooperation in order to address problems and conflicts (D5).

The realm of institutions covered four needs related to the development of new communication channels, development of coherent action strategies, strengthening cooperation with the world of science, and increasing the involvement of its representatives in climate actions (Figs. 5 and 6).

Development of new channels of communication (including social media) using not sophisticated but, rather, simple language for transferring knowledge into practice (N5) was reported by all representatives of the quadruple helix. Meeting this need would be conducive mainly to reducing the barrier formulated as sophisticated language and complicated data system (B8). The creation of new, simpler forms of communication

would also significantly increase the use of local experts and the knowledge and experiences of NGOs (B2) by launching an efficient flow of knowledge and information between stakeholders. In addition, it would reduce the adverse impact of low awareness and insufficient knowledge of CCA&M among the wider local community (B6). Satisfying the discussed need by weakening the described barriers at the same time may contribute to raising the level of education and society's sensitivity to the problems of climate change and the need for cooperation in this area (D1). At the same time, it can be expected that the diversification of communication, while simplifying the language of communication, will increase the availability of knowledge and scientific data on counteracting and adapting to climate change (D3).

The second need assigned to the realm of institutions concerned the *elaboration of coherent goals and strategies for CCA&M* (N6), as indicated by representatives of entrepreneurs, civic organizations, and local authorities. The development of common goals and ways of achieving them within the framework of climate actions would allow reduction of the negative impact of as many as seven barriers. Excessive levels of bureaucracy would be reduced to the greatest extent (B1), the problem of conflicting motivations of various stakeholder groups would be solved (B3), and conditions would be created for improving the quality of broadly understood climate education (B7). Moreover, the coherence of goals and strategies for CCA&M may limit the insufficient involvement of local experts and negligible use of the experience and knowledge of NGOs (B2). At the same time, the effect of this measure would improve the position of climate challenges on the list of development priorities formulated by local governments (B6) and would also lead to better cooperation between local authorities and entrepreneurs in the field of changes in regulations affecting enterprise operations (B9). The development of coherent targets and strategies for adaptation and mitigation of climate change would effectively strengthen four of the drivers identified, including, in particular, improvement of the quality of the strategic approach and defining a clear climate change action plan (D2) and creating an atmosphere conducive to openness and dialogue between stakeholders (D5). In addition, the definition of coherent objectives and strategies would lead to an increase in the quality of education and public ecological awareness (D1), as well as increasing the chances of allocating an adequate amount of civil budget resources to climate action (D6).

A great importance has been attached to *strengthening the collaboration between business and science* (N7), as indicated by representatives of all stakeholder groups. This should increase the use of local expertise (B2) and lead to a better mutual understanding of the specificities of each group's approach (B3). Moreover, intensified contacts between them may lead to the use of language that would facilitate communication between stakeholders (B8). In addition, it may help to reduce the barrier related to the lack of involvement of entrepreneurs in the process of formulating legislation affecting their activities (B9). Strengthening cooperation between science and business should stimulate most drivers. It should contribute to improving the quality of education (D1) by taking into account the needs of the local labor market and by involving entrepreneurs with practical experience in the education process. Another reinforced factor will be the improvement of access to scientific knowledge by entrepreneurs (D3), who, thanks to contacts with scientists, will have more knowledge about, for example, innovative solutions or existing databases. On the other hand, scientists, thanks to cooperation with entrepreneurs, could more easily identify good practices in the field of climate action and their results (D4). The high level of cooperation between representatives of the world of science and business should also directly increase their openness to dialogue (D5) thanks to the positive feedback effect.

The need to develop cooperation between stakeholders is firmly linked to the *strengthening of the engagement of scientists in climate action* (N8), as perceived by representatives of almost all stakeholder groups, with the exception of science and education. In particular, CSOs have accused scientists of lack of commitment to bottom-up climate action and interaction with other stakeholders. Changing this by reinforcing the involvement of scientists in climate action should result in improved communication, moving away from difficult and often hermetic scientific jargon (B8) and, thereby, increasing the importance of public knowledge about climate change (B6). It is also expected to reduce the differences in objectives and motivation between the different actors in climate actions (B3). Increased involvement of scientists in cooperative climate action will improve the availability of scientific knowledge and data on climate change, including on how to tackle its effects and adaptation (D3). More socially engaged scientists would contribute to improving the quality of education and consequently public awareness of the effects of climate change (D1). The abovementioned improvement in communication between scientists and other participants of climate actions should strengthen dialogue (D5) and make the climate actions agenda more visible and clearer for society (D2).

5. Recommendations for enhancing knowledge, values, and institutions as deep leverage points for cocreation in climate actions

The structure of the identified needs for action fits clearly into the three realms of leverage—knowledge, values, and institutional changes—proposed by Abson et al. (2017). Those realms are present at different levels of the hierarchy of the leverage points (parameters, feedback, design, and intent—see section 3). Realms of knowledge and institutional changes are placed on the design level, while the values refer to the level of intent (Fig. 7). All three belong to deep leverage points, and in our research have been included as factors for transformative change in climate change adaptation and mitigation strategies.

Needs for action identified by stakeholders as deep leverage points in the realm of knowledge include elaboration of new curricula for schools and higher education curricula focused on climate change challenges (N1) and promotion of comprehensive lifelong learning turning to all generations as well as decision-makers (N2). In this realm, we recommend strengthening the transfer of practical knowledge within our quadruple helix and its use for coherent realization of objectives and

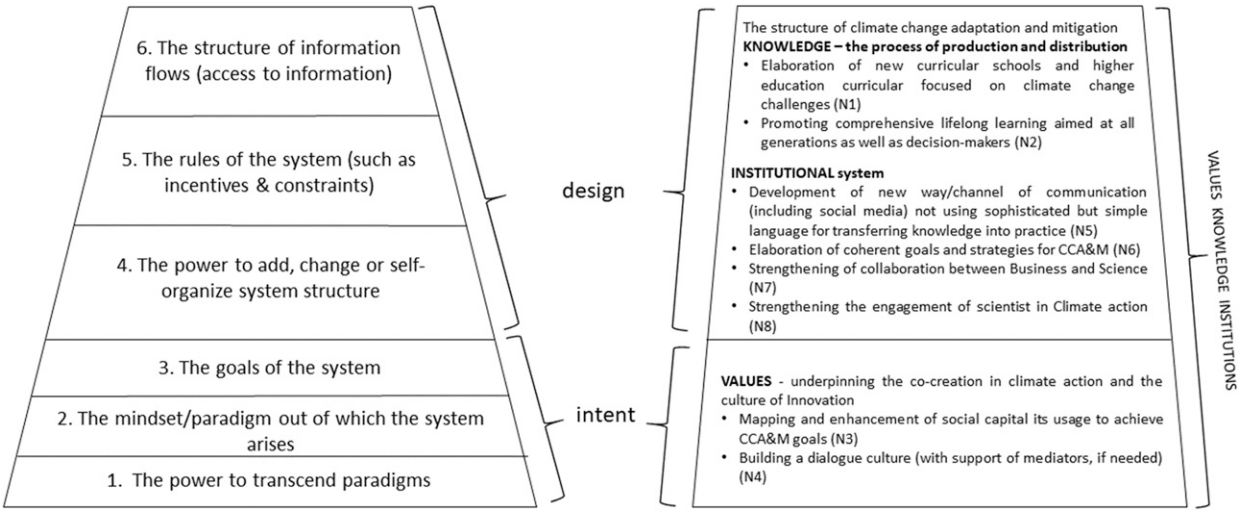

FIG. 7. Interpretation of knowledge, values, and institutions as realms of leverage points for cocreation process in climate action.

actions. This is a prerequisite for underpinning cocreation, as the recognition of present practice (section 4b) has shown that individual stakeholders have a long-established structure and culture of organization and work, which do not encourage the flow of knowledge or limit its transfer to one direction. The flow of knowledge between actors should be multidirectional and trigger mutual learning processes between stakeholders. This will strengthen the competences of all stakeholders and authenticate the decisions taken. Against this background, the way knowledge is created, shared, and used by stakeholders could be a key lever for enhancing cocreation processes. This understanding of leverage points in the realm of knowledge includes all places to intervene at design level (Fig. 7), that is, the structure of information flows (leverage point 6), the rules of the system (leverage point 5), and the power to add, change or self-organize system structure (leverage point 4).

Also, needs for action as leverage points related to institutional changes include all places to intervene in design. To the structure of information flows (leverage point 6) can be attributed the development of new channels of communication (N5). Stakeholders point out that knowledge about climate change alone will not support climate action unless the right framework for distribution and easy access to information are provided. In this area, we recommend opening up to widely available social media in order to reach a general public with applied scientific knowledge and information about the CCA&M's projects and actions. In the course of the activities within the institutions, it is important to remember to adapt and simplify the language of information provision. Using an understandable language instead of a scientific one fosters better communication between stakeholders and is an important factor for stimulating their involvement and creativity in the cocreation process.

Stakeholders also see the need for institutional changes that would lead to the elaboration of coherent goals and strategies for CCA&M, to enhance the engagement of scientists in climate actions and to collaboration between business and science. In the categories of leverage points, it refers to the development of a self-organized system of cocreation (leverage point 4). Stakeholders suggest that the implementation of these needs in the cocreation process needs to be supported by the rules and legal regulations that the institutions are entitled to establish. We therefore recommend that local government institutions develop cooperation standards and mechanisms for their implementation to create a sustainable framework for stakeholder collaboration. This will be a key lever to trigger stakeholder cooperation for climate actions (e.g., development of a joint vision for all the actors involved, improving the level of sense of agency among stakeholders).

Stakeholders indicate values as deep leverage points. Values refer to the intent level and are fundamentally important for cocreations, reflect the normative capacities underlying motivations inspiring actors to work toward a common goal. Thus, the values define the functionalities of the cocreation system. In the leverage-points model (Fig. 7), they are referred to as the main power to transcend paradigms (leverage point 1). Values influence the actions taken and the way stakeholders cooperate. A common system of values means that we share the same principles across all quadruple helix elements when deciding whether to take specific actions. In particular, we recommend reinforcing the role of knowledge in the creation of these values, as knowledge-based cocreation leads to a reevaluation of paradigms. A culture of innovation embraces the written and unwritten values, norms and attitudes in the system that influence the way various actors think and act. This is a decisive factor for the success of the cocreation process aimed at new relations between various stakeholders, novel means of communication, and novel solutions addressing the climate actions. In this context, mapping and enhancement of social capital and building a dialogue culture can have a decisive impact on CCA&M actions in the regions. These activities could lead to a transparency of the policy-making process and the involvement of all stakeholders

TABLE 2. Needs for action for cocreation on CCA&M identified in Poznań and findings of other comparable studies (source: authors' own research and authors' study of the cited references).

Categories of needs for action identified for Poznań	Categories of needs for actions in other studies				
	Germany (Munich, Berlin, and Sangerhausen; Wamsler 2017, 2016; Lehmann et al. 2015)	France (Annecy, Sète, Dunkerque, Cergy-Pontoise, Royan, and Agen; Simonet and Leseur 2019)	Ireland [Skibbereen (County Cork) and Clontarf (County Dublin); Clarke et al. 2016]	United States (New York; Bloomberg et al. 2010)	Peru (Lima) and Chile (Santiago) (Lehmann et al. 2015)
		Knowledge			
Rise of public and decision-makers' awareness	✓	✓	✓	✓	✓
Rise of the position of climate actions in the hierarchy of values	✓	✓	✓	✓	✓
Transferring knowledge into practice	✓	✓			✓
		Institution			
Elaboration of coherent goals and strategies for CCA&M using the experience and knowledge of scientists and local experts	✓	✓	✓	✓	✓
Development of new channels of communication (including the social media)	✓	✓	✓	✓	✓
Establish the rules and legal regulations that require systems thinking and increased stakeholder involvement	✓	✓	✓	✓	✓
		Values			
Sharing the common system of values (social and cultural) when deciding whether to take specific action		✓	✓		✓
Mapping and enhancement of social capital and its usage to achieve CCA&M goal		✓	✓		✓
Building a dialogue culture					
Openness to compromise					
The exclusion of particular interests					✓
Transparency of policy-making process					✓

from the start of the process with a bottom-up approach and conflict-sensitive adaptation measures taken.

We assigned comparable results obtained for cities in different countries to the categories of needs for action identified for Poznań to find out to what extent our results are consistent with other studies (Table 2).

The comparison shows that relevant categories of needs identified in other cities are very similar. The perceived needs are related to low awareness of climate change among society and authorities. All presented cases emphasize a lacking institutional tradition of participatory governance or using noneffective methods to knowledge sharing, information, and communication exchange. We confirm the role of regulatory requirements that can become barriers if they are inadequate or strong drivers if they are adequate—motivating and enabling innovation, which was also exposed in all the case studies cited.

The analysis reveals needs at the realm of values that are specific for Poznań such as the strong dependence of cocreation process on building a culture of dialogue and openness to compromise that results from an existing low level of social capital.

6. Conclusions

The research presented herein is an attempt to determine the conditions for cocreation of innovative knowledge for climate actions against the background of recognition of actual activity and cooperation of stakeholders. On the basis of the quadruple helix concept, we took into account representatives of academia and education, business, local government, and civil society. The results of the present practice recognition showed that the existing stakeholders' cooperation is usually of a superficial character or adopts the simplest forms of

consultation or knowledge transfer. The local government positions itself as a sovereign policy maker and administrator of budgetary resources. Both of these areas are very important for all other stakeholders, but in both cases the relationship with them is not a partnership. Academia and education are not systemically integrated with the other groups. Individual representatives are invited or share their expertise on their own initiative, get involved in climate action programming, or incorporate climate change content into educational programs. Similarly, business, as a rule, is not included in climate policy. Its activities are reactive in nature, taking advantage of the opportunities offered by subsidizing activities related to CCA&M, for example, switching to low-carbon energy sources or building renewable energy installations. It should be added that large companies finance CSOs' environmental awareness projects, which are related to CSR policy. Social organizations are primarily active in building social capital in relation to CCA&M. Among the activities identified, projects for raising public environmental awareness prevail. Another form is the organization of campaigns encouraging actions for the benefit of the environment, including climate actions against environmentally unfriendly projects and climate protection protests. CSOs participate in dialogue and debate mainly with representatives of local authorities and the media, promoting increased CCA&M activities.

Next, we systematized the opinions of each stakeholder group on barriers, drivers, and needs for action as cocreation factors. Thanks to the collected opinions of representatives of individual stakeholder groups, the needs for action for reducing barriers and supporting drivers, which determine the level of stakeholder groups' engagement in cocreation of climate action, have been identified and structured. Individual needs for action were treated as deep leverage points related to the acquisition of new knowledge, giving due importance to climate action in the system of values and changes in the functioning of institutions, which will enable transformational changes.

Needs for actions specifically highlighted by stakeholders refer to the realm of knowledge. The development of knowledge reinforces the scientific basis for decision-makers' decisions, for the rationalization of social behavior, and for the creation of an innovative education system including the training of specialists in the field of climate change prevention and adaptation. A great importance has been attached to knowledge developed through lifelong learning of all generations, which raises public awareness and raises the position of climate actions in the hierarchy of values. As a consequence, social capital and related readiness to active participation and cocreate innovative and effective actions are growing.

The second group of needs for actions connects to the value system. The needs identified by the stakeholders result from the lack of constructive dialogue, low culture of dialogue, reluctance to build compromise, and lack of agreement over particular interests. Needs for action also pointed out the need for institutional changes that will create conditions conducive to the development of common goals and strategies for CCA&M by all stakeholders. This will be reflected in the strengthening of collaboration between stakeholders as well as strengthening the engagement of scientists and local experts in climate actions. In this area of cooperation, stakeholders see a need to develop channels of communication, both through the use of social media to establish contact, exchange information, and maintain links, and also by simplifying the language of communication.

The conducted research allowed us to verify the functioning of the quadruple helix for climate action in the Poznań Agglomeration. A leverage-points perspective in our research allowed the recognition of influential leverage points relating to change in realms, which can lead to a transformative change in a complex system of cocreation for climate action.

We believe that our case study can provide a reference point for regions at a similar level of development, and the methods used as well as the results obtained can be applied to empower local stakeholders in climate actions.

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REFERENCES

Abson, D. J., and Coauthors, 2017: Leverage points for sustainability transformation. *Ambio*, **46**, 30–39, https://doi.org/10.1007/s13280-016-0800-y.

Ackermann, F., and C. Eden, 2011: Strategic management of stakeholders: Theory and practice. *Long Range Plann.*, **44**, 179–196, https://doi.org/10.1016/j.lrp.2010.08.001.

Adger, W. N., and Coauthors, 2009: Are there social limits to adaptation to climate change? *Climatic Change*, **93**, 335–354, https://doi.org/10.1007/s10584-008-9520-z.

Allen, M. R., D. J. Frame, K. Frieler, W. Hare, R. Knutti, M. Meinshausen, N. Meinshausen, and S. C. B. Raper, 2009: Greenhouse-gas emission targets for limiting global warming to 2°C. *Nature*, **458**, 1158–1162, https://doi.org/10.1038/nature08017.

Amundsen, H., F. Berglund, and H. Westskog, 2010: Overcoming barriers to climate change adaptation—A question of multilevel governance? *Environ. Plann.*, **28C**, 276–289, https://doi.org/10.1068/c0941.

Arnkil, R., A. Järvensivu, P. Koski, and T. Piirainen, 2010: Exploring quadruple helix: Outlining user-oriented innovation models. Quadruple Helix Research for the CLIQ Project Final Rep., 131 pp., https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.864.3864&rep=rep1&type=pdf#:~:text=The%20main%20objective%20was%20to,to%20support%20innovation%20more%20effectively.&text=Quadruple%20Helix%20(QH)%2C%20with,and%20user%2Dcentric%20innovation%20poli.

Aylett, A., 2014: Progress and challenges in the urban governance of climate change: Results of a global survey. Massachusetts Institute of Technology, Department of Urban Studies and Planning Rep., 67 pp., http://espace.inrs.ca/id/eprint/2835/1/Aylett-2014-Progress%20and%20Challenges%20in%20the%20%20Ur.pdf.

Bai, X., and Coauthors, 2018: Six research priorities for cities and climate change. *Nature*, **555**, 23–25, https://doi.org/10.1038/d41586-018-02409-z.

Barnaud, C. E., and Coauthors, 2018: Ecosystem services, social interdependencies, and collective action: A conceptual framework. *Ecol. Soc.*, **23**, 15, https://doi.org/10.5751/ES-09848-230115.

Barnett, M. L., 2019: The business case for corporate social responsibility: A critique and an indirect path forward. *Bus. Soc.*, **58**, 167–190, https://doi.org/10.1177/0007650316660044.

Bloomberg, M. R., J. D. Sachs, and G. M. Small, 2010: Climate change adaptation in New York City: Building a risk management response. *Ann. N.Y. Acad. Sci.*, **1196**, 1–3, https://doi.org/10.1111/J.1749-6632.2009.05415.X.

Bowler, D. E., L. Buyung-Ali, T. M. Knight, and A. S. Pullin, 2010: Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape Urban Plann.*, **97**, 147–155, https://doi.org/10.1016/j.landurbplan.2010.05.006.

Carayannis, E. G., and R. Rakhmatullin, 2014: The quadruple/quintuple innovation helixes and smart specialisation strategies for sustainable and inclusive growth in Europe and beyond. *J. Knowl. Econ.*, **5**, 212–239, https://doi.org/10.1007/s13132-014-0185-8.

——, E. Grigoroudis, and D. Pirounakis, 2015: Quadruple innovation helix and smart specialization knowledge production and national competitiveness. *Tech Monit.*, **32** (3), 19–27.

——, G. Acikdilli, and C. Ziemnowicz, 2019: Creative destruction in international trade: Insights from quadruple and quintuple innovation helix model. *J. Knowl. Econ.*, **11**, 1489–1508, https://doi.org/10.1007/s13132-019-00599-z.

Cavallini, S., R. Soldi, J. Friedl, and M. Volpe, 2016: *Using the Quadruple Helix Approach to Accelerate the Transfer of Research and Innovation Results to Regional Growth*. Committee of the Regions, European Union, 158 pp.

Chaudhary, S., A. D. McGregor, D. Houston, and N. Chettri, 2018: Environmental justice and ecosystem services: A disaggregated analysis of community access to forest benefits in Nepal. *Ecosyst. Serv.*, **29A**, 99–115, https://doi.org/10.1016/j.ecoser.2017.10.020.

Chingala, G., C. Mapiye, E. Raffrenato, L. Hoffman, and K. Dzama, 2017: Determinants of smallholder' farmers perceptions of impact of climate change on beef production in Malawi. *Climatic Change*, **142**, 129–141, https://doi.org/10.1007/s10584-017-1924-1.

Churski, P., K. Fagiewicz, T. Herodowicz, P. Kaczmarek, P. Lupa, A. Mizgajski, J. Morawska-Jancelewicz, and D. Ochota, 2020: State of the art of climate change adaptation and mitigation at Poznań Agglomeration (Poland). TeRRIFICA Project Rep., 52 pp., https://terrifica.eu/wp-content/uploads/2019/09/TeRRIFICA_POZNAN_state_of_art_OnlinePublication.pdf.

Clarke, D., C. Murphy, and I. Lorenzoni, 2016: Barriers to transformative adaptation: Responses to flood risk in Ireland. *J. Extreme Events*, **03**, 1650010, https://doi.org/10.1142/S234573761650010X.

Colls, N., and N. Ash, 2009: *Ecosystem-Based Adaptation: A Natural Response to Climate Change*. IUCN, 16 pp.

Etzkovitz, H., and L. Leydesdorff, 1997: *Universities and the Global Knowledge Economy: A Triple Helix of University–Industry–Government Relations*. Pinter, 256 pp.

Fischer, J., and M. Riechers, 2019: A leverage pointes perspective on sustainability. *People Nat.*, **1**, 115–120, https://doi.org/10.1002/pan3.13.

Forrester, J. W., 1969: *Urban Dynamics. Productivity Press*, 285 pp.

——, 1971: *World Dynamics*. Productivity Press, 144 pp.

Googins, B. K., and S. A. Rochlin, 2000: Creating the partnership society: Understanding the rhetoric and reality of cross-sectoral partnerships. *Bus. Soc. Rev.*, **105**, 127–144, https://doi.org/10.1111/0045-3609.00068.

Heikkinen, M., A. Karimo, J. Klein, S. Juhola, and T. Y. Anttila, 2020: Transnational municipal networks and climate change adaptation: A study of 377 cities. *J. Cleaner Prod.*, **257**, 120474, https://doi.org/10.1016/j.jclepro.2020.120474.

Hein, A. M., M. Jankovic, W. Feng, R. Farel, J. H. Yune, and B. Yannou, 2017: Stakeholder power in industrial symbioses: A stakeholder value network approach. *J. Cleaner Prod.*, **148**, 923–933, https://doi.org/10.1016/j.jclepro.2017.01.136.

Hunt, A., and P. Watkiss, 2011: Climate change impacts and adaptation in cities: A review of the literature. *Climatic Change*, **104**, 13–49, https://doi.org/10.1007/s10584-010-9975-6.

IPCC, 2014: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects*. C. B. Field et al., Eds., Cambridge University Press, 1132 pp., http://www.ipcc.ch/pdf/assessment-report/ar5/wg2/WGIIAR5-PartA_FINAL.pdf.

Jawgiel, K., 2017: Analiza spływu powierzchniowego i lokalnych podtopień na skutek deszczy nawalnych w Poznaniu na podstawie modelu Cloudburst (Analysis of surface runoff and local flooding due to torrential rains in Poznań based on the Cloudburst model). *Technol. Wody*, **4**, 34–37.

Kabisch, N., H. Korn, J. Stadler, and A. Bonn, 2017: *Nature-Based Solutions to Climate Change Adaptation in Urban Areas—Linkages between Science, Policy and Practice*. Springer Open, 342 pp.

Kaczmarek, T., 2017: Dynamics and directions of development of residential suburbanization in the Poznań Agglomeration (in Polish). *Acta Univ. Lodz. Folia Geogr. Socio-Oecon.*, **27**, 81–98.

Kuenkel, P., 2019: *Stewarding Sustainability Transformations*. Springer Nature, 321 pp., https://doi.org/10.1007/978-3-030-03691-1.

Kundzewicz, Z., and P. Kowalczak, 2008: *Zmiany Klimatu i Ich Skutki (Climate Change and Its Effects)*. Kurpisz, 206 pp.

Lam, D. P. M., A. I. Horcea-Milcu, J. Fischer, J. D. Peukert, and D. J. Lang, 2019: Three principles for co-designing sustainability intervention strategies: Experiences from southern Transylvania. *Ambio*, **49**, 1451–1465, https://doi.org/10.1007/s13280-019-01302-x.

Lee, T., and C. Koski, 2015: Multilevel governance and urban climate change mitigation. *Environ. Plann.*, **33C**, 1501–1517, https://doi.org/10.1177/0263774X15614700.

Lehmann, P., M. Brenck, O. Gebhardt, S. Schaller, and E. Süßbauer, 2015: Barriers and opportunities for urban adaptation planning: Analytical framework and evidence from cities in Latin America and Germany. *Mitig. Adapt. Strategies Global Change*, **20**, 75–97, https://doi.org/10.1007/s11027-013-9480-0.

Majkowska, A., L. Kolendowicz, M. Półrolniczak, J. Hauke, and B. Czernecki, 2017: The urban heat island in the City of Poznań as derived from Landsat 5 TM. *Theor. Appl. Climatol.*, **128**, 769–783, https://doi.org/10.1007/s00704-016-1737-6.

McAdam, M., K. Miller, and R. McAdam, 2015: Situated regional university incubation: A multi-level stakeholder perspective. *Technovation*, **50-51**, 69–78, https://doi.org/10.1016/j.technovation.2015.09.002.

Meadows, D. H., 1999: *Leverage Points: Places to Intervene in a System*. Sustainability Institute, 21 pp.

——, D. L. Meadows, J. Randers, and W. W. Behrens, 1972: *The Limits to Growth*. Universe Press, 211 pp.

Müller, N., W. Kuttler, and A. B. Barlag, 2014: Counter acting urban climate change: Adaptation measures and their effect on the thermal comfort. *Theor. Appl. Climatol.*, **115**, 243–257, https://doi.org/10.1007/s00704-013-0890-4.

Munang, R., I. Thiaw, K. Alverson, M. Mumba, J. Liu, and M. Rivington, 2013: Climate change and ecosystem-based adaptation: A new pragmatic approach to buffering climate change impacts. *Curr. Opin. Environ. Sustainability*, **5**, 67–71, https://doi.org/10.1016/j.cosust.2012.12.001.

OECD, 2011: Fostering innovation to address social challenges: Workshop proceedings. Secretary-General of the OECD Rep., 99 pp., https://www.oecd.org/sti/inno/47861327.pdf.

Parysek, J., and L. Mierzejewska, 2006: Poznań. *Cities*, **23**, 291–305, https://doi.org/10.1016/j.cities.2006.04.001.

Picketts, I. M., S. J. Déry, and J. A. Curry, 2013: Incorporating climate change adaptation into local plans. *J. Environ. Plann. Manage.*, **57**, 37–41, https://doi.org/10.1080/09640568.2013.776951.

Poznań City Council, 2014: Low carbon economy plan for Poznań Agglomeration. Accessed 9 March 2020, 308 pp., https://www.poznan.pl/mim/main/-,p,38278,38355.html.

——, 2019a: The climate adaptation plan for the city of Poznań to 2030. Accessed 9 March 2020, https://bip.poznan.pl/bip/uchwaly/uchwala-nr-x-144-viii-2019-z-dnia-2019-04-16,78779/.

——, 2019b: Strategy for rainwater and meltwater management for the city of Poznań (SRMM). Poznań City Hall Draft Doc., 154 pp.

Reckien, D., and Coauthors, 2018: How are cities planning to respond to climate change? Assessment of local climate plans from 885 cities in the EU-28. *J. Cleaner Prod.*, **191**, 207–219, https://doi.org/10.1016/j.jclepro.2018.03.220.

Reyes-García, V., A. Fernández-Llamazares, M. Guèze, A. Garcés, M. Mallo, M. Vila-Gómez, and M. Vilaseca, 2016: Local indicators of climate change: The potential contribution of local knowledge to climate research. *Wiley Interdiscip. Rev.: Climate Change*, **7**, 109–124, https://doi.org/10.1002/wcc.374.

Ricart, S., J. Olcina, and A. M. Rico, 2019: Evaluating public attitudes and farmers' beliefs towards climate change adaptation: Awareness, perception, and populism at European level. *Land*, **8**, 24, https://doi.org/10.3390/LAND8010004.

Sharpe, B., A. Hodgson, G. Leicester, A. Lyon, and I. Fazey, 2016: Three horizons: A pathways practice for transformation. *Ecol. Soc.*, **21**, 47, https://doi.org/10.5751/ES-08388-210247.

Simonet, G., and A. Leseur, 2019: Barriers and drivers of adaptation to climate change—A field study of ten French local authorities. *Climatic Change*, **155**, 621–637, https://doi.org/10.1007/s10584-019-02484-9.

Torabi, N. L., A. Mata, A. Gordon, G. Garrard, W. Wescott, P. Dettmann, and S. A. Bekessy, 2016: The money or the trees: What drives landholders' participation in biodiverse carbon plantings? *Global Ecol. Conserv.*, **7**, 1–11, https://doi.org/10.1016/j.gecco.2016.03.008.

Vallaeys, F., 2013: University social responsibility: A mature and responsible definition. Higher education in the world 5—Knowledge, engagement & higher education: Contributing to social change. Global University Network for Innovation Rep., 88–96, http://www.guninetwork.org/files/ii.4_1.pdf.

Van Well, L., and S. L. Scherbenske, 2014: Towards a macroregional climate change adaptation strategy in the Baltic Sea region. *Environ. Plann.*, **32C**, 1100–1116, https://doi.org/10.1068/c11243.

Wamsler, C., 2016: From risk governance to city–citizen collaboration: Capitalizing on individual adaptation to climate change. *Environ. Policy Gov.*, **26**, 184–204, https://doi.org/10.1002/eet.1707.

——, 2017: Stakeholder involvement in strategic adaptation planning: Transdisciplinarity and co-production at stake? *Environ. Sci. Policy*, **75**, 148–157, https://doi.org/10.1016/j.envsci.2017.03.016.

Wang W., F. van Noorloos, and T. Spit, 2020: Stakeholder power relations in land value capture: Comparing public (China) and private (U.S.) dominant regimes. *Land Use Policy*, **91**, 104357, https://doi.org/10.1016/j.landusepol.2019.104357.

Withmarsh, L., 2011: Scepticism and uncertainty about climate change: Dimensions, determinants and change over time. *Global Environ. Change*, **21**, 690–700, https://doi.org/10.1016/j.gloenvcha.2011.01.016.

Zwierzchowska, I., K. Fagiewicz, L. Poniży, P. Lupa, and A. Mizgajski, 2019: Introducing nature-based solutions into urban policy—Facts and gaps. Case study of Poznań. *Land Use Policy*, **85**, 161–175, https://doi.org/10.1016/j.landusepol.2019.03.025.