Available online at www.sciencedirect.com

ScienceDirect

Current Opinion in Environmental Sustainability

Joint knowledge production in climate change adaptation networks

Veruska Muccione[1], Christian Huggel[1], David N Bresch[2,3], Christine Jurt[4], Ivo Wallimann-Helmer[5], Meeta K Mehra[6] and José Daniel Pabón Caicedo[7]

Adaptation to changing and new environmental conditions is of fundamental importance to sustainability and requires concerted efforts amongst science, policy, and practice to produce solution-oriented knowledge. Joint knowledge production or co-production of knowledge have become increasingly popular terms to describe the process of scientists, policy makers and actors from the civil society coming together to cooperate in the production, dissemination, and application of knowledge to solve wicked problems such as climate change.

Networks are particularly suited to produce knowledge in a joint fashion. However, the process of joint knowledge production (JKP) in networks has rarely been examined. In this paper, we present a sketch of the adaptation network landscape and assess how joint knowledge production supports the development of solution-oriented knowledge in climate change adaptation networks. We conclude that the processes of JKP are diverse, complex, and highly dependent on the interests and roles of actors within the network. To keep such processes alive, signposts in form of analysis and intermediary products along the network lifetime should be positioned as means of stocktaking and monitoring for the future.

Addresses

[1] Department of Geography, University of Zurich, Zurich, Switzerland
[2] Institute for Environmental Decisions, ETH Zurich, Zurich, Switzerland
[3] Swiss Federal Office of Meteorology and Climatology MeteoSwiss, Zurich, Switzerland
[4] Bern University of Applied Sciences, School of Agriculture, Forest and Food Sciences (HAFL), Bern, Switzerland
[5] Department of Geosciences, University of Fribourg, Fribourg, Switzerland
[6] School of International Studies, Jawaharlal Nehru University, New Delhi, India
[7] Department of Geography, National University of Colombia, Bogotá, Colombia

Corresponding author: Muccione, Veruska (veruska.muccione@geo.uzh.ch)

Current Opinion in Environmental Sustainability 2019, **39**:147–152

This review comes from a themed issue on **Open issue**

Edited by **Eduardo Brondizio, Opha Pauline Dube** and **William Solecki**

For a complete overview see the Issue and the Editorial

Available online 12th November 2019

Received: 01 March 2019; Accepted: 26 September 2019

https://doi.org/10.1016/j.cosust.2019.09.011

Introduction

Climate change has repeatedly been referred to as a wicked problem [1]. Wicked problems are complex and contested problems that by their very nature are difficult to frame and solve. Recently, there has been a call to shift the focus from wicked problem definition, drivers and process understanding to problem solutions [2–4]. Solutions to wicked problems are context-dependent and there is in general no single solution to a wicked problem due to an ever-changing combination of factors and actors, which in turn influence the solutions [5]. Moving from understanding climate change science and its inherent processes (which are bio-physical, socio-economic, and cultural by nature) to the solution space requires new forms of knowledge generation. Research has shown how collaborations through social networks connecting different actors and stakeholders to develop knowledge and information can be pivotal in achieving socially desirable adaptation outcomes [6•,7].

In their seminal paper on the research for global sustainability within Future Earth, Mauser *et al.* [8••] refers to this knowledge as the co-production of knowledge for sustainability where researchers, policy makers and actors of the civil society cooperate in the production and dissemination of knowledge that is based on mutual recognition and learning. Co-production of knowledge requires integrated forms of knowledge generation and is performed through a continuous exchange amongst scientists and stakeholders [9,10].

In the past few years, the term 'co-production of knowledge' and its synonymous 'joint knowledge production (JKP)' (see Box 1) have gained increasing popularity [10] in the climate change community. In a systematic review of the use of the terms 'co-production of knowledge', Bremer and Meisch [10] found eight different perspectives going from the joint production of public services between citizens and government agencies to the extended science lens which looks at including knowledge from non-scientific actors as an integral part of the knowledge generation process. A shared view amongst the different lenses is that co-production of knowledge requires collaborative tools or arrangements to solve challenges inherent to wicked problems [6•,15,16••]. Therefore, collaboration is a pre-requisite to JKP [15,16••,17]. Notwithstanding, collaborations *per se* cannot

Box 1 Co-production of knowledge and Joint Knowledge Production (JKP)

A clarification of the concept of Joint Knowledge Production (JKP) is provided in Ref. [11••]. Ref. [11••] discuss JKP in the context of post normal science as a form of knowledge generation which is highly contextualized, heterogeneous and benefits from contributions of an extended and locally specific peer community (e.g. policy-makers and societal actors). Ref. [11••] assume JKP as distinct from co-production of knowledge as the knowledge that explicitly happens in projects and programs between science-policy-practice [11••]. Whereas the distinction between JKP and co-production of knowledge seems appropriate if JKP is underpinning recognizable actions that happen in well-defined adaptation projects, in more nuanced and indirect settings such as those of adaptation networks this distinction is not necessarily needed. We thus assume JKP and co-production of knowledge equivalent terms and use them interchangeably since both underpin knowledge that would not have been produced had the actors from science, policy, and society worked in isolation [12••,13].

A tangible example of Joint Knowledge Production Networks is provided by the Future Earth Knowledge Action Networks (KANs) whose scope, objectives, and operationalization is presented in Ref. [14]. KANs are networks of academics, public, and private stakeholders that implement knowledge co-production to improve the contribution of science to solve major sustainability challenges. Their objectives are to generate integrated knowledge which is usable, solution driven, interdisciplinary and transdisciplinary. Research questions and activities are designed through an inclusive process which involves both scientific communities and actors outside academia.

guarantee that the process of JKP or co-production will succeed in defining a solution space to wicked problems [18–20].

The scarcity of evidence on how collaboration processes happen and evolve has been highlighted in recent literature on the role of JKP in climate change adaptation [16••,21•] and it is not surprising that little evidence is available so far on whether networks are indeed delivering knowledge in a joint fashion or merely claiming to do so [17,21•]. The complexity of producing knowledge in a joint fashion or co-producing knowledge amongst scientists, decision-makers and practitioners has been known for a while [22,23]. Concepts such as 'co-production of knowledge' and 'JKP' have attracted much resonance [10,24,25] to the point that a stocktaking on whether or not such concepts are useful in the quest for solutions is timely needed.

In this piece, we investigate the conditions under which networks facilitate the co-production of knowledge and ultimately are able to generate actionable knowledge for climate change adaptation. In the following, we understand networks as social structures composed of scientists from different disciplines and societal actors from policy and practice. The terms 'co-production of knowledge' and JKP will be used interchangeably (see Box 1).

We explore the adaptation network landscape to critically assess whether and how JKP can potentially lead to actionable knowledge, where actionable knowledge is considered a prerequisite for enabling solutions to wicked problems such as climate change [7,16••,26••]. We then explore more generally the processes of JKP in networks and toward the end convene some recommendations for a more effective process of joint knowledge production in networks.

Progress toward JKP in climate change adaptation networks

In knowledge action networks owners of relevant types of knowledge and those capable of acting upon come together to solve wicked problems [27]. Knowledge action networks ultimately aim at producing, disseminating and using knowledge in decision-making and action for sustainability. Knowledge action networks have been identified as key instruments for JKP under the Future Earth's vision and future agenda [26••,14] (see Box 1). Studies have shown that the success of JKP in knowledge-action-networks depends on the degrees of actors' involvement and the level of deliberation in terms of open and accountable processes, which allow for inclusive and continuous learning [2,11••]. In this sense, knowledge action networks accommodate the different interests, values and perspectives of societal actors [26••]. In the following, we provide a few key examples of adaptation networks drawn from the wider landscape of collaboration in adaptation research-policy and practice to illustrate the dynamics of actor's involvement and their level of deliberation.

Practice oriented adaptation networks are civil society–public–private partnerships whose goal is to foster adaptation through institutional capacity building [28]. An example is the Global Adaptation Network and its regional networks, which aim to build climate resilience worldwide by connecting thematic UN platforms with the broader community (including scientists) [29]. Participatory action research has been identified as a key process in practice oriented networks to improve communications and collaborations amongst science–policy–local actors because it overcomes barriers in knowledge exchange and facilitates evidence informed decision making [30,19]. Participatory action research recognizes the value of scientific knowledge on pair with other forms of knowledge and it is particularly suited to accommodate traditional and indigenous knowledge as forms of knowledge in their own rights [12,30].

Participatory action research has been directly associated with the co-production of knowledge where actors are not merely associated to a process of knowledge generation but are the reasons for the process to take place. Recent research has highlighted a number of challenges and subsequent risks of relying too much on participatory approaches as a way to informing adaptation decision making [31]. It shows that participatory research can create challenges to scientific integrity, will have impacts on career progression of scientists as well as on their well-being and can be costly for research founders (as a result of, *inter alia*, the high number of participants, operational costs, costs of coordinating implementation, and potential costs of failure).

Along the same lines as the practice-oriented networks, albeit being guided by policy objectives, are networks as enablers of policy processes and action toward adaptation [32]. These networks are initiated as collaborations amongst science, policy, and practice to inform policy and policy processes and to support the development and implementation of adaptation at the national and subnational level. Collaborative entities as such bear the aspiration to produce knowledge in a transdisciplinary fashion, where transdisciplinarity is to be understood as the full participation of scientists from different disciplines (inter) and non-scientific actors in the production of knowledge (trans) [33]. Relevant examples are given by the regional networks created as part of the Klimzug Programme in Germany [16••,34] and the Knowledge for Climate in the Netherlands [16••].

Empirical investigations of these networks have shown that their underlying success, which is often obvious but should not to be underestimated, is the opportunity they offer to non-scientists to acquire system knowledge on scientific issues such as climate change. Still the way scientist's manage the role of communicators and distill appropriate information on wicked problems remain an underestimated challenge, which can to a certain extent hinder the move from knowledge formulation and learning to actionable knowledge [16••]. Hence, a key feature for an efficacious co-production process in policy enabling networks comprises building ongoing associations and interactions between scientists and other stakeholders, making sure that there is more than a two-way communication between the groups, and maintaining a focus on the production of actionable knowledge [35].

Science-driven adaptation networks comprise of scientists, decision-makers and practitioners, who collaborate to respond to specific policy needs in terms of providing information, further evidence and filling knowledge gaps. The process of enquiry to synthetizing existing knowledge and the exploration of fundamentally new insights (knowing that the former – also generates new knowledge) are the driving forces behind these collaborations [12]. An example of such networks is given by the Loss and Damage (L&D) Network, which provides science-based evidence and approaches to inform the policy discourse on L&D [36]. The L&D network encompasses both scientists and practitioners and at the same time interacts with climate policymakers. It focuses on knowledge generation through exchange between the involved actors, including new theoretical and conceptual approaches to L&D accompanying the policy process. It has so far operated delivered a number of initiatives at key policy events and a recent book as a key knowledge resource [36].

Notwithstanding, some research highlights the risk that the process of JKP in strongly science rooted networks might deliver more of the same kind of output albeit under a different name rather than in fact actionable knowledge [26••]. An example relates to the generation and dissemination of climate impact scenarios where there is on one side a claim to jointly develop and deliver the scenarios but in reality attempts often fall back on traditional unilateral scientific means of knowledge production [37]. In such cases, the role of JKP in advancing both science and policy action has to be assessed [21•]. While the former can be tracked through more easily monitorable metrics, such as number of peer-reviewed journal articles, the indicators to measure the latter vary from scientist–stakeholder relationships, access to science-based knowledge generated, how well users' perception of new information fits their needs and existing knowledge frames, and intensity and quality of interaction between science and societal actors [38]. And so, what to conclude from this? Maybe: Measuring outcomes by incorporating all these factors is quite complex and often finds no consideration.

Discussions and the way forward

The previous section provides a non-exhaustive sketch of the adaptation network landscape. The commonality amongst adaptation networks driven by either scientists, practitioners or decision makers is that they all are some form of knowledge action networks, where knowledge action networks are to be understood in the sense of initiatives amongst scientists, practitioners, and decision-makers to producing actionable knowledge to inform solutions to wicked problems.

Far from claiming to find common characteristics amongst these networks our aim is to highlight the contested processes of joint knowledge production amongst seemingly comparable entities. We found that existing models of JKP, such as sketching different stages in a JKP process from co-design to co-production and co-dissemination as in Mauser *et al.* [8••] or clearly delineating objectives of knowledge action networks [14] need to be broadened to better consider the high diversity and high non-linearity in JKP processes. Our JKP network analysis suggests that while we may look for common elements, every network and JKP process is eventually a unique process and endeavor that embarks on an uncertain journey [26••].

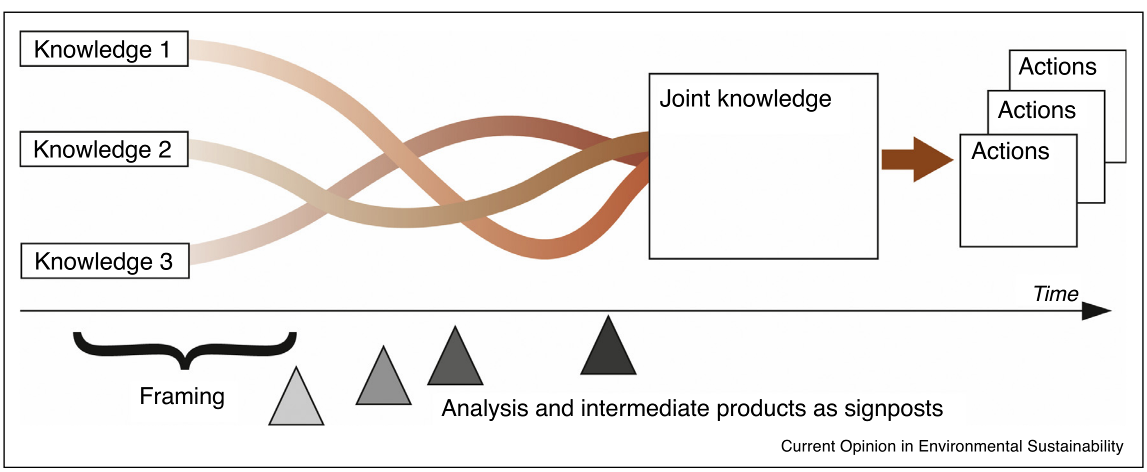
The more experiences can be documented and analyzed the more momentum the process gains. Hence, a need for more systematic reviews of knowledge production processes in climate change adaptation and sustainability networks will be necessary [16••,39].

Our experience with and review of adaptation networks also indicate that JKP as such does not happen by mere collaboration, but the processes of knowledge production have to be recognized, continuously reflected and researched, updated and upgraded. The most pertinent challenge in these networks is often to establish trust amongst the very diverse actors and thus dedicate enough time for the framing stage, while progressing in the co-production of knowledge to move closer to actions and solutions. Indeed, some knowledge action networks remain at the problem framing or agenda setting stage and the actual JKP may then rather be left as an aspiration [23,25]. The trade-offs between accommodating a sufficiently solid framing process and moving into the knowledge production space appear to be a challenge in JKP networks. JKP thus calls for an extended timescale to produce results in terms of knowledge production [40], yet this contrasts with the scope of common financing instruments, which are often a basis of enabling the network, and operations are then too quickly upscaled [41]. Thus, the shortcoming is that several of these networks remain focused either on establishing a framework [23] or too quickly move to an operational stage without the knowledge produced being able to retain the interests of all the actors involved and thus running against established principles of JKP [11••] and falling short of delivering integrated adaptation solutions.

We argue that in order to maintain the interests of all scientific actors a balance needs to be found between harmonizing different forms of knowledge and approaches and acknowledging and harvesting the diversity and possibly limited consensus [26••]. Where this balance lies, is not a priori predictable and needs to be actively negotiated in a network. Notwithstanding, the challenge remains on how to respect the credibility of the knowledge produced for all the actors, which might differ according to different types of knowledge and the systems within they are produced whether scientific, local, indigenous or tacit [11••].

We suggest that the process of producing joint knowledge is followed in parallel by an analysis of the processes of knowledge generation (within the network) while signposts and intermediary products are to be provided along the timeline such as the ones sketched in Figure 1. Signposts are meant to monitor and survey JKP and are positioned early enough to allow for timely adjustments ahead of instances where the agendas and expectations of the different actors start to diverge considerably or where interest is lost and achieving actionable outputs becomes challenging. Workshops or other forms of close exchange are an integral part of adaptation networks. However, the goal of such workshops must go beyond a mere exercise of exchange

Figure 1



Process of Joint Knowledge Production (JKP) in Networks.
The figure depicts the process of JKP in networks as it starts from a number of different forms of knowledges interacting and becoming interwoven along the timeline, where the pathways of knowledge increasingly narrow down but may not fully converge. The original knowledges are enriched, transformed but their identity is preserved. In the end, we may have co-existence and not necessarily harmonization of knowledges. Joint knowledge is produced in the indicated space (rectangle) based in which different adaptation actions are informed. Hence, knowledge processes may not end up in one single 'solution', but rather in a suit of more flexible and adaptive approaches. Furthermore, signposts and intermediary products are positioned along the timeline, in particular at or before spaces where the different knowledges interact and are shared, for example, at joint workshops. Changing colors of the different knowledge streams indicate a possible transformation of knowledge. Involvement and trust of the participants of the JKP process would ideally increase along the timeline.

without any evaluation of the network objectives, activities, and agenda.

A methodology widely used for revealing the characteristics of social networks and the collaborations amongst diverse actors is social network analysis (SNA) [6•,42]. SNA has been a tool extensively used in the current literature to understand social structures through graphical representation of nodes and links to exemplify actors and their ties [27,43,44]. The problem addressed through social network analysis in climate change adaptation is the collaboration potential of networks as enablers as well as hinderers to the implementation of adaptation [45]. Thus, a combined systematic assessment of processes and actors over the timeline of the network by employing methods such as SNA can deliver robust signposts on the knowledge generation processes, the role of actors, their ties and how these structures might evolve over time.

Methods employed in social network analysis can be directly integrated in the evaluation of the network and made explicit during stocktaking events such as workshops. In addition, visualizing networks and their products by using powerful tools of knowledge visualizations can help to monitor the complex web of interaction processes and actor ties and to identify where signposts for stocktaking should be located [46,47]. It is indeed such signposts and (intermediary) products that keep JKP alive and participants committed and engaged over time.

Conflict of interest statement

Nothing declared.

Acknowledgements

This work has been supported by a grant of the "swissuniversities Development and Cooperation Network (SUDAC) programme". We acknowledge support of the Executive Board and the Faculty of Science of the University of Zurich.

References and recommended reading

Papers of particular interest, published within the period of review, have been highlighted as:

- • of special interest
- •• of outstanding interest

1. Waddock S, Meszoely GM, Waddell S, Dentoni D, Waddock S, Waddell S, Dentoni D: **The complexity of wicked problems in large scale change**. *J Organ Change Manage* 2018, **28**:993-1012.

2. Kowarsch M, Garard J, Riousset P, Lenzi D, Dorsch MJ: **Scientific assessments to facilitate deliberative policy learning**. *Palgrave Commun* 2016, **2**:16092.

3. Kowarsch M, Flachsland C, Riousset P, Garard J, Jabbour J: **The treatment of divergent viewpoints in global environmental assessments**. *Environ Sci Policy* 2017, **77**:225-234.

4. Kowarsch M, Jabbour J, Flachsland C, Kok MTJ, Watson R, Haas PM, Minx JC, Alcamo J, Garard J, Riousset P *et al.*: **A road map for global environmental assessments**. *Nat Publ Gr* 2017, **7**:379-382.

5. Waddell S: **Societal change systems: a framework to address wicked problems**. *J Appl Behav Sci* 2016, **52**:422-449.

6. • Calliari E, Michetti M, Farnia L, Ramieri E: **A network approach for moving from planning to implementation in climate change adaptation: evidence from southern Mexico**. *Environ Sci Policy* 2019, **93**:146-157.

Calliari *et al*. is a research paper about the use of Social Network Analysis to reveal connections in multi-actor networks.

7. Laursen S, Puniwai N, Genz AS, Nash SAB, Canale LK, Ziegler-Chong S: **Collaboration across worldviews: managers and scientists on Hawai'i island utilize knowledge coproduction to facilitate climate change adaptation**. *Environ Manage* 2018, **62**:619-630.

8. •• Mauser W, Klepper G, Rice M, Schmalzbauer BS, Hackmann H, Leemans R, Moore H: **Transdisciplinary global change research: the co-creation of knowledge for sustainability**. *Curr Opin Environ Sustain* 2013, **5**:420-431.

The paper of Mauser *et al*. provides a framework on the concept of co-production of knowledge and the integration of scientific research across and beyond academia.

9. Howarth C, Monasterolo I: **Opportunities for knowledge co-production across the energy-food-water nexus: making interdisciplinary approaches work for better climate decision making**. *Environ Sci Policy* 2017, **75**:103-110.

10. Bremer S, Meisch S: **Co-production in climate change research: reviewing different perspectives**. *Wiley Interdiscip Rev Clim Change* 2017, **8**:1-22.

11. •• Hegger D, Lamers M, Van Zeijl-Rozema A, Dieperink C: **Conceptualising joint knowledge production in regional climate change adaptation projects: success conditions and levers for action**. *Environ Sci Policy* 2012, **18**:52-65.

The authors design a framework for joint knowledge production in climate change adaptation projects. The paper analyses the success of joint collaboration amongst scientists and policy actors. It concludes that the success depends on the degree of involvement of the actors and dominant discourse.

12. Hegger D, Lamers M, Van Zeijl-Rozema A, Dieperink C: **Conceptualising joint knowledge production in regional climate change adaptation projects: success conditions and levers for action**. *Environ Sci Policy* 2012, **18**:52-65.

13. Hegger D, Dieperink C: **Toward successful joint knowledge production for climate change adaptation: lessons from six regional projects in the Netherlands**. *Ecol Soc* 2014, **19**.

14. Future Earth: *Knowledge Action Networks. Framing and Operationalisation*. 2016.

15. Beers PJ, Geerling-Eiff F: **Networks as policy instruments for innovation networks as policy instruments for innovation**. *J Agric Educ Ext* 2014, **20**:363-379.

16. •• Schmid JC, Knierim A, Knuth U: **Policy-induced innovations networks on climate change adaptation – an ex-post analysis of collaboration success and its influencing factors**. *Environ Sci Policy* 2016, **56**:67-79.

The authors give a comprehensive overview of the processes of joint research in climate change adaptation network. It provides insights on the cooperation's satisfaction, learning effects, and potential for implementation.

17. Hermans F, Klerkx L, Roep D: **Structural conditions for collaboration and learning in innovation networks: using an innovation system performance lens to analyse agricultural knowledge systems**. *J Agric Educ Ext* 2015, **21**:35-54.

18. Bodin Ö, Robins G, Mcallister RRJ, Guerrero AM, Crona B, Lubell M: **Theorizing benefits and constraints in collaborative environmental governance: a transdisciplinary social-ecological network approach for empirical investigations**. *Ecol Soc* 2016, **21**:40.

19. Cvitanovic C, Hobday AJ, van Kerkhoff L, Wilson SK, Dobbs K, Marshall NA: **Improving knowledge exchange among scientists and decision-makers to facilitate the adaptive governance of marine resources: a review of knowledge and research needs**. *Ocean Coast Manage* 2015, **112**:25-35.

20. Cvitanovic C, Howden M, Colvin RM, Norström A, Meadow AM, Addison PFE: **Maximising the benefits of participatory climate adaptation research by understanding and managing the**

associated challenges and risks. *Environ Sci Policy* 2019, **94**:20-31.

21. Hegger D, Van Zeijl-Rozema A, Dieperink C: **Toward design**
• **principles for joint knowledge production projects: lessons from the deepest polder of The Netherlands**. *Reg Environ Change* 2014, **14**:1049-1062.
A reflection on how knowledge in adaptation programme, projects, plans, and strategies can be turned into action.

22. van Buuren A, Edelenbos J: **Why is joint knowledge production such a problem?** *Sci Public Policy* 2004, **31**:289-299.

23. Vogel C, Moser SC, Kasperson RE, Dabelko GD: **Linking vulnerability, adaptation, and resilience science to practice: pathways, players, and partnerships**. *Glob Environ Change* 2007, **17**:349-364.

24. Pollitt C, Hupe P: **Talking about government – the role of magic concepts**. *Public Manage Rev* 2011, **13**:641-658.

25. Swart R, Biesbroek R, Capela Lourenço T: **Science of adaptation to climate change and science for adaptation**. *Front Environ Sci* 2014, **2**.

26. van der Hel S: **Environmental science & policy new science**
•• **for global sustainability? The institutionalisation of knowledge co-production in Future Earth**. *Environ Sci Policy* 2016, **61**:165-175.
The paper highlights the process of co-producing knowledge in Future Earth. The paper asserts that the ambiguity around the concept of co-production of knowledge is useful since it allows actors with different perspectives to engage in the knowledge production process.

27. Muñoz-Erickson TA, Cutts BB: **Structural dimensions of knowledge-action networks for sustainability**. *Curr Opin Environ Sustain* 2016, **18**:56-64.

28. Baudoin M, Ziervogel G: **What role for local organisations in climate change adaptation? Insights from South Africa**. *Reg Environ Change* 2017, **17**:691-702.

29. Global Adaptation Network: *Global Adaptation Network*. 2017.

30. Burnside-Lawry J, Franquet R, Wairiu M, Holland E, Chand S: **Communication, collaboration, and advocacy: a study of participatory action research to address climate change in the Pacific**. *Int J Clim Change Impacts Responses* 2017, **9**.

31. Cvitanovic C, Howden M, Colvin RM, Norström A, Meadow AM, Addison PFE: **Maximising the benefits of participatory climate adaptation research by understanding and managing the associated challenges and risks**. *Environ Sci Policy* 2019, **94**:20-31.

32. Hauge ÅL, Hanssen GS, Flyen C: **Multilevel networks for climate change adaptation – what works?** *Int J Clim Chang Strateg Manage* 2018, **9**:58-69.

33. Pohl C: **From science to policy through transdisciplinary research**. *Environ Sci Policy* 2008, **11**:46-53.

34. Bardt H, Biebeler H, Chrischilles E, Mahammadzadeh M: **Klimzug: climate change in regions**. *Adaptation Strategies for Seven Regions*. 2012.

35. Armitage D, Berkes F, Dale A, Kocho-schellenberg E, Patton E: **Co-management and the co-production of knowledge: learning to adapt in Canada's Arctic**. *Glob Environ Change* 2011, **21**:995-1004.

36. Mechler R, Calliari E, Bouwer LM, Schinko T, Surminski S, Linnerooth-bayer J, Aerts J, Botzen W, Boyd E, Deckard ND *et al.*: **Science for loss and damage. Findings and propositions**. In *Loss and Damage from Climate Change*. Edited by Mechler R. Springer International Publishing; 2019:2-37.

37. Skelton M: **The social and scientific values that shape national climate scenarios: a comparison of the Netherlands, Switzerland and the UK**. *Reg Environ Change* 2017, **17**:2325-2338.

38. Meadow AM, Ferguson DB, Guido Z, Horangic A, Owen G: **Moving toward the deliberate coproduction of climate science knowledge**. *Am Meteorol Soc* 2015, **7**:179-191.

39. Trogrlic RS, Cumiskey L, Triyanti A, Duncan MJ, Eltinay N, Hogeboom RJ, Jasuja M, Meechaiya C, Pickering CJ, Murray V: **Science and technology networks: a helping hand to boost implementation of the Sendai framework for disaster risk**. *Int J Disaster Risk Sci* 2017, **8**:100-105.

40. Baird J, Plummer R, Bodin O: **Collaborative governance for climate change adaptation in Canada: experimenting with adaptive co-management**. *Reg Environ Change* 2016, **16**:747-758.

41. Muccione V, Orlowsky B, Allen SK, Huggel C, Salzmann N, Montoya N, Randhawa SS, Stoffel M: **Climate change research in bilateral development programmes: experiences from India and Peru**. *Dev Pract* 2018, **29**:336-348 http://dx.doi.org/10.1080/09614524.2018.1559799.

42. Kettle NP, Trainor SF, Loring PA: **Conceptualizing the science-practice interface: lessons from a collaborative network on the front-line of climate change**. *Front Environ Sci* 2017, **5**:1-9.

43. Cunningham R, Cvitanovic C, Measham T, Dowd A, Harman B: **Engaging communities in climate adaptation: the potential of social networks**. *Clim Policy* 2016, **16**:894-908.

44. Ziervogel G, Pasquini L, Haiden S: **Nodes and networks in the governance of ecosystem-based adaptation: the case of the Bergrivier municipality, South Africa**. *Clim Change* 2017, **144**:271-285.

45. Therrien M, Jutras M, Usher S: **Including quality in social network analysis to foster dialogue in urban resilience and adaptation policies**. *Environ Sci Policy* 2019, **93**:1-10.

46. Khoury CK, Kisel Y, Kantar M, Barber E, Ricciardi V, Klirs C, Kucera L, Mehrabi Z, Johnson N, Klabin S *et al.*: **Science–graphic art partnerships to increase research impact**. *Commun Biol* 2019, **2**:1-5.

47. Hermans LM, Haasnoot M, Kwakkel JH: **Environmental science & policy designing monitoring arrangements for collaborative learning about adaptation pathways**. *Environ Sci Policy* 2017, **69**:29-38.