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32

33 Abstract

34 Co-production is an increasingly popular approach for environmental and sustainability
35 research, but what is actually produced through its practice remains understudied. This
36 paper reviews recent examples of co-produced research alongside current theorization
37 on the topic. Focusing on the area of climate change adaptation, we find that co-
38 produced climate change adaptation research appears to be improving knowledge use,
39 among other positive outcomes, but a difference emerges between the range of
40 outcomes reported in practice and the scope of ambition conceived through theory. This
41 raises important questions about how the practice of knowledge co-production should
42 be evaluated and, fundamentally, what we should expect to produce through co-
43 production. We argue that understanding and reconciling the transformative potential of
44 science-practice collaborations within the context of the incremental progress achieved
45 through its current practice will catalyze a more integrated and actionable scholarship
46 and practice.

47 **Keywords:** Co-production, Climate Change, Adaptation, Outcomes

48

49 1. Introduction

50 As climate change impacts are increasing worldwide, there is a growing impetus to
51 develop knowledge and practices that can support adaptation decisions. In response,
52 researchers and practitioners, increasingly collaborate to produce actionable knowledge
53 through a process often called co-production [1–3]. In this paper, we refer to co-
54 production as a process that brings together diverse groups to iteratively create new
55 knowledge and practices [3]. Within climate change adaptation science, co-production is
56 becoming a widely accepted “best practice” for those who seek to (co-) generate
57 actionable knowledge [4,5]. This scholarship suggests that meaningful collaboration
58 between researchers and users of research will generate more accessible, relevant,
59 and credible knowledge, thus increasing the likelihood of its use. Some scholars also
60 anticipate that this will help reconstitute the social contract for science by displacing
61 longstanding separations between science and society and bringing about a more
62 interactive and engaged research culture ([6,7], see Arnott et al. in this issue).

63 Despite great expectations, very few systematic assessments reveal what co-production
64 actually produces for either its participants or other intended beneficiaries. There seems
65 to be a broad understanding that co-production can bear fruit, but there is less clarity on
66 the specifics such as the variety, quality, or abundance of its yield, and how this varies
67 under different conditions. Myriad aspirations for co-production have emerged, ranging
68 from generating enhanced and shared understandings to building adaptive capacity,
69 and even facilitating transformative social and policy changes [1,3,8]. However, close
70 observers question whether these aims are achieved or whether more ambition, or
71 caution, is to be called for, when pursuing co-production in the future.

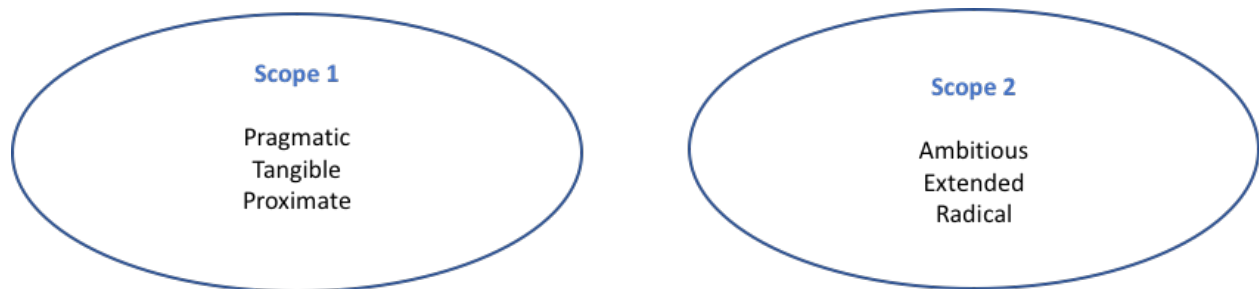
72 This paper starts with a review of the theorized outcomes of co-production in the climate
73 change adaptation space (hereafter, adaptation). We then review recent examples of
74 co-produced adaptation projects to examine outcomes in practice that are reported in
75 peer-reviewed publications. Finally, we compare outcomes across theory and practice,
76 consider the implications of these differences, and present a way forward for both the
77 theory and practice of co-production.

78 2.Co-production: Great expectations in theory

79 Although co-production is a widely used concept, scholars from different disciplines and
80 practitioners interpret the term in divergent ways [1,3]. For understanding the practice of
81 co-production within adaptation research, recent literature suggests two general scopes
82 of ambition, and outcomes, for co-production (Figure 1). One scope strives for the
83 generation of actionable knowledge, and the other seeks out transformation of norms
84 and structures within science and society. Scope 1 outcomes center around benefits
85 that emerge from the production and dissemination of decision-relevant knowledge and
86 services. For example, Scope 1 outcomes include generating knowledge that includes
87 the experience and perspectives of non-researchers who may in turn utilize this
88 knowledge to make adaptation decisions [4,8–10]. In contrast, Scope 2 outcomes may
89 change societal power structures and political systems, and may also reorder the
90 relationship between science and society. The Scope 2 outlook is less predictable and
91 bounded but anticipates that co-production can open up decision-making spaces;
92 reshape the science-public-policy interface; democratize science; broaden the scope
93 and meaning of evidence in decision-making; and ultimately redistribute power and
94 expertise among different groups within society [11–14]. So, while Scope 1 outcomes
95 tend to be relatively more pragmatic (relating to practical needs of society), tangible (are
96 easily discernible), and proximate (relatively near-term), Scope 2 outcomes are more
97 ambitious (in its transformative aspirations), extended (relating to longer-term changes),
98 and radical (in their reshaping of societal and scientific norms and structures) [8,9,15].

99 While we use these terms to distinguish two broadly categorized outlooks for co-
100 production that we see emergent in the current literature, we acknowledge the inherent
101 subjectivity in the terms employed to describe them. What is pragmatic, or radical, to
102 one group may not be to another; therefore, who defines matters when distinguishing
103 between them. The relationship between them is not straightforward either; and the
104 literature highlights both synergies as well as tensions between the two [16]. While
105 some scholars expect that Scope 1 outcomes can catalyze broader transformations of
106 governance and knowledge production processes over time [3,16], others suggest that
107 a solitary focus on Scope 1 outcomes without addressing the political and power

108 dynamics of co-production can reinforce existing power inequalities and therefore
109 undermine societal transformation [8] (also see Turnhout et al in this issue). The
110 literature is thus inconclusive as to whether Scope 1 outcomes enhance or undermine
111 the more transformative Scope 2 outcomes.



112

113 **Figure 1:** Two scopes of ambition for co-production - Scope 1 relates to the production and dissemination
114 of knowledge and services. Scope 2 relates to the transformation of norms and institutional structures
115 within science and society. Literature presents both synergies and tensions between these two outcomes.

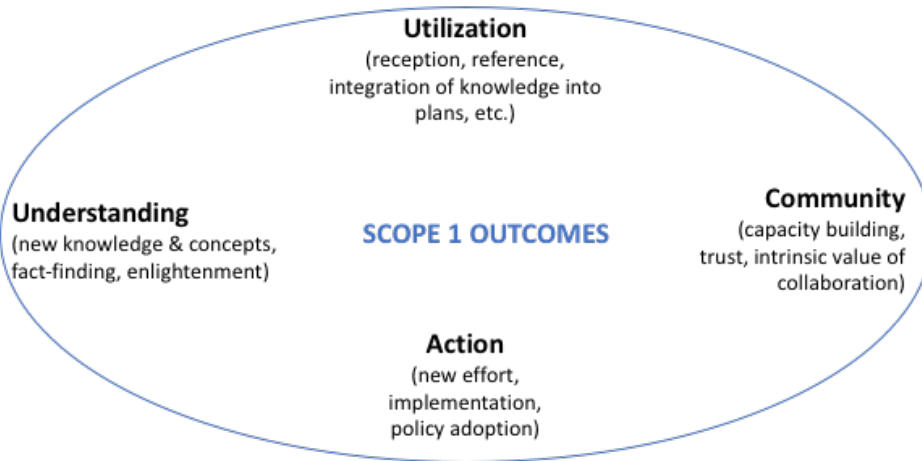
116 Beyond theory, there is a growing body of case studies that provide empirical evidence
117 for co-production outcomes in adaptation. These cases report success in generating
118 Scope 1 outcomes such as creation of relevant knowledge products, facilitating open
119 dialogue across the science and practice communities, and building critical capacity to
120 influence action [8,17]. However, these efforts have not necessarily led to the
121 anticipated Scope 2 outcomes in terms social, governance or direct policy changes
122 [8,17,18]. One study adds nuance, suggesting that suboptimal outcomes can emerge
123 when key dimensions of co-production are neglected, such as engagement over
124 sustained periods, iterative reflect-act cycles, and challenging of institutional barriers
125 [19]. They also suggest that ‘rigorous’ application of these key dimensions, can lead to
126 clearly positive—and in some cases radical—outcomes. With this context, recent
127 research on co-production and adaptation has focused on the political and institutional
128 barriers to realizing broader aspirations of changes in policy and practice [3,20–23].
129 These scholars call for greater engagement with the politics of co-production in ways
130 that critically appraise power imbalances between different actors while recognizing
131 multiple ways of knowing and understanding climate change.

132 3. What to expect when you co-produce in practice

133 To analyze co-production practice, projects were selected through systematic searches
134 in Scopus to identify examples reported in the peer-reviewed literature published
135 between 2016 and early 2019. This resulted in 21 co-production projects from 18
136 countries, which were analyzed for their intent, engagement approach, reported outputs,
137 outcomes, and evaluation (see Supplementary Material section 1 for more details).
138 Here, we focus on the reported outcomes as the basis for comparison with theorized
139 expectations (see Supplementary Material sections 2-4 for other details of the analysis).

140 Outcomes refer to the effects of co-production reported from the project which often
141 manifest through project outputs (i.e., outcomes describe what difference the project
142 made). Outputs refer to the products or activities that are generated as part of the co-
143 production effort that contribute towards project outcomes (i.e., outputs describe what
144 the project did) [24,25]. Overall, we found that the reviewed projects report one or more
145 of the categories of outcomes consistent with Scope 1 co-production, namely:
146 increasing utilization of knowledge in planning, deepening understanding of climate
147 issues, strengthening communities, and either directly or indirectly catalyzing adaptation
148 action (Figure 2). A majority of reviewed projects reported outcomes in terms of the first
149 three categories, with only a few projects undertaking any actions. Similar to the
150 conclusions from Bremer and Meisch [1], we observed that these different perspectives
151 often “converge, overlap, and influence” each other (p.13). Therefore, we do not attempt
152 a hard categorization of projects, but rather cover the range of reported outcomes.
153 Particularly the distinction between the ‘Utilization’ and ‘Action’ outcomes was blurry. An
154 outcome was coded as utilization if, for example, co-produced knowledge was added
155 into the text of a curriculum or an adaptation plan. The outcome was categorized as
156 action if that curriculum or adaptation plan was actually implemented or put into action.
157 Projects reported a variety of outputs that contributed to these outcomes. These
158 included peer-reviewed publications; other communication and outreach products;
159 models and decision support tools; workshops and training activities; strategies, plans
160 and policies; data and concepts; and direct adaptation interventions (see
161 Supplementary Material section 2 for details). Table 1 details the types of outcomes

162 reported in practice.



163

164 **Figure 2:** List of the types of Scope 1 outcomes reported by co-production projects, along with a brief
165 description. Note here that all categories represent Scope 1 outcomes because only 3 projects reported
166 achieving Scope 2 outcomes representing broader structural or transformative social and institutional
167 changes, and hence they could not be further sub-categorized.

Table 1: Details of the types of outcome categories with examples from the projects. In Column 2, “#” refers to the frequency of occurrence of the type of outcomes in the 21 projects reviewed. Column 3 broadly describes the types of outcomes reported in each category. Column 4 describes the most common theoretical literature referenced in projects to support each category of outcomes. Column 4 provides an illustrative example or quote of an outcome reported by the projects.

Outcome type	#	Description of Outcome Type	Relation to theory	Example or Quote on reported outcome
Scope 1: Deepening understanding	21/21	Outcomes oriented towards enabling a more holistic, integrated inclusion of non-academic and local knowledges, worldviews, experiences, and values. In some instances, outcomes were connected to particular objectives, such as generating enhanced climate simulations or scenarios [26] or better understanding local climate impacts [27], while in others it was unbounded by utilitarian concerns [28] with the outcomes geared towards prompting reflection, learning and awareness amongst participants.	Transdisciplinarity literature that argues for the importance of acknowledging the value of and integrating non-academic forms of knowledge.	Miller et al. [26] suggest that “ <i>Input from management partners at all stages of model development was critical for achieving the stated modeling objectives and allowed the research team to (1) Represent management-relevant aspects of vegetation composition, grazing, invasive species, and fire within a state-and-transition simulation model; (2) Quantitatively explore the effects of challenging and divergent climate scenarios and management alternatives on rangeland productivity and composition; (3) Ascertain important areas for further research to reduce uncertainty; and; (4) Find a balance between the abstraction and complexity of the model.</i> ” (p. 20).
Scope 1: Strengthening communities	16/21	Outcomes relate both to forming bonds that enable science-practice collaborations or foster capacity in the community itself. For example, increased abilities to identify local impacts or solutions, and changes in the trust and capacity for collaboration and research amongst participants.	Participatory Action Research (PAR) or the broader field of participation, where the engagement is valued as an end in itself rather than just a strategy to achieve other outcomes.	Kench et al [29] state that their effort: “ <i>offered an opportunity to formalize these trust relationships and the interchange of perspectives, to set boundaries, and to test the expectations and understandings of different actor</i> ” (p. 1499).
Scope 1: Utilization of knowledge in planning	14/21	Outcomes relating to the incorporation of new tools, models or knowledge in adaptation policies or plans.	Literature that describes co-production as deliberate interactions between groups of actors with the aim of improving	Jacobs et al. [31], state that: “ <i>this process {referring to the co-produced adaptation planning tool} has been introduced to a variety of operational and strategic planning contexts in NSW</i> ”

			the use and usability of knowledge (e.g., Lemos and Morehouse [4] Dilling and Lemos [30])	<i>Government including long-term strategic planning for water, marine estate and Aboriginal land management. At time of writing, for NPWS, this process has contributed to the development of a draft Adaptation Strategy...</i> (p. 214).
Scope 1: Catalyzing action	9/21	Outcomes go much beyond just incorporating the knowledge in policies and plans, and report on the implementation of these plans to generate concrete adaptation actions.	No discernible pattern in the type of literature referenced in support of this category of outcomes.	Key examples are: Joint implementation of adaptive farming practices (Bezner Kerr [32]) and Increasing the use of a planning tool that encourages decision-makers to take adaptive actions (Laudien [33]).
Scope 2 outcomes	3/21	Outcomes reported represent broader transformative or radical changes in society such as challenging traditional norms of what scientific expertise means or redistributing power dynamics among different groups within society.	No discernible pattern in the type of literature referenced in support of this category of outcomes.	Lavrillier and Gabyshev (2018) suggest that: <i>“This paper argues that the Evenki possess an environmental knowledge similar to a science: this knowledge is vast, difficult to acquire, and indispensable not only for adaptation to their environment (considered extreme by the West), but also for understanding frequent and increasing contemporary climate and environmental changes.”</i> (p.1) <i>“Indeed, we have seen that an emic science conceptualises not only the natural environment in its normal state, but also “anomalies”, “extreme events”, and the degrees of vulnerability faced by society. Therefore, Evenki emic science encourages the Western sciences to revisit the notion of “extreme” more generally and according to the viewpoints of various cultures and lifestyles.”</i> (p. 28)

Notably, only 3 projects [27,28,32] reported achieving Scope 2 outcomes i.e. more radical structural or transformative changes embedded in the theoretical promise of co-production. A noteworthy exception was the project reported by Bezner Kerr et al. [32], which indicated broader social changes, such as increasing farmers' confidence in their observational skills and challenging dominant agricultural models. They state that:

“Co-production of knowledge using participatory methods, combined with agroecological approaches that used readily available resources, may have led farmers to trust their own experimentation and informal networks more in relation to climate-change adaptation”, and “a participatory research model using agroecology can support experimentation with farming practices and increase knowledge sharing and flows, thereby challenging dominant agricultural models” (p.249).

This was also one of the few projects that engaged with the broader political context and power dynamics surrounding co-production; it reported a rare negative outcome of the process. The authors found that farmers in the project were blaming their own communities for causing changes in rainfall patterns (and climate change) due to their ongoing deforestation, thus adopting dominant narratives attributing responsibility for environmental decline to smallholder farmers. Taking this into consideration, the project team undertook efforts to develop new ways of knowledge exchange that openly discussed the political and power dimensions of climate change. In their description:

“[O]ur co-produced knowledge, while spurring change in farming practice, also reinforced unequal power dynamics in unexpected ways, as critical scholars of climate-change adaptation have noted in other sites. This realization amongst the research team has led to new efforts, both to develop effective ways to share current knowledge on climate change, that translates across cultural, gender and income divides, and to discuss more often and openly about broader political economy dynamics which themselves are implicated in climate change. At the time of writing this paper, we have developed and tested a new curriculum that integrates agroecology, nutrition, social equity and climate change, written in collaboration with smallholder farmers.” (p.249)

4. Comparing theoretical expectations to reported outcomes in practice

In comparing theoretical expectations of co-production to reported outcomes, we find insights that could help move both the theory and practice of co-production forward. For example, contemporary cases of co-produced adaptation knowledge demonstrate achievement of pragmatic outcomes (Scope 1), yet more fundamental reordering of society or science (Scope 2) are less prevalently reported than might be expected given the attention in the theoretical literature. This result suggests an opportunity for adaptation funders and practitioners, as well as co-production scholars and boundary spanners, to engage in greater dialogue between the intent and outcome of co-production and to open up to the possibility of seeking out these more extended outcomes. Furthermore, the literature reviewed here, for the most part, reports on the successful design and implementation of co-production projects geared towards Scope 1 outcomes. That is, there is no apparent discrepancy in intent and outcome reported by these projects. However, we found few projects that explicitly aimed for Scope 2 outcomes of co-production, which could explain why more Scope 1 outcomes of co-production are being reported as opposed to the broader Scope 2 ones.

Based on our review we recommend four key areas of improvement that may afford co-production practice an improved ability to demonstrate and report on the broader range of potential outcomes, including and beyond those defined by our Scope 1.

Support longer-term co-production, and diversify the types of engagement

approaches used: More than half the projects reported on successful albeit short-term co-production processes (refer Supplementary Table 2 for details). Theory suggests that larger structural changes (i.e. Scope 2 outcomes) are invariably more time intensive and deliberative than the one-off or smaller number of workshops and consultations reported [3,34–36]. While short-term events can shift participants' perspectives and are reported by the projects as sufficient for achieving specific Scope 1 outcomes [8,37,38], these changes may not be sustainable and may not push the boundaries of current systems [19]. Although we were not able to ascertain whether the short-term nature of

current co-production efforts are merely a reflection of funding constraints or an assumption that sufficient outcomes have been achieved, in-line with the literature, we argue that more regular or extended periods of engagement may be required for scope 2 co-production [37–39].

Relatedly, despite diverse intentions or motivations, more than half the projects undertook co-production through workshops or consultations. Notably, 3 of the projects that reported on utilizing novel approaches (such as longitudinal analyses, collaborative fieldwork, or developing a joint research partnership), also reported on slightly broader structural Scope 2 outcomes [27,28,32] such as challenging dominant notions of scientific expertise (refer Supplementary Table 2 for details). This suggests that more diverse, and in some cases more intensive, engagement practices may be needed to broaden and deepen the scope of co-production outcomes.

Use co-production to ask fundamental questions in addition to science

translation or value-add of existing science: Only 6 projects reported on producing new understandings in the sense of discovery-oriented, or basic, research (Supplementary Table 2). Most other projects focused on translating or enhancing (value-adding) existing science so that it can be applied in practice. While retaining focus on applied science is essential, this should not limit the use co-production from helping to answer fundamental science questions. This prevalent focus on application is perhaps closely linked with the length and type of engagement the projects undertook [34]. Five out of the six projects that focused on fundamental science questions, undertook novel methods of engagement, and four were long-term efforts (Supplementary Material 2). These longer projects stood out in our review as exemplary uses of co-production to develop new science. Conversely, projects using shorter-term workshop-like engagements, not surprisingly, reported on outcomes relating to better translation or value-add to existing knowledge which are more tangible outcomes to expect from such engagements.

Increase collaborative framing and designing of projects: Literature suggests that co-production in adaptation needs to start with co-defining the problem space [18,39,40]. In contrast, although the reviewed co-production projects exhibited a

collaborative, participatory approach to implementation, they often took place within pre-identified problem spaces and larger research agendas. Only 6 of the 21 projects that we reviewed explicitly co-defined the aim and focus of the research (refer Supplementary Table 2 for details). When project goals and frames are established before the co-production commences, it can render the problem space and project design immutable [34] (see also Turnhout et al in this issue). This could limit the capacity of co-production to engage with more radical structural changes. i.e. Scope 2 outcomes.

Increase evaluation of outcomes: The lack of rigorous methods to evaluate incremental co-production outcomes in adaptation or newly formed relationships among agencies or other stakeholders makes it difficult to ascertain whether broader changes may have occurred. Fifteen of the 21 projects we reviewed, did not report on monitoring or evaluating co-production outcomes. Hence validating outcomes reported by the participants of co-production can be difficult, and there may be greater opportunity for learning if participants commit to critical, reflexive evaluation as a part of their co-production practice [41,42]. Improved evaluation using both qualitative and quantitative methods would support meaningful and more consistent analyses, and pave a way forward for future co-production efforts [43].

5. Can we expect more from the co-production practice?

While our review points to a few areas where practice could be improved to incorporate more ambitious outcomes, some questions remain unanswered. First, it is unclear whether the more pragmatic aims of co-production projects can be viewed as intermediary benefits on the path towards more radical goals. After all, one perspective suggests that co-production is never confined to just a science project as it constantly engages in re-ordering social relations and practices [16]. Some may also argue that helping societies to adapt to climate change contributes to some amount of societal change. Yet, the temporal and funding constraints of projects can make it much harder

to identify, measure and document Scope 2 outcomes which are often long-term changes. Further, it is even tougher to ascertain the relationship between any one project and large-scale structural changes (contribution/attribution problem). Hence many researchers may not be comfortable in explicitly making ‘big claims’ that their project led to transformative social or institutional changes¹.

Secondly, we also consider whether many such Scope 1 outcomes (from the increasing number of co-production projects across the world), when analyzed cumulatively, present the level of intensity that can push more transformative societal changes. It could be argued that the very proliferation of this approach to doing research is, in itself, indicative of broader, more transformative changes in the way that science is practiced, irrespective of whether the projects themselves focus on Scope 1 or 2 outcomes. This leads us to also consider whether we should expect to see such radical outcomes or even intentions at a project level (our unit of analysis), as opposed to larger institutional level (e.g. at a program level) [8].

Finally, we also consider carefully the growing literature on an alternative perspective that argues that this pragmatic project-based Scope 1 focus may take away from, or even undermine, the more radical possibilities of co-production [22]. In this issue, Turnhout et al. argue that although it may be difficult to do so, confining co-production to project boundaries without engaging the wider political context within which projects are embedded, can limit or even hinder transformation by replicating existing power differences. This begs another question of whether more should be expected of co-production practice, especially at a project level, with respect to more radical outcomes that can sustain a new social contract between science and society.

6. Conclusions

All instances of co-production catalyze some form of outcome, but these outcomes can vary widely in their extent and nature. This paper compares theory and practice to help understand more precisely what is generated through the contemporary practice of co-

¹ We thank our anonymous peer reviewer for drawing our attention to this point.

produced climate change adaptation research. From how co-production is described in theory, we categorize two general scopes of ambition: the more pragmatic Scope 1 that generates actionable knowledge and the more radical aim of Scope 2 to transform norms and structures within science and society. We find that the contemporary co-production practice is successful in realizing improvements in deepening understanding, strengthening community, and knowledge utilization, among other beneficial outcomes most associated with Scope 1. However, there may be opportunities to expand beyond the ambition apparent in its current focus to include the more radical intentions embedded within Scope 2. While we suggest ways to improve and expand the current practice, questions still remain regarding the relationship between the two scopes. For example, in analyzing dozens of co-production projects reported as case studies, we question the suitability of the project as a unit of analysis for understanding the outcomes of co-production. We propose that to realize the full potential of co-production in support of climate change adaptation, a more transparent, conversant, and interactive analysis of co-production efforts is required. Our analysis here finds that there is a need to start acknowledging the prevalent (though successful) focus on Scope 1 outcomes and the limited engagement approaches used in co-production projects. Moving forward, we argue for a more critical analysis and reporting of individual efforts to understand what they are intending and are not intending to do, how they are doing it, and what they are and are not achieving.

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