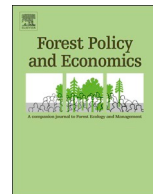




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Crossing the science-policy interface: Lessons from a research project on Brazil nut management in Peru

Luisa F. Ramirez*, Brian M. Belcher

College of Interdisciplinary Studies, Royal Roads University, Victoria, BC, Canada

ABSTRACT

There are high expectations for contemporary forestry research, and sustainability research more broadly, to have impact in the form of improved institutions, policy and practice and improved social and environmental conditions. As part of this trend, there has been an evolution of research approaches that move beyond isolated, reductionist, disciplinary science toward approaches that integrate disciplines (interdisciplinary) and that engage a wider range of research stakeholders (transdisciplinary) as a way to be more effective. While these approaches evolve, there are good opportunities to learn from the experience of projects that have had impact at some level. This paper presents lessons from a case-study of a research project that succeeded in crossing the science-policy interface. Our study characterizes the design and implementation of a research project on the influence of timber harvesting on Brazil nut production using transdisciplinary research (TDR) design principles, and empirically assesses project outputs and outcomes in relation to a project theory of change (ToC) based on document review and key informant interviews. The Brazil Nut Project included some TDR elements and realized a substantial part of its ToC. The interviews identified mixed perceptions of the research design, implementation and the extent of outcomes achievement from different stakeholder perspectives. Our analysis suggests that limited stakeholder engagement was a crucial factor affecting perceptions of legitimacy and relevance, the two main TDR principles underpinning the overall research effectiveness in our study. The application of the TDR analytical framework indicates substantial scope to improve research effectiveness, even without striving for a TDR theoretical ideal.

1. Introduction

Society, research funders and researchers themselves are raising expectations about the impact of research. Contemporary sustainability research is expected to contribute demonstrably to improved institutions, policy and practice, and ultimately to improved social and environmental conditions. While there is still a need for basic, curiosity-driven research, there are pressing social and environmental problems and threats that need attention and science-based knowledge to help solve them. However, it is well recognized that scientific knowledge is rarely sufficient to generate change (Cash et al., 2003; Kropp & Wagner, 2010; Van Kerkhoff & Lebel, 2006); scientific knowledge represents only one of many inputs to policy making (Pielke, 2008).

Indeed, the disconnect between science and policy is an issue of concern and discussion in many fields (Koch, 2018; Krott, 2005; Maryudi et al., 2018; Ramirez & Belcher, forthcoming; Salomaa et al., 2016). In forestry, recent conferences and special issues of journals (e.g., *Forest Policy and Economics* 16, 89 and 91) have focused on this subject. To effectively address sustainability problems, disciplinary forestry research approaches have become more interdisciplinary, integrating social and biophysical sciences (Maryudi et al., 2018). Effort has increased to integrate forestry science in policy making, with greater attention to mechanisms and processes of forest policy

formulation, communication, policy change (Böcher, 2016; Van Kerkhoff & Lebel, 2006) and knowledge translation, such as the role of boundary organizations to facilitate the science-policy interface (Hoppe, 2010; van Enst et al., 2016). Much of this work has called attention to the need for empirical research to learn how different contextual characteristics, actors and organizations interact and shape the integration of science in forestry policy (Hoppe, 2010; van Enst et al., 2016). Such research offers a more comprehensive view of the complexity of the social-ecological interactions that underpin forestry sustainability.

Acknowledging the complexity of sustainability challenges has led to innovative approaches to produce scientific knowledge (see: Clark et al., 2016; Lang et al., 2012) that cross disciplinary boundaries (Hirsch Hadorn et al., 2006) and incorporate strategies to facilitate the use of knowledge in policy and practice (see: Mauser et al., 2013). For example, sustainability science focuses on understanding the complex interactions between nature and society (Clark & Dickson, 2003). A recent special issue in *Frontiers in Ecology and the Environment* (Volume 15, Issue 10, December 2017) explores developments in “translational ecology”, adding to numerous other efforts to engage non-academic actors in the research process. Also known as transdisciplinary research (TDR), such approaches aim to integrate different types of knowledge, values and interests to improve the quality and the usability of

* Corresponding author at: Royal Roads University, 2005 Sooke Rd., Victoria, BC V9B 5Y2, Canada.

E-mail address: Luisa.Ramirez@royalroads.ca (L.F. Ramirez).

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knowledge (Jahn, 2008). They also focus on the integration of knowledge from different disciplines and are context-based (Bergmann et al., 2005). TDR approaches are intended to facilitate the co-production of knowledge, which lead to shared understandings of problems and their solutions (Clark et al., 2016; Lang et al., 2012). The key idea is that multi-directional, iterative communication is needed to produce actionable information that gets used to inform decisions (Böcher, 2016; Kirchhoff et al., 2013; Lemos & Morehouse, 2005).

However, while the aims and intentions of TDR approaches are laudable, its practice is more complex than traditional disciplinary research, with additional time and other costs. For example, traditional research funding mechanisms, methodologies and evaluation tools are not well suited, and conventionally trained disciplinary scientists may not have the necessary skills and capacity to effectively employ transdisciplinary approaches (Belcher et al., 2016; Willetts & Mitchell, 2016). Additionally, while there is considerable theoretical support for TDR, it remains to be proven that TDR approaches actually result in better outcomes.

In the meantime, as the theory around TDR, sustainability science, translational ecology and other related approaches develops, there is emerging experience in practise as researchers endeavour to incorporate improved engagement and communication into research projects.

This paper presents a case study of a conventional disciplinary scientific research project that deliberately aimed to influence forestry regulations related to timber harvesting and Brazil nut production in the Peruvian Amazon and which succeeded in crossing the science-policy interface. We analyze the case study through a transdisciplinary lens, assessing the way the project applied TDR principles in its implementation and the degree to which it achieved its intended outcomes.

This case was selected because: 1. there were clear indications that the research had informed the new national Forest Policy in Peru; and 2. the research design involved some elements of good practice according to TDR theory (e.g., deliberate engagement/outreach strategies). Through a theory-based evaluation and exploration of the relationship between research implementation and outcomes, we identify opportunities to improve sustainability research effectiveness.

We begin with a brief description of the Brazil Nut Project (BNP). The methods section describes the two-part analytical framework and the data and analyses used to: 1. characterize the BNP research design and implementation; and 2. assess the outcomes of that research. This complementary two-part analysis provides the opportunity to examine the relationship between research design and outcomes achievement. The results and analysis are presented in two subsections; first, research design and implementation are analyzed in the light of the transdisciplinary research quality criteria, and second, we present the research outcome evaluation. In the discussion and conclusion section, we draw lessons from the case study for designing and implementing effective research and reflect on the use of the assessment tools.

2. Case study

The Center for International Forestry Research (CIFOR) conducted research between 2012 and 2015 to assess the impact on Brazil nut production of timber harvesting in Brazil nut concessions (Rockwell et al., 2015). The BNP aimed to provide science-based evidence to inform and enable multi-use forest management. There were strong indications that the research did inform the policy discourse in Peru, and the research findings are footnoted in the relevant technical guidelines of the Peruvian National Forest Policy. It was therefore selected for our analysis as a good case in which to explore the mechanisms and design elements that may have contributed to research knowledge being used in a policy context.

Brazil nut (*Bertholletia excelsa*) is one of the most important non-timber forest products (NTFPs) in Peru and across the Amazon Basin (Guariguata et al., 2017). Brazil nut trees grow in mixed forests,

alongside commercially valuable timber species. In Peru, Brazil nut harvesting is predominantly managed in 40-year concessions operated by families. Brazil nut production contributes to the annual income of approximately one-third of the population in the Department of Madre de Dios (Peru) (Hodgdon & Martinez, 2015).

In 2004, a timber harvesting quota of 5 m³/ha of species other than Brazil nut was authorized as a complementary activity in Brazil nut concessions located outside protected areas. This quota did not have a scientific basis (Cossio-Solano et al., 2011). An analysis of timber harvesting intensities in Brazil nut concessions conducted by CIFOR between 2004 and 2010 indicated that timber harvesting had been higher in Brazil nut concessions (3.19–3.81 m³/ha/year on average) than in concessions exclusively dedicated to timber extraction (1.05–3.48 m³/ha/year) (Cossio-Solano et al., 2011). These findings raised concerns among some Brazil nut harvesters and conservation-oriented non-governmental organizations (NGOs) about potential damage and ecological risks that timber harvesting could have for the sustainability of Brazil nut production.

The BNP therefore set out to answer the question: “To what extent is Brazil nut production at the individual level affected in a logged forest landscape?” (Rockwell et al., 2015, p. 3). The research was conducted in the Department of Madre de Dios (Peruvian Amazon). It used a quasi-experimental design that entailed mapping existing productive Brazil nut trees ($n = 499$), logging gaps (≤ 5 years old) and distance to nearest productive Brazil nut trees in five concessions covering 4000 ha of forest. The field work, conducted from January to April 2012 and January to April 2013, involved concessionaires from the five concessions and ten students from the forestry engineer program at Universidad Nacional de Madre de Dios.

The BNP findings suggest that Brazil nut production at the level of the individual tree is not affected when timber extraction takes place at least 100 m from the nearest productive Brazil nut tree and when logging intensities are below 1–2 trees/ha (Rockwell et al., 2015). Although the research does not specify the recommended timber extraction frequency, timber harvesting plans in the region are approved annually.

The project intended to provide scientific information to policy makers and forest managers. The research was done in the context of a new national forestry law that was passed in 2011. The technical guidelines for Brazil nut concessions under the new law were drafted between 2015 and 2016, coinciding with the release of the scientific findings of the BNP. A first version of the technical guidelines, approved February 1, 2016, cited the BNP and directly adopted the project recommendations. However, a modified version of the technical guidelines approved on July 25, 2016 reverted to the previous unscientific timber harvesting quota of 5 m³/ha. The BNP research recommendation was maintained only as a footnote.

3. Methods

3.1. Characterizing the research from a transdisciplinary perspective

We used the Transdisciplinary Research Quality Assessment Framework (TDR QAF) developed by Belcher et al. (2016) to characterize the design and implementation of the BNP. The TDR QAF provides a set of criteria (Table 1), organized under the principles of relevance, credibility, legitimacy and effectiveness, that are theoretically required in good quality transdisciplinary research. The full set of criteria definitions can be found in Belcher et al. (2016).

We recognize that the BNP project was not intended or designed deliberately as a TDR project and our analysis is not intended to judge the project against a TDR ideal. Rather, we use the principles and criteria of the QAF descriptively, as a convenient checklist to review the range of activities and the way they were carried out in the BNP as a part of understanding how and why the work did or did not succeed in contributing to individual outcomes.

Table 1
Transdisciplinary research quality assessment framework.

Relevance:	Credibility	Legitimacy	Effectiveness
<ul style="list-style-type: none"> ● Clearly defined socio-ecological context ● Socially relevant research problem ● Engagement with problem context ● Explicit theory of change ● Relevant research objectives and design ● Appropriate project implementation ● Effective communication 	<ul style="list-style-type: none"> ● Broad preparation ● Clear research problem definition ● Objectives stated and met ● Feasible research project ● Adequate Competencies ● Research approach fits purpose ● Appropriate methods ● Clearly presented argument ● Transferability/Generalizability of research findings ● Limitations stated ● Ongoing monitoring and reflexivity 	<ul style="list-style-type: none"> ● Disclosure of perspective ● Effective collaboration ● Genuine and explicit inclusion ● Research is ethical 	<ul style="list-style-type: none"> ● Research builds social capacity ● Contribution to knowledge ● Practical application ● Significant outcome

Table 2
Interview participants.

Stakeholder group	Interview participant affiliation	Number of interviews
NGOs	NGOs	8
Researchers	Research Institute IIAP	1
	Researchers from other organizations	2
	University professor	1
	Student involved in the research field activities	1
Government	Regional government	3
	National government	2
Resource users	Brazil nut concessionaires	2
	Leaders from Brazil nut concessionaires	2
	<i>Regentes</i>	2
	Illegal logger	1

3.2. Data collection

Data were collected through document review and semi-structured interviews with key informants. Documents used included research reports for project funders, project outputs, emails, meeting minutes, meeting invitations, presentations, websites and government documents, among others. A first set of key informants was identified by the evaluation team and the lead researcher from the BNP. Additional informants were identified through snowballing when doing interviews in the cities of Lima and Puerto Maldonado, Peru, between December 4 to 21, 2016. Respondents ($n = 24$) (Table 2) included representatives from NGOs working in the region, research institutes, regional government, national government, concessionaires, leaders from Brazil nut associations and *Regentes*.¹

All but two interviews were audio-recorded (with participants' approval) and transcribed. Each interview, lasting between 45 and 60 min in duration, was conducted by two evaluation team members. The interview process started with closed questions related to the interviewees' backgrounds and association with the Brazil nut topic, followed by broad questions about Brazil nut management and policy processes, relevant knowledge needs and knowledge sources and ended with specific questions about the BNP and its findings and recommendations.

This research had ethical approval from Royal Roads University. Research participants were informed about the objectives of the research and the use of the information collected. Quotations from participants are used with their consent.

¹ *Regentes* are licensed professionals in the forestry field with training and professional experience in the formulation of management plans and operational plans, which are authorized to elaborate management plans for concessionaires and other clients.

3.3. Data analysis

Scoring against the QAF criteria was done by four expert reviewers based on information from the document review and interviews. QAF scoring was performed with reference to the BNP's intended purpose, defined by the intent to contribute to improving sustainable multi-use management of Brazil nut concessions through the integration of Brazil nut and selective timber harvesting. A content analysis approach was applied. Interview fragments that implicitly or explicitly referred to any of the QAF criteria and principles (Table 1) were coded in NVivo and used to define scores for each of the QAF criteria. The scores were assigned using a scale from 0 to 2. A zero value was used when there was no evidence that a criterion was considered or addressed; a value of one was given when a criterion was partially but incompletely satisfied; and a value of two was assigned when a criterion was fully satisfied.

3.4. Outcome evaluation

The outcome evaluation assesses whether and how the BNP influenced policy and practice. Research evaluations of this kind build on advances in program evaluation that have been designed to deal with complex systems in which an intervention is one of many causal factors and which aim to enhance learning (as opposed to accountability). A Theory of Change (ToC) is often used as an analytical framework in theory-based evaluation approaches (e.g., Realist Evaluation (Pawson & Tilley, 1997), Outcome Mapping (Earl et al., 2001), Contribution Analysis (Mayne, 2008), Outcome Harvestings (Wilson-Grau & Britt, 2012) and the RAPID Outcome Assessment method (Overseas Development Institute (ODI), 2012), among others). A ToC is a model of the causal relationships between a project's activities (the interventions) and results, with attention to the primary pathways and assumptions about how the research is expected to contribute to a change process and what are the key actors and steps in the change process. It sets out testable hypotheses of a change process by working back from long-term goals to identify the conditions that theoretically must be in place for the goals to occur. It is then possible to identify and seek the necessary evidence to assess actual achievements against expected outcomes at each stage of the ToC. Belcher et al. (2017) combined and adapted these approaches for application in a research-for-development context. In the current study, we followed this approach to:

3.5. Document the project theory of change

This was done as a participatory activity in a two day workshop with one of the two lead researchers of the project and the evaluation team in Lima, Peru, from November 28 to 29, 2016. The ToC was documented as a flow-chart illustrating the research activities, outputs and multiple-levels of outcomes, as well as assumptions about the underlying mechanisms of change.

3.6. Identify data needs and data sources

The outcome evaluation tests whether or not each stage in the ToC occurred as hypothesized. We constructed an evidence table that lists each step in the ToC, indicates data needed to prove or disprove each step and lists potential data sources.

3.7. Data collection

Information was gathered through semi-structured interviews and document analysis as described in the TDR QAF. See previous subsection for details.

3.8. Data analysis

Information collected through document review and interviews was deductively coded according to the project's ToC steps and documented in the evidence table (see Appendix B). This table provided the basis for the analysis to assess whether or not each outcome in the ToC was achieved and if the causal logic was sound.

4. Results and analysis

4.1. Assessment of TDR quality criteria in the Brazil Nut Project

In this section we apply the TDR criteria (Fig. 1, Appendix A) to characterize research design and implementation and assess research quality.

Relevance: Relevance refers to the perceived value and usefulness of

the research outside of academia (Table 1), which is strongly determined by the way research is conducted, such as the breadth of project preparation, research execution and dissemination of the findings (Belcher et al., 2016). All the criteria linked to the relevance principle were addressed to some extent (Fig. 1a; see Appendix A for details), with an average score of 64%.

The document review and interviews indicated a comprehensive consideration of the social-ecological context of the research problem. For instance, the research design was based on previous research conducted by CIFOR in 2011 and a pilot assessment in 2012. As a part of the research planning, meetings were held in two villages and also with the associations of Brazil nut concessionaires, NGOs and students from the local university. These meetings aimed to raise awareness of the project, gain local support and learn concessionaires' perceptions of the costs and benefits of logging and other factors affecting Brazil nut production.

This approach to research design helped the researchers to define and describe the context in detail. As a result, social (e.g., importance of Brazil nut harvesting as livelihood), ecological (e.g., ecological importance of Brazil nut), and logistic aspects of the research context (e.g., access to concessions and field assistants' security) were considered in the research problem definition and implementation.

Regarding the social relevance of the research problem, interviews with key informants indicated that stakeholders appeared to agree that the research topic, in principle, was relevant. However, as the following quotation suggests, the research question was defined without concessionaires' input: "it was CIFOR that started the topic of the variation in [Brazil nut] production and we thought it was important..." (Asoc2). Yet, the research answered a question that, according to participants

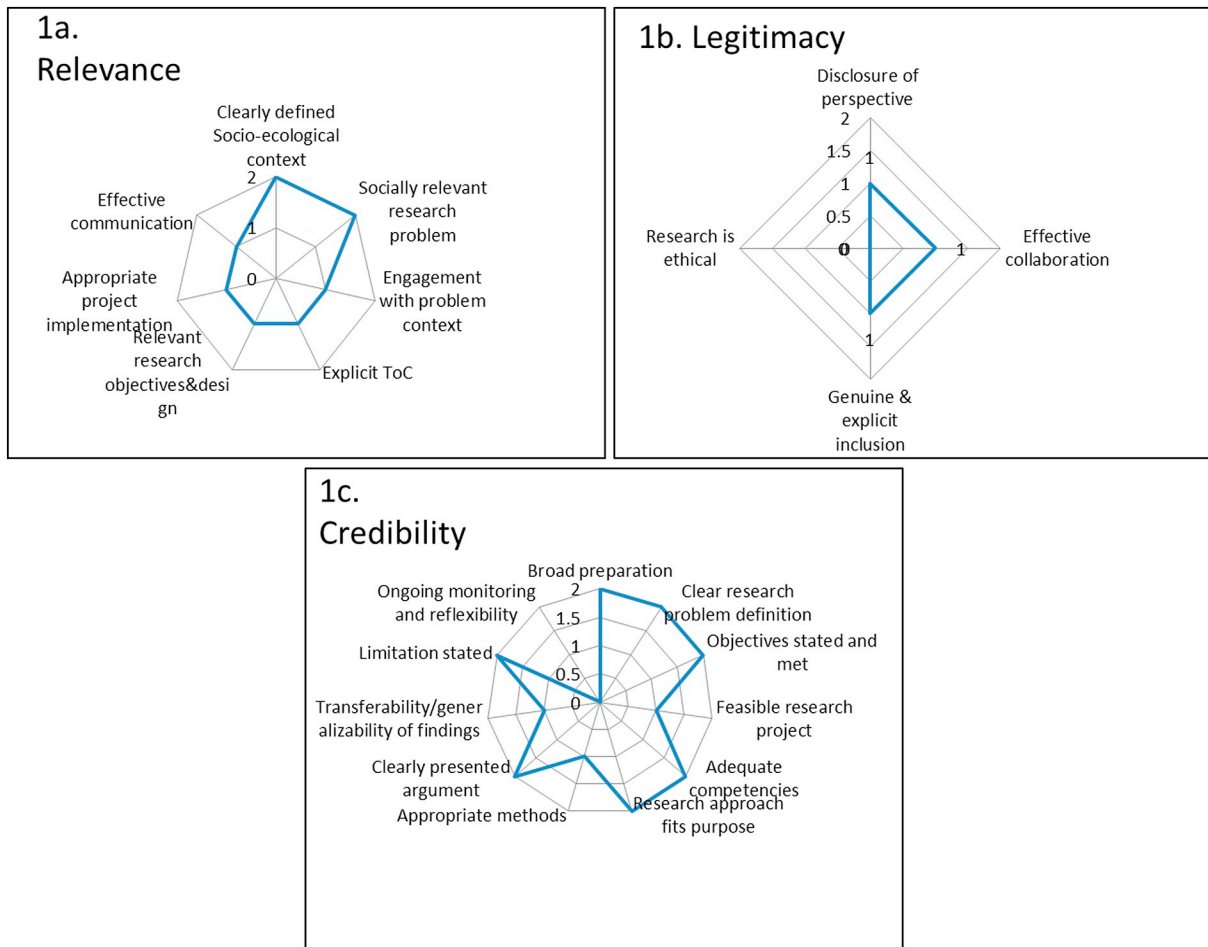


Fig. 1. Results of the scoring of the TDR QAF criteria for the Brazil Nut Project case.

from NGOs with long experience in the region (one focused on environmental law aspects and the other on conservation issues), “was required to inform timber extraction management actions in Brazil nut concessions” (NGO9) and to know “if both activities [Brazil nut production and timber harvesting] are compatible” (NGO3).

Regional actors (government, NGOs, concessionaires, and *Regentes*) identified numerous factors in addition to timber extraction that may affect Brazil nut production (e.g., climate change, lack of regeneration, nutrients in the soil, age of the trees, productivity and forest fragmentation, among others). Thus, research focused on understanding and managing those aspects of Brazil nut production might have been considered more relevant by those stakeholders. Other research themes identified by participants as relevant were learning about aspects of governance and the concessionaires' organization capacity (Researcher2, NGO9, Gov4).

Research planning and implementation did include efforts to engage Brazil nut concessionaires in workshops, meetings and research activities. The researchers also started communications with concessionaires at the beginning of the project and conducted meetings to share preliminary findings. However, this reached only a small proportion of Brazil nut concessionaires in the region. The project funding was cut half way through the research which, according to the researchers, limited stakeholder engagement and dissemination opportunities. Other limitations for engagement and dissemination can be linked to aspects of the research design. For instance, as pointed out by one respondent, the communication of findings “was looked at as an action instead of a process” (NGO4), limiting opportunities for meaningful stakeholder engagement. Other interviewees noted the difficulty to communicate scientific information to non-academic audiences and local capacity limitations (e.g., literacy and organization) (NGO4, NGO7). The project used several strategies to disseminate results, including a seminar held in the region, international conferences, a peer-reviewed publication, an Infobrief (a popular summary of the key findings and recommendations) in Spanish, blogs and videos. Findings were also shared and discussed in a face-to-face meeting with officers from the Peruvian National Forestry Service (SERFOR) in Lima in September 2015. The direct connection with policy makers was critical to inform the first version of the Brazil nut management guidelines.

The interviews and document review confirm that these communication efforts did reach a diverse set of actors at the beginning and during the data collection stages. However, some key actors felt that there was insufficient dissemination and discussion of final results with stakeholders (Gov1, Gov2, Gov3, Gov4, NGO3, NGO8, Reg1, Reg2). Although outreach activities were affected by an interruption of the research funding, most of the project engagement and communication strategies were focused on policy makers and academia.

In summary, despite efforts to identify and engage key actors and communicate the findings, the research's assumption based on a mainly rational approach to inform policy, coupled with a funding cut that restricted opportunities for outreach, limited the influence of the research.

Credibility: Credibility refers to whether or not the research findings are robust and the knowledge produced is scientifically trustworthy (Belcher et al., 2016, p. 8). The TDR QAF includes 11 criteria related to research credibility. As indicated in Fig. 1c, most of these criteria were addressed to some extent in the BNP. Criteria such as clear definition of the research problem, objectives stated and met, and adequate competencies were fully satisfied. The researchers built on the multiple use forest management literature to help identify the research problem and define the objectives. As such, the research recognizes “the complex nature of diversified livelihood strategies and the importance of looking beyond timber production as the only management objective” (Rockwell et al., 2015, p. 2). Based on their literature review, the researchers identified that, although the integration of Brazil nut and selective timber extraction had been studied, research evaluating Brazil nut production in selectively logged forest had not been undertaken

(Rockwell et al., 2015). Thus, the research problem was identified as a knowledge gap and the research objective was clearly stated and met (see Appendix A for details). Statements from academic interviewees (a professor and students from the local university) confirm the skills and competency of researchers to undertake the research (Appendix A).

The methods used in the research are well described and validated in the peer reviewed publication (Rockwell et al., 2015). Yet, there were several statements from different actors, including government representatives, NGOs and concessionaires, which indicate doubts about whether or not the methods fit the purpose. The main methodological concerns, as perceived by non-academic actors, were that the sample size and the sampling period limit the representativeness of the research (see Appendix A) for complementary information.

Information provided in the scientific publication suggests a broad preparation. The research was supported by a strong conceptual understanding of smallholders and multi-use management relevant to the context of the Brazil nut concessions. There is no evidence, however, that the project incorporated an inter-disciplinary approach that might have considered a broader range of Brazil nut management issues and policy processes. Given the intended application of the research, a review of policy making process and aspects of management would have been useful to enhance the achievement of the research outcomes. As suggested by one participant, a broader approach could have helped understand historical aspects of Brazil nut harvesting and timber extraction practices, which are important to characterize the system and provide better understanding of governance systems that resource users have developed based on their needs and the market dynamic.

The analysis also shows that, although the project funding was sufficient to accomplish the main research objective, the funding cut reduced the project's capacity to deal with challenges and adapt to changes. This reduced the ability of the project to, for example, identify and engage with a broader range of stakeholders (such as *Regentes*) and to share research results and recommendations widely.

Another key criterion for research credibility is the clarity of the argument and the consistency between the analysis and interpretation of findings and conclusions. By traditional scientific standards, the research provides a sound analysis and interpretation of data and the conclusions are well justified (see: Rockwell et al., 2015). Some interviewees, however, were less convinced due to perceived limitations in the representativeness of the sample, the lack of consideration of other factors that may affect Brazil nut production and the fact that reduced Brazil nut production has been also reported in concessions without timber extraction (Appendix A).

The researchers explicitly discussed the research limitations in the publication (Rockwell et al., 2015) and limitations related to the process through which the project intended to achieve the research outcomes (e.g., comprehensive identification and inclusion of key stakeholders, effective communication strategies) were also identified and discussed during the workshop to document the project's ToC.

The project's credibility score is relatively high (77%). The BNP used accepted scientific methods and was vetted through scientific peer review. Yet, some stakeholders expressed concerns about research design (small sample size and short sampling period) and interpretation of results, which affected their perception of the research's credibility. This highlights the difficult challenge in science communications of managing the different ways that various stakeholders use to validate knowledge claims. Non-scientists may not understand or may not trust scientific processes for a variety of reasons.

Legitimacy: Legitimacy refers to the perception of fairness through which research is conducted (Table 1) and how it takes into account actors' values, concerns and perspectives (Belcher et al., 2016; Cash et al., 2002). Fig. 1b shows that although almost all the criteria associated with legitimacy were addressed to a degree, none of the criteria were fully satisfied. The overall legitimacy score is low at 38%.

For instance, while reference to aspects of the disclosure of perspective such as funding source and research assumptions are

acknowledged in academic publications and project reports, some resource users suggested that the researchers have “hidden interests” (Appendix A), which indicates that the researchers' perspective was not sufficiently clear for all actors.

Similarly, one of the concessionaires identified the association of concessionaires as the most important and trustworthy source of knowledge and, as illustrated in the following quotation, expressed doubts relating to a lack of transparency in research.

“Well, there were some projects [...] several NGOs [any non-governmental organization conducting research or implementing projects] but we don't really know what they say [...] what their objective is. [...] How much money did the project receive? Sometimes the project lasts 9 months or 1 year and when it finishes they disappear.” (Con2).

Another aspect that might have affected the perceived legitimacy pertains to the objectives. Although the objectives of the study were shared widely, it was not explained to participants that the research aimed to inform policy and that the research findings would be targeted toward policy makers. This was indicated by a concessionaire's answer to the question of how the research results influenced the technical guidelines:

“We couldn't really find that out [what happened]. I don't know if the State requested that information; maybe in those cases [it does], to regulate” (Con2).

The criterion related to research ethics scored a zero only because there was no formal ethical review conducted as specified by the assessment criterion. There is no suggestion that the research was unethical; it simply calls attention to the need for an explicit ethical review of data collection, management and reporting.²

The deliberate inclusion of and collaborative work with five concessionaires and ten undergraduate forestry students during the field work were crucial for the successful implementation of the research. This approach contributed substantially to the achievement of key aspects of research effectiveness (i.e., building social capacity, contribution to knowledge); however, the data indicate that other actors with a crucial role in the management of Brazil nut concessions (e.g., regional authorities dealing with timber extraction and Brazil nut harvesting permits and rules enforcement, regional NGOs and *Regentes*) were not included in the research process. This, as well as the relatively small number of concessionaires ($n = 5$) that volunteered to participate (notwithstanding deliberate recruitment efforts), limited the legitimacy of the research as perceived by those actors.

Interviews with government participants indicate that policy making is based on knowledge from different sources such as: “Research, working committees, meetings; everything is welcomed” (Gov5). Referring to the use of the research findings, one participant said: “scientific evidence is important. It will be predominant in the mid and long term. [For now] what prevails is a gradual process without abrupt changes” (Gov5). The informant justifies the modification of the technical guidelines where the research findings were only acknowledged in a footnote and the previous timber extraction quota (5m³/ha) was maintained. This point underscores the importance of stakeholder participation and acceptance of research findings for research uptake in policy making. Thus, in the case of the BNP, legitimacy is a critical attribute of research that influences whether or not policy makers use research-based knowledge in decision making.

Effectiveness: Research effectiveness means that research generates knowledge and stimulates actions that address the problem and contribute to solutions and innovations. Research effectiveness may be assessed *ex ante*, in terms of potential to drive or contribute to change, or *ex post*, as a measure of realized change. As our study includes an empirical outcome assessment, we will discuss the effectiveness principle below.

4.2. Outcome evaluation

4.2.1. The theory of change of the Brazil Nut Project

The BNP addresses the challenge of optimizing multi-use forest management. In addition to informing Brazil nut concession management, it was intended that the work would support the development of sustainable multi-use forest management and would help facilitate a paradigm shift toward a holistic, social-ecological system-based management approach. The research was expected to contribute to popularizing multi-use management in Latin America by providing an impetus for further scientific investigation in the region. At the same time, it was intended that concessionaires would be empowered by the influence of scientifically-informed multi-use management, enabling them to benefit more from their concessions, leading to better livelihood outcomes. The project was expected to contribute to the following end-of-project outcomes:

1. The Amazonian research community use the study to inform ongoing research and enhance their influence on multi-use management beyond Peru;
2. National policy makers take findings into account when drafting management guidelines;
3. Regional policy makers are supportive of the findings and uphold their implementation locally; and
4. Enforcement officers are informed and understand findings and ensure management plans are technically sound.

Two main interconnected impact pathways were defined:

1. An academic pathway that informs and influences research-for-development agendas around multi-use management in the Amazon region. This pathway uses standard academic mechanisms and existing research and donor networks, along with targeted dissemination and engagement activities to increase knowledge uptake.
2. A policy pathway that intends to shape policy agendas to include project results in management guidelines at local, regional and national levels. The policy pathway is navigated through engagement with allies in an advocacy coalition to equip decision makers.

Finally, the project's ToC was based on the following three main assumptions:

1. Governments are interested in using scientific evidence to inform policy.
2. The project design involved stakeholders appropriately and sufficiently for knowledge translation. This implies that the right actors are engaged, the research is perceived to be legitimate, and results are presented in appropriate language/units and are accessible to intended users.
3. Policy pathways are sufficient to influence concessionaires practice.

4.2.2. Achievement of outcomes

Fig. 2 shows the anticipated project outcomes and how the research team expected their project outputs and activities to help achieve the outcomes. As illustrated in Fig. 3, most of the intermediate outcomes were achieved (see Appendix B for details). Outcomes in the ToC are linked either to policy or academic pathways according to the target group and type of objective pursued. With respect to the academic pathway, the analysis indicates that the research succeeded in creating awareness, providing base-line information for international researchers and donors, building technical capacity (training students and concessionaires directly involved) and informing the national forestry policy (management guidelines). Students improved their research skills and learned firsthand from concessionaires about Brazil nut management and acquired expertise in the topic. The interaction

² CIFOR now has an explicit ethical review process in place for all research.

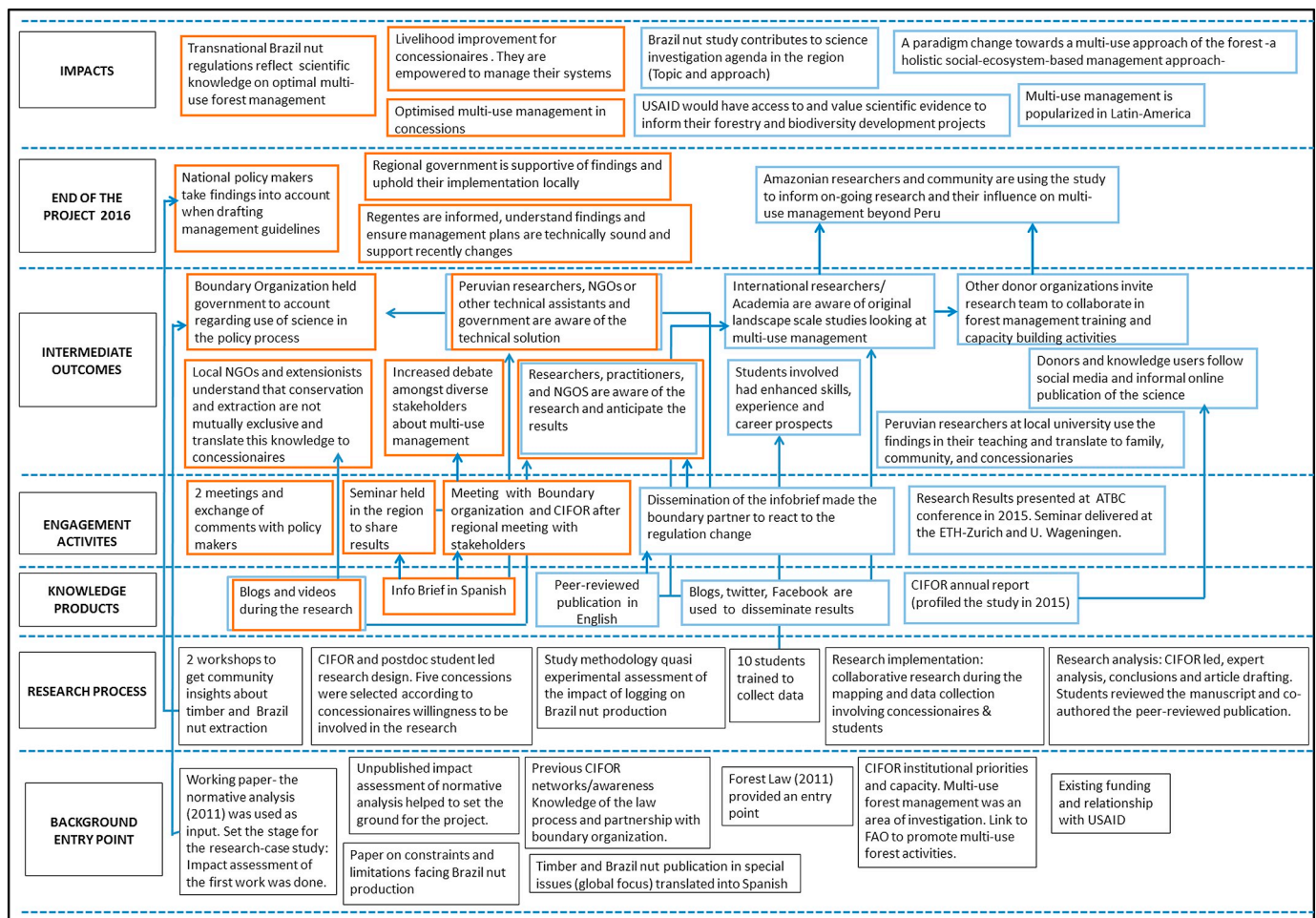


Fig. 2. Theory of Change for the Brazil Nut Project case. (Orange boxes are related to the policy pathway and blue boxes to the academic pathway, the presence of the two colours means that the outcome belongs to the two pathways). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

between concessionaires, students and researchers fostered mutual trust and empathy (Stud1, Con2).

The evidence shows that the project successfully engaged with the boundary partner³ in the policy pathway. The boundary partner recognized the relevance of the research findings for informing forestry policy and became an advocate for science-based approaches for the design of forestry policy (Appendix B). Yet, the intervention of the boundary partner occurred only when the management guidelines were in the process of being modified.

Intermediate outcomes related to improved awareness and understanding by the regional government, NGOs and practitioners about the implications of combining conservation and extraction practices, and about options for sustainable management of Brazil nut concessions, were not fully achieved. This may be directly related to the lack of specific activities to engage with regional stakeholders (NGOs, *Regentes* and government), as illustrated in the ToC (Fig. 2). In addition, according to interviews, only personnel from the national forestry service and the boundary organization were directly informed about the

³ A boundary organization is defined as an organizational structure that is perceived as credible and legitimate by actors in both sites of the boundary, serves as a bridge between actors, and facilitates participation across the boundary (Cash et al., 2002). The BNP identified a NGO focused on environmental law topics as a boundary partner. CIFOR and the boundary partner have an ongoing working relationship and have collaborated in previous projects related to timber extraction in Brazil nut concessions.

research findings. Although some stakeholders learned about the research through meetings held in the region by researchers, the majority found out about the findings only through the government's published management guidelines.

There is no substantial evidence that the end-of-project outcome "Amazonian researchers and the community are using the study to inform ongoing research" has been realized. However, a researcher from the Peruvian Amazon Research Institute acknowledged that the methods used in the project have provided insights for new research that is being conducted by the Institute.

It is too early to make conclusions about whether or how the research has contributed to poverty reduction, biodiversity conservation and climate change. However, the fact that Brazil nut regional management regulations partially incorporate and reflect scientific knowledge on multi-use forest management that was produced by the BNP's research indicates an important step along the policy pathway. There is also evidence that the research agenda in the region has been informed by the BNP and that donors are using the research findings to inform forestry and development projects (at least two projects related to Brazil nut are using the research as a baseline, see Appendix B).

According to NGO informants, the BNP findings have also sparked debate at the regional level around Brazil nut concession management. Meetings and debates with resource users, *Regentes* and the forestry authority leading to the modification of the Brazil nut management guidelines took place in the region in 2016 after the first version of the technical guidelines was approved and published.

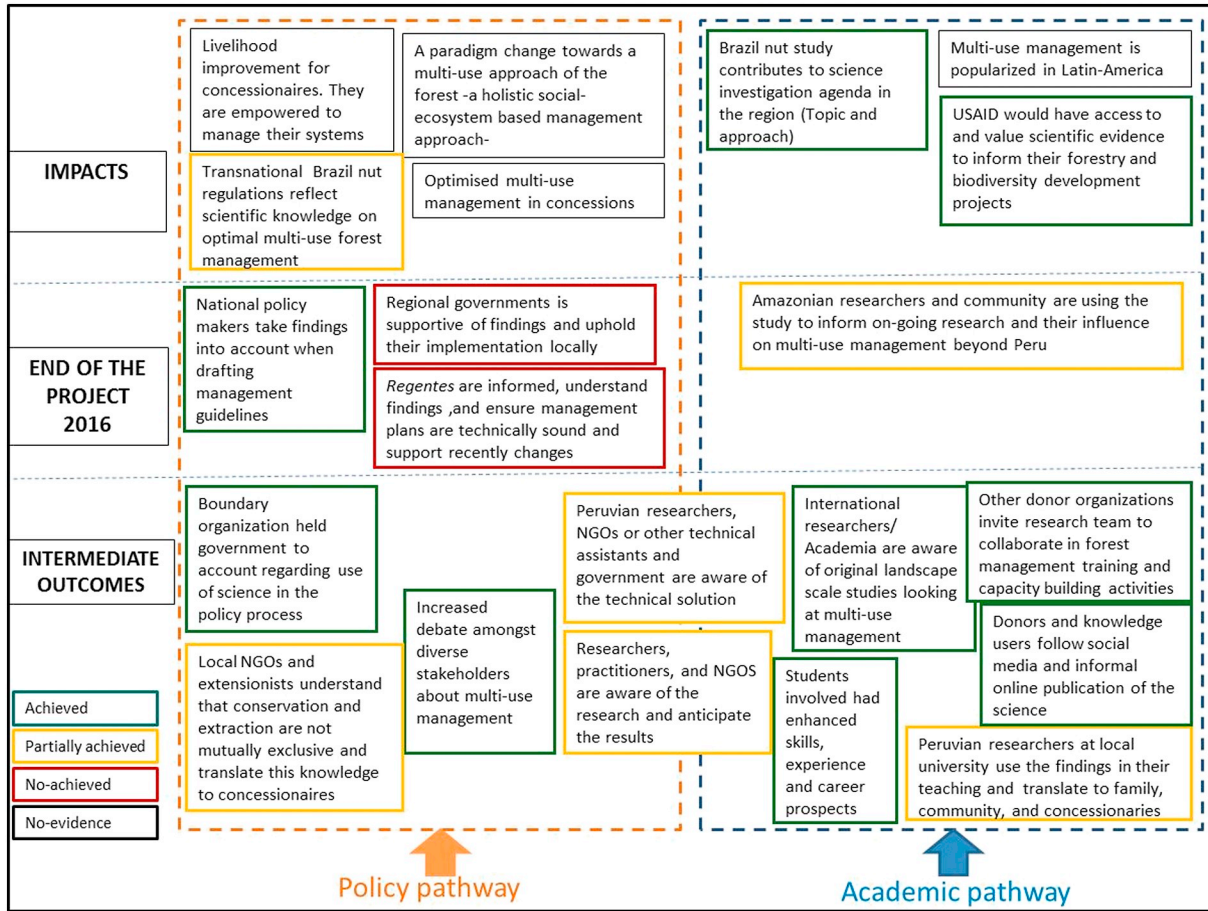


Fig. 3. Brazil Nut Project Outcomes achievement based on the Theory of Change. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

The interviews indicated that stakeholders, including *Regentes*, NGOs, regional and national government representatives, have become more aware about the possibilities of using science in policy. This is an unexpected positive outcome associated with the partial inclusion of research findings in the Brazil nut management guidelines and marks an important precedent for shaping future policy making processes.

Finally, as suggested by an informant from a boundary organization, context issues such as the lack of tradition in making decisions based on scientific evidence, complex political processes in the region and short timeframes to inform and make policies are key factors that define the science-policy interface in Peru (NGO4).

The ToC assumption that governments would be interested in integrating evidence-based policy held true. Other assumptions (see Section 4.2.1) about effective engagement of the right actors and the use of appropriate means for engagement and knowledge translation were not fully realized. Similarly, the assumption that “the results are perceived to be legitimate” held true with respect to policy makers at the national level and a boundary organization, but as indicated in the assessment of TDR principles (Section 4.1), the results were not perceived as legitimate by all regional stakeholders.

The project’s main assumption was that reaching policy makers at the national level would be sufficient to link science and policy. Our analysis suggests that more engagement with regional stakeholders throughout all the research stages was needed to effectively contribute to the intended outcomes.

4.2.3. Research effectiveness

The outcome evaluation and additional data analysis (Appendix A) indicates that all the criteria associated with the effectiveness principle

in the TDR QAF were at least partially satisfied (Fig. 4). The research made an important contribution to the knowledge of Brazil nut ecology. The use of the research findings to draft the Brazil nut management guidelines indicates that the research made a practical contribution to forest management and that it contributed to achieving a significant outcome: providing scientific information used to draft forest management guidelines.

According to interviews with concessionaires and students, the project’s contribution to building social capacity was significant, but limited to the five concessionaires and ten students directly involved in

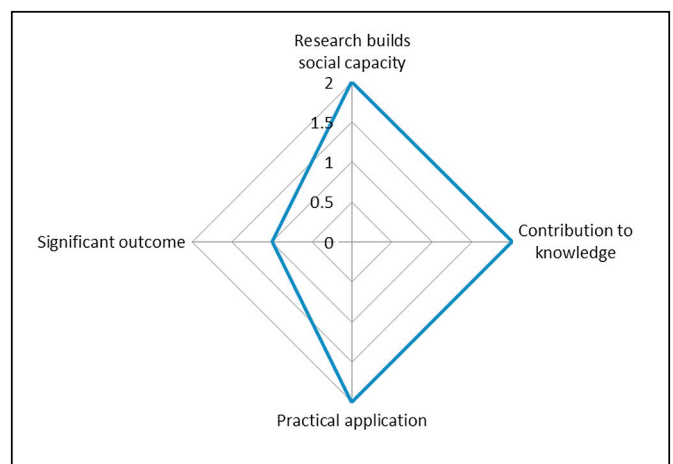


Fig. 4. Research effectiveness.

the field activities. Students improved their technical skills to conduct research, gained first-hand knowledge regarding Brazil nut production and developed a social perspective about the concessionaires work and struggles. Concessionaires developed a more comprehensive understanding of how timber extraction and other forest practices can affect Brazil nut production. Thus, according to the TDR assessment framework, the overall effectiveness of the research is high (88%), but contextual characteristics, such as local realities and interests, and the effective identification of key stakeholders and inclusion in the research process limited the full accomplishment of the intended outcomes.

5. Discussion

The analysis presented here depicts the science-policy interface in a rather linear and structured way to maintain the focus on primary pathways. However, as further examined by Ramirez and Belcher (forthcoming), policy processes are complex, especially in the Global South where they are subject to high political uncertainty and where top-down policy making is challenged by multilevel governance processes (Koch, 2018; Ramirez & Belcher, forthcoming). A linear science-policy process reflected in the BNP ToC may hold under certain circumstances but, as demonstrated by our analysis, the effectiveness of such an approach greatly depends on contextual characteristics and political moments.

The application of the TDR QAF and the outcome evaluation indicate that aspects of legitimacy and relevance were the more important factors underpinning research effectiveness. While not all the intended research outcomes were fully achieved, the BNP produced new knowledge that was used in drafting new timber extraction management guidelines. As well, the BNP contributed to building capacity. From a transdisciplinary perspective, although the achievement of outcomes was not complete, the research was effective in other ways.

Similarly, according to the TDR QAF, the BNP addressed well aspects of research credibility. Yet, regardless of the high standards of research credibility followed in the BNP research, perceived shortcomings in the research design pointed out by several stakeholder groups interplay with aspects of legitimacy, such as more effective and ongoing inclusion of stakeholders and collaboration. This aligns with Weichselgartner and Kasperson's (2010) comparative analysis on the use of science for risk management and decision making. They found that knowledge users that perceived findings to be untrue also perceived them as unfair, suggesting an interlinked relationship between research credibility and legitimacy.

The BNP begins to move beyond disciplinary research approaches. It recognized the need and value of stakeholder collaboration and engagement for solving a complex sustainability problem. The project included many elements of TDR. Nevertheless, viewed through a transdisciplinary lens, it is clear that additional effort to identify and integrate key stakeholders (e.g., NGOs, regional government, *Regentes*) could have increased the impact of the research. One of the key principles in TDR is broad stakeholder engagement in problem identification to help identify the most relevant, real-world research issues (Lang et al., 2012). In the BNP, the relevance of the research problem was validated by some NGOs, but not by all Brazil nut producers. Similarly, the engagement of stakeholders in knowledge exchange was limited to a one-way communication of findings; as a result, mechanisms for knowledge co-production and sharing were not in place. Unidirectional communication is often found in disciplinary research where knowledge is viewed as something explicit that can be passed between people through the dissemination of results (Fazey et al., 2013). Although this unidirectional approach can be useful to inform scientific and, in some cases, non-scientific audiences, it is less effective for sustainability problem solving purposes where multi-directional processes that involve knowledge sharing and co-production are more appropriate (Fazey et al., 2013). As suggest by various authors, effective knowledge exchange and uptake is a continuous social process where knowledge

accumulates and influences thinking over time (Bowen & Zwi, 2005; Georgalakis et al., 2017).

In this case study, stakeholders' opinions were an important input to policy making. The linear approach of knowledge to policy – based on the assumption that filling a knowledge gap would be sufficient to make scientific knowledge usable in policy making (Weiss, 1999) – proved to be wrong in this case. Indeed, as indicated in our analysis, stakeholders' perceptions of research credibility (i.e., concerns about research design aspects) mattered for policy making.

Effective knowledge uptake requires channels of communication based on relationships of trust with key actors (e.g., researchers, policy makers, middle-level implementers and resource users) and meaningful engagement in knowledge co-production (Sen et al., 2017). In the BNP, regardless of the efforts to communicate research aspects and findings to different stakeholders at different stages of the research process, the unidirectional approach to communication and the lack of continuity and consistency in communication and engagement activities by researchers limited knowledge uptake. Furthermore, the lack of integration and participation of stakeholders in knowledge exchange processes limited opportunities to consider actors' knowledge, values and concerns, undermining their perceptions of the legitimacy and even the relevance of the research.

For instance, in the BNP, post-research discussions among the forestry authority, resources users and *Regentes* that resulted in the modification of the technical guidelines took place without participation of the researchers, missing the opportunity for their input and help to contextualize the research findings. Stronger partnerships with regional stakeholders (e.g., NGOs) and a more explicit and early engagement with the boundary partner might have provided mechanisms for the researchers to have an active role in such discussions and make findings more useful for informing and improving policy.

Long-term commitment of researchers during and after the formal end of the project has been pointed out as one of the key aspects for achieving trust and accountability, and ultimately to increase the probability for research findings to inform policy making (Enquist et al., 2017). Although such long-term researchers' engagement is constrained by funding and capacity limitations, a TDR approach could provide mechanisms to foster ongoing collaboration with stakeholders and to support post-research activities that in some cases are crucial for improving the achievement of the long term outcomes and impacts of research. However, we also recognize that there are significant transactions costs involved with higher levels of engagement. Effort will be needed to develop research approaches that efficiently achieve sufficient relevance, legitimacy, credibility and effectiveness in context (Belcher et al., 2016; Cash et al., 2002).

6. Conclusions

The TDR research quality framework, together with a theory-based evaluation based on ToC, provide valuable analytical tools to understand the links between research design and implementation and the achievement of outcomes, and also to identify critical factors underpinning the effectiveness of research. The TDR quality criteria proved to be useful to analyze aspects of research design and implementation that influence scientific knowledge validation and uptake.

Nonetheless, we identified in our analysis that the TDR QAF can still be improved. Particularly, the inclusion of additional criteria in the legitimacy principle to help address aspects of trust and power might be needed. Similarly, we found that the effectiveness principle might be more precisely named and defined to indicate how aspects of research design and implementation are oriented to position research to generate a positive change in environmental sustainability. These and other aspects in relation to the TDR QAF warrant further examination.

In the BNP, engagement and communication with stakeholders were identified as key factors underpinning the achievement of outcomes. These aspects are related to perceptions of credibility (by lay actors),

legitimacy and relevance. Although direct communication with policy makers was effective to provide research input to the management guidelines, low levels of participation and collaboration with regional stakeholders reduced the overall perceived legitimacy of the research and unidirectional communication of results undermined perceptions of research relevance.

Contextual issues (e.g., corruption, low levels of public education in science, high reliance on natural resources) limiting research validation and uptake are often difficult to overcome; however, a transdisciplinary approach may better address those issues through collaboration and meaningful engagement of stakeholders and consideration of the socio-political context in problem definition, research design and production of knowledge. As illustrated in the analysis of the BNP, a better understanding of the policy making process and particularly the impact of recent changes that provide mechanisms for public participation in forestry policy in Peru is needed to maximize research usability in policy.

The main takeaway message for researchers, research managers and research funders seeking to improve the effectiveness of research in informing and contributing to improved policy and practice is to: 1. ensure the relevance of the research by defining the research problem and the research question with adequate reference to the social, environmental, economic and policy context; 2. warrant that the science is sound, with appropriate inter-disciplinary integration as needed for the purpose; 3. understand and represent the values and interests of key stakeholders in the research design and implementation, so they will be more likely to appreciate, accept and support the results and recommendations; and 4. incorporate appropriate engagement and communication, and/or partner with others who can support engagement and communication, to help position the research for use.

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Declaration of interest

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.forpol.2018.07.018>.

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