Environmental Science and Policy 112 (2020) 1–9

Contents lists available at ScienceDirect

Environmental Science and Policy

journal homepage: www.elsevier.com/locate/envsci

Allying knowledge integration and co-production for knowledge legitimacy and usability: The Amazonian SISA policy and the Kaxinawá Indigenous people case

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ARTICLE INFO

Keywords:
Transdisciplinarity
Science-policy interface
Participation
Indigenous and Local Knowledge
Indigenous Peoples and Local Communities
Ethnoecology
Ethnopedology
Environmental policy
Assessment
REDD+
Adaptive co-management
Knowledge systems

ABSTRACT

Environmental policies that aim to enhance nature conservation, biodiversity, and well-being of Indigenous Peoples and Local Communities (IPLC) rely on knowledge integration and co-production processes that include both science and Indigenous and local knowledge (ILK) systems. While these processes are expected to safeguard the diversity of knowledge systems, uneven power relations among participants often prevent them from achieving this which can affect the legitimacy and usability of the outcomes of these processes. Using a case study in the Acre state (Brazil), where policy practitioners implemented the REDD + policy System of Incentives for Ecosystem Services in the Brazilian Kaxinawá Nova Olinda Indigenous Land, we investigate how participants manage challenges to safeguard knowledge diversity and usability during policy assessment and planning. Our findings show how, despite the use of participatory approaches, knowledge diversity ended up being compromised because policy practitioners were insufficiently attentive to power asymmetries and their implications. This, however, did not negatively affect the usability of the knowledge outcomes. Rather than focusing on the perfection of participatory methods, we call for a practical ethics that relies on culturally and ethically sensitive dialogues and that include continuous reflection. Such reflection will enable adaptation and improvisation to be able to respond to emerging power dynamics in an adequate and timely manner, thereby ensuring both the legitimacy and the usability of the outcomes of knowledge integration and co-production.

1. Introduction

Global environmental policies and instruments such as the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) and the Convention on Biological Diversity emphasize the important contribution of Indigenous peoples and local communities (IPLC) to enhance global environmental conservation, biodiversity, and human well-being (Tengö et al., 2017). IPLC support up to 80 % of the planet's biodiversity (FAO, 2017) and the sustainable management of natural resources in their territories is of the utmost significance (CBD, 2016). Therefore, policies are needed to support IPLC in maintaining their Indigenous and local knowledge (ILK) and contributions to biodiversity. In this context, scholars have argued for the importance of co-production of knowledge that includes policy practitioners - with which we mean those involved in policy making, planning and implementation - and IPLC and that aims at the integration of ILK and scientific knowledge in the assessment of resource management (Tengö et al., 2017). Scholars have also argued for the importance of adaptive collaborative management or – or co-management (ACM), which allows for participation, reflection, and learning to enable the adaptation of management practices in response to changes in local social-ecological systems (SES) (Berkes, 2009). A core concern recognized in literature on knowledge integration and ACM is that participatory processes and outcomes must ensure the diversity and integrity of knowledge systems of different groups of participants, so that knowledge legitimacy and usability are safeguarded (Cash et al., 2003; Dilling and Lemos, 2010).

Knowledge legitimacy is achieved when all participants (policy practitioners as well as IPLC) consider the outcomes of knowledge integration and co-production to be valid according to the diverse meanings and contents of their knowledge systems (Tengö et al., 2017).

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https://doi.org/10.1016/j.envsci.2020.04.018
Received 26 June 2019; Received in revised form 29 April 2020; Accepted 29 April 2020

This means that this diversity is respected and remains recognizable. As this diversity is also linked to practices, contexts, and needs of knowledge holders, legitimacy also implies usability (Lemos et al., 2018). Policy practitioners have faced challenges to safeguard knowledge diversity and usability when integrating and co-producing knowledge with IPLC (Turnhout et al., 2020). Different knowledge systems use different methods and styles of reasoning and the boundaries between them can be difficult to be overcome. Nonetheless, shared objects, concepts, areas, or problems can serve as boundary objects and points of encounter for the integration of knowledge systems (Carlile, 2002). While integration is the departing point to interrelate different knowledges, so that knowledge can be co-produced (Pohl et al., 2010), the diversity these systems comprise can be jeopardized, if uneven power relations among participants result in the prioritization of certain forms of knowledge over others (Turnhout et al., 2019). In integration and co-production processes this is a regular occurrence since scientific knowledge is still often conceived as superior to ILK (Latulipe and Klenk, 2020). When these processes are guided by this conception, there is the risk that ILK is either excluded or stripped from its meanings and translated into scientific terms to fit dominant policy frameworks. This form of 'extraction' of knowledge (Klenk et al., 2017, p.1) affects knowledge diversity and usability.

In this article, we investigate how participants in processes of knowledge integration and co-production manage challenges to safeguard knowledge diversity and usability during policy assessment and planning. We use an in-depth case study in the state of Acre (Brazil). In this case policy practitioners from the Brazilian Agricultural Corporation EMBRAPA were tasked with the implementation of a policy called "System of Incentives for Ecosystem Services" (SISA, acronym in Portuguese). As part of this process, these policy practitioners collaborated with Indigenous people from the Amazon Kaxinawá Nova Olinda Indigenous Land (KNOIL) to integrate and co-produce knowledge about soils and landscape as part of the planning of ACM in that area. The SISA policy is part of the Global "Reducing Emissions from Deforestation and Forest Degradation" (REDD+) program and is committed to respecting the diversity of ILK and enhancing conservation and well-being (Sills et al., 2014). This study contributes to the burgeoning field of scholarship on co-production in three ways. First, while much of the literature focuses on science-policy-society interactions in a Western context (Leith et al., 2014; Posner and Cvitanovic, 2019), this study focuses on interactions between Western science and ILK systems (e.g. Matuk et al., 2020). Second, we explicitly address the role of power and the challenges of co-production, thereby complementing existing literature that predominantly focuses on best practices and methods (Turnhout et al., 2020). Third, we offer an in-depth exploration of what happens when knowledge systems meet. In so doing, our analysis provides valuable insight into the practice of knowledge integration; on how integration can involve the bridging of knowledge systems, and on what methods and attitudes can support this. These contributions support the further development of innovative approaches, such as the multiple evidence-based approach (Tengö et al., 2017) and the IPBES' ILK Approach (Hill et al., 2020), which aim to avoid forms of integration that reduce diversity.

2. Knowledge integration and co-production

The drive to knowledge integration in the domains of environmental policy and nature conservation stems from the recognition that resource management happens within complex social-ecological systems; that assessing these systems is important to inform policy and planning; and that these assessments must be based on knowledge that is co-produced by actors who hold different knowledge systems (Tengö et al., 2017). Processes of knowledge integration and co-production have been studied in different fields, including science and technology studies (Jasanoff, 1998), social learning (Berkes, 2009), and ethnoecology (Toledo and Barrera-Bassols, 2009). This literature highlights that a prevailing dichotomy between scientific and non-scientific forms of knowledge (i.e. ILK) has prevented these processes from resulting in legitimate and usable knowledge outcomes. Although universally valid definitions of scientific knowledge that demarcate it from other forms of knowledge are mostly absent (Gieryn, 1983), scientific knowledge is still often seen as neutral, universal, and credible whereas ILK is depicted as value-laden and context-based. Criticisms of this dichotomy have argued that all forms of knowledge, including science, are shaped by values and worldviews and are embedded and produced in local contexts and practices (Raffles, 2002; Ludwig, 2016). This does not mean that there are no differences between different traditions and cultures of knowledge, but rather that these differences are not set in stone (Turnhout et al., 2019). From this perspective, no knowledge system is a priori superior to another. Yet, integration and co-production processes are often characterized by uneven power relations that prevent their participants from appropriately managing knowledge diversity together. This shapes these processes in ways that reproduce knowledge dichotomies and compromise the legitimacy and usability of their outcomes in local contexts. Such relations unfold from power asymmetries between (elite) government and science actors and (non-elite) IPLC actors, for example when policy practitioners depoliticize participatory processes, when they fail to adequately respond to power dynamics, or when they prioritize scientific knowledge that aligns with policy over ILK (Turnhout et al., 2020).

We suggest that integration and co-production processes have to meet two objectives to deliver legitimate outcomes, both of which require sensitivity to power relations among knowledge systems and holders. The first is *to safeguard knowledge diversity* (Tengö et al., 2017). Processes should facilitate IPLC to mobilize those contents and meanings of their knowledge that are relevant to include. This process of mobilization is a critical part of the process and it refers to the process "to bring out and articulate knowledge into a form that can be shared with others" (Tengö et al., 2017, p. 18). Subsequently, by means of processes of dialogue, synthetization, and translation, new knowledge can be created, while conceptualizations and categorizations of both ILK and scientific knowledge are integrated (Bowker and Star, 2000). This ensures that this new knowledge is legitimate, relevant, and in accordance with knowledge holders' practices, worldviews, values, and needs. A central premise here is that knowledge is not just representational but an inextricable dimension of so-called knowledge-practice-worldviews (k-p-w) assemblages (Toledo and Barrera-Bassols, 2009; Matuk et al., 2019). When knowledge fails to account for the classification categories, criteria, or indicators that are used to express local values and relationships, it will not be legitimate and it will be unable to inform actual practices. This brings us to the second objective: to *safeguard knowledge usability*. Ensuring this usability requires care to elicit the different contexts in which knowledge will be applied and to ensure that knowledge meets the needs of policy practitioners and IPLC (Dilling and Lemos, 2018).

To achieve the objectives of knowledge diversity and usability, processes of knowledge integration and co-production must involve a levelling of power-relations among participants (Tengö et al., 2017). This can be achieved via an 'intercultural approach' (Rist and Dahdouh-Guebas, 2006, p.473). This approach can be enacted by means of 'technologies of humility' (Jasanoff, 2003, p.376); methods and attitudes that help participants to recognize and reflect on power and knowledge differences. To exercise humility towards IPLC, scientists and policy practitioners need to interconnect with the cultures of IIPLC and make sense of their contexts and knowledge systems (Echeverri, 2005). Respect for knowledge differences can also be enacted via 'methodological bricolage' (Kincheloe, 2008, p.4). This notion suggests that, instead of merely using pre-designed methods or frameworks, policy practitioners improvise and adjust their approaches and methodologies. In so doing, policy practitioners are able to attend to the unfolding of participatory dynamics and facilitate mutual learning and articulation of knowledge differences. In this approach, knowledge

integration is done by means of dialogue which helps participants to contrast knowledge systems and identify knowledge correspondences and complementarities side-by-side (Albuquerque et al., 2014). This integration involves both the translation of different categorizations (without prioritizing the nomenclature and meanings of one knowledge system over the other) and the co-production of new categories that knowledge holders recognize as meaningful.

The central ethic is one of power sharing among participants which enables them to "reason together" (Jasanoff, 1998, p.173) and create common meanings. To do so, policy practitioners need to listen to locals, be aware of uneven power relations that take place in knowledge processes, and negotiate knowledge in a transparant manner. Finally, the co-validation of knowledge outcomes (e.g. bridged classifications) is vital to enable the correction of misunderstandings and ensure that outcomes reflect the different categories and indicators that formed the basis of the integration and co-production (Bowker and Star, 2000). Such ethical sensitivity is also important to achieve the objective of knowledge usability (Rist and Dahdouh-Guebas, 2006; Klenk et al., 2017). This ethical sensitivity requires not only an understanding of the relevance of the diversity of the knowledge systems but also of the risks of extractive modes of knowledge integration (Hill et al., 2020). This understanding can be facilitated by creating space for the 'reflexive questioning' by all participants of possible hidden assumptions, emerging dynamics or nontransparent decisions and courses of actions (Klenk et al., 2017, p.6).

In this section, we have presented a number of guidelines which combine attitudes (humility and ethical sensitivity) and methods (methodological bricolage, reasoning together and reflexive questioning) that help to create the conditions that foster the development of these attitudes and ensure legitimate outcomes. We will use these to analyze and reflect on our case study and particularly on the ways in which the policy practitioners from EMBRAPA and IPLC navigated the challenges of knowledge integrations and attempted to produce legitimate and usable knowledge outcomes.

3. Material and methods

KNOIL is located in Feijó (Acre state - Brazil). It covers 27,000 ha and comprises 492 Kaxinawás who speak Portuguese and *Hãtxa Kuin*, and who obtain subsistence mainly from local livelihoods via traditional practices such as hunting, agriculture, gathering, and fishing. KNOIL is a priority Amazon area of biodiversity where policy practitioners from the Brazilian Agricultural Corporation Embrapa have been involved in the implementation of the SISA policy since 2011. This policy has been applied in KNOIL as a pilot project and is dedicated to respecting ILK and the needs of IPLC. It follows from a longer history of Acrean environmental policies that have addressed IPLC since the 1990s (Sills et al., 2014). This study reports on the implementation of SISA with Kaxinawás.

Free and prior informed consent was obtained from Kaxinawás in accordance with the Brazilian regulation on Genetic Heritage and ILK (Law 13,123; 2015). This entailed a signed approval of Kaxinawás for this research. The first three authors and the fifth author collaborated with the Embrapa co-authors in analyzing the data to evaluate the legitimacy and usability of knowledge outcomes of SISA. Data was collected via an ethnoecological approach of action-research that links social and natural sciences and includes locals in the data collection an validation (Albuquerque et al., 2014). Data was collected in KNOIL and in Rio Branco (city of the SISA headquarters), and included:

- Participant observation while living in KNOIL for a month. During this time, the first author engaged with Kaxinawá's daily resource management and governance practices and with the practices of the policy practitioners as part of their work with Kaxinawás;
- Interviews with 40 Kaxinawás of varied ages and genders, and with 20 SISA policy practitioners;
- Multiple workshops with an average of 35 Kaxinawás present. Workshops included: i) circles of culture (Freire, 2000) where locals had rounds of dialogues to report and evaluate policy processes; and ii) participatory mapping made via dialogues and transects in KNOIL with Kaxinawás (i.e. types of soil classes; landscape units that present common characteristics, and land uses) (Albuquerque et al., 2014).

Interviews and workshops were organized to track and analyze the knowledge processes and methods that the policy practitioners used to integrate and co-produce knowledge with Kaxinawás, and to find out how decisions were made about the selection of knowledge that would inform planning; by whom; and on the basis of what criteria. Interviews were semi-structured, allowing respondents to freely and openly share their views on the processes and their outcomes. They were taped and transcribed. The interviews were made while visiting the houses of Indigenous families and their different areas of resource management. This data supported the facilitation of the dialogues during the workshops. During these workshops, data from observations and interviews was deepened and cross-checked with the group of participants – for example to gain insight into impasses that occurred during the processes of knowledge integration and co-production.

We undertook qualitative coding of data transcribed from interviews and workshops, and of SISA reports (i.e. do Amaral, 2015) to identify the extent to which our guidelines (section 2) could be identified in the case study. We used the method of thematic coding (Nowell et al., 2017) in two rounds. First, we analyzed transcripts, workshop notes, and reports for the general occurrence of references to knowledge diversity and usability. For example, when a interviewee made a statement about land use, we checked if we could identify any knowledge dimensions in that statement. In a second round, we used thematic coding to more specifically identify the reference to or the practicing of the guidelines we discuss in section 2. Finally, we analyzed whether the policy practitioners and Kaxinawás were able to navigate challenges of power asymmetries - as far as these were present in their own experience - to manage knowledge differences and to co-produce outcomes recognizable as legitimate and usable by both of them.

4. Results

The knowledge processes involving the implementation of the SISA policy in KNOIL consisted of two main steps: assessment and ACM planning. Below, we present our findings for each of the steps.

4.1. Assessment

The assessment started with policy practitioners and Kaxinawás getting acquainted with each other. The policy practitioners invited Kaxinawás to participate in the selection of informants and sampling areas, to build trust, and to show respect for their authority. The policy practitioners used an intercultural approach to interact with Kaxinawás, by expressing an interest in knowing the Kaxinawá culture and by participating in community activities. The quotes below attest this approach:

> "*We know that our work involves a complex intercultural interference. This is why we were concerned with constructing an open dialogue with Kaxinawás, to understand the most diverse criteria and meanings of their resource management ….*" (Policy practitioner, Interview 2).

> "*The policy practitioners spent time with us… They wanted to understand our knowledge, the way we live, why we use our lands as we do, and what we think we need to improve in our practices to achieve our needs…"* (Kaxinawá, Interview 23).

4.1.1. Knowledge mobilization

As a first step, the policy practitioners used dialogue methods,

including circles of culture to facilitate the mobilization of Kaxinawá knowledge pertaining to the characterization of the KNOIL social-ecological context of resource management and governance. The dialogues focused on identifying the Kaxinawá land uses and on understanding how management practices had been adapted in response to landscape and territorial changes. Via this data, the policy practitioners became aware of Kaxinawá resource management and how this was inherited from ancestors and Incas who coexisted in the Peruvian and Brazilian Amazon since ancient times; from colonizers who enslaved Kaxinawás for "rubber tapping" in the 19th century; and from other IPLC and (non) governmental institutions with whom contact has increased in the last three decades. It also become clear that the Kaxinawá's form of agriculture, although often called 'slash-and-burn', is actually closer to agroforestry; that it focuses on subsistence; and that it has mostly conserved ecosystems. Moreover, Kaxinawás highlighted the central role of their worldviews for their resource management and governance. These worldviews stressed the importance of community and democracy, and included animist values that show a spiritual connection with nature's biophysical entities (cf. Matuk et al., 2020). For instance, nature is valued as providing food and medicine, but also as a source of knowledge and spirituality. Such values have guided a stewardship with nature that is based on reciprocity, via which Kaxinawás aim to supply the needs of both Kaxinawás and nature's (non)living entities.

The characterization of the KNOIL context was followed by a joint identification of priority needs of Kaxinawás to be aligned with the SISA goals. The policy practitioners identified that Kaxinawás sought mainly to enhance food security and livelihood sovereignty while also enhancing the sustainability of resource management in alignment with their k-p-w. These needs were aligned with the SISA goal to enhance ecosystem services and maintain the rain forest cover at 88 % of the territory of Acre by enhancing bio-cultural diversity. One policy practitioner explains:

> "*We aligned Kaxinawá and SISA needs by considering that Kaxinawás, as other IPLC, have conserved forests with their culture and knowledge. So, by helping them to strengthen sustainable access for their livelihoods, we enable them to keep contributing to biodiversity*… (Policy practitioner, Interview 17).

After familiarizing themselves with the Kaxinawá context, the policy practitioners used participatory mapping to allow Kaxinawás to mobilize their knowledge and identify specific landscape and soil classifications that are relevant to plan resource management in KNOIL. Kaxinawás shared their tacit, explicit, oral, and heterogeneous knowledge which ended up in a shared classification. This classification consisted of five landscape units (Table 1, Fig. 1) which Kaxinawás distinguished according to topography; vegetation; and humidity. Subsequently, Kaxinawás indicated nine criteria that they use to distinguish the ten soil classes that receive different land uses in KNOIL. These criteria included: landscape topography; vegetation; humidity; clay type; color; presence of "clay cracks" (expansible clay); presence of plant roots; stoniness; and "massapê" – clayey soils with a compromised drainage and with gleyic, plinthic or vertic properties (IUSS Working Group WRB, 2015). Kaxinawás referred to soils using different names that include these criteria. These names reflect different levels of importance of these criteria for different Kaxinawás. To synthesize these criteria, the policy practitioners asked Kaxinawás to rank them in order of importance. Out of the nine criteria, Kaxinawás selected the four most important ones that they considered sufficient to identify soils. Landscape classes were included together with other soil classification criteria Kaxinawás use to distinguish soils (Table 1).

Subsequently, the policy practitioners mobilized their own knowledge, by classifying the soils and landscapes of KNOIL. Using the system of Tricart and Kiewitdejonge (1992), the policy practitioners identified 5 landscape units which were subsequently integrated, or, as Tengö et al. (2017) put it, weaved together, with the five landscape units that Kaxinawás had identified (Fig. 1). These units were represented together with soils, as they occur in association with 5 (major) reference soil classes, each of which can comprise several other specific soil classes according to Brazilian and international classifications (Embrapa, 2013; IUSS Working Group WRB, 2015). In the case of KNOIL, the policy practitioners found that these 5 major classes included 47 specific soil classes (Fig. 2). To classify these soils, the policy practitioners collected, described, analyzed, and classified soils using more than 100 criteria derived from these Brazilian and international classification systems. Kaxinawás contributed to this process by indicating what variations in soil properties are relevant to manage resources in KNOIL.

Table 1
Kaxinawá categories and criteria of soil classification.

Criteria	Name	Categories	Name
Massapê	Massapê (Kaya)	Present	Mae kuxipa tesh
		Absent	Mae kuxipa te make
Texture	Clay type (Mae husi husipa)	Clay	Mae tesh
		Clay mixed with sand	Mae maxi husia
		Sand	Mae txasha kapa
Color	Color (Ushna)	Reddish	Huxi
		White	Hushupa
		Purple	Aku
		Red	Taxipa
		Black	Mexupa
		Yellow	Paxinipa
		Grey	Akunepa
Landscape unit	Land shape (Mae betsa pabu)	Riverside lands	Matxi kaya pashku kesha
		Low lands	Mae papa
		Middle lands	Mae txeima
		Firm lands of valleys and of tops	Mae matxi manâ
		Watershed divide	Matxi pashku kesha txeima

Although Kaxinawás and the policy practitioners each mobilized knowledge in distinct processes, these processes also involved co-production:

> "*We exchanged knowledge with Kaxinawás during all activities we did to identify their land uses, soils, and landscapes. We were not there to teach, but to share and learn*" (Policy practitioner, Interview 7).

> "*When we accompanied policy practitioners to identify soils, we were like teachers and students. We told them knowledge we naturally have about the lands, and we also learned aspects of soils that they consider important*" (Kaxinawá, Interview 1).

In the end, the knowledge that was mobilized consisted of policy practitioners' and Kaxinawás' distinct classifications (Table 1, Fig. 2) which formed the basis for the process of integration.

4.1.2. Knowledge integration and co-production

When it came to knowledge integration, the policy practitioners and Kaxinawás relied on processes of synthetization and translation. The policy practitioners asked Kaxinawás to indicate names of landscape and soil categories that they identified previously. All Kaxinawás referred to landscape units using the same names, so these were maintained. However, this was not possible in the case of soils. As we mentioned before, Kaxinawás used different names to refer to the 10 soil classes that they identified in KNOIL. This posed a challenge to integrate the Kaxinawá knowledge diversity because the policy practitioners wanted Kaxinawás to settle on a single name for each class, to establish fixed soil names that would allow for a clear communication during the planning process. In response to this challenge, the policy

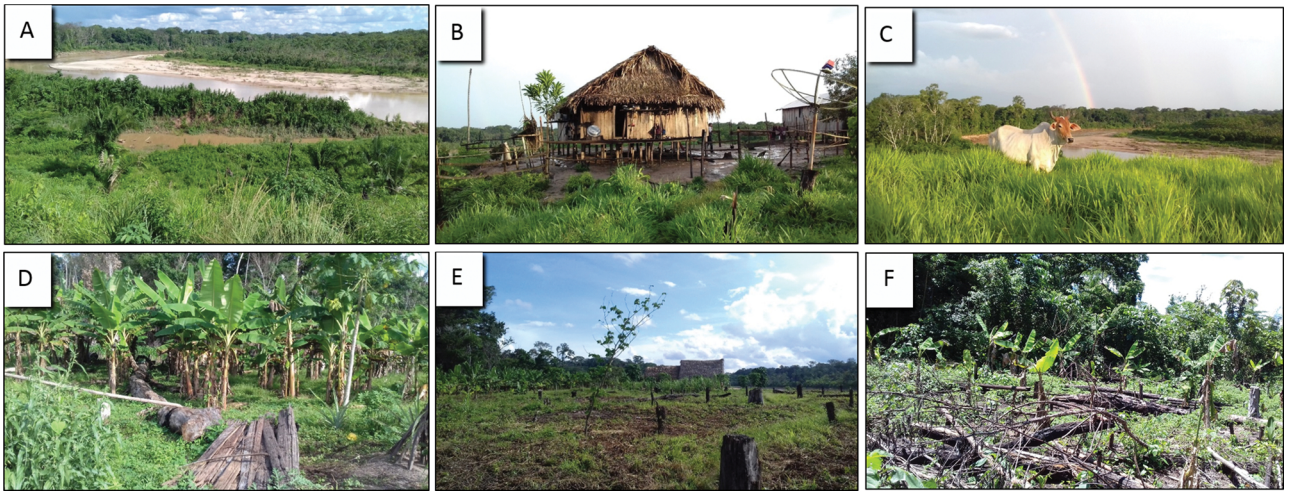

Fig. 1. Landscape units and land uses of KNOIL. A) Conservation area in riverside floodplain; B) Dwelling in slope; C) Cattle in firm land of valley; D) Wetland of depressions with shifting cultivation; E) Cleared area in firm land of tops; F) Riverbed flat tops with shifting cultivation.

practitioners invited Kaxinawás to come up with names they could agree on, as this policy practitioner reflects:

> "*After we assessed how the Kaxinawás distinguish soils, we asked them to search for a name that could express each class… It took time for them to define and agree on names because they use different names to call soils*" (Policy practitioner, Interview 34).

Subsequently, the policy practitioners integrated the scientific and Kaxinawá knowledge by bridging and weaving correspondences and complementarities between the 47 specific classes they had identified to the 10 soil classes that Kaxinawás had identified. Since those 47 classes accounted for slight variations in soil properties that are irrelevant to plan land use in KNOIL, the policy practitioners grouped them in 10 classes – that have similar physical, chemical, and morphological properties – and weaved them together with the 10 soil classes Kaxinawás use for planning land use. This process resulted in an

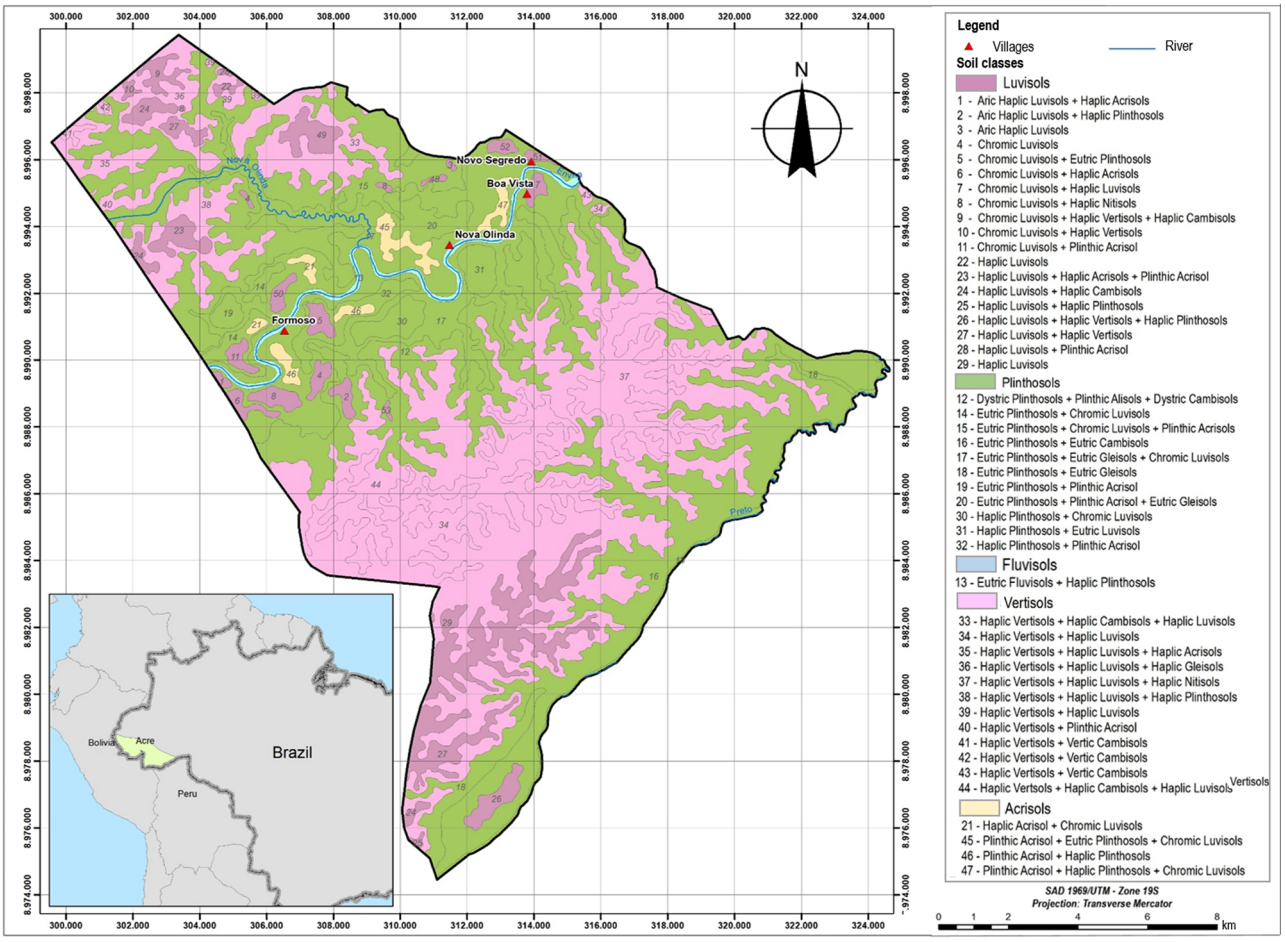

Fig. 2. SISA policy practitioners' scientific classification of the soils in KNOIL - Acre, Brazil.

Table 2
Integrated Kaxinawá and scientific soil classifications and related land use types.

Soil names	Classification criteria				Land use types
	Landscape classes	Massapê	Texture	Color	
Mai taxipa maxi sesea husia (Red clayey earth) - Plinthic Acrisol	Mae txeima (Middle lands)/ Slope	Present	Sand mixed with clay/ Medium	Red and white, red dots/ Dark reddish grey, red mottling (plithite)	Cattle grazing
Mai taxipa maxi husia (Red sandy and clayey earth - Haplic Acrisol	Mae Txeima (Middle lands)/ Slope	Absent	Sand mixed with clay/ Medium	Reddish/ Brown to strong brown	Shifting cultivation/agroforestry gathering, hunting
Mai bena kuru kaya kesha (Riverside new sandy earth) - Fluvic Regosol	Mae papa (Lowlands)/ Wetlands of depressions	Absent	Sandy/ Sandy	White/ Light grey	Annual crops (peanut, watermelon, cassava, beans jerimun)
Mai taxipa (Red earth) - Haplic Luvisol	Mae txeima (Middle lands)/ Slope	Absent	Sand mixed with clay/ Medium	Red/ Dark reddish brown	Shifting cultivation/agroforestry, gathering, hunting
Mai kuin sesea (Painted massapê) - Eutric Plinthosol	Mae papa (Lowlands)/ Wetlands of depressions	Present	Sand mixed with clay/ Medium	White/ Light grey, red mottling	Shifting cultivation (cassava, maize, banana, yam, taioba), agroforestry (i.e. coffee, fruits), conservation
Mai bena papa maxiá (New grey earth with massapê) - Eutric Gleysol	Matxi kaya pashku kesha (Lowlands)/ Riverside floodplain (including igarapés[1])	Present	Clayey/ Clayey	Grey/ Greyish	Soil extraction for ceramics, conservation
Mai kuin tesh kaya (True massapê) - Haplic Vertisol	Matxi pashku kesha txeima (Watershed divide)/ Riverbed flat tops	Present	Clayey/ Clayey	Purple/ Very dark grey to brown	Shifting cultivation and conservation, gathering, hunting
Mai kuin bena kaya (True new earth) - Sandy Cambisol	Mae matxi manâ (Firm lands)/ Firm lands of valleys or of tops	Present or absent	Sand mixed with clay/ Medium	Red/ Reddish brown to brown	Cattle grazing
Mai bena sesea taxipa (New painted earth) - Plinthic Cambisol	Mae matxi manâ (Firm lands)/ Firm lands of valleys or of tops	Present	Clayey/ Clayey	Grey painted with red dots/ Light grey, red mottling (plinthite)	Shifting cultivation/agroforestry, banana
Mai bena maxia (New sandy earth) - Haplic Cambisol	Mae matxi manâ (Firm lands)/ Firm lands of valleys or of tops	Absent	Sandy/ Sandy	Grey/ Light grey	Shifting cultivation/agroforestry, gathering, hunting

identification key that includes both scientific and Kaxinawá names and criteria for soil classification and associated land uses (Table 2). While Kaxinawás contributed indirectly to this weaving of knowledge, the policy practitioners did not include Kaxinawás directly. The policy practitioners' reasoning for this was that it is not SISA's intention to teach IPLC about scientific classifications but to create a common basis of knowledge that builds on ILK. Yet, this exclusion meant that Kaxinawás did not validate this identification key.

Another challenge emerged when the policy practitioners needed to accommodate the 10 combined scientific and Kaxinawá soil classes to represent them on a map with the scale of 1:100,000 which the resolution of available georeferenced data allowed. To do so, the soil classes with the scientific names Gleysols and Cambisols, which occur in narrow bands in KNOIL, had to be grouped with soil classes they occur close to. This is why these soil classes are presented in the map (Fig. 3) in association with and not separate from the other soil classes. The 10 soil-specific categories presented in Table 2 are aggregated in 5 groups of categories in the map. The map thus represents two corresponding sets with 5 soil categories each. The association of soil classes is common in pedology (Embrapa, 2013) and it was not a problem for Kaxinawás, once they were aware that the policy practitioners would consider the differences of these soils to plan ACM.

The knowledge integration processes resulted in two main outcomes: the identification key and the map. When discussing the legitimacy of these outcomes, one issue came to the fore. While the policy practitioners explained that Kaxinawás chose the soil names that were used in the identification key, Kaxinawás reported that the chosen names were agreed on the basis of a majority of Kaxinawás. Most Kaxinawás agreed with these names because they understood from the policy practitioners that they had to create a single name for soils. However, not all Kaxinawás recognized these names as legitimate:

> "*After asking us about the names we give to soils, the policy practitioners asked us to create a unique name to call each soil… I understand these names in the table and in the map, but we do not call the soils with these exact names in our tradition…*" (Kaxinawá, Interview 32).

4.2. Planning

When it came to planning ACM, Kaxinawás and the policy practitioners relied on the four classification criteria and category names that were mobilized by Kaxinawás to refer to soils (Table 1). The policy practitioners stated that they did not use the assessment outcomes (i.e. map and identification key) because these were produced mainly for the scientific community. Nevertheless, the knowledge that was mobilized was considered useful for the policy practitioners to identify knowledge correspondences and complementarities and to develop planning strategies with Kaxinawás. Kaxinawás said that they could rely on oral communication and on their own mental maps to plan ACM; however they wished they could have used the outcomes of the assessment to disseminate knowledge that they built with the policy practitioners to those KNOIL members who did not participate in the SISA processes.

4.2.1. Knowledge mobilization, integration, and co-production

While the planning of ACM built on knowledge produced in the assessment step, the use of this knowledge to address concrete land use practices and needs in KNOIL required new knowledge mobilization, integration, and co-production processes.

These processes involved the bridging of Kaxinawá and policy practitioners' knowledge on land use and resource management as well as discussion of technical measures on how practices could be improved to enhance environmental conservation, bio-cultural diversity, and livelihoods. Kaxinawás and the policy practitioners reflected on the interplays between different land uses, including the challenge to ensure food and livelihood security, sovereignty, and how to enhance

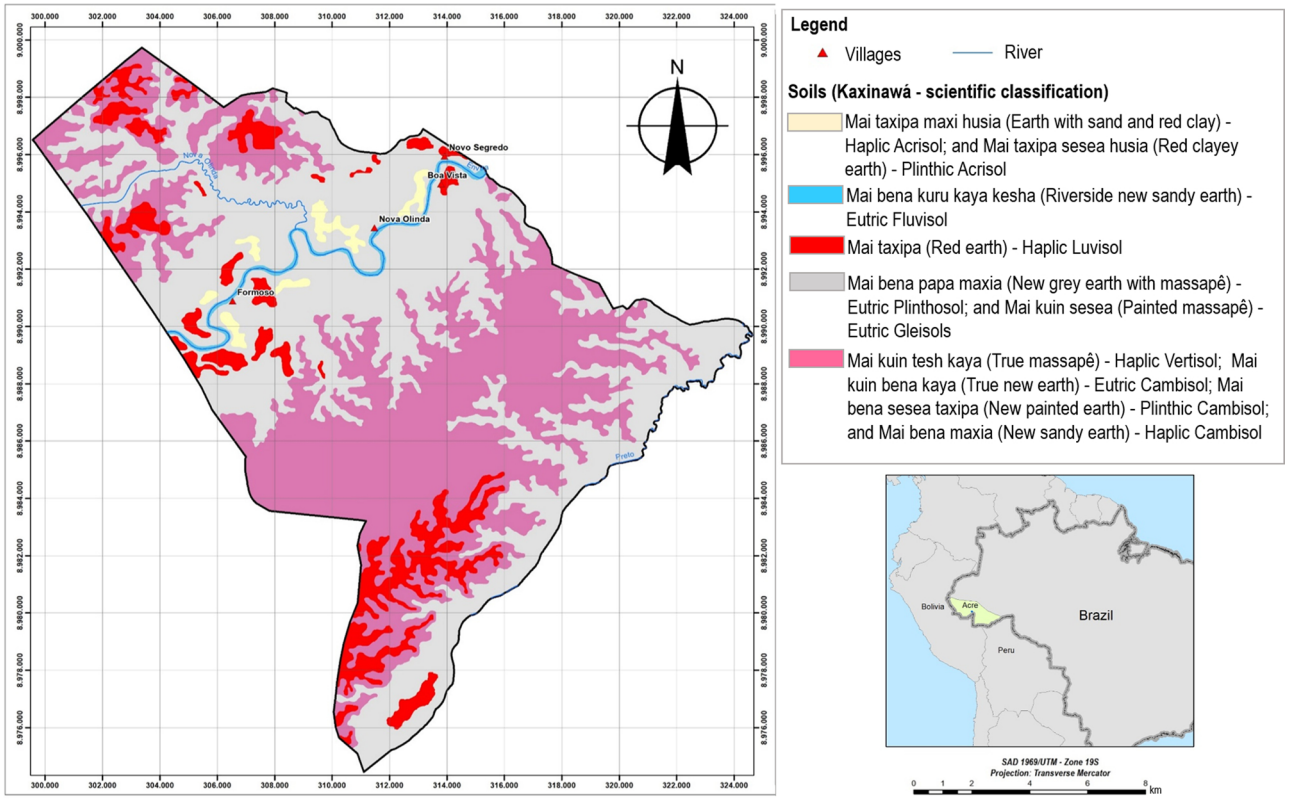

Fig. 3. Integrated Kaxinawá and scientific classifications of the soils of KNOIL - Acre, Brazil.

ecosystem services. The policy practitioners supported Kaxinawás to reflect on management options and on their possible impacts but they did not guide Kaxinawás' choices.

Two main planning strategies were co-produced to address both local needs and SISA goals in accordance with the Kaxinawá knowledge. First, slash-and-burn agriculture was adapted. Kaxinawás reported that they had realized that the clear-felling of pristine forests had become unsustainable due to the increasing Kaxinawá population density and demand for resources, and due to the fixing of the territorial border in the 1970s. The policy practitioners suggested to increase agricultural productivity and avoid the clearing and burning of pristine forest because this reduces biodiversity and causes intensive nutrient leaching. Instead, the policy practitioners recommended to use shifting cultivation methods in existing fallows that are in a good state of ecological restoration and that are more suitable for crops. These fallows are located in areas that were previously used for agriculture but were left without crops for the regeneration of secondary forest and soil fertility. Additionally, the policy practitioners suggested to increase soil fertility by intensifying the use of fruit trees in agricultural areas and by transforming them into robust agroforestry systems. Kaxinawás agreed with these changes and added to them the creation of a nursery orchard to work as a bank of seeds for these systems.

The second ACM planning strategy was aimed at increasing food security by reducing crop losses. Because both crops and cattle used to be placed close to the houses of Kaxinawás cattle were damaging crops. As Kaxinawás had no income to protect crops from cattle with fences, which would be the first recommendation by the policy practitioners for them to manage this problem, the policy practitioners facilitated Kaxinawás to reflect on other management options. The policy practitioners proposed to place cattle in soils distant from the houses that are suitable for pastures or to quit cattle grazing. Because cattle grazing is a practice that was inherited from colonizers and Kaxinawás wanted to strengthen their cultural patrimony, most Kaxinawás preferred to quit it. A few families decided to maintain herds but restrict them to Plinthosols that are distant from houses and crops.

4.2.2. Knowledge application

Kaxinawás and the policy practitioners applied the ACM planning strategies via experimentation in areas selected for communal use in KNOIL. Once this experimentation worked successfully, Kaxinawás started applying these strategies by themselves. The application of the knowledge that was co-produced during the processes was performed by both Kaxinawás and the policy practitioners. The process enabled Kaxinawás to review their tacit knowledge and to increase the accuracy of their evaluation of lands' suitability. For instance, traditional approaches used by Kaxinawás to assess soil humidity and texture, like making holes in the soils with knives or feeling the soil texture between the tongue and teeth, were complemented with approaches that policy practitioners use to examine the subsoil. The adoption of planning in practice has resulted in an optimization of the Kaxinawá land use and management. These practices were incorporated into the Kaxinawá governance (e.g. rules to allocate cattle grazing and shifting cultivation). In addition, Kaxinawá community members who participated intensively in the SISA processes became knowledge (agroforestry) agents and disseminated the knowledge that was built with the SISA policy practitioners to KNOIL community members who did not participate in these processes.

The assessment and planning that we discussed in this section involved challenges as well as positive outcomes. The subsequent section will discuss these in relation to our conceptual framework and the guidelines we presented earlier.

5. Discussion

Our findings suggest that the SISA knowledge integration processes in KNOIL partially achieved the objectives of safeguarding knowledge diversity and usability. While the outcomes of the assessment and planning processes were generally considered to be legitimate, relevant, and appropriate to the local context, we also highlighted challenges to maintain knowledge diversity, particularly in the knowledge integration process. This resulted in Kaxinawás not recognizing the outcomes

of this step as legitimate. This happened despite the efforts of the policy practitioners to include categories in the assessment that contained names that Kaxinawás indicated and to weave together the Kaxinawás' and scientific classifications while attempting to respect diversity. A key moment was the request by the policy practitioners that Kaxinawás create single names for their soil classifications, which was contrary to how Kaxinawás signify soils. This demonstrates a dominant role of policy practitioners in setting the terms for knowledge integration. It also illustrates how uneven power relations can pervade integration and co-production processes even though participatory methods were employed to prevent this. It should be noted however, that our analysis shows that knowledge usability was not affected (cf. Cash et al., 2003). We suggest that this can be explained by the fact that the policy practitioners and Kaxinawás used the indicators they identified to decide land use and resource management as a boundary object; as common language that denoted an area of common concern (Carlile, 2002). This enabled them to co-produce knowledge that was usable, despite the shortcomings in conserving knowledge diversity as a whole.

Despite this challenge to knowledge diversity and legitimacy, the knowledge processes in KNOIL reflected many of the guidelines presented earlier. An intercultural approach (Rist and Dahdouh-Guebas, 2006) was visible during most parts of the assessment and planning, when the policy practitioners actively shared power with Kaxinawás and both sides engaged in the processes. The policy practitioners also expressed humility; they actively stepped back from their authority and expertise to craft the mobilization of their scientific knowledge with Kaxinawás, to synthesize the Kaxinawá knowledge, and to align Kaxinawá needs and SISA goals. The policy practitioners did so by using dialogue methods to facilitate the Kaxinawás to structure and synthesize their classifications, and to create and identify knowledge correspondences and complementarities. As such, the policy practitioners employed methodological bricolage (Kincheloe, 2009), which allowed them to account for the different socio-ecological influences (across time and space) on Kaxinawá resource management and planning.

While attempting to exercise ethical sensitivity to safeguard knowledge usability and diversity, 'reflexive questioning' (Klenk et al., 2017) was lacking on why Kaxinawás resisted to agree on a common and fixed nomenclature for soils. Confronted with this response, the policy practitioners could have paused the process to reason together with Kaxinawás (Jasanoff, 1998) and adapt the process where necessary. Our data suggests that Kaxinawás did not disagree explicitly with the policy practitioners, but rather that they did not fully understand the implications of the knowledge integration for the usability of its outcomes. Moreover, the policy practitioners reduced their involvement in the development of the identification key and the map. By excluding Kaxinawás from the finalization of knowledge outcomes, the policy practitioners prevented Kaxinawás from having a final say about their legitimacy.

Coming back to the central objective of our article, our analysis has demonstrated that during the knowledge co-production process, the specified guidelines provided by the intercultural approach, humility, and methodological bricolage were important in ensuring knowledge usability. At the same time, knowledge diversity was partly sacrificed due to extant uneven power relations and due to shortcomings in exercising ethical sensitivity and reflexive questioning.

6. Conclusion

Our case has shown that knowledge differences can be overcome when policy practitioners share power with locals to shape integration and co-production processes and outcomes. We also saw that these processes are rarely perfect. Even with appropriate methods and attitudes in place, challenges will often occur and uneven power relations are difficult to overcome in practice. But, as our analysis has also demonstrated, these challenges do not have to sacrifice the legitimacy of the process as a whole. In our case, challenges to knowledge diversity did not create unsurmountable problems for knowledge usability.

A first lesson that we draw from our analysis relates to the facilitation of knowledge processes. The KNOIL case showed that to share power with IPLC, policy practitioners can include more flexibility and adaptation in these processes; that is, they can improve their use of methodological bricolage. In our case, this could have resulted in the inclusion of diverse contents, nomenclatures, and meanings that would better reflect the heterogeneity of ILK. Moreover, to empower locals to negotiate taken-for-granted assumptions that structure knowledge processes, policy practitioners must be transparent about their assumptions and expectations, and about the implications of knowledge choices. Continued reflection will help to correct and adapt processes and mitigate misleading and misunderstandings in earlier parts of the process.

A second lesson refers to the policy and planning processes that assessments are meant to inform. Our case resembles other documented examples (e.g. Nadasdy, 2003; Ayana et al., 2015) in which the exclusion of IPLC from the finalization and validation outcomes amounted to an extractive mode of knowledge production and compromised legitimacy and usability. To avoid this, care should be taken to include IPLC in the formulation of the policy frameworks that guide the integration of ILK and in the production of the knowledge outcomes that will be presented to scientific and policy communities. Although we agree with the SISA policy practitioners that it is neither ethical nor the role of policy practitioners to teach science to IPLC, we suggest that policy practitioners can share knowledge outcomes with IPLC throughout the entire process of policy implementation – e.g. by using non-technical and local terms and by familiarizing locals with scientific terms and concepts that are relevant and complement their knowledge (Albuquerque et al., 2015).

We conclude with a call for attention to the relation between knowledge diversity and power. IPLC's resource management, knowledge, and SES are dynamic and need to adapt in face of global changes and policy goals. While it is difficult to completely avoid uneven power relations, extraction, and reduction of knowledge diversity (Lemos et al., 2018; Turnhout et al., 2020), continuous reflection on whether power is effectively shared is needed for these processes to result in legitimate outcomes. This reflection should account for which meanings may have been lost and created during the process; how these meanings resonate with understandings and needs of IPLC; and whether the consequences of knowledge choices are culturally and ethically justifiable. This requires a redirection of the focus of knowledge integration from the perfection of methods and frameworks towards a practical ethics that is able to addresses and mitigate the political implications and consequences of knowledge integration processes as they arise in practice.

Declaration of Competing Interest

The authors declare no conflict of interest.

Acknowledgments

We thank the Brazilian Coordination of Improvement of Higher Level Personnel (CAPES) – which sponsors the first author's PhD in the Wageningen University (WUR) (project 99999.001429/2015-09), and Embrapa, for offering access to data and contributing to the paper. Most importantly, we thank all Kaxinawá partners who contributed to this research.

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