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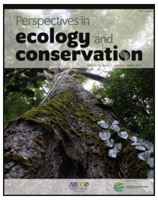

Essays and Perspectives

Ecosystem-based adaptation to climate change: concept, scalability and a role for conservation science

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ABSTRACT

Societal adaptation to climate change requires measures that simultaneously reduce poverty, protect or restore biodiversity and ecosystem services, and remove atmospheric greenhouse gases. Ecosystem-based adaptation to climate change is the type of adaptation that aims to combine these outcomes and is particularly relevant to developing nations that safeguard most of the planetary biodiversity and healthy ecosystems. Although conceptually new, ecosystem-based adaptation is fastly gaining traction both as a research arena and as an integrated policy instrument. This paper aims to revisit this concept and to discuss the science and policy challenges faced by it. It argues that ecosystem-based adaptation is a policy mix that promotes adaptive transition, which is a step towards sustainability transitions. It faces two major challenges in promoting transitions towards adaptation and sustainability. First, research on ecosystem-based adaptation mostly takes place within the socio-ecological systems framework, which is often carried out in isolation from socio-technical systems research. It is widely recognized that both types of research should be integrated, for the benefit of science and policy-making, and the paper discusses the potential of ecosystem-based adaptation in providing such bridge. Second, there is a divide between global and local research and policy, while at local level this divide is related to the setting (e.g., coastal, urban, rural). The resulting mosaic of information lacks integration, which hinders scalability of actions and policies. Finally, I examine the opportunity for ecological and conservation scientists to interact with social, economic and political scientists on ecosystem-based adaptation research, and discuss how timely this opportunity is for Brazil.

Introduction

Even in the most optimistic greenhouse gas emission (GHG) scenarios mean planet temperature is likely to increase at least by 2 °C until the year 2100 (IPCC, 2013). The Paris Agreement to combat climate change adopted in December 2015 under the United Nations Framework Convention on Climate Change (UNFCCC) stipulates that parties will pursue efforts to limit temperature increase to 1.5 °C above pre-industrial levels by 2050. However, even if all national commitments in the Paris agreement are accomplished, mean planet temperature is likely to increase at least by 2.6–3.1 °C until the year 2100 compared to pre-industrial levels (Rogelj et al., 2016). Consequences of a temperature increase equal or beyond 2 °C include ice-melting in the Arctic and glaciers with consequent sea-level rise and continental flooding (Grémillet et al., 2015), negative impacts upon human health (Watts et al., 2015), increased species extinction rates (Urban, 2015), biome shifts (Anadón et al., 2014), marked decline in agriculture productivity (Rosenzweig et al., 2013), and negative impact on energy generation (Vliet et al., 2016). Such bleak future scenarios suggest that carbon mitigation will continue to be relevant and must speed up, but alone will not suffice to halt or circumvent ongoing climate trends. Thus, adaptation strategies are needed to boost resilience of vulnerable socio-ecological systems (for definitions of these and other concepts used in this paper, see the Glossary in Table 1). Nevertheless, the extreme scenarios projected at >2 °C, or even worse at >4 °C, by the end of this century, also suggest that there are limits to adaptation, which is in harmony with the notion that climate change and biosphere integrity are two core planetary boundaries that, if continuously transgressed, may drive the Earth system into a new state, undesirable for humankind (Steffen et al., 2015).

As compared to human systems, there is more abundant and comprehensive evidence of climate-change impacts for natural systems, and the most vulnerable are those that lost a significant

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Table 1
Glossary of terms used across this paper.

Concept	Definition	References
Adaptation	'The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects.'	Field et al. (2014)
Adaptive development	'A form of development that mitigates climate change risks without negatively influencing the well-being of human subjects and ecosystems by using incentives, institutions, and information-based policy interventions to address different components of climate risks.'	Agrawal and Lemos (2015)
Adaptive transition	Pathway towards sustainability transitions that combine processes of transformations in technologies, ecologies, economies, livelihoods and lifestyles, while developing local adaptive capacity. It increases accessibility and adaptability of modern as well as local/indigenous technologies and practices and thus reduces vulnerability.	Pant et al. (2015)
Conventional development	Currently predominant development model, where economy is central and social capital and natural capital are perceived as externalities. Built capital – houses, cars, roads, factories – is the limiting factor in this model.	Costanza (2015)
Green infrastructure	'A network of natural, semi-natural and restored areas designed and managed at different spatial scales (from local to global), that encompasses all major types of ecosystems (marine, terrestrial and freshwater), and that aims to conserve biodiversity, mitigate emissions of greenhouse gases, enable societal adaptation to climate change, and deliver a wide range of other ecosystem services'.	Silva and Wheeler (2017)
Impact	'Effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period.'	Agard and Schipper (2014)
Life supporting systems	The portion of natural systems that provides the physiological necessities of life, such as water, air, nutrients, food.	Folke (1991)
Planetary boundaries	'Scientifically based levels of human perturbation of the Earth System beyond which planetary functioning may be substantially altered. Transgression of such boundaries creates substantial risk of destabilizing the Holocene state of the Earth System in which modern societies have evolved.'	Steffen et al. (2015)
Policy mix	Interactions and interdependencies between different policies as they affect the extent to which intended policy outcomes are achieved.	Flanagan et al. (2011)
Resilience	The capacity of systems (natural and human) to cope with hazardous events responding or reorganizing so that structure, function and identity are maintained, while capacity for adaptation, transformation and learning is also maintained.	Field et al. (2014)
Socio-ecological systems research	'How resource dependent society interacts with nature to develop an adaptive capacity in response to various shocks and stresses' (e.g., climate change, extreme events, biodiversity loss, and desertification).	Pant et al. (2015)
Socio-technical systems research	'Science-society interactions for effective change management, such as transitions to low carbon systems of ecological farming, plant-based diets, ecotourism and renewable energy, in response to unprecedented social and environmental impacts of industrialization in developed countries.'	Pant et al. (2015)
Sustainable adaptation	'Adaptation measures that also contribute towards social equity and environmental integrity.'	Brown (2011)
Sustainable development	A type of development whereby the Earth, its ecosystems, and its people interact towards the mutual benefit and sustenance of all, at multiple scales, and over succeeding generations. What is considered sustainable may vary in space and time throughout a given transition process towards sustainability.	Spangenberg (2011)
Sustainability science	Focuses on understanding the complex dynamics that arise from interactions between human and ecological systems. It "requires collaboration between perspectives in developed and developing human societies, among theoretical and applied scientific disciplines, and must bridge the gap between theory, practice, and policy."	Clark (2007), Bettencourt and Kaur (2011)
Sustainability transitions	Transformation process by which traditional systems shift to more sustainable modes of production and consumption. It is multistakeholder, multidimensional, and often operates in the long-term.	Markard et al. (2012)
Vulnerability	Propensity or predisposition of a given system (natural or social) to be adversely affected by a given driver. In the case of climate change, types of driver include climate variability, extremes and hazards.	Burkett et al. (2014)

portion of their life supporting systems (IPCC, 2014). For human systems, the IPCC recognizes that the poor people are the most vulnerable to climate impacts (Fisher et al., 2014; Magrin et al., 2014). Indeed, one of the main conclusions of the Working Group II in the fifth assessment report of the IPCC (2014) is that practices that promote sustainable development in the present – by combining social justice, environmental health and economic productivity – reduce future risks imposed by climate change and are thus adaptive. Starting from this premise, the question is how a given society moves from a conventional development pathway to sustainable development. This paper's argument is that ecosystem-based adaptation to climate change (EbA) is a key instrument to drive such transition to sustainability and that it is as much a political challenge as it is a scientific and technological endeavor. It has three central objectives: (1) to add precision to the definition of EbA, by bridging literature on climate change adaptation and literature on sustainability transition; (2) to discuss how EbA research and policy moves from local to global and vice versa; and (3) to discuss the need for conservation scientists to adhere to the EbA research and policy agenda. Finally, we use Brazil as an example of the opportunity for sustainability transition that EbA might represent to a developing country rich in natural wealth.

Issues with a new concept

Table 2 shows various definitions of EbA, but clearly the one used by the United Nations' Convention of Biological Diversity (CBD, 2009) is the most widely adopted: the use of biodiversity and ecosystem services (BES) *as part* of an overall adaptation

Table 2
Different definitions and examples of ecosystem-based adaptation to climate change (EbA) found in the literature.

Definitions
The use of biodiversity and ecosystem services (BES) as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change (CBD, 2009)
Policies and practices that are based on the premise that ecosystem services protected or restored reduce the vulnerability of society to climate change (Vignola et al., 2009)
The use of natural capital by people to adapt to climate change impacts, which can also have multiple co-benefits for mitigation, protection of livelihoods and poverty alleviation (Munang et al., 2013)
The use of BES into climate change adaptation strategies, taking into account the multiple social, economic, and cultural co-benefits for local communities (Shaw et al., 2014)
Practices that promote socio-ecological resilience by fostering ecosystem services, through ecosystem management that enable people to adapt to the impacts of climate change and reduce their vulnerability (Ojea, 2015)
Examples
Sustainable management, conservation and restoration of ecosystems, as part of an overall adaptation strategy that takes into account the multiple social, economic and cultural co-benefits for local communities (CBD, 2009)
Ecosystem restoration enhances critical ecosystem services (e.g., water flow or food and fisheries provision), and protecting or restoring natural infrastructure (e.g., barrier beaches, mangroves, coral reefs, and forests) buffers human communities from natural hazards, erosion and flooding (Munang et al., 2013)
Ecological restoration, payment for ecosystem services, creation and effective management of protected areas, and community management (Magrin et al., 2014)
Sustainable water management to provide water resilience, disaster-risk reduction through the restoration of coastal habitats, and sustainable agricultural management to enhance livelihoods and increase resilience (Shaw et al., 2014)
Forest products from agro-biodiversity can provide safety nets to local communities when climate variability causes crop failures; coral reefs protection against erosion and wave damage is less expensive than building dykes and levees (Ojea, 2015)

strategy to help people to adapt to the adverse effects of climate change. This definition suggests that EbA is the BES component of any given policy mix designed to promote climate change adaptation. I argue that this notion is misleading and creates a confusion between policies, practices and science oriented to address BES conservation and management with those oriented to address climate change adaptation. Similarly, other existing definitions of EbA treat BES as central and the human component secondarily. For instance, for some, EbA practices *assume* (does not *ensure* or *promote*) that ecosystem services flow reduces societal vulnerability to climate change (Vignola et al., 2009), while for others they *take into account* (rather than directly *address*) the multiple social, economic, and cultural co-benefits for local communities (Shaw et al., 2014). There is also a confusion eventually made, especially by some environmentally-oriented organizations or academics, to conceptualize EbA as the adaptation of ecosystems to climate change rather than the use of ecosystems for human adaptation to climate change, as pointed out by Doswald et al. (2014).

I propose that EbA is a policy mix that includes typical BES-related policy instruments and tools, but also socioeconomic and development-related policies. To fit the EbA framework, policy instruments typical of the biodiversity conservation agenda (e.g., establishment and effective management of protected areas, community management of natural areas, ecological restoration, and others) will be part of a mix that includes mechanisms and policies of income generation, poverty reduction and/or infrastructural development, and carbon mitigation. This policy mix will therefore reduce societal vulnerability and is adaptive to climate change. For instance, protected areas will only generate income for neighboring populations via ecotourism if adequate management plans favoring public use exist (e.g., Tortato and Izzo, 2017), as well as infrastructure for transportation and accommodation (e.g., Krüger, 2005); community management will be more effective if technical and managerial advice is available for the local actors (e.g., Hutchings et al., 2015); and payment for ecosystem services will work if investors see the added value of their investments, and both conservation and socioeconomic goals are achieved locally (e.g., Grima et al., 2016). To fit the EbA framework, practices such as payment for ecosystem services, protected areas, community management, etc., should also mitigate GHG emissions, as Locatelli et al. (2011) described for various cases in Latin America. EbA, by combining conservation and socioeconomic goals while mitigating GHG emission, has a great potential to serve adaptation purposes and to promote sustainable development. Table 2 shows additional examples of types of EbA practices found in the literature.

Sustainability transitions

For any given society to shift from a conventional development pathway to a sustainable development pathway, a transition process is expected to take place. This sustainability transition requires policy mixes given the complexity it entails. The argument here is that EbA is an specific type of policy mix that pushes forward sustainability transitions that, in the end, ensure BES conservation or restoration and carbon mitigation, while promoting livelihood improvements to a given community or society. Thus, EbA can be a particularly relevant trigger of sustainability transitions, especially in developing nations that safeguard most of the planetary biodiversity and healthy ecosystems.

Literature on sustainability science and sustainability transitions is often divided into two approaches: research on socio-ecological systems and research on socio-technical systems. Studies on socio-ecological systems (SES) examine how society interacts with nature, and how such interactions can be adaptive to events such as climate change and other impacts (Pant et al., 2015). SES research has examples of transitions to reduce public health threat (Rael et al., 2016), to reduce vulnerability to natural disasters (Munang et al., 2013), and to promote adaptive BES conservation (Mathevet et al., 2016), most of which emphasize the relevance of participatory decision-making in such systems (Castro et al., 2016). Studies on socio-technical systems (STS) examine science–society interactions for transition to low carbon systems in specific sectors (agriculture, energy, industry, etc.) in response to climate change and other impacts (Pant et al., 2015). There are several examples of sustainability transitions studies in specific productive sectors such as energy (Rogge and Reichardt, 2016), agriculture (Ponisio and Kremen, 2016), industry (Hess, 2014), which often highlight how technological innovation is a key driver of such transitions targeting lower carbon budgets. Research on SES and STS is often carried out in isolation from each other and several authors (Smith and Stirling, 2010; Pant et al., 2015) argue that both approaches should be integrated, both in science and in policy-making.

Expectedly, the divide that exists between SES and STS approaches is felt also in the EbA arena. References to adaptation to climate change usually evoke images of infrastructural interventions. For instance, a survey of 92 projects funded by the Global Environmental Facility found two times as much references to adaptation through physical infrastructure than to green infrastructure (Biagini et al., 2014). Physical infrastructure is often costly and aimed at restoring or overcoming limitations imposed by scarcity of natural resources of one or several kinds. EbA approaches arguably provide cost effective, flexible and broadly applicable adaptation alternatives (Munang et al., 2013; Ojea, 2015). It is reasonable to assume that if mangroves are protected or restored dikes may not be necessary (Locatelli, 2010; Martin and Watson, 2016); and that if hillsides are not deforested contention work may not be required (Surjan et al., 2016). Furthermore, physical infrastructural measures alone may face setbacks related to long-term viability, effectiveness or environmental soundness (Shaw et al., 2014), such as in the case of river transposition to avoid drought, for instance (Lemos et al., 2016). However, rather than ruling out infrastructural or ecosystem-based adaptation, it is possible that in many cases they can and should be integrated through specific policy mixes. Silva and Wheeler (2017) argue that this can be favored if green infrastructure is perceived and treated as a necessary complement to development, manmade physical infrastructure.

The integration between SES and STS research is what some argue to be necessary to better inform adaptive transition processes (Smith and Stirling, 2010; Pant et al., 2015). Adaptive transition, in turn, is a pre-requisite to sustainability transition in systems vulnerable to climate change. Indeed, Agrawal and Lemos (2015) clarify that development and adaptation are not synonyms. While development policies (when sustainable) aim to solve poverty through economic growth, to address inequality through redistribution of wealth, and to prevent environmental degradation through sustainable resource use, adaptation policies primarily address vulnerability and risks. So, these authors coined the terminology ‘adaptive development’ to refer to a type of or a step in the development process that avoids or reduces risks without negatively impacting human systems and natural systems. I argue that the process of adaptive transition (sensu Pant et al., 2015) incites adaptive development (sensu Agrawal and Lemos, 2015), which is a key step to foster transition from a conventional to a sustainable development paradigm. This, starting from the premise that the adaptation process in question is sustainable. Brown (2011) warns that not all adaptation is sustainable, and coined still another term, ‘sustainable adaptation’, which I argue is possibly a synonym of EbA (for further clarification on the terminology used in this topic, Glossary in Table 1). Fig. 1 depicts EbA as a policy mix and as a topic in interdisciplinary science within the SES research framework and policy domain. However, it also shows that further integration between SES and STS, and between EbA and physical infrastructure adaptation (in science and in policy) can boost adaptive development processes leading to sustainability.

Global and local reach, and their connectivity

Adaptation requires capacity to allocate and also to combine different types of resources for an uncertain future in a given place (Lemos et al., 2016). Thus, the deployment of EbA strategies and instruments shall vary depending on the local setting. Whether the locality in question is urban, rural, coastal, or in the middle of low populated wilderness areas – such as in most of the Amazon, for instance – the adaptive strategy will vary largely. Therefore, scientific literature on EbA is still somewhat divided between global and local focus, and at local level it is divided according to the setting. Munroe et al. (2011) reviewed 132 papers on EbA and found that nearly half (45%) were from developing countries. They also found a predominance of papers focused on urban or rural, wetlands, forests and coastal ecosystems. However, a recent review on urban EbA covered 110 papers in 112 cities and there was a strong bias towards Europe and North America (Brink et al., 2016). Coastal vegetation, including mangroves, both in continental and in small island countries, have been highlighted as important for EbA (Mercer et al., 2012; Duarte et al., 2013; Martin and Watson, 2016), but is still short of a thorough and integrated review effort (but see Sierra-Correa and Kintz, 2015). In rural areas, for small holder farmers – especially based on studies located in Mesoamerica (Vignola et al., 2015) – EbA practices may improve the ability of crops and livestock to maintain crop yields and/or buffer biophysical impacts of extreme weather events or increased temperatures under climate change.

Different localities will often have teleconnections with other localities with similar or different profiles, which can be more (e.g., roads, energy, etc.) or less (e.g., commercial trade, telecommunications, etc.) visible, and add further complexity to the adaptation strategy and process. For example, an urban megacity may rely on water that runs superficially in rivers that cross neighboring rural municipalities, and this water, in turn, may spring on the top of an uninhabited cold mountain vulnerable to climate change. This connectivity demonstrates that local sustainability depends on sustainability at a broader spatial scale (Morton et al., 2014). There is a big gap in such types of studies, but recent advances in analytical tools point to the large potential of this line of research to the science-policy interface (Liu et al., 2015, 2016).

As in the case of science, policies range from global to local approaches, such as global agreements (e.g., United Nations’ Conventions), national adaptation plans, municipal EbA strategies, and local governance arrangements at smaller territories (Table 3). A key challenge is that global agreements do not always have an immediate or easy translation into national and sub-national policies, while local EbA solutions do not always scale up beyond a municipality or a given community. From a global perspective, Ojea (2015) argues that despite recent excitement with EbA, there are still barriers for mainstreaming it into international climate policy related to governance, effectiveness, time scale of processes, financing and scientific uncertainty. At national level, a review by Pramova et al. (2012) showed that only 22% of the National Adaptation Plans of 44 developing countries incorporated ecosystem components. At sub-national level, the use of ecosystems in helping people adapt to climate change is limited partially by the lack of information on where ecosystems have the highest potential to do so, which can probably be overcome by spatial prioritization efforts (Bourne et al., 2016). However, whenever such policies already exist, approaches vary. For instance, adaptation policies in Swedish municipalities are mainstreamed through an ecosystem services perspective, while in German municipalities climate mitigation is the focus (Wamsler and Pauleit, 2016). Moreover, ecosystem-based approaches to climate change are not often systematized or labeled as such in Germany or Sweden (Wamsler and Pauleit, 2016) or in most other places across the planet (Munroe et al., 2011).

The science-policy interface and a role for conservation science

The science required to approach EbA is necessarily inter- and transdisciplinary, since it demands integration of social, economic, environmental, so as to be applicable to policy-making (Table 4). EbA research thus fits to the framework of sustainability science, since the core research agenda of the latter simultaneously requires transdisciplinary scientific rigor (Lang et al., 2012) and to result in measurable societal impacts (Bettencourt and Kaur, 2011). Key challenges of sustainability science include the need to integrate perspectives from both developed and developing societies, from theoretical and applied disciplines, from science and policy (Ascher, 2007; Aronson, 2011), as it is clearly also the case of EbA research. For instance, Schoolman et al. (2012) have shown that although more interdisciplinary than many fields, sustainability science falls short of expectations about integration of its three parts: economic, social, and environmental. Interestingly, these authors show that the economic pillar has the fewest papers published but is the one that is most integrative of the environmental and the social pillar. The environmental pillar, on the contrary, has the most

Table 3
Range and scope of policy arrangements and scientific niches of ecosystem-based adaptation to climate change (EbA). Acronyms: UNFCCC, United Nations Framework Climate Change Convention; CBD, Convention on Biological Diversity; UNCCD, United Nations Convention on Combat to Desertification; SDG, Sustainable Development Goals; OTCA, Organization Treaty for the Amazonian Cooperation; UNASUR, Union of South American Nations; CARICOM, Caribbean Community.

Policy	Main characteristics
Global Conventions	UNFCCC, CBD, UNCCD, SDG: a web-page search for the term 'ecosystem-based adaptation' shows that it is explicitly mentioned in all four global agreements.
Regional Agreements	Regional development agreements that include socio-ecological agendas refer to potential EbA practices, but do not mention the term explicitly (e.g., OTCA, UNASUR, CARICOM) (webpage search for the term 'ecosystem-based adaptation').
National Adaptation Plans (NAPs)	Ecosystem components are present in a small proportion of NAPs of developing countries (Pramova et al., 2012).
Subnational Government Plans	Adaptation plans, especially those including ecosystem components, are less frequent at sub-national level in developing countries (Bourne et al., 2016). Whenever present, EbA is not often explicitly mentioned even in developed countries (Munroe et al., 2011; Wamsler and Pauleit, 2016). However, large cities are more active in planning for adaptation especially in developed countries (Araos et al., 2016).
Self-organized, bottom up approaches	There are various accounts and anecdotal reports of EbA taking place at local level (e.g., watershed committees, local governance, NGO initiatives etc.). Most of them, however, lack scientific robustness in performance evaluations. As a result, many such efforts are not scaled up (Munroe et al., 2012; Wamsler et al., 2016).
Science	**Main characteristics**
Predominant disciplines	Although the topic clearly demands an interdisciplinary approach, it still seems slightly biased towards natural sciences (Schoolman et al., 2012; Doswald et al., 2014). It fits the domain of sustainability sciences.
Location specific	Studies on converted land (urban and rural) are predominant as compared to coastal ecosystems, wetlands, wilderness areas, and coupled systems (Munroe et al., 2012)
Recurrent themes	Restoration and payment for ecosystem services are often treated as EbA even when socioeconomic are not fully considered (Ojea, 2015).
Some knowledge gaps	There are more EbA-relevant studies than direct assessment of EbA interventions; difficulties in incorporating and translating into assessments the non-scientific knowledge available; analysis of the timescales, and physical, ecological, and socio-economic conditions under which EbA may or may not be successful (Doswald et al., 2014).

Table 4
Policies that have the potential to deliver EbA actions in Brazil, when appropriately designed as policy mixes.

	Policies	Brief description
National (mostly socioecological)	Native Vegetation Protection Law	Legislation that defines the proportion of land inside private properties that must be protected or restored (Brancalion et al., 2016). Established in 2012.
	National Policy for Restoration of Native Vegetation (PROVEG)	Policy that aims to induce, promote and incentivize restoration of degraded areas (at http://www.planalto.gov.br/ccivil_03/_ato2015-2018/2017/decreto/D8972.htm) Est. 2017.
	National Plan for Management of Indigenous Lands (PNGATI)	Policy that aims to promote conservation, restoration and sustainable use of natural resources within indigenous lands, while ensuring the integrity of the indigenous heritage and the improvement of the quality of life of the indigenous peoples, respecting their sociocultural autonomy (at http://www.funai.gov.br/pngati/). Est. 2012.
	National System of Protected Areas (SNUC)	Legislation that defines the categories of the national system of protected areas and respective regulations (at http://www.mma.gov.br/areas-protegidas/sistema-nacional-de-ucs-snuc). Est. 2000.
	Bolsa Verde	Social safety net program based on conservation inside private properties of the rural poor (BRASIL, 2013). Est. 2011.
National (mostly socio-technical)	Incentive Program for Alternative Sources of Electric Energy	This program is a financial incentive mechanism to wind, biomass and small hydro energy generation (at http://www.mme.gov.br/programas/proinfa/). Est. 2004.
	Low Carbon Agriculture Program	Incentive mechanism that aims to promote specific agricultural activities based on best management practices that include both hard (e.g., recycling of industrial waste, biological nitrogen fixation) and socio-ecological technologies (restoration of degraded pastureland, livestock intensification, integrated crop-livestock-forestry systems, etc. (Sá et al., 2017). Est. 2010.
National (integrated)	National Climate Change Adaptation Plan	Integrated policy which covers adaptation considering the following sectors: agriculture, water, food and nutrition, biodiversity and ecosystems, cities, disaster management, industry and mining, infrastructure, vulnerable populations, vulnerable peoples, health, and coastal zones (at http://www.mma.gov.br/clima/adaptacao/plano-nacional-de-adaptacao). Est. 2016
Sub-national	There are various sub-national policies in place, from municipal adaptation plans to state-level payment for ecosystem-service schemes that, mixed with some of the national command-and-control or incentive policies listed above may promote EbA. However, it has been argued that from a biodiversity conservation viewpoint there is more sub-national and national-level policies directed to forest ecosystems than to non-forest ecosystems (Overbeck et al., 2015).	

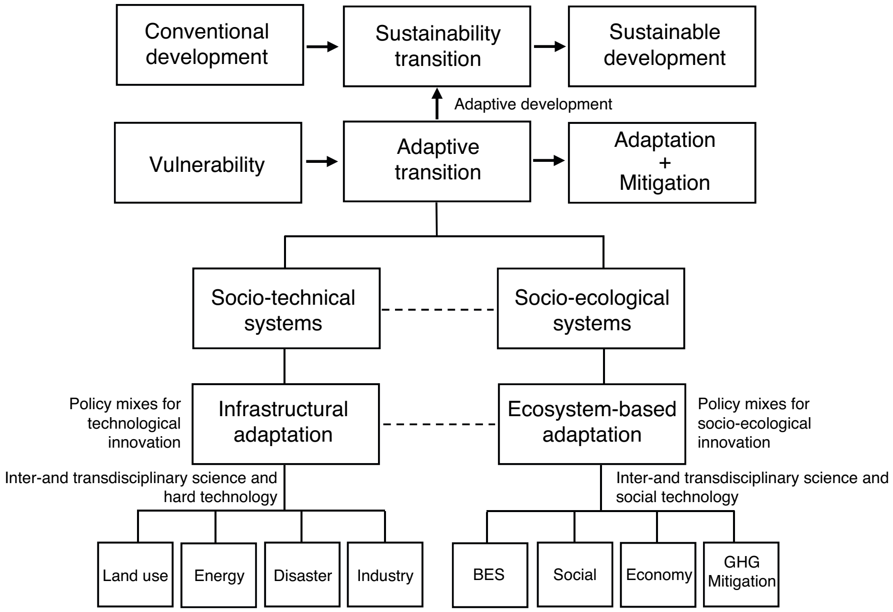

Fig. 1. Diagram shows the relationships between climate change research and policy with the domain of sustainability transitions. Adaptation (with GHG mitigation) is a necessary step towards sustainable development in places vulnerable to climate change. Adaptation and sustainable development processes are linked via adaptive development. EbA is a policy mix that links policies related to BES, socio-economics and carbon mitigation, and can be an important driver of adaptive transitions. However, EbA research is mostly framed within the SES arena. Further integration between EbA and infrastructure-based adaptation, and between SES and STS research, is necessary to inform adaptive transition and derived sustainability transition processes.

articles but draws the least from outside disciplines. This pattern echoes some of the challenge of EbA research, where part of the environmentally-oriented literature takes for granted (rather than evaluates or measures) that some BES-related policy instruments (protected areas, payment for ecosystem services, REDD, community management, restoration) are adaptive to climate change (see Doswald et al., 2014).

EbA's basic scientific premise is that there is a direct connection between BES and human wellbeing that, whenever promoted, is adaptive to climate change. This premise should indeed be turned into testable hypotheses, since systematic and quantitative work on the linkages between BES and human wellbeing are rare in literature, despite recent efforts to use quantitative indicators and integrated models to assess such linkages (Yang et al., 2015a,b). This scientific gap is eventually translated by policy-makers as uncertainty, which hinders EbA implementation (Ojea, 2015).

I believe that conservation science is still a step away from examining the links between BES and human wellbeing, which is a pre-requisite for successful EbA research and practical application. This demands involvement of conservation scientists and a more intense dialogue between them and scientists in other disciplines related to climate change, political sciences, and human wellbeing. This effort cannot be nature-centric (as conventional conservation is sometimes labeled) or anthropocentric (as the so-called 'new conservation science' is accused of being; see debate in Soulé, 2013; Doak et al., 2014; Kareiva, 2014; Miller et al., 2014), but something that builds precisely on the links and causal relations between nature and human wellbeing. Colloff et al. (2017) argue that 'normal' science no longer 'works' because the world itself has changed so much, and therefore conservation science should enter 'post-normal' times. In their view, redirection of conservation science would involve four important steps: (1) build new framings of the links between ecosystems and society; (2) develop new relationships and roles for conservation science; (3) develop new models of how conservation links to society and social change and (4) search for new approaches for implementing adaptation for conservation outcomes. In this respect, recent evidence of the rise in international collaboration networks on in interdisciplinary studies at the interface biodiversity-climate change (Dangles et al., 2016) is a positive symptom.

EbA: an opportunity for Brazil

Brazil's NDC (nationally determined contributions) to the UNFCCC of reduction on carbon emissions is based on a sustainable land-use component and a sustainable energy component (BRAZIL, 2015). The sustainable land-use component includes zeroing illegal deforestation in Amazonia, restoring 12 million hectares of degraded land, restoring additional 15 million hectares of degraded pasture lands, and strengthening the low carbon agriculture program. The sustainable energy component includes increasing the biofuels share in the energy mix and increasing the contribution of renewables (other than hydroelectricity) to the energy matrix. Brazil's commitment is explicit about its EbA vocation when it says: "(...) the implementation of policies and measures to adapt to climate change contributes to building resilience of populations, ecosystems, infrastructure and production systems, by reducing vulnerability and through the provision of ecosystem services" (BRAZIL, 2015, p. 2). In that sense, it is in harmony with other global agreements signed by Brazil, such as the CBD's Aichi targets to 2020 (which include zero extinction, 15% of degraded lands restored, sustainable agriculture; see Mittermeier et al., 2010) and the Sustainable Development Goals (SDG; which include climate stability, zero poverty, and land and oceans protected; see Griggs et al., 2013).

Unlike the NDC of many other countries at the Paris agreement (e.g., Australia, Canada, United States; Hoehne et al., 2017), Brazil's adherence to the above mentioned global goals are anchored by a set of national policies. For instance, if farmers comply to the Native Vegetation Protection Law (see brief description of this and other relevant legislations in Table 4), the climate goal of restoring 12 million hectares of degraded land by 2030 will possibly be accomplished (Brancalion et al., 2016; Soares-Filho et al., 2014). However, for this command-and-control policy to be put on the ground, incentive mechanisms (such as sub-national payment for ecosystem service schemes), and other market policies (such as eco-certification) will most likely be necessary. Similarly, the zero illegal deforestation target in Amazonia will be more efficiently accomplished if command-and-control policies are coupled to incentive mechanisms, such as Bolsa Verde (BRASIL, 2013).

These policies are mostly socio-ecological in scope, but Brazil also has socio-technical policies that are relevant to achieving climate, biodiversity and development goals, such as the Low Carbon Agriculture Plan and the Incentive Program for Alternative Sources of Electric Energy. Both SES- and STS-related policies appear integrated in the National Adaptation Plan, which has a strong focus on EbA. There is an increasing body of evidence showing that conflicts and unsustainability emerge from the lack of integration among sectors and among sectoral policies, particularly when development and market policies do not account for environmental and/or social issues (e.g., Franks et al., 2014) and vice versa (e.g., Adams and Hutton, 2007). Then, the existence of too many sectoral policies can also be confusing and the right policy mix must be put in place to find the appropriate synergies. For instance, to avoid massive species extinction, voluminous carbon emission and consequent socio-economic setbacks for the Cerrado hotspot, Strassburg et al. (2017) have recently proposed that a policy mix comprising BES (that increase nature protection), social (that foster economic incentives for conservation and restoration), and agricultural (that promote sustainable intensification) policy instruments, aligned via improved land-use planning as the main policy support tool. In the Amazon, Pinho et al. (2014) have shown how BES policies and poverty alleviation policies historically moved from conflicting sectoral policies to successful mixes that reduce deforestation and improve livelihoods. In the Atlantic rainforest, a combination of civil society initiatives, such as the Atlantic Forest Restoration Pact, with national level legislation (e.g., Law of Protection of the Atlantic forest), with sub-national payment for ecosystem service legislation, is also experiencing local success in some cases (Scarano and Ceotto, 2015). Thus, to promote EbA actions, the set of policies laid out as examples in Table 4 should be treated as a mix, promoting synergies and assessing eventual trade-offs to facilitate management and implementation.

How to percolate these national policies to municipalities, watershed and local communities remains challenging. FBPN/ICLEI (2015) searched for local cases of EbA practices in Brazil according to a set of criteria that included (i) use of BES; (ii) be adaptive to local people and societies; and (iii) include climate change vulnerability assessments. They found only 11 cases in 9 states. These results show that much needs to be done at local level to streamline EbA into sub-national and local agendas in Brazil.

In opposition to this overall positive perspective, the current political and economic crises in Brazil are reasons for concern. In the political front, there is pressure on some of the existing environmental legislation and poor decision-making from a sustainability viewpoint (e.g., Azevedo-Santos et al., 2017; Ruaro and Mormul, 2017). In the economic front, the estimated costs of achieving the goals set by the NDC are high (e.g., Hof et al., 2017), including those related to biodiversity conservation (Cunha et al., 2016). Moreover, science budget has been cut by nearly half (Angelo, 2017). If these current challenges imply inaction as regards climate, biodiversity and sustainable development goals, the outcome would be devastating. For the Cerrado biome, for instance, business as usual native vegetation removal would mean, by 2050, extinction of 480 endemic plant species (over three times all documented plant extinctions since the year 1500), a carbon emission equivalent to 2.5 times all the emissions reductions achieved in the Amazon between 2005 and 2013 (Strassburg et al., 2017), and consequent socio-economic setbacks (e.g., Oliveira et al., 2015). The socio-ecological vulnerability to climate change of other Brazilian biomes (e.g., Atlantic forest and Caatinga), including rural and urban settings, is also well known (Torres et al., 2012).

Final remarks

EbA still lacks a major and integrated review effort (see Munroe et al., 2012, for a proposed review framework), which will hopefully be easier to undertake as the concept and the realm are more precisely defined, as this paper attempted to do. EbA is a policy mix that has the potential to, while adapting to climate change, drive sustainability transitions. It combines policies that can be sectoral or integrated, and demands socio-ecological research, while having the potential to bridge this with socio-technical research. While research is currently conducted at specific localities, there remain obstacles to mainstream EbA into the international climate agenda. Brazil offers an exciting research agenda on the streamlining of a global commitment into national policies through to local design and implementation, with a strong potential for a very active science-policy interface. Indeed, if current political and economic obstacles are circumvent, Brazil may soon have in place one of the largest EbA programs at national level, since the necessary legislation is already in place and some of it under implementation. Conservation science has the opportunity to play a key role in this science-policy agenda, internationally, and of course also in Brazil. This will require a more frequent and intense dialogue between conservation scientists and scientists in other disciplines related to climate change, political sciences, and human wellbeing. The success of conservation science to set geographic conservation priorities can be applied to set priorities for the deployment of EbA strategies. The understanding of complex natural processes derived from the interaction between species, and between them and their environment, also promoted by ecological and conservation science, can lend itself to search for the links, connections and causal relations between nature and human wellbeing. *Perspectives in Ecology and Conservation* can become a key arena for this exciting debate (Metzger et al., 2017).

Conflicts of interest

The author declares no conflicts of interest.

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