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Adaptation in the Anthropocene

How we can support ecosystems to enable our response to change

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Key messages

- Ecosystems provide people with services that enable adaptation to climate change, which we refer to here as 'adaptation services'.
- But adaptation services do not flow automatically: some input from people is needed.
- We identified five types of mechanisms that support the production of adaptation services.
- These mechanisms are related to: (i) multifunctional and traditional ecosystem management, (ii) proactive management of transformed ecosystems, (iii) use of novel adaptation services, (iv) collective ecosystem management, and (v) appreciating, using and valuing adaptation services.
- Understanding these mechanisms can lead to an improved flow of adaptation services and more options for livelihoods and well-being under climate change.
- This InfoBrief summarizes the findings of a paper published in the *Philosophical Transactions of the Royal Society Series B* (Lavorel et al. 2020).

Introduction

In 2000, Nobel Laureate Paul Crutzen was attending a meeting of the International Geosphere-Biosphere Programme where the word 'Holocene' was repeated so many times that he just could not bear it any longer: "Stop saying the Holocene! We're not in the Holocene any more" Crutzen burst out; "We are in the…the… [searching for the right word] …the Anthropocene!" (Steffen 2013). The term, subsequently published by Crutzen and Stoermer (2000), was based on the premise that humans have altered the Earth's systems to such a degree that the planet has entered a new epoch – the Anthropocene.

It is clear from the Anthropocene concept that humans have modified this planet to a point that is affecting all living beings. Climate change is just one example of such modifications. The Earth is already now 1.3 °C degrees warmer than during the pre-industrial period (1880–1900), and even if national pledges to limit greenhouse gas emissions are implemented, the likely projection is for at least 3 °C of global warming (Lenton et al. 2019). Adaptation has become a necessity now and for the future.

The concept of the Anthropocene highlights the interdependent relationship between people and nature and thus underscores our environmental responsibilities, particularly the need to lessen our negative impacts on ecosystems. In order for people to adapt their livelihoods under climate change, they will need to be able to identify and use a subset of ecosystem services – called *adaptation services*, or *nature's contribution to adaptation* –that can provide them with options for adaptation now and into the future.

Adaptation services can be provided, for example, by including nitrogen-fixing trees in agroforestry systems that

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regulate soil, water and microclimates, and thus minimize drought risks to crops. Another option is to ensure we have forests that regulate water flows and reduce the impacts of floods on communities. In coastal areas, mangroves provide adaptation services by supplying people with durable water-resistant wood, nursery habitats for commercial fin fish, crustaceans and mollusks, and natural protection against storms and sea level rise (Pramova et al. 2012; Guerry et al. 2015).

Under climate change, some ecosystems will transform while others will persist, albeit with some changes in structure and processes. The ecosystem properties that enable persistence (e.g. resilience to climate stresses due to the presence of different species performing similar roles) are part of nature's contribution to our adaptation. Ecosystems that transform will supply novel adaptation services, and the ecosystem properties (e.g. genetic variability or landscape connectivity) enabling this transformation are also part of the contribution. In addition, services not previously used may become valuable under climate change (latent adaptation services) (Colloff et al. 2016; Lavorel et al. 2020).

But nature's contribution to adaptation does not, and will not, automatically flow to people. Human inputs are often needed, such as applying knowledge (e.g. best practices for reforestation of degraded lands), building infrastructure (e.g. irrigation, water canals), providing labor (e.g. planting trees), adding value to services and using them (e.g. hiking trails for ecotourism, marketing of forest fruits), and mobilizing institutions and communities (e.g. governance for ecosystem conservation). Ultimately, adaptation services can support adaptation only if people co-operate to mobilize resources, knowledge and skills, and engage and adapt institutions accordingly.

So how can people work with nature to improve adaptation to climate change? What can be done when decisions and actions for enhancing a particular adaptation service affect the delivery of other services, or affect overall biodiversity, or the well-being of other stakeholder groups, resulting in so-called trade-offs?

We explored these questions through five case studies with different social and ecological characteristics. For each case study, we examined how people's inputs for securing nature's benefits have helped, or can help, adaptation by asking: What are the actions? Who are the agents? What are the inputs?

We discovered how:
- traditional ecosystem management practices that target multiple services can increase ecological resilience and balance trade-offs
- the proactive management of transformed ecosystems can lead to multiple benefits
- the use of novel services can help people adapt, especially if they depend on ecosystems for their livelihoods
- collective ecosystem management is important for balancing trade-offs across social groups, places and time
- appreciating, using and valuing adaptation services generate positive feedback loops supporting nature-based adaptation.

More details on the methods and results can be found in the study by Lavorel et al. (2020) "Co-producing ecosystem services for adapting to climate change".

Traditional and multifunctional management can increase ecological resilience

In the case study site of Lautaret (Lavorel et al. 2017; Lavorel et al. 2019), located in the upper Romanche valley of the French Alps (see Figure 1), farmers have been managing terraced meadows with the same technique since the middle of the 20th century. The broader landscape was shaped by three different land uses: cultivated terraces at 1300–1900 m.a.s.l., grazed grasslands at 1900–2200 m.a.s.l. and alpine summer pastures at 2200–2700 m.a.s.l. Farming systems are still traditional, with fodder self-sufficiency and summer transhumance.

Livestock rearing has been maintained and abandonment is rare, unlike in many other European mountain regions. Farmers show a strong attachment to place and this has motivated them to develop complementary activities in the tourism sector for supplementing household income and enabling their farming practices to persist. Farms produce lamb, beef, cheese and heifers, and transhumant herds from the southern part of the region graze the summer pastures. Even though farm economies depend heavily on agri-environmental subsidies, and on tourism for off-farm employment and real estate revenue, young local and incoming farmers are replacing retirees. These younger farmers are innovating with fresh approaches to marketing and the development of sustainable buildings and new forms of nature-based tourism and education.

In the future, if farmers decide to introduce novel crops, their production would depend upon the same social capital as the production of resilient fodder: collective land allocation, solidarity and ability to work together, and maintenance of access to parcels of land. These shared practices, which have been present in Lautaret for a long time, could reduce the trade-offs between crop-intensive management and grassland-regulating services. Furthermore, novel products such as vegetables, berries and medicinal plants could be sold to locals and tourists along with the more traditional livestock products (meat and cheese) through new shared retail infrastructure.

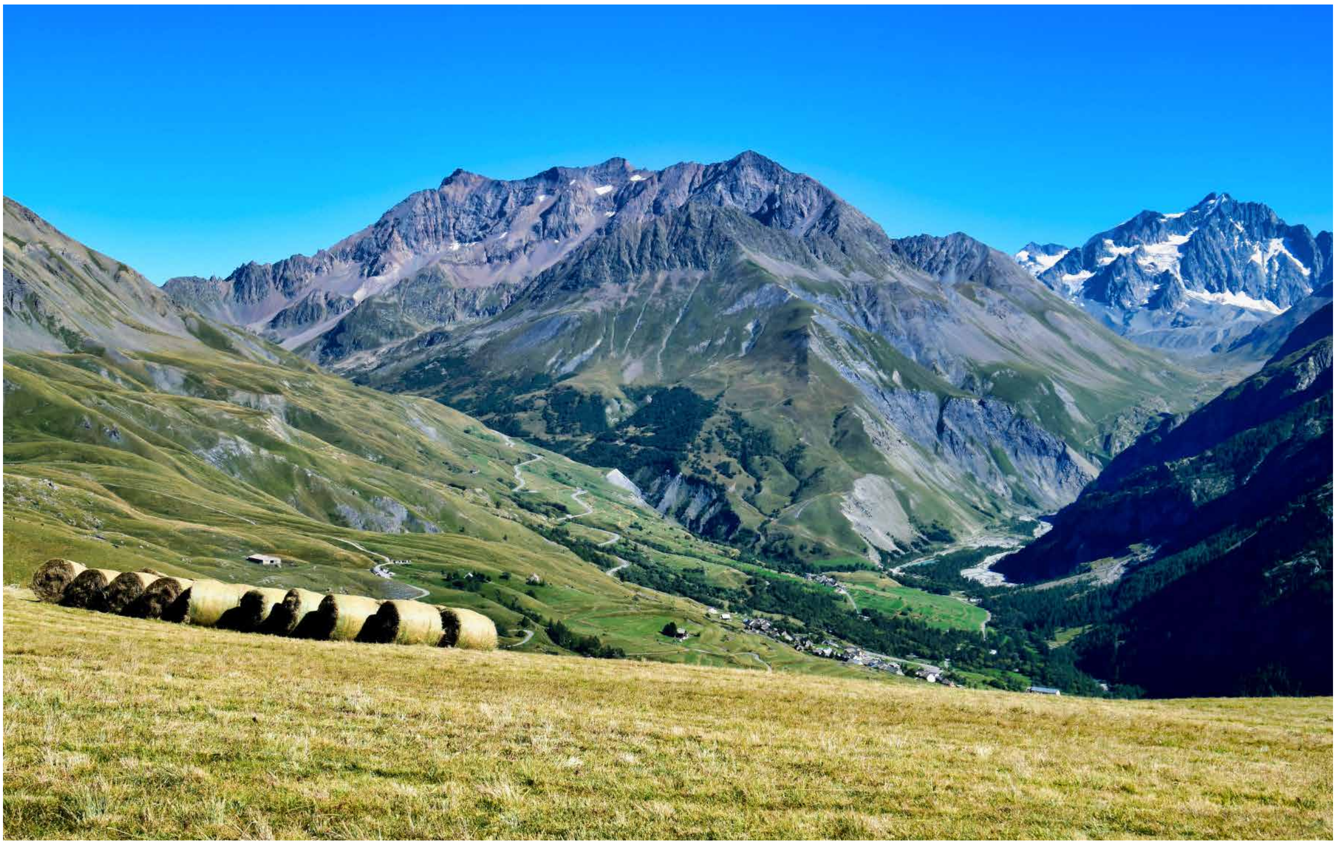

Figure 1. Lautaret study site (photo by Bruno Locatelli).

The traditional and multifunctional landscape management of terrace cultivation, fertilization, mowing and summer grazing has shaped the function of ecosystems and their services in Lautaret. Stakeholders identify and value several grassland ecosystem services such as fodder production, regulation of soil fertility and stability, water quality regulation, and cultural heritage and scenic beauty. These services also have benefits for adaptation. As climate variability and drought risk increase, landscape and grassland management support erosion control and the resilience of fodder production. Diversification of farmer income with additional marketable products and nature tourism, based on the conservation of plant and animal biodiversity, is also supported.

Proactive management of transformed ecosystems can have multiple benefits

The shrublands of the Riverina, our second case study site located in the Murray–Darling Basin in Australia (Collof et al. 2016), were once floodplain woodlands (see Figure 2). Vegetation clearing in the 19th century caused the ecosystem to transform into saltbush shrublands adapted to high salt concentrations and low moisture availability.

In the late 1980s, graziers discovered they could successfully raise lambs on saltbush and started to manage these shrublands for new grazing systems based on the production of prime lamb meat. In addition, they revegetated riparian zones to improve water quality by planting native tree species and shrubs, thus lowering saline water tables below the root zone.

The holistic landscape management of the graziers delivers several ecosystem benefits of value for adaptation. The native trees and shrubs regulate water quality and reduce overall ecosystem vulnerability to climate change as they are highly resilient to rainfall variability and drought. They also act as shelterbelts for lambing, stimulating weight gain and reducing mortality. The sustainable, low-input grazing systems support the production of wool and saltbush lamb meat and the related markets and supply chains, providing a good income to the farmers. The profits were good enough to encourage the spread of the grazing and salinity management practices to other regions affected by dryland salinity.

It was not only profits that prompted the spread of these new practices. Graziers were empowered to experiment and learn by doing while being supported by extension services, researchers and government agencies. This strong ownership of ideas and practices ultimately led to the improved and sustainable ecosystem management present today.

Figure 2. Southern Riverina, Australia. Left: weeping myall *Acacia pendula* woodland and right, transformation to chenopod shrubland after land clearing, dryland salinity and repeated, severe droughts. The shrubland now supports a highly drought-resistant grazing system for saltbush sheep (photos courtesy of Murray Fagg, copyright holder, and the Australian National Botanic Gardens www.anbg.gov.au/photo).

The use of novel services can help people adapt

In northern Mali, when Lake Faguibine dried out and invasive Prosopis trees spread in the former lakebed (Figure 3), novel ecosystem services appeared from this newly formed forest (see the case study described in Brockhaus et al. (2013) and Djoudi et al. (2013)).

Lake Faguibine was a productive area for agriculture and fishing but the area experienced prolonged dry phases in the 20th century and the lake had dried out by the end of the 1970s. Acacia and Prosopis trees then started occupying the lakebed. Prosopis was first introduced by a development project in the 1980s to counter desertification and lake siltation. The highly invasive species occupied the area more quickly than local species such as Acacia.

Some women started to harvest wood and produce charcoal for trade as a livelihood diversification strategy. These women developed new practices in the ecosystem such as harvesting and processing, but faced barriers such as the lack of transportation for marketing. The new forest resources also became an important source of fodder for the livestock herders, especially during dry years when forest use intensifies. The analysis of the local adaptations revealed the emerging role of the novel forest products in supporting livelihoods (formerly based on water from the lake), and the transition from forests as a safety net to a daily subsistence base and a fundamental part of adaptive strategies to environmental and climatic change.

But contrary to the Riverina case study, the new forest resources were not managed. There was no thinning or back cutting of fringes and the forest resources were at risk of not being available or accessible in the long term. Since the lake dried out, development programs and politicians have sought to bring the water back and restore the lake's

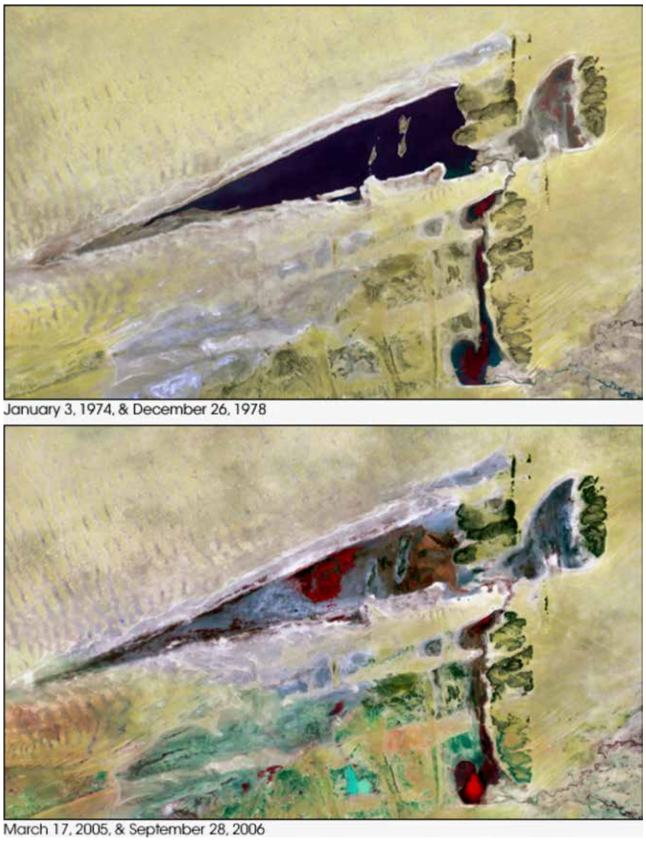

Figure 3. Drying of Lake Faguibine, Mali. The images show vegetation as red, water as blue, and bare ground in shades of beige and gray. Image courtesy of NASA Earth Observatory (earthobservatory.nasa.gov/images/8991), created by Jesse Allen using Landsat data provided by the United States Geological Survey (USGS).

ecosystem functions. Some community members have also expressed their preference for the 'return of the lake', in part due to psychological barriers and traumatisms arising from the massive change and transformation, showing a marked discrepancy between the perception of the novel forest and the de facto use of its products by part of the population, particularly women.

Collective ecosystem management is important for balancing trade-offs

The flow of certain ecosystem services, such as those related to water quality and quantity, involve different actors in different locations. For example, in the Mariño watershed of the Peruvian Andes (Figure 4; Vallet et al. 2019), communities at high elevations protect wetlands and mountain forests, while the National Water Authority manages water distribution to urban areas. In other places in the Peruvian Andes, communities have constructed 'amunas' – a traditional system of canals that transports water from temporary rainy season streams to grasslands, where the water infiltrates into soils and recharges aquifers.

The Mariño River watershed is situated in the Apurimac region of the southern Peruvian Andes, one of the poorest regions of Peru. Subsistence agriculture predominates at high and mid elevations, with livestock as a means of livelihood diversification. At low elevations, both crop and livestock farming are commercially oriented and generally more intensive. The urban areas are located in the cities of Abancay and Tamburco and encompass approximately 60,000 inhabitants.

The input of upstream actors supporting the flow of water adaptation services relates to activities such as conservation and restoration, while downstream actors capture, transport and use the water. The upstream communities influence the quantity and the quality of the water, but they do not participate in the decision-making regarding broader watershed management and water allocation. Powerful actors such as national authorities and local politicians often apply a top-down approach to water management and may not recognize all the stakeholders involved in supporting the flow of services.

This creates conflict and can jeopardize the supply of water adaptation services in the future. In the Mariño watershed, water is predominantly channeled downstream to urban areas. In the eastern part of the watershed, there were periods where almost no water was left for agricultural use and for the surrounding ecosystems. Several farmer groups were consistently trying to open the channel gates and redirect

Figure 4. Mountain forests and lake in the Mariño watershed in Peru (photo by Bruno Locatelli).

some water to their fields. Downstream farmers were the most affected, resulting in an additional level of conflict between upland and lowland farming communities. Multistakeholder coordination and management is thus needed, to balance all the diverging interests and needs.

Acknowledging adaptation services enhances nature-based adaptation

Indonesian communities in the upper watersheds of Western Kalimantan and Central Java (Figure 5) have recognized the value of forest regulating and provisioning services for adapting to climate variability and hazards (Fedele et al. 2017, 2018). This has reinforced conservation efforts, extended plantation and agroforestry best practices, and stimulated the marketing of forest products.

Landscapes in Central Java consist of mixed patches of agriculture and secondary forests of mostly planted teak and pine, with drought being the main climate hazard. Farmers noted that changes in forest cover exacerbated the effects of drought. People then started planting teak and mahogany in private gardens (agroforestry) and on the least-productive dry rice fields. Over time, the community perceived multiple benefits related to soil fertility, water quantity and quality, and availability of diverse products such as firewood, resin and fodder.

The success of the initiative encouraged farmers from neighboring villages to plant trees on their land and in their gardens, and this practice started spreading. In 2004, the forest gardens of three village hamlets became a certified community forest and were awarded the natural resource management label *Lembaga Ekolabel Indonesia*. Harvest rules were also established – people are to replant 10 times the number of trees cut in community forests and follow additional regulations related to thinning, tree spacing and minimum-diameter harvesting.

Communities used timber and other tree products to overcome food and income shortages during droughts and floods. They sold valuable forest products, such as teak, mahogany and firewood. The perceived values of agroforestry and forest restoration and conservation created positive reinforcing feedback loops that increased the spread of these practices: the supply of more adaptation services led to a broader adoption of positive land-use changes based on trees and the use of forest products.

Enabling adaptation services for a good Anthropocene

Our stories illustrate that enabling mechanisms occur at three different levels along the flow of adaptation services, from the ecosystem level to the use and benefit levels.

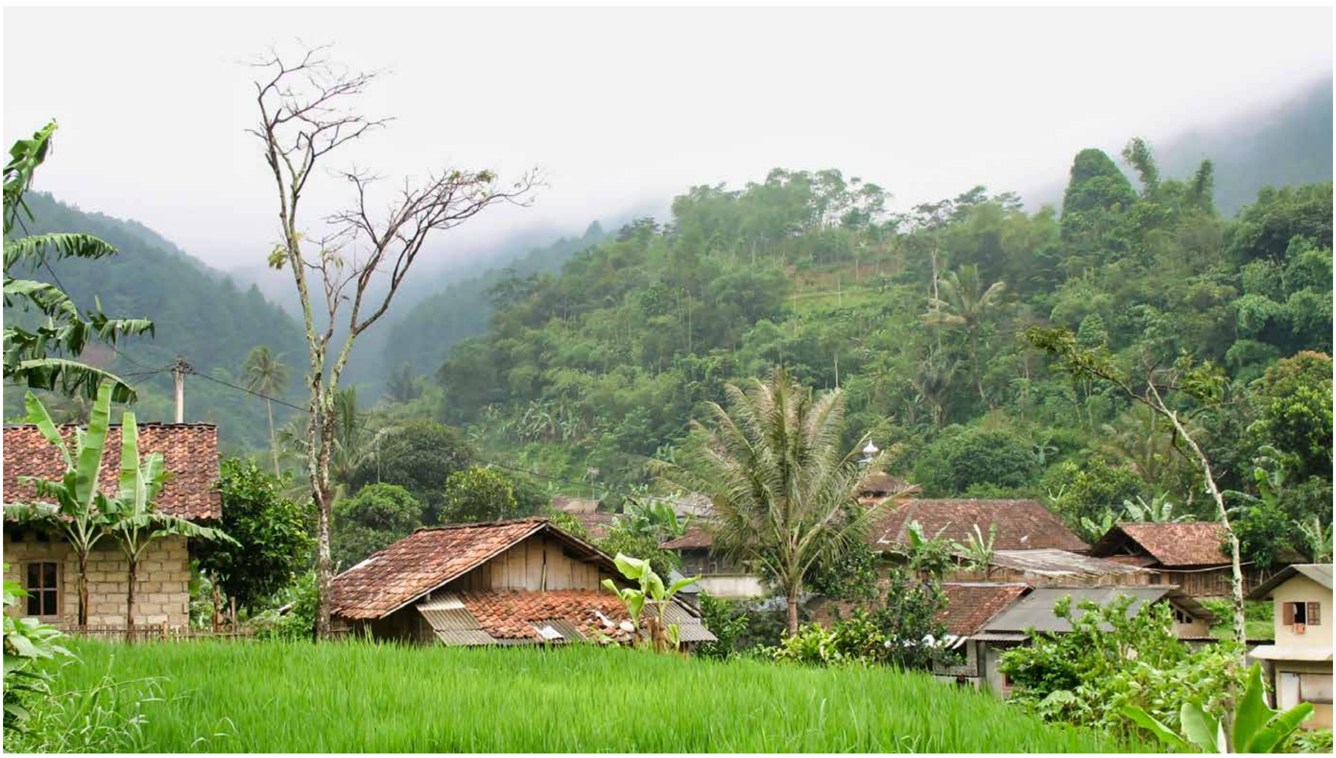

Figure 5. Rural landscape in Java, Indonesia (photo by Bruno Locatelli).

1. At the first level, there are ecosystem and landscape management practices that build ecological resilience, persistence or transformation, for example, the saline shrubland management activities in the Australian Riverina.
2. At the second level, people capture the flow of services by accessing, redirecting or harvesting activities. Examples include the harvesting of tree products in Mali's Lake Faguibine and the construction of traditional water transportation canals in the Peruvian Andes.
3. At the third level, people recognize, use and appreciate the benefits they derive from ecosystem services, for example, through the commercialization of forest products as in Central Java and the establishment of alternative tourism as in the French Alps.

All three levels of enabling mechanisms often occur together and can ensure a sustainable supply of ecosystem and adaptation services. With the exception of Lake Faguibine in Mali, where there was no ecosystem management, this was happening in all of our case studies. Our case studies also illustrated five different mechanisms that can support the adaptation of people to climate variability and change and that can enable the flow of adaptation services.

Ecosystem services turn into adaptation services when people deliberately manage ecosystems to adapt to changes. On the one hand, adaptation services can be regarded as a subset of ecosystem services, as they include the same categories of provisioning, regulating and cultural services. On the other hand, the concept of adaptation services is different as it puts a special focus on:

- the capacity of an ecosystem to transform under climate change and provide novel services
- the capacity of an ecosystem to persist under climate change and to supply services currently not in demand but likely to become important in the future (latent adaptation services).

The concept is useful for both identifying the ecosystem properties and functions that support adaptation and for evaluating potential trade-offs between current ecosystem services and latent or novel adaptation services. An analysis of the enabling mechanisms along the flow of adaptation services can highlight the actors and human input that can support or hinder adaptation across locations, time scales and stakeholder groups.

Even though our case studies have mostly provided evidence of reactive responses to environmental and climatic change, proactive adaptation planning can benefit from insights into the mechanisms driving trade-offs and co-benefits. By focusing on enabling mechanisms, actors and decision-makers can build agency for targeting critical interventions, activating new synergies and co-benefits, and overcoming any barriers to the adoption, management and use of adaptation services.

For example, in the French Alps, grassland management can become the main entry point for adaptation: bundles of adaptation services supplied by different grassland types (e.g. resilient fodder, erosion control, aesthetic value) can be identified and managed. In the Australian Riverina, regulating services (e.g. erosion control) are likely to become increasingly recognized as essential for the supply of other services, yet are likely to remain vulnerable to overexploitation. Management practices can thus be set up for controlling overgrazing and preventing erosion and ecosystem transformation into degraded grassland. But processes will be needed to identify when and where managing for ecosystem transformation rather than persistence becomes the only viable option.

In Mali's Lake Faguibine, the contribution of forests to adaptation will depend on their management. The Prosopis forests have enabled people to cope with stress, at least in the short term. In the long term, if no management mechanisms are integrated, the coping strategies can have adverse impacts on the resource itself, which could become degraded. And this could ultimately lead to an increased vulnerability of both people and ecosystems.

Documenting, analyzing and building on the enabling mechanisms that support both people's adaptation and biodiversity, and demonstrate multiple benefits across scales, can help strengthen and scale up responses to climate change and other sources of vulnerability. These 'seeds of a good Anthropocene' paint a realistic and optimistic vision of what the world can be (Bennett et al. 2016). By recognizing and understanding the processes that lead to the emergence and growth of these seeds, all of us will be better equipped to develop inspirational visions of sustainability and transform human–environment relationships.

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Recommendations

- Understanding the mechanisms that support or hinder the flow of adaptation services can lead to better and more proactive adaptation planning.
- The five mechanisms described in this brief can motivate decision-makers and communities to target critical interventions.

- They can build agency for scaling-up effective responses to climate change and for balancing trade-offs among responses.

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