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Forest-based adaptation:
transformational adaptation
through forests and trees

Forest-based adaptation: transformational adaptation through forests and trees

by

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Abbreviations and acronyms

AFOLU	agriculture, forestry, and other land use
CBD	Convention for Biological Diversity
CIFOR-ICRAF	Center for International Forestry Research and World Agroforestry
COONAPIP	National Coordination for Indigenous Peoples of Panama
EbA	ecosystem-based adaptation
Eco-DRR	ecosystem-based disaster risk reduction
FAO	Food and Agriculture Organization of the United Nations
FFF	Forest and Farm Facility
FFPO	forest and farm producer organization
GCF	Green Climate Fund
IPCC	Intergovernmental Panel on Climate Change
KPI	key performance indicator
NAPs	national adaptation plans
NbS	nature-based solutions
NBSAP	national biodiversity strategies and action plan
NDCs	nationally determined contributions
NGO	non-governmental organization
NWP	Nairobi Work Programme
SDGs	Sustainable Development Goals
UNEA	United Nations Environmental Assembly
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UN-REDD	United Nations Programme on Reducing Emissions from Deforestation and Forest Degradation
VNFU	Viet Nam Farmers' Union

Executive summary

Climate change is an existential challenge, and forests and trees provide an important part of the solution. Protected, sustainably managed and restored forests store and sequester carbon, and provide a host of biodiversity benefits and other ecosystem services that help people and ecosystems adapt to climate change. They regulate rainfall, stabilize local climate, protect coastal areas and mountain slopes, and provide food, fuel, fibre and fodder for local communities facing climatic threats.

Yet, forests and trees are already affected by climate change, including through more frequent and intense wildfires, pest and disease outbreaks, floods and drought. The role of forests and trees in mitigating climate change and buffering the most vulnerable from its impacts depends on their ability to adapt and maintain resilience in a warming world.

Forest-based adaptation is an ensemble of climate actions that employ forests and trees in support of climate change adaptation and resilience, including sustainable forest management, forest conservation and restoration, reforestation and afforestation. Forest-based adaptation can help address the gaps between current adaptation actions and the adaptation needed for reducing climate-related risks and impacts, while contributing to most of the Sustainable Development Goals and promoting strong synergies with mitigation.

This FAO technical paper unpacks the concept of forest-based adaptation and describes policy spheres that could bolster the role of forests and trees in providing adaptation and resilience benefits. It introduces a set of ten principles for using forests and trees to promote transformational adaptation, which were developed with leading experts from the Center for International Forestry Research and World Agroforestry (CIFOR-ICRAF) and other partners. It describes the policy implications of each principle and draws on examples from diverse forest ecosystems and management practices to illustrate their application in practice.

Several key lessons emerge:

- Forest-based adaptation is a political and governance issue that must mobilize all stakeholders to combine top-down and bottom-up approaches.
- Forest-based adaptation must address the social causes of vulnerability, including inequity and justice.
- Recognizing the linkages between ecological and social diversity provides opportunities for transformation, since the adaptation of people and ecosystems is intertwined.
- Changes resulting from climate impacts must be anticipated; uncertainty and trade-offs must be accepted, addressed and internalized into socioecological systems.
- Forest-based adaptation requires a transformation of relationships.

The contributions of forests and trees to transformational adaptation are vast and still gaining traction. There is a need to further integrate forests and trees into national climate policies and planning, and actively engage local people in adaptation decision-mak-

ing, as part of a package of strategies to improve resilience in the face of increasing risks and uncertainty. Through examining the concept of forest-based adaptation and providing examples of its application on the ground, this technical paper can serve as a useful resource for a wide range of stakeholders working on forest- and tree-based solutions to the climate crisis.

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1. INTRODUCTION

Climate change is already affecting every region of the earth, with risks distributed unevenly both across and within countries (IPCC, 2021). Without deep reductions in greenhouse gas emissions, every fraction of a degree of global warming makes adaptation more challenging, and in some cases impossible (IPCC, 2022a). **Transformational adaptation**, which changes the fundamental attributes of a social-ecological system in anticipation of climate change impacts, is now being called for to address the climate crisis (ibid).

The recently published Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report highlights the substantial contribution of forests to **climate change mitigation and adaptation** (IPCC, 2021, 2022a, 2022b). While the ability of forests to store and sequester carbon is widely accepted in climate policy and action, the role of forests in providing multiple benefits that contribute to the adaptation and resilience of people and ecosystems is still gaining traction. Furthermore, trees outside of closed canopy forests (i.e. trees on farms, urban trees in parks, yards and streets, etc.) are an important but often overlooked natural resource, including for climate change adaptation and mitigation (Skole *et al.*, 2021; Somarriba, López-Sampson and Sepúlveda, 2021). Forests and trees can help people adapt to climate change through the ecosystem services that they provide, but they themselves must also adapt and maintain their resilience, including to be able to continue to store and sequester carbon (Locatelli *et al.,* 2010; Meybeck *et al.,* 2021).

Risk management provides a framework for understanding the increasingly severe, interconnected and often irreversible impacts of climate change on ecosystems, biodiversity, and human systems, and how to best reduce adverse consequences for current and future generations. In the context of climate change, risk can arise from dynamic interactions among climate-related hazards, and the exposure and vulnerability of affected human and ecological systems (IPCC, 2022a). Risk can also be introduced by inappropriate human responses to climate change, in what is termed **maladaptation** (Schipper, 2020). Adaptation plays a key role in reducing exposure and vulnerability to climate change. For its part, **resilience** is commonly understood as the capacity to bounce back after a disturbance. However, more broadly, the term resilience describes not just the ability to maintain essential function, identity and structure, but also the capacity for transformation (IPCC 2022b).

There is increased recognition of nature's potential not only to reduce climate-related risks but also to improve people's lives and livelihoods: "In a changing and increasingly uncertain world, nature can be humanity's strongest ally in adapting to climate change and reducing disaster risk" (UNFCCC, 2021). The key role of nature in helping address the climate crisis is reflected in concepts such as nature-based solutions (NbS),[1] eco-

[1] The United Nations Environmental Assembly (UNEA) resolution in Nairobi in March 2022 formally adopted the definition of nature-based solutions as: "actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems, which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services and resilience and biodiversity benefits" (UNEP, 2022a).

system-based adaptation (EbA),[2] and ecosystem-based disaster risk reduction (Eco-DRR),[3] which have grown in prominence in global and national policy spheres, but also among multilateral development banks and within the private sector. These concepts share the idea that ecosystems, typically when in good condition, can sustain society's efforts to adapt to environmental change by regulating risks and providing livelihoods in the face of climate change (Seddon *et al.,* 2019). They open important policy windows and opportunities for forests and trees to be a central part of climate change adaptation and resilience strategies.

The Food and Agriculture Organization of the United Nations (FAO) is collaborating with the Center for International Forestry Research and World Agroforestry (CIFOR-ICRAF) and other partners to enhance the role of forests and trees in adaptation policy and action at global, national and local levels. This effort builds on earlier work undertaken by these organizations focused on guidance for forest managers and national policymakers to incorporate climate change considerations into their decision-making (FAO, 2013; FAO, 2018a); a framework methodology for vulnerability assessments of forests and forest-dependent people (Meybeck *et al.,* 2019); and guidelines for addressing forestry and agroforestry in national adaptation plans (NAPs) (Meybeck *et al.,* 2020), among others. This FAO technical paper unpacks the concept of forest-based adaptation and illustrates the policy implications of a set of principles for using forests and trees for transformational adaptation. It can serve as a tool for FAO's support to its Members towards fulfilling the goals of the Paris Agreement, including through the design and implementation of nationally determined contributions (NDCs) and NAPs, in line with the FAO Strategy on Climate Change 2022-2031. It can also serve as a useful resource for a wide range of stakeholders working on forest- and tree-based solutions to the climate crisis.

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2 EbA is the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people adapt to the adverse effects of climate change (Secretariat of the Convention on Biological Diversity, 2009). EbA can be considered nested within the broader concept of Nature-based Solutions (EbA has been identified as equivalent to "NbS for adaptation") and shares common elements with a variety of approaches to building the resilience of socioecological systems (Gilruth et al., 2021; UNEP, 2022).

3 Eco-DRR is the combination of sustainable ecosystem management and disaster risk reduction approaches towards more effective responses, resilience, and recovery when faced with disaster events (UNDRR, 2020).

2. WHAT IS FOREST-BASED ADAPTATION?

Forest-based adaptation is an ensemble of climate actions that employ forests and trees in support of climate change adaptation and resilience (Box 1). It includes actions to both strengthen the adaptive capacity and resilience of forests to climate change (e.g. through pest and disease management, integrated fire management), as well as acknowledging the benefits that society derives from forests and trees, including food, livelihoods, biodiversity, climate regulation, and hydrological services. These benefits have been defined as "adaptation services", specific ecosystem services with the potential to reduce climate change exposure and enhance resilience (Jones, Hole and Zavaleta, 2012). Forest-based adaptation thus includes activities such as sustainable forest management, forest conservation and restoration, reforestation, natural regeneration, afforestation, agroforestry and silvopastoral systems, and urban tree management, among others (see Section 2).

Forests and trees can help address the gaps between current adaptation actions and the adaptation needed for reducing climate-related risks and impacts, which is beginning to be recognized in climate change policies (Seddon *et al.,* 2019; UNEP, 2022b). Forests can also contribute to the achievement of most of the 17 Sustainable Development Goals (SDGs) with synergies across sectors (Friends Of EbA, 2022). In recognizing that adaptation applies to human and natural systems, this technical paper addresses the adaptation services and resilience capacities[4] that forests and trees provide to individuals, households, communities and societies, as well as the need for forests and trees to adapt and maintain their resilience in the face of climate change.

[4] In line with the *United Nations Common Guidance on Helping Build Resilient Societies*, resilience is understood as "the ability of individuals, households, communities, cities, institutions, systems and societies to prevent, anticipate, absorb, adapt and transform when necessary, in an efficient and effective manner, when facing a wide range of risks while maintaining an acceptable functioning level without compromising the long-term prospects for sustainable development, peace and security, human rights and well-being for all" (UN, 2021).

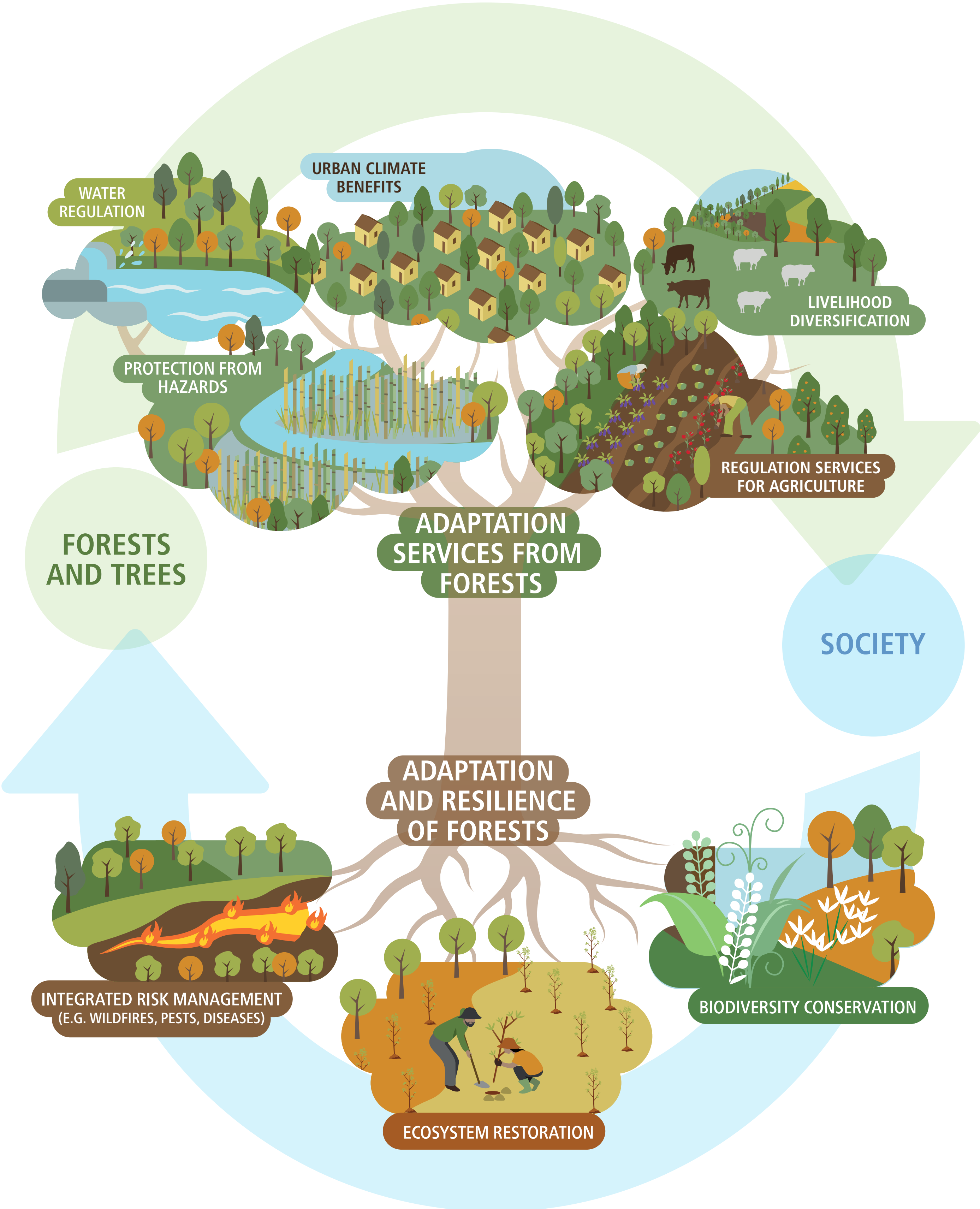

Figure 1. Forest-based adaptation
Source: elaborated by authors

BOX 1.

Forest-based adaptation as per the IPCC

The IPCC's Sixth Assessment Report makes specific reference to forest-based adaptation as a climate adaptation option with high feasibility and high synergies with mitigation (IPCC, 2022a). According to the Working Group II report on "Impacts, Adaptation and Vulnerability", forest-based adaptation includes sustainable forest management, forest conservation and restoration, reforestation and afforestation. Along with the warning that projected climate change, combined with non-climatic drivers, could cause the loss and degradation of much of the world's forests, the IPCC report calls for the adaptation of forests to climate change, as well as a recognition of the adaptation services that derive from forests and trees.

The report makes a distinction between adaptation solutions for natural forests (including measures such as conservation, protection and restoration) and those for managed forests, which consider sustainable forest management, diversifying and adjusting tree species composition to build resilience, and managing increased risks from pests and diseases and wildfires (ibid.). In all cases, the report highlights the need for cooperation with local communities and recognition of Indigenous Peoples' rights.

According to the IPCC, there is robust evidence that forest-based solutions support ecosystems' capacity to adapt to climate change, including through microclimate regulation, increased groundwater recharge, improved quality of air and water, reduced soil erosion, and improved and climate-adapted biodiversity habitats.

The IPCC report also recognizes agroforestry as an effective climate adaptation option, with co-benefits, advantages and disadvantages that vary depending on the context. Agroforestry - understood as a form of ecosystem management that combines agriculture, livestock, and forestry - increases vegetation, enhances soil quality, stores soil carbon and reduces the spread of fire. Beyond these benefits, agroforestry shelters livestock and crops in heat waves, can protect against drought, preserve ecosystem services, enhance resilience to pests and diseases, and provide higher levels of ground to decrease soil erosion. Agroforestry solutions have "strong ecological and adaptive co-benefits (high confidence), including improved provision of ecosystem services, synergies with the water-energy-land-food nexus, and positive outcomes in agricultural intensification, job diversification and household income" (ibid.).

2.1 Adaptation and resilience of forests

The world has lost 420 million hectares, approximately 10.34 per cent of its total forest area, in the last 30 years (FAO, 2022a). This trend is set to continue, with projected climate change and non-climatic drivers causing loss and degradation of much of the world's forests (IPCC, 2022b), reducing their potential to deliver adaptation services (UNFCCC, 2021). Anthropogenic climate change, deforestation, poor land management and other causes of land degradation can push forest areas towards an ecosystem collapse that is potentially irreversible (Bergstrom *et al.,* 2021; Nobre and Borma, 2009). Approximately 23 percent of intact, undisturbed forests are deemed to have reached their threshold for abrupt decline and are experiencing a further reduction of resilience (Forzieri *et al.,* 2022).

Expressions of climate change, such as increases in temperature, changes in precipitation, changes in seasonal patterns, increased atmospheric greenhouse gases, and increased intensity and frequency of extreme weather events, are already affecting forests worldwide (Olsson *et al.,* 2019). Climate variability and limitations in water availability will reduce the resilience of tropical, temperate, arid and boreal forests, meaning that these ecosystems are less likely to recover from environmental perturbations (Sanderson *et al.,* 2012; Forzieri *et al.,* 2022). Climate change may also constrain the cooling benefits of forests by altering the biophysical effects and increasing forest vulnerability to wildfires and drought (Brandão *et al.,* 2019; Lawrence *et al.,* 2022). These environmental drivers are increasing the mortality of trees and shifting forest vegetation dynamics (Bauman *et al.*, 2022; McDowell *et al.,* 2020). Rising mean temperatures and changes in precipitation patterns will shape future forests by selecting species more adapted to the new conditions, changing ecosystem structure, composition and function.

Non-climatic perturbations also reduce the resilience of forest ecosystems. Land-use change and timber extraction have reduced vegetation stature, altered species composition in many forests, and contributed to biodiversity loss (McDowell *et al.,* 2020). Social and political factors such as the poor enforcement of existing laws, lack of accountability, urban settlement expansion, and the overexploitation of non-wood forest products can also increase forest vulnerability (FAO and CIFOR, 2019). Degraded forests provide fewer ecosystem services, contribute to and exacerbate the effects of climate change and biodiversity loss, are less productive (Kramer *et al.,* 2022), and are more susceptible to major damage by pests and disease and damaging wildfires. Climate change has already expanded some pests' host range and geographical distribution, and may further increase the risk of pest introduction to new areas (FAO and IPPC, 2021) with severe costs to country economies (Eschen *et al.,* 2021). Climate change and land-use change are projected to make wildfires (unusual or extraordinary vegetation fires with negative impacts) more frequent and intense, with a global increase of extreme wildfires of up to 14 percent by 2030, 30 percent by 2050 and 50 percent by 2100 (UNEP and GRID Arendal, 2022).

Measures for buffering forests from forest disturbances have been largely reactive, seeking to respond to damage rather than prevent it. However, forest adaptation also includes facilitating ecosystem shifts and transitions towards new stages through measures such as enhancing landscape connectivity (e.g. corridors and buffers), conserving biodiversity hotspots and genetic diversity in natural forests, modifying forest plantation management, facilitating natural regeneration, and even assisting flora and fauna migration (Locatelli *et al.,* 2008).

Proactive and integrated management interventions should consider the spatial, temporal, ecological, and societal context of ecological threats, such as preventing destructive wildfires before they begin (UNEP and GRID Arendal, 2022). Clearing invasive alien tree species can reduce the impact of climate change on drought streamflow, helping mitigate the impact of extreme drought conditions (Holden *et al.,* 2022). Proactive management of pests and diseases can buffer this major threat to natural and planted forests worldwide (Fischbein and Corley, 2022). Integrated risk management aims to improve forest resilience to ecological threats through the engagement of stakeholders and coordination of activities before, during, and after large ecological disturbances (Wollstein *et al.,* 2022). Forests are not the same around the world - each has its own ecosystem, biodiversity, interaction with local communities, and vulnerability to natural disturbances and climate change. Ecosystem management solutions should be informed by collaboration with local communities and forest users to include scientific, local and Indigenous knowledge, practices and innovations into understanding how forests and trees respond to climate change (Roshani *et al.,* 2022).

2.2 Adaptation services from forests and trees

Adaptation services can be understood as ecosystem contributions to social adaptation (Lavorel *et al.,* 2020), "nature's contribution to adaptation" (Colloff *et al.,* 2020), or specific ecosystem processes and services with the potential to reduce climate change exposure and enhance resilience capacities (ibid; Lavorel *et al.,* 2015; Jones, Hole and Zavaleta, 2012).

According to Pramova *et al.,* (2012), forests and trees provide the following adaptation services:

1. Forests and trees provide goods to local communities facing climatic threats.
2. Trees in agricultural fields regulate water, soil, and microclimate for more resilient production.
3. Forested watersheds regulate water and protect soils for reduced climate impacts.
4. Forests protect coastal areas from climate-related threats.
5. Urban forests and trees regulate temperature and water for resilient cities.

In the following subsections, we build on this classification to highlight the key role of forests and trees for adaptation and resilience.

2.2.1. Forests and trees provide livelihood diversification and coping strategies

In adapting to environmental change, communities mobilize resources and networks, diversify livelihoods and exchange support. Forests and trees are central to these adaptation strategies. Forests are a source of fibre, fuel, food and fodder, and they provide livelihoods for millions of people. About 33 million people - representing one percent of global employment - are estimated to work directly in the formal and informal forest sector (FAO, 2022a). On a global scale, 95 percent of all people outside urban areas - 4.17 billion people - lived within five kilometres of a forest in 2019, and 75 percent - 3.27 billion people - lived within one kilometre (Newton *et al.,* 2022). People depend on wood and non-wood forest products (such as charcoal, firewood, wild fruits, mushrooms, roots, and fodder) for their livelihoods (Shackleton and Shackleton, 2012; Paumgarten and Shackleton, 2011). In 24 countries surveyed in sub-Saharan Africa, Asia and Latin America, forests contributed 20-25 percent of total cash and subsistence income for households in forest-adjacent communities, a figure on par with the contribution of agriculture (Angelsen *et al.,* 2014). Small forest growers contribute significantly to sustainable forest management and restoration in the tropics: up to 90 percent and 60 percent of the industrial wood in India and Viet Nam, respectively, comes from small growers (Nambiar, 2021).

Forests also constitute important safety nets, particularly among the rural poor (Mantey and Teye, 2021; Wunder *et al.,* 2014). The additional cash and subsistence income from tree products strengthens coping capacities in times of need and helps maintain local livelihoods (Razafindratsima *et al.,* 2021). Wild-harvested forest foods, including hunting, add to the food security and nutrition of forest-adjacent people, especially in remote areas in the tropics and subtropics: one global comparative analysis found that 77 percent of surveyed rural households engaged in wild-food collection (Hickey *et al.,* 2016). Underutilized tree products have untapped potential in meeting peoples' subsistence and commercial needs (Jansen *et al.,* 2020; Mbow *et al.,* 2021). Food-producing trees and perennial crops play important roles in people's food security and nutrition, not only through the diversity of goods and income generation but also in the provision

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of ecosystem services for agriculture, as discussed in the next section (Gergel *et al.,* 2020; Ickowitz *et al.,* 2022).

Forest products, including bush meat, can contribute to poverty alleviation if paired with forest management policies and equitable market access for small-scale producers (Razafindratsima *et al.,* 2021). Effective policies for poverty alleviation are context-dependent, but ecotourism, community forest management, and agroforestry are some examples of actions that can enhance the resilience of forest-based communities (Hajjar *et al.,* 2021). Investments and policies aimed at improving ecosystem services and livelihoods require special consideration of the rights and needs of local communities, marginalized groups, women, youth, and Indigenous Peoples, which is essential to enhance local adaptive capacity and resilience (Razafindratsima *et al.,* 2021; Robson *et al.,* 2020).

2.2.2. Forests and trees provide regulating services for agrifood systems

The current global food system fails to deliver accessible and nutritious food to all, as reflected in the increases in hunger and malnutrition in all its forms (Dornelles *et al.,* 2022). Forests and trees can play a considerable role in transforming agrifood systems with clear adaptation benefits. They provide income, nutrient-rich foods and crucial ecosystem services for agriculture, including pest and disease control, pollinator habitat, microclimate control, water and nutrient cycling, carbon sequestration, soil erosion control and nitrogen fixation (Ickowitz *et al.,* 2022).

The role of forests in regulating local, and in some cases, regional climate is essential for agriculture. For example, at all latitudes, forests promote local climate stability by reducing extreme temperatures in all seasons and times of day (Lawrence *et al.,* 2022). At the plot scale, the presence of woody perennials on agricultural land can buffer crop level temperature and, under specific conditions, water supply (Cardinael *et al.,* 2021). Large-scale deforestation of tropical forests would increase global mean temperatures and alter precipitation patterns around the world (Lawrence and Vandecar, 2015). Tropical forest degradation leads to increases in surface temperature making forests drier and more flammable (Longo *et al.,* 2020), all of which has negative implications for agriculture.

Agroforestry systems that combine cash crops with food sources play a crucial role in helping farmers adapt to climate change (e.g. by diversifying livelihoods, reducing crop losses from climate-induced pests and diseases, improving soil health and contrasting erosion, protecting farms from extreme weather events). Trees in agro-ecosystems play a critical role in contributing to biodiversity conservation in agricultural landscapes through *in situ* conservation, by providing habitats to wild species, connecting fragmented habitats and providing stepping-stones between protected area networks (Schroth *et al.,* 2004; van Noordwijk, 2021). Trees and forest patches are also useful and profitable to farmers as they provide a range of goods and services for soil health and fertility along with fuelwood, management of pests and diseases, erosion control and water runoff. Landscape and forest management can help ensure the continued availability of pollinators and thereby increase resilience and the productivity of forestry

and agriculture (Krishnan *et al.,* 2020). When native species are employed, agricultural systems that include trees can increase the diversity of natural predators that help control pests and diseases (Lamichhane, 2020). Integrating trees on farms and practising agroforestry promotes diversity in production systems and increases the resilience of landscapes to shocks and stresses (Duguma and Minang, 2020). Agroforestry systems can harness ecosystem services and create more resilient food systems and livelihoods (Kuyah *et al.,* 2020).

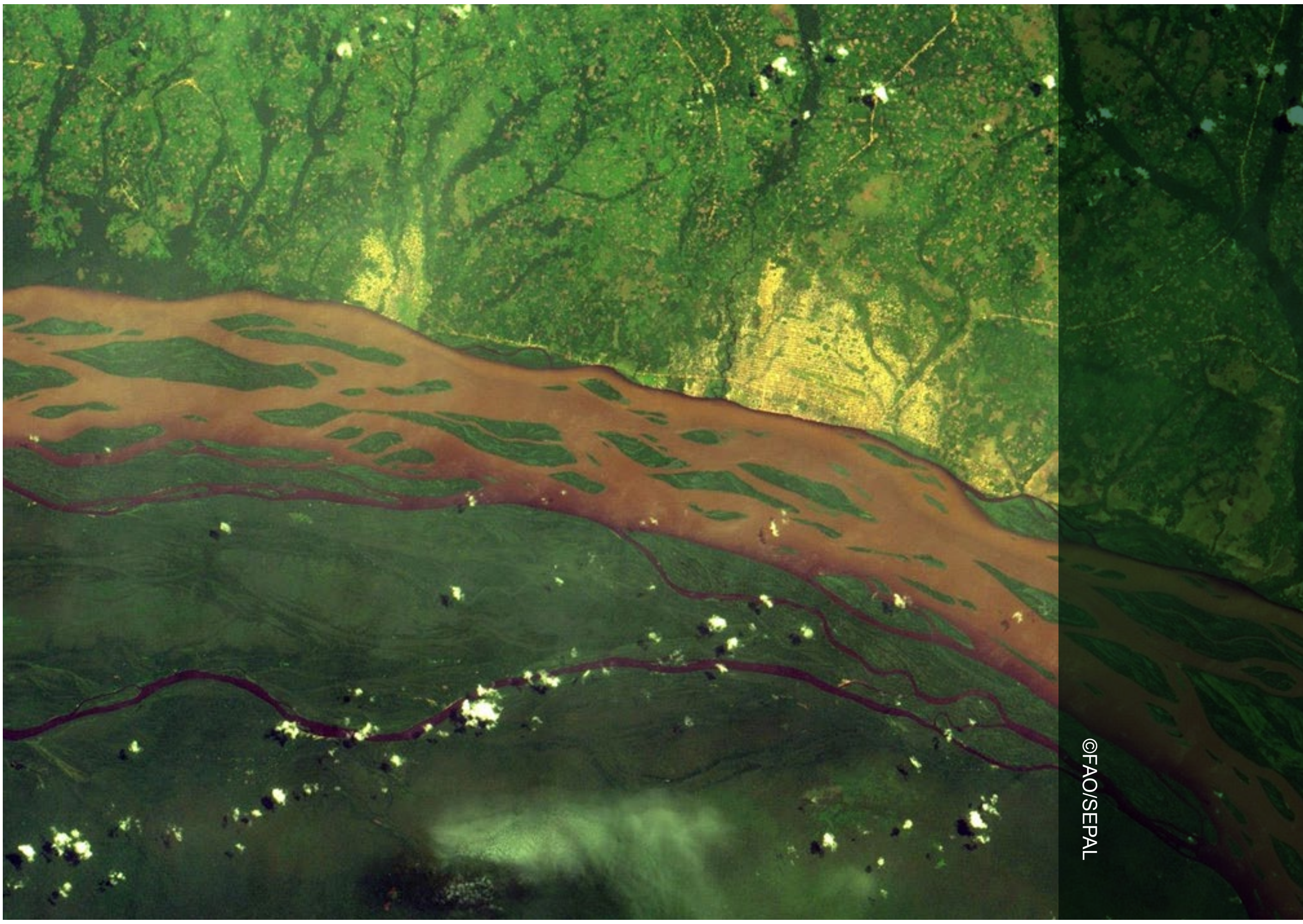
2.2.3. Forests regulate water cycles and protect soils

Forests, water and climate are inextricably linked (Creed and van Noordwijk, 2018). Forests move water locally and globally, influencing rainfall interception, evapotranspiration, water infiltration, and groundwater recharge (Ellison *et al.,* 2017; Lawrence and Vandecar, 2015). Forest-water interactions and their implications for local and regional water availability are complex and context-dependent, and these interactions have not been fully considered in policymaking (Ellison, 2018).

Forests and trees are prime regulators within the water, energy and carbon cycles (Ellison *et al.,* 2017). Nearly 20 percent of annual average precipitation is regulated by vegetation through moisture recycling, although there is a large variability on the global scale (Keys, Wang-Erlandsson and Gordon, 2016). Tree cover expansion impacts water availability locally through its effects on the radiation balance, infiltration and soil water storage, evaporation, streamflow and precipitation (Ellison, 2018; Hoek van Dijke *et al.,* 2022). Forest cover change has a significant impact on runoff and its components (i.e., base flow and surface runoff): decreasing forest cover increases runoff, whereas afforestation has the opposite effect (Ding *et al.,* 2022). Native forests contribute to regulating base flows during dry seasons and peak flows during rainfall events, both of which are services of utmost importance for the adaptation of people to climate variability and change (Pramova *et al.,* 2012). Forests can help prevent floods and droughts in specific contexts. Through water retention, forests can retain excess rainwater, prevent extreme run-offs and reduce the damage from flooding (EEA, 2015). Forests can also contribute to the availability of freshwater through groundwater recharge and watershed regulation (FAO, 2022a). At the same time, some tree species have been reported to increase pressure on water catchments, and invasive alien tree clearing has been demonstrated to be a successful nature-based solution in South Africa (Holden *et al.,* 2022). These measures are important for managing hydroclimatic risks, but they will need to be combined with other adaptation options as climate change accelerates (ibid.).

Degraded forests alter the water cycle and create drier soils, and this is more pronounced in more extreme dry seasons (Longo *et al.,* 2020). Soil erosion is linked to desertification and changes in precipitation. Vegetation cover plays an important role in soil conservation (Rodrigues *et al.,* 2020). Conversely, deforestation leads to soil compaction, soil erosion, transpiration loss, reduced infiltration, and increased water runoff, all of which can promote flooding (Ellison *et al.,* 2017). Forests also improve the water quality in watersheds by minimizing sediments and runoff (Mello *et al.,* 2018).

Governing forest-water-climate interactions is a difficult task given their transbound-



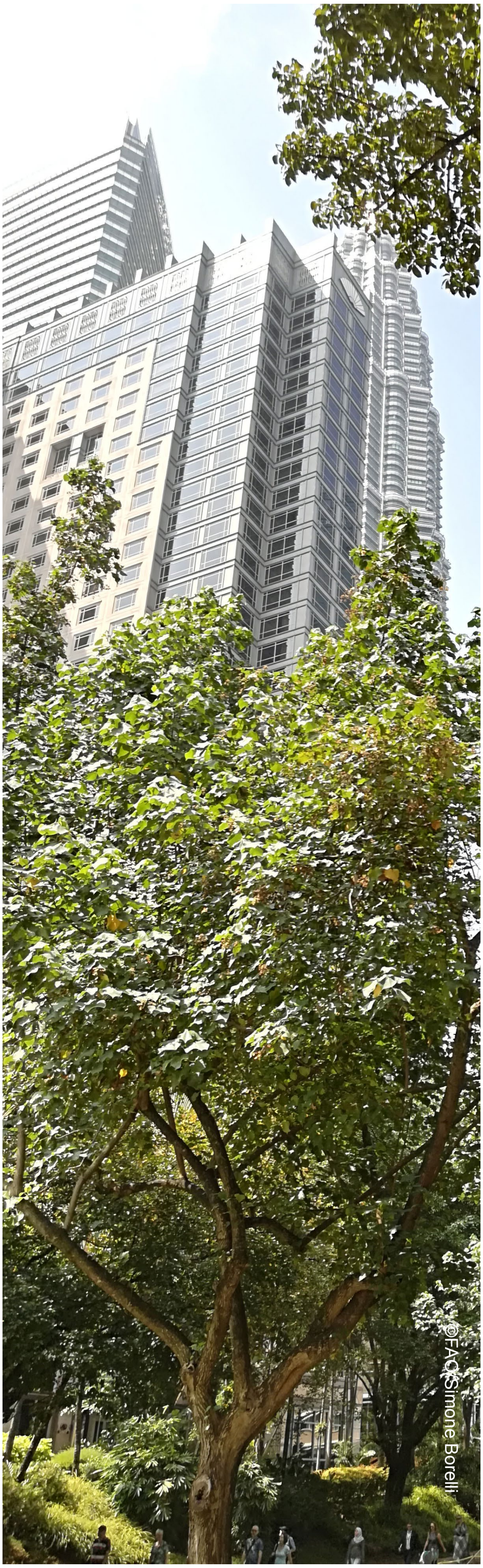
ary nature, but investments in forests can serve as a cost-effective measure for water management and climate change adaptation (FAO, 2022a; Keys, Wang-Erlandsson and Gordon, 2016). Understanding these relationships can support efforts to enhance ecosystem services through cross-continental transfers of water, infiltration and groundwater recharge, and terrestrial surface cooling (Ellison, 2018).

2.2.4. Forests protect communities from hazards

Coastal forests, such as mangroves, can protect coasts from tropical storms, sea-level rise, floods, salinization, and erosion due to their ability to absorb and dissipate wave energy and stabilize coastal land. Mangrove ecosystems alone provide flood protection benefits exceeding USD 65 billion per year and protecting more than 15 million people (Menéndez *et al.,* 2020). They also serve as the basis of livelihoods for fishing communities worldwide (zu Ermgassen *et al.,* 2020). However, mangroves and coastal forests alone are not enough to protect from climate risks, and they should be part of an overall adaptation strategy that can combine green, grey and blue infrastructure to increase the resilience of ecosystems and the adaptation of coastal communities and economies. Most importantly, mangroves contribute indirectly to global food security and nutrition by supporting fisheries and aquaculture (FAO, 2022b). Mangroves and other coastal forests are also an essential part of the continuum of ecosystems that may contain coral reefs, sea grasses, peatlands, and upland and mountain forests, all interconnected and supporting the resilience of the landscape. For example, the “ridge to reef” approach promotes a holistic intervention targeting environmental degradation in the uplands (ridge) that impacts coastal ecosystems through sedimentation and restoring the shoreline and protecting marine ecosystems (reef) thereby reducing coastal communities’ exposure and vulnerability to storm surges and flooding (Bainbridge *et al.,* 2018).

Beyond the illustrative example of mangroves, forests in general can be part of disaster risk reduction efforts in the face of hydrometeorological hazards, such as floods (van Noordwijk, Tanika and Lusiana, 2017; Tembata *et al.,* 2020) as discussed in the previous section, storm surge (Kayum, Shimatani and Minagawa, 2022), landslides (Forbes and Broadhead, 2011), avalanches (Zurbriggen *et al.,* 2014), and erosion of riverbanks and coastlines (Bessinger *et al.,* 2022).

In montane areas, forests are particularly effective for protecting against some types of abiotic disturbances, like snow avalanches, rockfalls, debris flows, shallow landslides, surface erosion and floods (Lingua *et al.,* 2020). Protection services have been reported to be higher when dealing with diverse, multispecies high-stand forests (Scheidl *et al.,* 2020). Properly designed forest management can support specific forest structures that fulfil, maximize and sustain the protective function of forests (Lingua *et al.,* 2020). Studies carried in shade-grown coffee systems have found that, at the farm scale, more diverse and complex agroforestry systems are less negatively affected by landslides caused by extreme events such as tropical cyclones (Philpott *et al.,* 2008).



Despite these benefits, increasing forest disturbances can weaken their protective functions (Sebald *et al.,* 2019). Social vulnerability is tied to inequities in access to livelihood-dependent resources and exposure to shifts in such access as bioclimatic and socioeconomic conditions change (Turner *et al.,* 2021). Thus, the degradation of ecosystems and their services can exacerbate peoples' exposure to natural hazards and impacts from climate change, reducing access to safe, sufficient natural resources needed for livelihoods and undermining long-term development (see Blackmore *et al.,* 2021).

2.2.5. Urban forests regulate temperature and water in cities

Urban forests and trees have an important role to play in urban adaptation to climate change. Urban areas are projected to accommodate two-thirds of the world's population by 2050 (UN DESA, 2018). Thus, urban trees and green spaces will be ever more relevant, and this can be reflected in land-use planning and regulations that recommend ensuring a fixed percentage of the city surface area be covered with green spaces (see C40 Cities 2021).

The urban heat effect is a local phenomenon that is an example of how a city's surface composition and size can intensify the impacts of climate change (Cariñanos *et al.,* 2018). Green spaces, green roofs and trees in cities can reduce the heat island effect by as much as 12 degrees Celsius (Schwaab *et al.,* 2021). Urban trees are proven to provide substantial urban cooling, thermal comfort and heat stress reduction, as well as energy saving, decreasing the energy consumption for cooling (Moss *et al.,* 2019). Trees influence urban climate via shade provision and evapotranspiration, a cooling phenomenon during which the water circulates from the tree's roots to its leaves (Winbourne *et al.,* 2020).

Trees and urban parks can reduce floods by facilitating water penetration into subsoil (Friends Of EbA, 2022). The presence of forests in cities has a significant effect in decreasing the rate of water flow through the urban landscape (Chan *et al.,* 2021). They are also a cost-effective flood prevention mechanism: planting more trees in the streets of Portland, United States of America, proved to be three to six times more effective in managing stormwater than conventional drainage systems (Depietri and McPhearson, 2017).

Moreover, trees in cities provide habitats for biodiversity (Endreny, 2018), thus contributing to resilient urban ecosystems (Schlaepfer *et al.,* 2020). Urban and peri-urban forests play an important role for city residents, providing environmental, social and economic services (Thorn *et al.,* 2021; Shackleton *et al.,* 2015). Urban trees contribute to food security (Vannozzi Brito and Borelli, 2020) and provide forest products that can be used for bioenergy (Roeland *et al.,* 2019). Urban forests can regulate air-quality (FAO, 2022a) and contribute to carbon sequestration and uptake of micropollutants (Pace *et al.,* 2021), yet space constraints limit the extent of urban tree canopies relative to the current magnitude of emissions (Pataki *et al.,* 2021). As such, urban trees are more effective for adaptation than mitigation strategies (ibid.).

Furthermore, urban trees provide multiple health benefits for physical and mental health by enhancing the quality of life as well as recreational functions (Doimo, Masiero and Gatto, 2020). Forests provide invaluable educational services, as well as spiritual and cultural benefits (Solomou *et al.,* 2018). However, urban forests tend to be highly susceptible to collapse: historic practices often promote low-diversity tree communities to meet the demands of a taxing urban environment and the preferences of citizens (Paquette *et al.,* 2021).

3. POLICY SUPPORT FOR FOREST-BASED ADAPTATION

Forests and trees are crucial in the climate change adaptation context, since they are affected by climate change and must adapt, while playing a key role in people's adaptation and resilience across sectors and scales (Locatelli *et al.,* 2010; Meybeck *et al.,* 2021). This means that forest-based adaptation can be used to meet multiple policy objectives. Here we focus on climate policy but also refer to complementary policy spheres that could bolster the role of forests and trees in providing adaptation and resilience benefits.

Adopted by Parties at the COP21 of the United Nations Framework Convention on Climate Change (UNFCCC) in 2015, the Paris Agreement is an international treaty that aims to keep global warming under 1.5 degrees Celsius relative to pre-industrial levels. It provides a clear policy framework for promoting forest-based adaptation through various means. Parties are expected to communicate their enhanced ambition through NDCs (as outlined in Article 3 of the Agreement) and long-term strategies for climate change mitigation. The agriculture, forestry, and other land use (AFOLU) sector is critical in NDCs given its potential for large-scale mitigation and adaptation, including through reduced deforestation, improved forest management, and forest restoration (Dooley *et al*., 2022). Many countries highlight the potential of forests in their NDCs (Box 2). However, a significant number of country targets are conditional on international climate finance, highlighting the need for continued support to enhance forest-related components (Haupt *et al.,* 2021).

Forests are given specific attention through Article 5 of the Agreement, which encourages Parties to conserve or enhance sinks of greenhouse gases, including forests. This has provided the framework for the proliferation of initiatives to Reduce Emissions from Deforestation and forest Degradation (REDD+) at national, subnational and local scales (Duchelle *et al.,* 2019; Parrotta *et al*., 2021). While the emphasis is on conserving carbon stocks, this also includes "alternative policy approaches" such as adaptation approaches for the sustainable management of forests. Article 6 rules enable international voluntary cooperation for climate change mitigation, and Article 6.8 focused on non-market approaches encompasses adaptation and resilience as well.

Furthermore, Article 7 defines a Global Goal on Adaptation to enhance adaptive capacity and resilience, reduce vulnerability and contribute to sustainable development. Each Party should engage in planning processes on adaptation, including the formulation of NAPs, vulnerability assessments, monitoring and evaluation, and economic diversification. Better integration of forests and trees into NDCs for adaptation can be supported by the long-term NAP process (Meybeck *et al.,* 2021; Box 3).

The first Global Stocktake in 2023 provides another opportunity to draw attention to the key role of forests and trees for adaptation and resilience. As outlined in Article 14 of the Paris Agreement, the Global Stocktake will regularly assess its implementation and the world's collective progress on mitigation, adaptation and means of implementation, along with cross-cutting issues that include ecosystem-based approaches.

BOX 2.

Forests in nationally determined contributions

Nationally determined contributions (NDCs) are country commitments towards helping achieve the goals of the Paris Agreement. NDCs are self-determined and include national climate targets, policies and measures for both climate change mitigation and adaptation. A key aspect of the Paris Agreement is the commitment to enhanced ambition: NDCs are to be updated periodically, and each submission is meant to express more ambitious goals than its precedent (Art. 4). As of 1 August 2022, 163 Parties plus the European Union had submitted new/updated NDCs, while 30 countries had submitted their first NDC and only three countries had not formally joined the Paris Agreement through the submission of an NDC (www.climatewatchdata.org/).

In the new/updated NDCs, AFOLU is one of the most represented areas for joint mitigation and adaptation efforts. As of 2021, 79 percent of the NDCs include forest-related actions, such as afforestation, reforestation, and sustainable forest management as mitigation tools (Crumpler *et al.*, 2021). Adaptation actions have also grown for the AFOLU sector in the new/updated NDCs, with forests being mentioned in 68 percent of these actions. Furthermore, agricultural subsectors are listed as adaptation areas in 95 percent of the new/updated NDCs, and most of these include forests as a subsector for adaptation with actions such as forest restoration. Some of the new/updated NDCs refer to the potential for mitigation and adaptation co-benefits in climate change actions, such as agroforestry and restoring native vegetation. The climate targets, goals, policies and measures set out in NDCs can converge with the 2030 Agenda for Sustainable Development by aligning with 169 targets underpinning the 17 SDGs (Northrop *et al.*, 2016). The AFOLU sector, and in particular forests and trees, offer multiple opportunities in this regard (Crumpler *et al.*, 2019).

Other policy spheres that can bolster the role of forests and trees in providing adaptation and resilience benefits include:

- Under the UN Convention for Biological Diversity (CBD), the negotiations on the post-2020 Global Biodiversity Framework will determine the implementation, monitoring and review of national plans and targets on biodiversity. The Framework establishes action targets for 2030, which include ecosystem-based approaches to minimize the impact of climate change (Target 8). At the country level, National Biodiversity Strategies and Action Plans guide the conservation and sustainable use of biodiversity in national policies as well as in sectoral or cross-sectoral activities, which is described further in the next section.
- The Sendai Framework for Disaster Risk Reduction 2015-2030 (Sendai Framework) was the first major agreement of the post-2015 development agenda and provides countries with concrete actions to protect development gains from the

risk of disaster. It advocates for "The substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries". Countries contribute through national disaster risk management policies to the seven global targets and 38 global indicators of the Sendai Framework to measure progress made by all countries on disaster risk reduction by the year 2030.

BOX 3.

Forests in national adaptation plans

National adaptation plans (NAPs) are national policy instruments that allow countries to identify their adaptation needs for climate change and build resilience through the process of planning and coordinating actions across all sectors, levels of governance and geographies with a focus on protecting vulnerable groups, communities, and ecosystems. Since 2015, the number of NAPs submitted by countries to the UNFCCC has been steadily increasing, and this number is expected to continue to grow. As of 31 August 2022, 37 NAPs had been submitted to the UNFCCC. In October 2021, the Least Developed Country Expert Group reported that 129 out of 154 developing countries were in the process of developing a NAP. Since many countries include adaptation goals in their NDCs (in fact, 94 percent of new or updated NDCs mention adaptation components), formulating and implementing NAPs can have a reinforcing effect on NDC targets.

The intersectoral approach of the NAP is fundamental for creating a comprehensive approach to adaptation given the linkages between forests and other sectors. As of December 2021, the NAP Global Network reported that 13 out of the 30 submitted NAPs included forestry as a priority sector in their adaptation plans. Even more countries mentioned specific ecosystem-based approaches in their adaptation measures. In a 2020 evaluation of 19 submitted NAPs, forests were recognized as a vulnerable ecosystem to climate change along with freshwater and coastal/marine ecosystems. However, the forestry sector was more likely to be treated separately in policy actions, and the potential of forests and trees in reducing climate risks was overlooked (Terton and Greenwalt, 2020). A general evaluation of the NAP formulation and implementation by the United Nations Environment Programme (UNEP) highlighted greater progress with addressing adaptation gaps and laying the groundwork in the early stages of NAP formulation than in later stages of preparing adaptation measures, implementation and putting effective monitoring and evaluation systems in place (UNEP, 2021). This is largely attributed to a lack of institutional capacity to implement cross-sectoral strategies and have long-term monitoring systems (UNFCCC, 2021).

- Urban parks and green spaces are increasingly recognized for their contributions to building resilient cities. The New Urban Agenda was adopted at the United Nations Conference on Housing and Sustainable Urban Development (Habitat III) in Quito, Ecuador, in 2016. It recognizes that large green spaces and urban forests are the backbone of urban green infrastructure, interconnecting a complex mosaic of large and small green spaces. Furthermore, they are the prerequisites for safeguarding the health and functioning of such infrastructure in city planning. Green infrastructure includes a wide set of components, from city parks to urban forests and peri-urban parks, as well as the greenery of cemeteries, gardens, and street trees, among other options.
- The recently-launched UN Decade on Ecosystem Restoration (2021-2030), which is co-led by FAO and UNEP, also provides a key opportunity to promote the importance of forest landscape restoration - including forested peatland and coastal wetland restoration, and integration of trees on farms - for climate change mitigation and adaptation through its many initiatives and partner networks (FAO, 2022a). The best-practice principles developed to guide ecosystem restoration activities under the UN Decade, including through a focus on biodiversity, ecosystem health and integrity, inclusiveness and equity, can support improvement in the adaptive capacities and resilience of ecosystems and people (FAO, 2021).
- The United Nations Food Systems Summit, held in 2021, sought to promote the transformation of agrifood systems, from part of the problem to part of the solution in facing the planetary crises of climate change, hunger and poverty. To harness the role of food systems in fulfilling the Sustainable Development Agenda 2030, some countries have synthesized the proposals from their local and national dialogues into national food systems transformation pathways that can inspire forward-looking collaborations.[5]

[5] In the context of the UN Food Systems Summit, 116 countries presented their national pathways for food systems transformation. As part of the Summit's action area "Boost nature-based solutions", at least 27 countries included actions in their national pathways directly linked to forests, including enhancing forest restoration, ensuring sustainable forest management, halting deforestation or reducing forest degradation. Some countries referred to their REDD+ strategies and other, mainly from Europe, highlighted the objective of ensuring that global food value chains do not cause deforestation. Furthermore, at least 18 countries also proposed measures for developing agroforestry, as an action under the agroecology theme. FAO has set up a database to facilitate information sharing on the content of the national pathways submitted by Members in the context of the UN Food Systems Summit: https://datalab.review.fao.org/datalab/dashboard/food-systems-summit/

4. PRINCIPLES AND POLICY IMPLICATIONS FOR USING FORESTS AND TREES FOR TRANSFORMATIONAL ADAPTATION

Although principles exist in relation to climate change adaptation action (Hallegatte, Rentschler and Rozenberg, 2020; Soanes *et al.*, 2021), none is specifically elaborated to guide the use of forests and trees in promoting transformational adaptation. To fill this gap, CIFOR-ICRAF and FAO led the development of ten principles based on a literature review and a series of workshops organized in 2021, which included a diversity of scientists with expertise on linking forests, trees and adaptation (Djoudi *et al.*, 2022). In this section, we introduce each principle, discuss the policy implications, and highlight a case study for each that illustrates its application in practice.

BOX 4.

Principles to leverage the power of forests and trees for transformational adaptation (Djoudi *et al.*, 2022)

Principle 1. Communities first: Enable local stakeholders, including Indigenous Peoples and local communities, to be at the centre of adaptation and forest and tree management. Adaptation is context specific and needs to emerge from bottom-up processes that articulate with other levels. Top-down planning can lead to maladaptation.

Principle 2. Policy integration: Adopt an intersectoral and multilevel approach to link forest and tree management to other policies that address climate-related risks (e.g. climate policies, watershed management, carbon projects).

Principle 3. Empowerment, capacities and assets: Recognize the roles of different stakeholders in forest and tree management. Enable and enhance empowering structures, institutions, and collective decision-making mechanisms on adaptation, which include the voices of the most vulnerable or marginalized.

Principle 4. Rights and distributive justice: Promote equitable access to the ecosystem services generated by forests and trees, and address structural inequities hindering sustainable forest- and tree-based livelihoods. Protect the rights of Indigenous Peoples, women, youth, and others who face barriers to adaptation.

continues ...

BOX 4. *(continued)*

Principle 5. Diversity is key for adaptation: Harness the role of social-ecological diversity in forest and tree systems for nature-based and transformational adaptation.

Principle 6. Co-production: Co-produce knowledge on multiple forest and tree systems with diverse stakeholders and diverse knowledge systems (e.g. Indigenous, local, scientific).

Principle 7. Scenarios and monitoring: Envision future scenarios and adaptation pathways to assess climate-related risks for people, forests and trees, and use them in decision making. Integrate local knowledge in participatory monitoring.

Principle 8. Trade-offs and synergies: Understand, manage and internalize trade-offs between adaptation and mitigation, and between different ecosystem services and users of forests and trees. Build on the capacities of forests, trees and people to enhance adaptation and mitigation synergies.

Principle 9. Proactive transformation: Identify, enable and engage pro-active transformational adaptation and enhance the role of forests and trees to facilitate multiple transformations: transformation of ecological systems, of food systems, and of human-nature relationships, into desired states.

Principle 10. Adaptive management: Promote adaptive learning and enable relevant stakeholders to build open, flexible management processes, which allow them to harness the benefits of forests and trees to manage uncertainties and cope with change.

4.1 Policy implications of the principles

PRINCIPLE 1. Communities first

This principle speaks to the ability of forest communities and Indigenous Peoples to manage forests to build resilient futures that respond to their own visions and needs. It focuses on the importance of recognizing local agency and the rights of local people to determine adaptation futures that adequately address context-specific realities. Locally-led adaptation differs from top-down planning in the sense that it is designed, managed and monitored by local communities. It builds upon a deep understanding of vulnerability contexts and inequalities, employs local metrics for measuring "success", and recognizes local decision-making processes and institutions. This community-based approach addresses the fallacy that adaptation is a purely scientific and technical issue to be solved by external experts.

Despite local actors' efforts to re-frame adaptation decision-making and engage with governments (Lavorel *et al.*, 2020), top-down governance systems can prove a barrier to collaborative action (Colloff *et al.*, 2021). There is considerable experience of participatory development to date, particularly in relation to local involvement in project planning and implementation (Forsyth, 2013; Hügel and Davies 2020). This wealth of experience has also been a source of learning from errors, trade-offs and unforeseen or unwanted consequences (see Cooke and Kothari 2001; Ferguson 1994), yet implementation remains full of challenges and uncertainty (Samaddar *et al.,* 2021; Cattino and Reckien, 2021). For example, the need to recognize all actors, and the dynamics between them, is fundamental to avoid "elite capture" from potentially reinforcing pre-existing and often overlooked power dynamics between local elites and marginalized populations (García-López, 2019; Persha and Andersson, 2014). While most adaptation planning processes employ consultation and multistakeholder engagement, local communities are often excluded from having ownership over the adaptation interventions intended for them (Tye and Suarez, 2021). Locally-led forest-based adaptation can help respond to business-as-usual climate adaptation planning that occurs at international and national levels, with marginal participation from local actors (Coger *et al.,* 2022).

Policymakers are called upon to increase local agency and autonomy in adaptation planning and implementation. To build stronger links between local and national adaptation planning, effective and transparent information sharing mechanisms is key for accountability (Fox, 2015). This should include all relevant sectors and put in place efficient and integrative coordination processes to increase the accountability of local decision makers to their constituents to avoid corruption and elite capture (Agrawal *et al.,* 2009). For example, Nepal promoted a local, bottom-up approach coined 'Local Adaptation Plans of Action' (LAPAs) to foment the participation of local government and community associations in adaptation planning (Regmi *et al.,* 2016; Vij *et al.,* 2019). This approach was later replicated in Asia and Africa, illustrating the potential of inclusive and decentralized bottom-up adaptation planning (Chaudhury *et al.,* 2014). Similarly, recent work by research institutes on developing principles for locally-led adaptation has provided renewed emphasis on community-based decision-making and bottom-up collaboration (Tye and Suarez 2021; Coger *et al.,* 2022).

Transformational locally-led adaptation puts both social and ecological considerations at the heart of all actions, policies and programmes aiming to protect and restore landscapes and ecosystems to adapt to climate change. Such an approach addresses adaptive capacity effectively, simultaneously increasing resilience, human well-being, and biodiversity. The focus on rights-based approaches and collaboration with stakeholders at various levels implies recognizing land stewards as drivers of locally-led transformations, not solely as project recipients. Recognizing local stakeholders implies dedicating time and resources to bottom-up processes and providing capacity development for government officials with regards to inclusion of the most vulnerable.

CASE STUDY 1.

Locally-led landscape transformation to reverse degradation

Heavily impacted by the droughts of the early 1970s and 1980s, farmers of the Sahel initiated a remarkable landscape transformation, in a striking example of endogenous, locally-led adaptation. By ingeniously modifying traditional agroforestry, water and soil management practices to restore soil fertility and health, they set in motion a positive feedback loop that triggered a broad ecosystem recovery cycle over the course of three decades. From "zaï" planting pits and stone bunds to retain rainfall and conserve soils in Burkina Faso, to farmer-managed natural regeneration of valuable trees in the Niger, land-based practices are now spreading from farmer to farmer through knowledge-sharing venues, schools and networks supported by non-governmental organizations (NGOs) and research organizations, including CIFOR-ICRAF (Reij, Tappan, and Smale 2009).

Once a desert fringe, eroded and heavily degraded, this part of the Sahelian landscape has been transformed into productive and agrobiodiverse land, with an impressive reversal of degradation and desertification across six million hectares (Garrity and Bayala, 2019). Over 200 million new trees have grown, with a total production value estimated at over USD 260 million, providing food security, demonstrated resilience against recent droughts, and an increased income potential of 18-24 percent for about three million people (Magrath, 2020). Studies analysing what triggered the regreening trend show that forest decline was halted when several factors came together to support the shift from vicious to virtuous cycles, and from maladaptation to resilience. The reversals toward reforestation were triggered by institutional changes in governance, allowing more autonomy to communities, that translated into gains in livelihoods and eventually in the biophysical environment (Sendzimir, Reij and Magnuszewski, 2011). Farmers, once the passive victims of droughts, resource loss and conflict, have transformed themselves into agents of change and true stewards of the land. At the policy level, key changes in forestry laws and government decentralization enabled this transformation by encouraging greater local ownership and control over natural resources.

This example shows that inclusive and bottom-up adaptation planning happens when policy allows communities autonomy over the adaptation process, and when assets and resources are provided. It shows also the crucial importance of agency to harness the ability of forest communities and Indigenous Peoples to manage forest resources and lands to build the resilient futures that respond to their own visions and needs. Such social mobilization is reflected in FAO's contribution to the African-led Great Green Wall through the Action Against Desertification Programme, which restores degraded lands while enhancing the resilience of rural communities (Sacande *et al.*, 2020).

PRINCIPLE 2. Policy integration

Mainstreaming climate into all stages of policymaking in other policy sectors, also known as "climate policy integration", despite being recognized for its importance, still faces many barriers to implementation. There is need for coherence between climate change mitigation and adaptation policies, long-term economic development plans, and sustainable development objectives, which the IPCC has termed "climate-resilient development pathways" (IPCC, 2022a). Integration across sectoral policies (e.g. climate, watershed management, biodiversity conservation, landscape restoration, economic planning) requires horizontal overarching governance structures for cross-sectoral coordination (Di Gregorio *et al.,* 2017).

For example, integrating landscape approaches into public and private-sector strategies and policies can help address conflicts and trade-offs between economic growth and conservation interests in specific contexts, and identify strategic opportunities to deploy high-quality forest-based adaptation, beyond the siloes of sectoral perspectives (Miller *et al*., 2022). Land-use planning can help create a shared vision of the multiple goals of sustainable landscapes and help embed that vision into relevant jurisdictional strategies (Browder *et al.,* 2019). This requires adequate knowledge and information, evidence-based, inclusive and transparent decision processes, as well as governance mechanisms and instruments to maximize synergies and balance trade-offs between different objectives, with due consideration for social equity. Strategic multistakeholder processes, including diverse actors such as Indigenous Peoples, women, youth, government agencies, practitioners, donors, private-sector actors and research institutes, are key to address divergences and trade-offs in landscape planning (Larson, Sarmiento Barletti and Heise Vigil, 2022).

Climate policies that promote governance enhancements across sectors and levels of decision-making through participatory mechanisms can exemplify policy integration. The REDD+ experience has highlighted how global forest-based climate initiatives can promote governance innovations in national policies and programmes fomenting collaborative processes that engage people constructively across the boundaries of public agencies, levels of government, and public, private and civic spheres (Korhonen-Kurki *et al.,* 2018). Subnational governance mechanisms have been suggested as ideal spaces for policy coherence between climate adaptation and biodiversity management plans (Casey, 2022). However, multilevel and cross-sectoral coordination requires an explicit understanding of the political dimensions of landscape governance to effectively promote conservation and development synergies (Larson *et al.,* 2018; Ravikumar *et al.,* 2018), since applying technical fixes to political problems has repeatedly failed (Myers *et al.,* 2018). Community forestry and "opening up" state-owned forests for local management can exemplify the operationalization of this principle across multiple levels of government. For example, forest decentralization and devolution processes have promoted social forestry and community forestry programmes and even forest tenure reform in some jurisdictions (Libert-Amico and Larson, 2020; Wong *et al.,* 2020).

Discussions between actors with different and often conflicting perspectives requires a shared understanding of the context, as well as tools to facilitate the monitoring of the relationships between different elements and dimensions of social and ecological systems (Meybeck *et al.,* 2021; Evans *et al.,* 2021). Recent innovative policy mechanisms have proven to foment cross-sectoral collaboration, such as natural capital accounting (measuring and valuing ecosystem services can create further understanding of these services among policymakers) or integrating green and blue infrastructure into infrastructure standards, regulations and procurement policies (UNEP, 2022b). Furthermore, the multisectoral nature of NDCs and NAPs, because they are economy-wide, can help facilitate such cross-sectoral collaboration and address multilevel planning (Meybeck *et al.,* 2020).

CASE STUDY 2.

Forests for life: policy integration through Colombia's REDD+ results-based payments programme

Colombia's updated NDC, presented in 2020, stipulates enhanced mitigation ambition, as well as an adaptation component that integrates economic sectors and indicates synergies with the SDGs. This NDC was the product of a participatory consultation process. It also was built upon a risks and vulnerability analysis at the national, department and municipal scales, with a focus on agroecological systems and productive sectors such as agriculture and cattle ranching. Priority economic sectors (transport, energy, agriculture, livelihoods, health, water, commerce, tourism and industry) consider climate change in their planning instruments and will be implementing adaptation actions.

These connections across adaptation priorities, policy sectors, and territorial planning, along with linking adaptation targets to SDGs and the Sendai Framework, illustrate the policy integration that the country has promoted. The sectoral adaptation plans also call for bringing together traditional, local, and scientific knowledge through multi-stakeholder forums and exchanges that include the participation of primary sector producers and their organizations, along with subnational jurisdictions coordinated in a national roundtable.

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The NDC includes cross-sectoral approaches on reducing deforestation and carbon pricing. Forestry-based mitigation measures account for roughly 70 percent of the mitigation planned in Colombia's updated NDC. The updated 2020 NDC also sets targets for restoring approximately 963 000 hectares of forest area by 2030, as well as establishing 370 000 hectares under sustainably managed plantation forests.

Colombia's promotion of community forestry is an example of reducing barriers to community engagement in natural resource governance to support climate change adaptation. Over 53 percent of the country's national forest area lies in Indigenous territories; of these, about 90 percent is considered relatively undisturbed (FAO and FILAC, 2021). Recognizing that forests are a crucial component of the livelihoods of Indigenous Peoples, Afro-Colombian, and farmer communities in Colombia, the country's Forest Management and Deforestation Control Strategy is called "*Bosques territorios de vida*" (Forests - territories of life).

Since 2018, through Colombia's national strategy on REDD+ (Gobierno de Colombia, 2018), and with support from the UN-REDD Programme, the FAO-European Union Forest Law Enforcement, Governance and Trade Programme, and other partners, the country has been able to strengthen forest governance with participation from local communities, farmers, and regional environmental institutions. Colombia's approach to results-based payments, as expressed in the country's REDD+ Strategy implementation, has allowed for strengthening community forestry organizations, improving community-based monitoring, and overcoming bottlenecks in accessing formal markets and fair prices for forest products. For example, a collaboration between the Yurumanguí River Basin Community Council and the *Red Faisán* in 2020 allowed for lowering the market entry cost for community forest producers, ensuring access to legal and fair business. The objective of this collaboration was to reduce brokerage costs and provide viability to fair prices and legal business, pairing Yurumangui's community-based sustainable forest management, which is protected by national regulations, with the corporate social responsibility work of *Red Faisán*. These partnerships between local communities, governments, and industry users can scale up forest management that is beneficial for climate adaptation.

The implementation of community forest monitoring actions also strengthens local forest governance and the ability of communities to take early action to adapt to climate change. In collaboration with the UN-REDD programme, national guidelines for community forest monitoring were produced to strengthen participatory monitoring (FAO, 2018b). The associated capacity development facilitated community participation in national policy processes, articulation with the National Forest Monitoring System, and better planning of their forest landscapes. These guidelines facilitate collaboration to provide high-quality and updated information on forest changes, which in turn informs decision-making on suitable strategies for forest management. As such, community forestry and participatory forest monitoring are key aspects of forest-based adaptation.

PRINCIPLE 3. Empowerment, capacities and assets

There is a need to deepen the understanding of vulnerability to better understand the impacts of inequality on climate change adaptation needs and options through differing access to forest land and resources (Ece, Murombedzi and Ribot, 2017; Eriksen *et al.,* 2021). A shallow understanding of the vulnerability context creates maladaptive pathways which can reinforce, redistribute or create new sources of vulnerability and maladaptive outcomes (IPCC, 2022a).

Many forest-dependent communities have been conserving forests for generations, and often have contributed the least to global warming (Chancel, 2022). Yet, they are at the frontline of climate-induced risks, battling forest fires, droughts and floods. Climate change is impacting them disproportionately, especially women and youth.

With joint responsibility for managing much of the world's remaining forests and securing food for many of the world's poor, the resilience of local people is also essential for global climate solutions (Macqueen, 2021a). Working with forest-dwellers and land users to build bottom-up planning strategies based on democratic participation is the premise for local decision-making over adaptation and resilience actions (Fox, 2015). Capacity development programmes need to be co-produced to respond to context-specific needs and support strategies for building climate resilience through diversity (Macqueen, 2021a). Technical assistance and extension programmes with holistic approaches can promote sustainable agrifood systems, agroforestry and sustainable forest management in an integrated and inclusive manner. Equitable governance that recognizes local knowledge and institutions, with supportive legislative and policy arrangements, can serve to empower local communities to continue with long-term biodiversity conservation and sustainable forest landscape management (Dawson *et al.,* 2021).

Although there is a need for further ambition to enhance the forest-related components of NDCs and NAPs, there is also a gap in ensuring access to funding for forest-based adaptation options. To be successful, these require adequate, timely, predictable, accessible and gender-responsive financial resources, as well as technology transfer and capacity building. Despite recognition that forest communities and Indigenous Peoples are efficient forest protectors, they received less than one percent of official development assistance for climate change mitigation and adaptation over the last ten years — just USD 270 million per year on average (Rainforest Foundation Norway, 2021). Along with the commitments for making funding available for adaptation (Swann *et al.,* 2021), climate finance needs adequate tracking mechanisms and monitoring, focused on how it will enable transformational change (Soanes *et al.,* 2021). It also needs to be gender-inclusive, support youth initiatives, and urgently make funding available and accessible to Indigenous Peoples, Afro-descendant, and local community women's organizations in countries in the Global South that have been historically under-supported and under-funded.

CASE STUDY 3.

The Forest and Farm Facility: Empowering forest and farm producer organizations

At UNFCCC COP 26, governments and philanthropic foundations pledged to spend USD 1.7 billion between 2021 and 2025 to support tenure rights for, and forest management by Indigenous Peoples and local communities as part of the Glasgow Leaders' Declaration on Forests and Land Use. To realize this pledge in the spirit it was made, funds need to be channelled directly to local communities. However, getting significant funds to reach the ground level is challenging.

The Forest and Farm Facility (FFF) explores ways to unlock climate funding for those communities by supporting Indigenous Peoples, local communities and their forest and farm producer organizations (FFPOs). It helps strengthen their organizations and develop their capacity to i) access climate finance, and ii) influence policies so that they take into account local interests.

The FFF has strengthened FFPO's capacity to formulate project's proposals and helped them to link to large investment projects (Forest and Farm Facility, 2022). For example, in Ecuador, capacity development and strategic alliance-building led to increased administrative skills and growing confidence among three FFF-supported Amazonian FFPOs - Wiñak, Kallari and Tsatsayaku. This in turn has enabled them to gain more access to resources for productive activities by linking them to the World Wide Fund for Nature and the USD 50 million Proamazonía projects.

The FFF developed a toolkit to help connect national forest and farm organizations with climate-change finance globally (Diaz and Kerr, 2020). A FFF policy brief calls on donors to recognize locally controlled organizations as a force for climate resilience and to scale up this approach to support millions of members through collective investments (Macqueen, 2021b).

In addition, the FFF supports FFPOs to develop written advocacy agendas and promote direct changes in policies and decisions in their favour. Policies at the subnational level have strong impacts on rural people's livelihoods and the resilience of their territories. FFPOs are particularly adept at accessing these more local levels of government to obtain faster results. Many gains have come from this subnational work.

For example, the Viet Nam Farmers' Union (VNFU) organized roundtables and focus groups with local government and private-sector actors which have enabled the development of conducive local regulations, produced action to improve local roads, and increased farmer access to finance. The FFF-VNFU team helped 14 FFPOs prepare advocacy strategies in 2021 to promote policies favouring higher-value, long-rotation forestry, organic production, and cooperative development at the commune, district and provincial levels. As a result, new land-use certifications were issued on 266 hectares; the construction of 17.5 km of village and forest roads to improve market access; and the enabling of farmer access to USD 2.1 million in new capital from private-sector enterprises, government programmes and development banks.

Furthermore, the FFF facilitated training, workshops, and peer-to-peer learning exchanges on climate-resilient business models for adaptation and mitigation in Viet Nam. Demonstration sites were set up on over 5,661 hectares to showcase business models ranging from long-rotation magnolia and acacia plantations, Forest Stewardship Council-certified timber, multipurpose tree production, and diversification through agroforestry. Diversifying value chains and buyers, certifying products through organic and other sustainability standards, improving packaging, and adopting digital marketing, all contributed to increasing the resilience of these FFPO businesses. By promoting agroforestry value chains and sustainable forest management practices, organized producers illustrate the social, economic and political co-benefits of forest-based adaptation.

PRINCIPLE 4. Rights and distributive justice

Securing local land and resource rights strengthens adaptive capacities. Limiting these rights decreases resilience, as vulnerable groups may face specific challenges in adapting to climate change and need specific resources. It is crucial to recognize the legitimate and effective ownership of local communities and Indigenous Peoples over their forests and lands to be able to build resilient futures. With secure tenure rights also comes the opportunity to engage in and benefit from climate finance, forest markets and other land-based investments.

Recent reports recognize the 476 million Indigenous people in 90 countries as custodians of an estimated 80 percent of the world's biodiversity (FAO, 2021). According to a study led by the Resources and Rights Initiative, Indigenous Peoples and local communities hold at least 958 million hectares of land in countries spanning most of the world's endangered tropical forests - yet have legal rights to less than half of their lands (RRI, Woodwell Climate Research Center and Rainforest Foundation US, 2021). Women's tenure rights have long been ignored, which increases their vulnerability: globally, less than 15 percent of all landholders are women (FAO, 2018c). Considering the diversity of customary arrangements, there is no one strategy that fits all contexts (Doss and Meinzen-Dick 2020), and specific attention should be placed to customary and communal tenure regimes and rights (Dawson *et al.,* 2021). For example, recent efforts to strengthen women's land rights in sub-Saharan Africa have focused on systemic registration through individual or joint land titling. However, this one-size-fits-all approach is not delivering change for women as it fails to reflect the region's diverse customary and legal landscape (Sutz, 2021). As such, complementary and flexible strategies are required.

Rights are included in the preamble of the Paris Agreement, highlighting the importance of prioritizing the needs of specific vulnerable groups and communities, such as women, children, and Indigenous Peoples. However, rights-based approaches tend to be poorly reflected in climate policies, and they remain a gap in adaptation planning (Ensor *et al.,* 2015). Thematic NAP guidance has been produced for forestry, gender, water, human settlements, agriculture, and health. Yet, none provide a holistic approach to rights, or refer to rights-based language to clearly highlight countries' obligations to fulfil those rights and address the unique needs of vulnerable groups and communities (Anschell *et al.,* 2022).

To fulfil climate ambitions, NAPs and NDCs should recognize the importance of rights and equity in adaptation. Addressing tenure insecurity has proven a successful strategy in conserving ecosystem services (FAO and FILAC, 2021). Climate action needs to further the rights agenda, not oppose it. For example, the vast majority of tropical forested countries seeking to benefit from international forest carbon markets have yet to define in law and in practice the rights of Indigenous Peoples, local communities and Afro-descendant Peoples over carbon in their customary lands and territories (RRI, Woodwell Climate Research Center and Rainforest Foundation US, 2021). This lack of clear rights poses substantive risks to both communities and investors, creating uncertainty as to who will benefit from carbon markets, offsets and emission reduction strategies.

Donors and policymakers have been called upon to strengthen collective territorial rights, compensate Indigenous Peoples for the ecosystem services they provide, facilitate community forest management and strengthen territorial governance and Indigenous Peoples organizations (Rainforest Foundation Norway, 2021). New funding models that are adapted to meet local requirements and capacities are needed. Innovative intermediary mechanisms such as the Tenure Facility, the Peoples Forests Partnership and CLARIFI, can play important interim roles in the delivery of finance and institutional strengthening for securing tenure rights, including for women.

CASE STUDY 4.

Shea tree management and value chains

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Across Africa, stretching from Senegal to South Sudan, about two billion shea trees (*Vitellaria paradoxa*) grow in agroforestry landscape of the Sahel savannah. In most of those regions, women control the production and the commercialization of shea products (Elias and Arora-Jonsson, 2017; Elias 2015). Shea remains one of the few tree products that women have a full access to, and they often control the income they make from shea. The customary practice around shea guarantees this access to women, while men usually control many other income sources.

Demand for shea butter produced in West Africa has nearly doubled in the past ten years, and shea is now an important ingredient in food and cosmetic products worldwide (Jasaw *et al.,* 2015). The industry is centered on women: more than 16 million rural women in Africa contribute to their household incomes by collecting and processing shea kernels.

A study led by CIFOR-ICRAF in Burkina Faso aimed to examine the contribution of woodlands and trees towards increasing women's adaptive capacity and decreasing household's risk of food insecurity caused by recurring extreme droughts (Koffi, Djoudi and Gautier, 2015). The researchers implemented household surveys (n=240) once each month and registered the goods sold or bought by the household every five days to follow the local market cycle. Shea nuts were found to be the primary source of income for the most vulnerable women in case of food shortage.

Findings from the study show that women living in households at high risk of food insecurity and who sold shea nuts were four times more likely to be able to feed their families by buying cereals than those who did not sell shea nuts. The security of rights over shea products allowed women to build a safety net strategy and to increase their adaptive capacity to curb household food insecurity when faced with drought. This study highlights that securing access rights to forests and tree products plays an important role in the adaptation of tree- and forest-based livelihoods. Policies that reinforce the rights of the most vulnerable to access key resources provided by forests and trees will increase the adaptive capacity and resilience of the most vulnerable in the face of climate change.

PRINCIPLE 5. Diversity is key for adaptation

Biodiversity conservation, sustainable management and leveraging ecosystem services (e.g. through preserving ecosystem functionality and ecosystem services provision and delivery) have strong synergies with climate change mitigation and adaptation. Biodiversity stabilizes ecosystem productivity by increasing resistance to extreme weather events (Isbell *et al.,* 2015). Conserving natural forest biodiversity is crucial for ecological functions such as pollination (Di Sacco *et al.,* 2021). Diversifying crops, livestock, and trees on farms increases resilience by strengthening the ability of the agroecosystem to respond to climate stresses, reducing the incidence of insect pests, diseases and weed problems, and providing alternative sources of income (Lakhran *et al.,* 2017).

Achieving positive biodiversity outcomes through forest-based climate action requires explicit articulation of biodiversity goals, identifying and addressing threats to biodiversity, as well as tailoring interventions and monitoring plans to national biodiversity conservation efforts (Panfil and Harvey, 2016). It also requires the full and effective participation of local communities and Indigenous Peoples who bring diverse cultural, social and knowledge to the identification of levers for transformative change (Priebe *et al.,* 2022). It is critical to acknowledge and to take into account the diverse ways that nature, biodiversity and ecosystem services are conceived and valued across cultures and societies (IPBES, 2016).

The post-2020 biodiversity framework can leverage forest diversity, social diversity and trees on farms to contribute to biodiversity objectives, resilience, and the long-term environmentally-sound productivity of forest landscapes (Strauss *et al.*, 2022). This will require appropriate information on forest extent and condition (intactness), and more information on the ecosystem services that forests provide. Information about agroforestry species and their uses and values will also be needed, building upon local knowledge (Chiputwa *et al.,* 2020). Necessary governance mechanisms include economic incentives, mainstreaming in agricultural policies, technical back-stopping and appropriate forest and tree tenure regulations. It will also involve investing in production, delivery and use of quality tree seeds and seedlings, as well as appropriate market development to add maximal value to the range of tree products (Graudal *et al.,* 2021). Neglected and underutilized species that have been overlooked in agricultural research and industry include many tree foods found in forests and which could be mainstreamed into cultivation and food systems (Dawson *et al.,* 2019).

Forest conservation and restoration can enhance the co-benefits of biodiversity and ecosystem conservation and promote synergies among mitigation and adaptation (Terton *et al.,* 2022). National policy coordination is needed to enhance synergies between biodiversity and climate change adaptation through national adaptation planning and the national biodiversity strategies and action plan (NBSAP) processes. National governments need to enhance national-level collaboration between the various ministries that deal with environment and forestry issues. To seek the highest synergy potential, common national funds that finance mitigation, adaptation, and biodiversity conservation simultaneously or develop joint programmes and projects that address the three measures are urgently needed (Morita and Matsumoto, 2018).

CASE STUDY 5.

Knowledge-to-action: Integrating forest and grasslands into adaptation strategies

The Nairobi Work Programme (NWP) is the UNFCCC's knowledge-to-action hub on adaptation and resilience. The NWP enhances country- and region-specific adaptation actions by identifying and closing knowledge gaps in partnership with subregional partners and networks and thematic expert groups. In partnership with its thematic expert group on biodiversity and climate change, representing 25 experts, knowledge continues to be curated about how integrating biodiversity into resilience-building actions can strengthen ecosystems and the services they provide.

In recognizing that the three Rio Conventions - on Climate Change, Biodiversity, and Desertification - are intrinsically linked, the NWP has also sought out synergies with other treaties such as the CBD.

Biodiversity underpins healthy ecosystems, upon which many adaptation actions rely upon. Forest and grassland biomes are home to critical biodiversity and ecosystem functions and services. The loss of forest and grassland ecosystems undermines opportunities to enhance adaptation. Knowledge about how forest and grassland biodiversity plays in the delivery of adaptation services has yet to be fully integrated into adaptation strategies. However, the NWP has documented adaptation efforts in some countries that have begun to:

- show where and how forest and grassland biodiversity and ecosystems have been integrated into adaptation strategies at various scales;
- conserve and restore biodiversity and ecosystems, with many examples of how countries are already using integrated forest and grassland approaches to adapt to climate change;
- enhance resilience to climate change impacts through targeted and actionable knowledge to scale up adaptation strategies that integrate ecosystems and biodiversity; and
- strengthen long-term collaboration to address knowledge gaps and inform the knowledge needs of countries, including informing the preparation of proposals to access the finance needed to implement adaptation action.

One of the case studies that the NWP has highlighted to respond to adaptation knowledge gaps is the Bishnupur community forest enterprise from Nepal, which promoted restoration based on native species of trees for honey production. This "Trees for Bees" approach was documented and supported for replication in neighbouring regions, resulting in increased financing for similar initiatives by the Green Climate Fund (GCF).

Adaptation knowledge gaps continue to be addressed, guided by and in collaboration with UNFCCC constituted bodies and institutional arrangements such as the NWP through, for example, the following knowledge outputs:[6]

- promoting synergies between biodiversity and climate change adaptation through the NAP and NBSAP processes;
- addressing gender inequities in forest and trees-based adaptation to address the climate urgency; and
- strengthening capacity for long-term monitoring, evaluation and learning for ecosystem-based adaptation.

6 See details of the collaborative actions: www4.unfccc.int/sites/NWPStaging/Pages/Biodiversity_actions_to_close_knowledge_gaps.aspx

PRINCIPLE 6. Co-production

The sophisticated environmental knowledge systems and worldviews held by local communities, farmer families, agroforesters, forest-dwellers and Indigenous Peoples include essential resources, practices, and concepts for understanding, using, and managing forest ecosystems. This knowledge is critical for informing and guiding scientific research, development projects and conservation policies, as illustrated by the use of indigenous, local and scientific knowledge by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (see IPBES, 2019). The recognition and preservation of indigenous food systems, along with the knowledge and values embedded in them, is essential to protect and sustainably manage forests, biodiversity and other natural resources.

Awareness of co-production mechanisms can facilitate proactive management and governance for collective adaptation to ecosystem transformation (Lavorel *et al.,* 2020). Power imbalances determine whose values, rules, and knowledge prevail in adaptation decision-making (Locatelli *et al.,* 2022; Wyborn *et al.,* 2019). Co-production processes that attend to power dynamics can be empowering, but those that do not will likely reproduce or exacerbate existing power imbalances (Turnhout *et al.,* 2020). Co-production implies putting different forms of knowledge into dialogue, but this is not a simple conversation: "co-production is a political practice which is inevitably imbued with unequal power relations that need to be acknowledged but cannot be managed away" (ibid.). Communities of practice have been suggested as one way of speeding up the social learning processes and knowledge exchange in the face of global changes. In the world recovering from COVID-19 and the forced digital leap, combined with the expansion of mobile networks and smart devices, exchanges between online communities are being harnessed to promote adaptive capacity at an unprecedented scale.

For example, Indigenous food systems, including the knowledge and values embedded in them, model the sustainable use of natural resources (FAO, 2021). Their preservation is essential to protect and sustainably manage forests, biodiversity and other natural resources. This is yet another reason why inclusive governance needs to be promoted, including care for women, Indigenous peoples and other under-represented groups in multistakeholder forums (Evans *et al.,* 2021).

The UNFCCC COP16 in Cancún (2010) marked a critical shift to an approach towards adaptation that includes local, Indigenous, and traditional knowledge. Since then, the discursive space for incorporating local, Indigenous and traditional knowledge around adaptation has expanded (Ford *et al.*, 2016). However, much is still to be done in the praxis to move from the awareness of the importance of knowledge co-production towards fully integrative and effective co-production. While there is a consensus on the importance of knowledge co-production for adaptation, a recent analysis of NAPs of African countries found no references to knowledge co-production practices in the NAPs (UNESCO, 2018). Multistakeholder platforms can help facilitate exchanges between holders of diverse worldviews and different knowledge systems (UNESCO, 2018). A successful outcome of such processes would be that adaptation measures based on multiple knowledge sources are identified, implemented and enhanced.

CASE STUDY 6.

Co-producing adaptation options

In the Riverina region of southeastern Australia, grazers developed a sheep grazing system that adapted to the anthropogenically-created saline landscape (Colloff *et al.*, 2021), exemplifying the co-production of adaptation options that used local knowledge. In an ecosystem that was once a floodplain woodland but was transformed into a saline shrubland through vegetation clearing, the adapted grazing system promoted a transformatively different ecosystem through moderate grazing and holistic land management and revegetation. This novel ecosystem and its innovative management system enabled a drought-resistant land management approach through revegetation, benefiting both grazing and biodiversity.

To achieve this new grazing system, the co-production of knowledge by local grazers, researchers, and government agencies was needed. Local grazers were empowered to produce knowledge through experimentation and learning from their own experiences, which generated a greater sense of ownership of the new grazing system and better adoption into practice. Traditionally, knowledge had been produced by scientists and extension officers and their research was imposed on the local grazer communities. In this instance, local grazers were allowed to decide how research was conducted and adopted, empowering them and creating a sense of ownership over the research produced.

The feelings of empowerment and ownership led to a high adoption of the grazing practice since the grazers felt like they could use the knowledge in the ways they best saw fit (ibid.). This co-production of knowledge generated several other co-benefits and had few trade-offs. Along with the empowerment of local communities, the new style of grazing practice was based on salt-tolerant shrub species that had previously been regarded as of low value and unsuitable to support sheep grazing. However, these shrubs provided habitat for biodiversity, as well as regulating ecosystem services, and helped create a more resilient and drought-resistant ecosystem overall. Additionally, the new grazing system allowed for the creation of new markets for saltbush-fed lamb and improved profitability which helps sustain the local grazing practices.

This study shows the potential for transformational adaptation when local and experiential knowledge is recognized, along with the necessity for collaboration between local communities, researchers, government agencies, and other actors. It also exemplifies the importance of empowering local communities through the co-production of knowledge and the benefits that can accrue for the community and ecosystems in the face of climate change.

PRINCIPLE 7. Scenarios and monitoring

Integrating forest-based adaptation into planning is challenged by the need to monitor biophysical, sociocultural, and economic impacts, which are usually context-specific. Monitoring and evaluation frameworks are often blind to trade-offs and do not help to enable synergies between different outcomes. They tend to focus on outputs and value for money and fail to assess the longer-term qualitative dimensions of adaptation and resilience, such as flexibility, learning and capacity development (Kaika, 2017; Thonicke *et al.,* 2020). There are also challenges to integrate uncertainty into planning through future scenarios and other foresight exercises, as well as building the resilience of institutional frameworks to respond to unforeseen change (Libert Amico, Ituarte-Lima and Elmqvist, 2020; McDonald and McCormack, 2021). Horizon-scanning involves seeking and researching signals of change in the present and their potential future impacts.

Monitoring frameworks should be developed through participatory approaches to reflect community-driven design to accommodate both donor reporting functions and the generation of local-level data and information to support management actions and community initiatives (Duguma *et al.,* 2020). For example, participatory community workshops in the Solomon Islands facilitated by NGOs and researchers served to build shared visions for the future and change the approach to adaptation (Colloff *et al.,* 2021). Rather than planning for the near future, community members envisioned a future for their grandchildren. This allowed for participants to consider multiple options for livelihood adaptation, such as sustainable forestry and community savings groups. Strategies for a desired future in the Solomon Islands were prioritized during community workshops, which set the stage for the community to submit applications to donors for their agreed-upon adaptation initiatives. Adaptation monitoring is complex; not only because adaptation touches multiple sectors (making indicator selection difficult), but also because monitoring frameworks are often built to satisfy donor or national reporting needs, with universally applicable frameworks, and therefore may not fully capture the impacts at community levels (Gilruth *et al.,* 2021).

CASE STUDY 7.

Large-scale ecosystem-based adaptation in the Gambia

Large-scale Ecosystem-based adaptation (EbA) in the Gambia: Developing a Climate-resilient, Natural Resource-based Economy[7] is the country's largest adaptation project, financed by the GCF and implemented by UNEP with technical support from CIFOR-ICRAF. It aims to develop a sustainable natural resource-based economy, promote livelihood strategies, and cushion communities from climate change impacts.

As part of this project, the Gambian Ministry of Environment Climate Change and Natural Resources needs timely and adequate information to manage its forest and agroforestry resources in the face of climate change. In response, CIFOR-ICRAF helped the government design an EbA platform (http://portal.ebagambiawebsite.com/) that includes biophysical and socioeconomic baseline data, project data in the form of key performance indicators (KPIs) and geo-referenced base maps, and hardware/software requirements for data processing. Following Duguma *et al.,* (2020) and Gilruth *et al.,* (2021), key performance indicators (KPIs) were developed through a participatory process. Stakeholders identified subindicators for each KPI, which were easier for local practitioners to apply, making the monitoring exercise practical and accessible. This

[7] www.greenclimate.fund/project/fp011

bottom-up process to validate indicators meant tagging them to EbA activities preferred by local communities, such as beekeeping, fruit production, and sale of woodfuels. Field data were collected to build the indicators, and the platform was used for aggregation and analysis. The result was a process for KPI development, a framework for monitoring and evaluating EbA, and a set of initial applications for management support.

The development of community-driven KPIs can help enhance the Gambia's adaptation efforts through channeling project funds towards results that directly benefit local people. Local participation in adaptation monitoring in this project allowed for the EbA platform to be applied to confirm which indigenous tree species have the greatest survival rates, as well as to learn which multipurpose community group interventions have greatest potential for long-term sustainability (Gilruth *et al.,* 2021). The day-to-day collection and aggregation of local feedback for the EbA platform helps create dialogue between project managers and local communities. Furthermore, the platform serves to build project data and high-level KPIs required for donor reporting. Although it would need to be adjusted depending on context and user needs, the EbA monitoring framework and process could be used for EbA projects in other locations with similar objectives.

PRINCIPLE 8. Trade-offs and synergies

Recent studies call for deepening our understanding of trade-offs and synergies between mitigation and adaptation (Sharifi, 2020; Locatelli *et al.,* 2015). Trade-offs imply that mitigation measures could undermine potential adaptation, and vice versa. For example, conserving a forest can reduce emissions and provide carbon benefits (mitigation), potentially to the demise of neighbouring communities who rely on the forest for their livelihoods. On the other hand, harvesting that forest for timber may serve to generate income (adaptation), but would lead to increased emissions. Synergies, for their part, refer to the co-benefits or positive secondary effects between these different approaches (i.e. promoting one will strengthen the other as well).

Transformational adaptation requires resolving current socioecological trade-offs, considering potential trade-offs, and increasing future synergies and co-benefits (Lavorel *et al.,* 2020). Trade-offs and co-benefits need be to be made explicit so that stakeholders can acknowledge that the co-production of adaptation services entails multiple feedbacks which can amplify or buffer them (ibid.). Research on transformational adaptation heeds an urgent call to move from a system that is only offering trade-offs, to systems that offer co-benefits and win-win synergies (Brockhaus *et al.,* 2021).

Future climate warning adds pressure to the urgency to overcome carbon-centric metrics and recognize forests and trees for both their mitigation and adaptation contributions (Lawrence *et al.,* 2022; Windisch *et al.,* 2022). Climate policy integration can be used to consider potential trade-offs and mutual benefits between adaptation and mitigation when mainstreaming climate change into land-use planning and policies (Locatelli *et al.,* 2020). For example, landscape management, even when not motivated by climate-related objectives, presents many opportunities for integrating adaptation and mitigation through the design and implementation of management practices that deliver societal adaptation, ecological adaptation and climate mitigation outcomes (Duguma, Minang and van Noordwijk, 2014; Locatelli *et al.,* 2015). Climate policy integration is needed to consider both potential trade-offs and mutual benefits between adaptation and mitigation when mainstreaming climate change into land-use planning and policies (Locatelli *et al.,* 2020).

CASE STUDY 8.

Adaptation services and trade-offs from wet peatlands

Peatlands are ecosystems in which the peat soil, formed by at least 30 percent dead, partially decomposed biomass, has accumulated naturally in waterlogged and often acidic conditions (Lindsay *et al.*, 2014). Peatlands in their pristine state are wetlands that provide ecosystem services to support adaptation and resilience. However, when drained these benefits are rapidly lost, and peatlands become prone to persistent fires and flooding.

Despite representing less than three percent of global land cover, peatlands store at least twice more organic carbon than the world's above-ground biomass (Dunn and Freeman, 2011). Although present in 169 countries, most governments do not have specific policy mechanisms for peatlands. Temperate and boreal peatlands have been drained for centuries (Holder *et al.*, 2004) for cropping, plantations, forestry, grazing, peat extraction (for energy, horticulture) or infrastructure development (FAO, 2014). Tropical peatlands, for their part, have faced degradation only in recent decades (Hergoualc'h *et al.*, 2017; Mishra *et al.*, 2021).

Drained peatlands provide services including food production, income generation, and transportation benefits through drainage canals. However, people living on drained peatlands are exposed to subsidence (with impacts to infrastructure) and risks of fire and flooding, with associated health risks.

Rewetting can reduce the trade-offs and maximize synergies between the mitigation and adaptation benefits provided by peatlands. This halts subsidence, supports adaptation to further sea-level rise and torrential rains, provides water filtration services, and reduces the risk of persistent and recurrent fires. Rewetting peatlands, including in forested areas, can also increase the resilience of the whole landscape, even if, as a trade-off, it often reduces tree growth. Hydrological benefits of peatland restoration are particularly evident on peatlands in upland areas, where they regulate the flow of water affecting the river basin (see FAO, 2015). In Indonesia, where drainage-based oil palm and acacia plantations have been rewetted, traditional fishing practice 'beje' helps increase fish catch for selling and to improve the nutrition status of the communities (Setiadi and Limin, 2015).

A key concept is 'paludiculture' (Geurts *et al.*, 2019; Dienle-Tan *et al.*, 2021), or biomass production on wet and rewetted peatlands (Wichtmann *et al.*, 2016). Various traditional and innovative approaches have been developed to sustainably produce fish, nuts, feed for livestock, construction materials, rubber, biomass for energy in wet peatlands (Greifswald Mire Centre, 2022). However, efforts targeted at developing products and sustainable value chains for paludiculture face the challenge of outstripping the short-term benefits from drainage-based peatland management.

To promote adaptation and mitigation synergies on peatlands, there is a need to understand and resolve the trade-offs between the ecosystem services that they provide (e.g. for carbon, flood risk reduction or livelihoods) and the actors that benefit from these services - often without knowing it. These trade-offs need to be managed efficiently for a just transition. Identified win-win solutions that allow keeping wet peatlands wet and rewetting drained peatlands need to be adopted to wider areas and different contexts.

PRINCIPLE 9. Proactive transformations

Retrofitting adaptation into existing development agendas can drive maladaptive outcomes (Eriksen *et al.,* 2021). Unless adaptation is rethought in a transformational perspective, it may reproduce patterns of exclusion and also worsen vulnerabilities (Djoudi *et al.,* 2022). Trade-offs between one land use or the other are related to trade-offs between the ecosystem services they provide (e.g. carbon or livelihoods) and the different actors that use those ecosystem services (e.g. environmental ministry or local communities). For example, the choice of tree species for landscape restoration programmes in the Sahel responds to the interests of different groups: employing eucalyptus provides timber and woodfuel, ecosystem services historically managed by men. On the other hand, choosing shea trees could provide adaptation services to women and strengthen their resilience capacities, since women are the historical managers of the shea butter value chain, which is a crucial source of income managed by women. This proactive choice towards transformational adaptation is meant to facilitate the transformation of both ecosystem and relationships, affirmatively supporting vulnerable groups.

Incorporating transformational adaptation into policy and practice is a complex process, which needs deep social and institutional changes. Some authors suggest therefore that mainstreaming transformation into policies can start with pathways of incremental changes that build towards transformation (Street *et al.,* 2022).

Forests have a role to play in promoting transformational changes, shifts in power relations, discursive practices, and incentive structures that lead away from unsustainable and unjust pathways (Brockhaus *et al.,* 2021). Forests and trees could play a pivotal role in transforming agrifood systems from being part of the problem, to part of the solution to the triple planetary crises of climate, pollution and biodiversity loss, as discussed in the UN Food Systems Summit in 2021. Tree-based, nutrient-dense food production could be incentivized by re-orienting agricultural investments and repurposing production incentives towards nutrient-dense foods through mechanisms, such as subsidies for nutritious crops, payments for ecosystem and nutrient services, and integrating nutrition objectives into forest conservation and restoration programmes in consideration of local peoples (FAO, UNDP and UNEP, 2021; Ickowitz *et al.,* 2022).

CASE STUDY 9

Community monitoring technology for transforming local forest governance

Two-thirds of Panama's forests lie within Indigenous territories (FAO and FILAC, 2021). Recognizing that Indigenous Peoples are the main inhabitants of Panama's forests and play a crucial role in their stewardship, FAO and partners worked to develop communities' capacity for monitoring deforestation and forest degradation in their territories. What initially began as technical training was transformed into a locally appropriated land management tool for promoting Indigenous rights over forests and territories.

The technical transfer provided by FAO on developing flight plans, maintaining drones, processing images and elaborating maps was shared with Indigenous youth from the Coordination for Indigenous Peoples of Panama (COONAPIP) who soon found other applications of these technologies. For example, they began to use the drones to identify native endogenous species, analyse forest cover change, and even explore sites of interest and sacred sites.

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The new knowledge and capacities acquired allowed Indigenous communities to generate high-quality data to inform the decisions they make on managing their forests. With the support of partners such as FAO, UN-REDD, the Rainforest Foundation US and the Tenure Facility, Indigenous organizations created Geo Indígena. This initiative provides high-quality technical services in mapping and monitoring of co-managed protected areas towards halting deforestation. It supports local governance through coordination with the traditional authorities of Indigenous Peoples of Panama, the COONAPIP, and national authorities. According to one Geo Indígena member, "We used to make verbal complaints … but now, with the geographical coordinates and photos of the environmental crime at hand, things are different and more effective" (Geo Indígena, 2022).

The work of Geo Indígena has not only fed into forest protection. It also promotes forest governance, gender-inclusivity, and land-use planning. Furthermore, the work of Indigenous monitors has also provided technical support to claims for rights and resources by local authorities, such as the creation of a new Indigenous region in 2020. The newly recognized Comarca Naso Tjër Di has its own technical units, or "*Klung Kjer*", for community forest monitoring, which are responsible for controlling and monitoring the approximately 160 000 hectares of this Indigenous territory, with a focus on the perimeter and other critical areas. "The threats to the forest never end, and nor will the work of our communities to save the future of our children" (Geo Indígena, 2022).

With the Mesoamerican Alliance of Peoples and Forests and The Ford Foundation, Geo Indígena has provided capacity development and peer-to-peer national and international exchanges with other Indigenous organizations and local communities seeking to appropriate mapping and monitoring technologies to empower locally-led adaptation options to manage and conserve forests.

This transformation of conventional forest monitoring methods, into tools for leveraging political claims and strengthening local decision-making over historically reclaimed lands and forests, illustrates the proactive transformation that forest-based adaptation promotes, since transformations in forests should not be isolated from the rest of society, but should go hand in hand with other social-ecological transformations.

PRINCIPLE 10. Adaptive management

The need for adaptive management of forests in the face of climate change is widely agreed upon by scientists and practitioners. Maintaining relatively healthy ecosystems and the provision of ecosystem services under the influence of climate change requires continuous and increasing efforts (Jandl *et al.,* 2019). New approaches are required for situations in which future ecological conditions will dramatically worsen (Molina *et al.,* 2021) Adaptive management requires risk-based planning approaches and multistakeholder decision-making (Prokhorova, Moiseeva and Govedar, 2021).

Under substantial human influences, forests are highly likely to be largely altered, potentially leading to the emergence of novel ecosystems or alternative stable states. Ecosystems are rapidly being transformed into new, non-historical configurations owing to a variety of local and global changes associated with primarily biotic change (extinction and/or invasion), primarily abiotic change (e.g. land use or climate change) and a combination of both (Hobbs, Higgs and Harris, 2009). Ecosystems with no historical analogue are expected to become increasingly common in future (IPCC, 2022a). This calls for a revision of conservation and restoration norms and practices away from the traditional place-based focus on existing or historical assemblages. Management thus needs more flexible, novel measures to address the significant uncertainty this generates (Mori, Lertzman and Gustafsson, 2017).

Adaptive management implies flexible programming and learning, with systems to monitor, evaluate and adjust based on re-assessments of risks and vulnerabilities. For example, after Hurricane Dean devastated subsistence and commercial agriculture in

Mexico's Yucatan Peninsula, government regulations on forest harvesting allowed for low-income subsistence farmers to adapt to the damage of the hurricane by shifting to charcoal harvesting (Schramski and Keys, 2013). Locally led adaptation efforts must be able to shift tactics and approaches in tandem with changes in the operational environment (Coger *et al.,* 2022). Institutions, laws and policies must also be able to adapt to unpredicted change (Libert Amico, Ituarte-Lima and Elmqvist, 2020).

CASE STUDY 10.

Once there was a lake

Lake Faguibine in Mali shows the benefits and challenges of adaptive management to harness ecosystem services when the decision context changes (Djoudi, Brockhaus and Locatelli, 2013). Due to a change in water flows, Lake Faguibine dried out, enabling a forest ecosystem to develop. This dramatic change in the environment meant that fishers and pastoralists lost their livelihoods, but the new forest ecosystem created a space for adaptive capacity in the community. It produced the opportunity for poor women to harvest wood and produce charcoal, which was reinforced by the migration of men out of the community in search of other opportunities. While the novel ecosystem gave more economic power to these women, barriers to market access prevented full economic potential from being realized. Other ecosystem services were not adequately harnessed, such as fuelwood for other groups and fodder and shade for livestock herders. The novel ecosystem was not managed, creating the risk that adaptation services will not exist in the future.

This case study provides valuable lessons for future adaptive management and highlights the opportunities that exist when a decision context changes. Not only did the environment change, but so did the community's social dynamics and relationship with natural resources. The novel ecosystem provided women of a low status with more power due to the change in natural resource access, but farmers and fishers lost natural resources for their livelihoods. This change in power is common with decision context changes, and those who are at risk of losing their livelihoods may be reticent to change or leave the community, as did the men in this case study who migrated out of the community to seek new economic opportunities.

New knowledge and rules on harvesting natural resources arose as women had to learn how to use forest resources and take on new responsibilities. Charcoal production emerged as a new livelihood option for the poorest and most vulnerable women. However, there were also challenges in accessing markets and extension services, particularly since the novel ecosystem changed local tenure arrangements: the lake had been managed by local communities, whereas the new forest fell under the government's jurisdiction, with corresponding regulations on non-wood forest products. Different social groups responded in different ways to this unexpected change. Communities are not homogeneous, and they have different vulnerabilities and power for different groups. These complexities are important to understand when analysing the adaptive management strategy of a community during a decision context change.

5. CONCLUSION

Forests and trees are key to solving the climate crisis. They provide essential adaptation services, and their mitigation potential depends on their ability to adapt and stay resilient in the context of climate change.

Forest-based adaptation is a political and governance issue that must mobilize all stakeholders to combine top-down and bottom-up approaches. Local communities, Indigenous Peoples, farmers, silvopastoralists, wood and non-wood harvesters, are forest and tree stewards. Through sustainable management, they can be drivers of locally-led transformations needed to respond to a changing environment. The case study in the Sahel illustrates how locally-led ecosystem restoration and sustainable management has transformed entire ecosystems based on traditional environmental knowledge and local innovations. Sectoral perspectives, which fail to recognize the connections between local, subnational, and national levels, may prove to increase disaster risks rather than decreasing vulnerabilities. Ignoring local stakeholders, their knowledge and livelihoods, hinders transformation. Forest-based adaptation requires an enabling environment that recognizes multiple stakeholders, across sectors and levels, to link actions in the field with policy reforms through bottom-up processes. The experience with REDD+ results-based payments in Colombia illustrates how there is an opportunity to use existing forest-based mitigation frameworks to promote adaptation and resilience benefits through purposeful policy integration.

Forest-based adaptation must address the social causes of vulnerability, including inequity and justice. Forest-based adaptation implies empowering local communities and their organizations by transferring meaningful powers over forests and trees. As seen from the Forest and Farm Facility, working with farmer and forest producer organizations allows for co-designing capacity development strategies that respond to local needs and interests. Recognizing and protecting rights and ensuring access to funds and resources are crucial strategies to address the social causes of vulnerability and inequity. Securing access to forests and trees can strengthen the resilience capacities of households to prevent, anticipate, absorb, adapt and transform when faced with disaster risks and crisis, including women as seen from the case of shea production.

Recognizing the linkages between ecological and social diversity provides opportunities for transformation, since the adaptation of people and ecosystems is intertwined. Forest protection, restoration and sustainable management can help simultaneously address the climate and biodiversity crises. As highlighted by the Nairobi Work Programme, there are clear opportunities to integrate the adaptation services provided by ecosystem biodiversity into national climate policies and build bridges between the Rio Conventions. Adaptation knowledge gaps can be addressed through co-production processes that create open dialogues between local, scientific and Indigenous knowledge, as seen in the grazing study from Australia.

Changes resulting from climate impacts must be anticipated; uncertainty and trade-offs must be accepted, addressed and internalized into socioecological systems. Building transformational adaptation implies engaging various types of actors and forms of knowledge. The Gambia GCF project experience shows how participatory monitoring can help provide updated data to decision-making processes based on context-specific conditions. Changes in practices and local innovations are required to move from a system that is only offering trade-offs, to systems that offer co-benefits and win-win synergies, as illustrated in the peatlands case.

Forest-based adaptation is a transformation of relationships. Learning and flexibility through accountable mechanisms can facilitate the pro-active transformation of forests and trees into desired states so they can play a pivotal role in the larger transformations. The Geo Indígena experience highlights that forest mitigation techniques, when co-produced with local stakeholders, can transform local governance to strengthen adaptive capacities and resilience. Unexpected changes in ecosystems and the decision context can be leveraged to harness adaptation services and avoid maladaptation through rights-based approaches as illustrated in lessons learnt from Lake Faguibine in Mali.

Transformational adaptation is needed to address the climate crisis. The contributions of forests and trees to transformational adaptation are vast and still gaining traction. There is a need to further integrate forests and trees into national climate policies and planning, and actively engage local people in adaptation decision-making, as part of a package of strategies to improve resilience in the face of increasing risks and uncertainty.

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