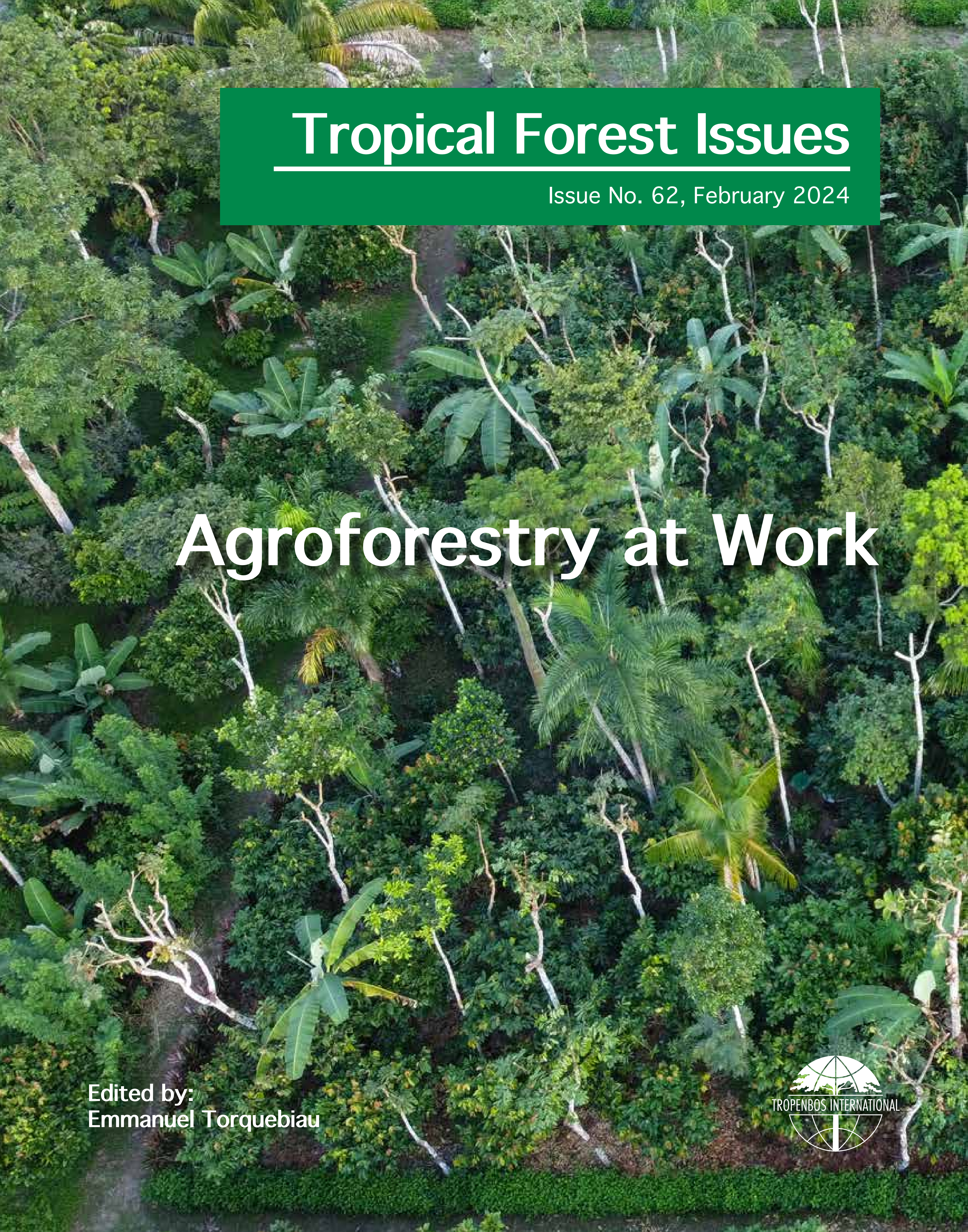

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Agroforest in Krui, Sumatra, Indonesia. Photo: E. Torquebiau

1.3

The agroforestry-biodiversity-climate change nexus

Emmanuel Torquebiau

“Biodiversity loss and climate change are inseparable threats to humanity that must be addressed together. They are also deeply interconnected in ways that pose complex challenges to effective policy-making and action.” These are the words of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES 2020, para.1).

“Agroforestry is a nature-based solution — by combining perennial plants (trees and shrubs) and annual, herbaceous plants (crops) and sometimes animals, it basically mimics nature.”

In a coordinated work between IPBES and the Intergovernmental Panel on Climate Change (IPCC), the two world-recognized organizations declared that “the functional separation between climate change and biodiversity creates a risk of incompletely identifying, understanding and dealing with the connections between the two, and, in the worst case, may lead to taking actions that inadvertently prevent the solution of one or the other, or both issues” (Pörtner et al. 2021: 4).

Due to climate change and biodiversity loss, land becomes less suitable for agriculture. This has severe consequences for food security. When land becomes degraded and there is an increasing demand for food, pressure on land increases, further exacerbating the risk of forest and land degradation.

This state of affairs brings us to a point where it seems to make sense — in fact, it is urgent — to look for initiatives that can simultaneously address the problems of the changing climate and decreasing biodiversity. As far as the climate is concerned, these initiatives must address both adaptation (i.e., adjusting to today's or tomorrow's climate and its consequences) and mitigation (i.e., decreasing sources or increasing sinks of greenhouse gases, or GHGs). In terms of biodiversity, solutions must take into account that plant and animal wildlife (including insects and microorganisms) is disappearing at unprecedented rates, and that agro-biodiversity (i.e., the part of biodiversity that includes useful plants and animals and their wild relatives) has been strongly affected by human activities and represents today only a minute portion of what it used to be at the origin of agriculture, around ten thousand years ago.

The land-use sector (agriculture, forestry and other land uses) has intimate connections with climate change and biodiversity. The sector is victim, cause and solution. Victim, because worsening climatic conditions (e.g., heat, drought, extreme events, etc.) strongly influence the primary productivity of both plants and animals, which must consequently adapt, be they wild or domesticated. Cause, because the sector emits 23% of total net anthropogenic emissions (Shukla et al. 2019). Agriculture is among the top emitters (artificial fertilizers, carbon release through ploughing, emissions by ruminants, etc.), together with land-use changes due to deforestation. Solution, because the sector can mitigate climate change through increasing CO2 capture via photosynthesis, supporting carbon content in soil and biomass, and by reducing emissions through ecologically sound practices.

Regarding biodiversity, the land-use sector is also at the heart of the debate. The variety of land uses on the planet harbour innumerable species and — perhaps more importantly — provide an array of ecological niches and landscapes where those species can thrive, reproduce and disseminate. Both natural and human-made landscapes have made Earth what it is: a planet where environmental conditions are compatible with human life. The biodiversity loss in recent decades is unprecedented in human history and represents a diminishing not only of today's environmental wealth but also of the world's evolutionary history and its potential to further evolve (DeClerck and Martínez-Salinas 2011). In other words, biodiversity is both a resource and a dynamic process that allows ecosystems to function.

And the number one human activity that explains biodiversity loss is agriculture, for four main reasons: the conversion of natural ecosystems into farms and ranches; the intensification of management in long-established cultural landscapes; the release of pollutants, including GHGs; and the associated impacts from value chains, including those from energy, transportation and food waste (Dudley and Alexander 2017).

Agroforestry is one of the most promising initiatives that can simultaneously address both climate change and biodiversity. The main reason for this is the fact that agroforestry is a land-use system that is based on so-called nature-based solutions — "a concept of vital and urgent significance" — one that "means more than you might think," according to an editorial in *Nature* in 2017 (Nature 2017). Why is agroforestry a nature-based solution? Because by combining perennial plants (trees and shrubs) and annual, herbaceous plants (crops) and sometimes animals, it basically mimics nature.

Take tropical agroforests: these dense, mixed, multi-layer agroforestry associations, with a diversity of planted trees and crops, are often found around households and villages and sometimes cover entire landscapes; for instance, in Sri Lanka and Indonesia. At first glance, they resemble natural forests, with which they are sometimes confused (see photo, previous page). Although agroforests are dense, the large number of associated species means that each plant appears in small numbers. Spontaneous bio-diversity co-exists with planted species, and multiple ecological interactions characterize these agroforests, which require no intensive agricultural management. Fruit, wood, fodder, vegetables, honey, eggs, etc. are harvested all year round. In the face of climate change, these human-made forests behave like natural forests, adapting to seasonal hazards while capturing carbon.

Take shade-tolerant crops cultivated under tree cover, such as coffee (see photo , facing page), cocoa, yerba mate and rustic pineapple varieties. Here, trees provide the climate buffering role that they originally played in the natural environment where the wild relatives of those crops were initially found. There's not much difference, actually, between the dense forests of Ethiopia were wild coffee was first

Coffee growing under shade trees, Usa, Tanzania. Photo: E. Torquebiau

domesticated and the tree-shaded plantations of Bolivia or Brazil; between the wild cocoa bushes of the Amazonian rainforest undergrowth and today's shaded cocoa fields in DRC or Ghana; between the araucaria forests of South America and raising cattle or growing yerba maté under those same trees; between the wild pineapple of the Amazon and the varieties grown nowadays under Mexican trees.

Take scattered trees in parkland (see photo, next page), a ubiquitous farming practice in semi-arid and subhumid Africa. Here, the model is the African savanna, carefully mimicked by millions of African farmers who practise farmer managed natural regeneration (FMNR). Among sorghum, cowpea or millet crops, farmers protect hundreds of naturally growing tree species and tend them for their multiple benefits. This amazing agrobiodiversity performance includes plenty of tree-delivered services such as soil improvement, wind erosion control, temperature buffering, and shelter for people and animals. It also encompasses multiple tree products such as food, fodder, wood, fibre, medicinal substances, gums, oils and handicraft material.

Take homestead agroforestry as it exists in Bangladesh (see photo, page 26), Ethiopia and India, among other places. Around dwellings, a variety of useful trees provide shelter for people and a supportive climatic environment for poultry, fish ponds and small ruminants. An array of understorey shrubs and nutritious herbaceous crops complement the starchy diet obtained from rice or other cereals. The high agrobiodiversity of these areas is a source of commodities that can be harvested throughout the year. Homestead agroforestry plots have also a key social role, as they are a place for community life and interactions at the village level.

The list can go on. When compared to the monocultures of industrial agriculture and forestry, most agroforestry systems have higher biodiversity or better responses to the climate change challenge, if not both. Several recent scientific papers confirm this. In 2019, Udawatta et al. published a worldwide review analyzing 110 articles covering the period 1991–2019. Their results show that that floral, faunal and soil microbial diversity are significantly greater in agroforestry as compared to monocropping on adjacent croplands. Other studies have shown the contribution of agroforestry to biodiversity at the landscape scale (Schroth et al. 2004). In heterogeneous landscape mosaics, agroforestry trees influence ecological processes such as the movements of animals, the dispersal of plants, the microclimate and the fluxes of water or soil nutrients, as well as the dynamics of both pests and useful auxiliary species.

Agroforestry parkland in Senegal. Photo: L. Leroux

As far as climate change is concerned, several articles confirm the positive role than agroforestry can play. Tropical agroforestry is an important sink for atmospheric carbon, particularly due to the presence of tree biomass, but also from reduced soil erosion, improved soil structure and increased soil organic matter (Gupta et al. 2017). Agroforestry therefore has much potential to become an important climate change mitigation strategy that can underpin various national and international policies. In a study in Africa, where 15% of farms had a tree cover of more than 30%, Mbow et al. (2014) show that agroforestry can simultaneously achieve both mitigation and adaptation goals. A meta-analysis of soil carbon sequestration in agroforestry (De Stefano and Jacobson 2018) indicates that soil carbon is higher in agroforestry fields when compared to agriculture or pastures (but not when compared to forestry). A recent perspective article in the journal *Nature Climate Change* (Terasaki Hart et al. 2023) describes agroforestry as the largest agricultural natural climate solution opportunity, comparable to other prominent natural climate solutions such as reforestation and reduced deforestation.

It is thus not surprising to find that prominent international organizations have included agroforestry as an option worth considering to address the challenges faced by today's industrial agriculture. In its 2019 *Summary for Policymakers*, a Special Report on Climate Change and Land, the IPCC states: "Solutions that help adapt to and mitigate climate change [...] include inter alia: water harvesting and micro-irrigation, restoring degraded lands using drought-resilient ecologically appropriate plants; agroforestry and other agroecological and ecosystem-based adaptation practices (high confidence)" (Shukla et al. 2019: 22). In the section on sustainable land management, the same IPCC report states: "The following options also have mitigation co-benefits. Farming systems such as agroforestry, perennial pasture phases and use of perennial grains, can substantially reduce erosion and nutrient leaching while building soil carbon (high confidence)" (Shukla et al. 2019: 23). The recently published *Global Sustainable Development Report 2023* (UN DESA 2023), which takes stock of progress achieved so far towards the 2030 Sustainable Development Goals, has identified a series of key shifts to accelerate progress under entry points such as economy, food and energy. Agroforestry is noted twice as a recommended intervention, under food systems and nutrition patterns, and under global environmental commons.

Project Drawdown, a well-regarded nonprofit think tank that "advances effective, science-based climate solutions and strategies," cites several agroforestry options among quantitatively significant solutions to climate change: multistrata agroforestry (layered trees and crops), silvopasture (the integration of trees, pasture and forage into a single system) and tree intercropping (combining trees and crops); see Project Drawdown 2023. All three options are described as having "co-benefits" — i.e., they can both mitigate climate change through carbon sequestration and contribute to improved biodiversity and resilience.

Interestingly, similar conclusions are reached by the authors of the IPBES-IPCC report (Pörtner et al. 2021), who warn the world about the risks caused by the connections between biodiversity loss and climate change. They write in the sustainable agricultural and forestry practices section: "Measures such as the diversification of planted crop and forest species, agroforestry and agroecology enhance biodiversity and nature's contributions to people in landscapes focused on the production of food, feed, fibre, or energy. These measures can also reduce climate-induced losses of food or timber production by increasing adaptive capacity" (Pörtner et al. 2021: 17).

A synergy in response to biodiversity and climate change thus seems to be a recognized strength of agroforestry. Several recent studies nevertheless point to the fact that knowledge gaps and structural or functional shortcomings remain. For example, Quandt et al. (2023) note that helping farmers reduce climate risk and understand the adaptation benefits of agroforestry to specific climate hazards suffers from a lack of integrated biophysical-socioeconomic research spanning different geographic areas. Several studies (e.g., Cardinael et al. 2018) highlight the fact that the potential of agroforestry in mitigating climate change depends on the land-use type it replaces. For example, the carbon balance is mostly negative when converting from forests to agroforestry, but is positive when converting croplands to agroforestry. Some systems are more effective for above-ground carbon sequestration (e.g., improved fallows), while others perform better for soil carbon sequestration (e.g., agroforestry with animals).

And in order to realize the full potential of agroforestry for climate change mitigation, other GHGs, such as methane and nitrous oxide, should also be considered (Feliciano et al. 2018). A meta-analysis addressing patterns of shade plant diversity in agroforestry across Central America (Esquivel et al. 2023) reveals that this diversity is highly skewed towards secondary forest species and tree species that are useful for farmers, and that its conservation value is much lower than that of natural forests.

Last but not least, although agroforestry exists in many forms, it is often absent from policy documents and not recognized in the relevant national statistics, documents and plans (Mulyoutami et al. 2023; Buttoud et al. 2013).

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Homestead agoforestry, Rajsahi, Bangladesh. Photo: E. Torquebiau

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