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Rethinking cocoa agroforestry: towards sustainable coexistence of remnant, spontaneous and planted trees

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Côte d'Ivoire, the world's leading cocoa producer, has lost most of its forest cover over the past fifty years, resulting in a severe erosion of biodiversity and ecosystem services. In this context, agroforestry appears to be a relevant solution, yet current implementation approaches, often based on standardised tree planting, struggle to restore biodiversity and sustainably increase carbon storage. Our results show that a more effective approach relies on the complementarity between remnant, spontaneous and planted trees within cocoa farms. Remnant trees ensure carbon stocks and forest heritage, spontaneous trees drive the future dynamics of tree cover, and planted trees support farmers' incomes and strengthen food security.

CONTEXT

Côte d'Ivoire accounts for more than 40% of world's cocoa. While cocoa underpins the national economy, it has also been the main driver of deforestation. More than 90% of the country's forest cover has disappeared in five decades, causing massive losses of biodiversity and essential ecological services such as climate regulation and soil fertility. In response, public and private initiatives have largely focused on distributing millions of tree seedlings to cocoa farmers. However, survival rates are generally low, the diversity of planted species remains limited, and the ecological benefits are modest.

At the same time, most cocoa fields already contain three often overlooked tree cohorts:

- **remnant trees**, large trees retained during the initial forest clearing;
- **spontaneous trees**, arising from natural regeneration;
- **planted trees**, deliberately introduced by farmers.

These three are rarely recognised in agricultural and forestry policies, yet they are increasingly threatened by agricultural intensification, high cocoa tree density and insecure land tenure. Recognising and managing this existing tree capital is central reconciling cocoa production with climate and biodiversity objectives.

KEY MESSAGES

- Large-scale tree-planting programmes in agroforestry limited effectiveness in restoring biodiversity and carbon, underscoring the need for more adapted agroforestry practices.
- Remnant, spontaneous and planted trees each provide essential agronomic services, including shade, microclimate regulation and soil fertility.
- Remnant trees hold the largest carbon stocks and preserve biodiversity inherited from former forests.
- Spontaneous trees, originating from natural regeneration, generate high carbon inflows and represent the future of tree cover in cocoa farms.
- Planted trees, selected by cocoa farmers, contribute to income and social functions and strengthen household food security, but their ecological contribution remains more limited.

Agroforestry programmes based on mass planting often fails due to high mortality, limited technical support, transplant shock, and the choice of poorly adapted or unwanted species. As a result, gains in biodiversity and sustainably increasing carbon storage.

Our research draws on original data from 150 cocoa farms across climatic and historical gradients in Côte d'Ivoire. More than 12,000 trees were inventoried and detailed farmer surveys documented each tree's origin (remnant, spontaneous or planted) and its individual history within the plot, systematically quantifying the material and non-material uses that motivate its conservation. This tree-by-tree approach reveals how farmers' decisions shape biodiversity, carbon dynamics and socio-economic benefits.

Diversity and complementarity

Remnant and spontaneous trees are far more diverse than planted trees. Remnant trees reflect the legacy of former forests, while spontaneous trees demonstrate the strong regenerative capacity (at least 280 seedlings per hectare and 33 tree species per farm). Planted trees - often fruit or exotic species - contribute little to biodiversity but strengthen food security and farmers' incomes. Biodiversity and livelihoods therefore depend on the complementarity of all three cohorts.

Carbon stocks and flows

Remnant trees hold the largest carbon stocks due to their size and age. Spontaneous trees grow rapidly, generating substantial carbon inflows and ensuring future tree cover. Planted trees contribute little to carbon storage. Climate mitigation benefits thus arise from combining legacy stocks with dynamic regeneration.

Agronomic services

All tree cohorts directly support cocoa production by providing shade, regulating microclimate and improving soil fertility. These services are highly valued by cocoa farmers but remain under-recognised in policies.

Socio-environmental drivers

Our analyses show that carbon stocks and flows, as well as biodiversity, are strongly influenced by:

► Forest history of cocoa farms: farms established after forest clearing retain higher levels of carbon and biodiversity;

► Cocoa tree density: excessive cocoa densities reduce both carbon stocks and biodiversity;

► Farmers' botanical knowledge: better species recognition encourages the conservation and management of valuable trees;

► Land tenure security: landowners are more willing to conserve and enrich tree cover on their farms.

Together, these factors explain much of the variability observed among cocoa farms. They highlight that forest cover dynamics are shaped as much by social practices and land tenure arrangements as by ecological factors.

A renewed approach to agroforestry

These findings demonstrate that agroforestry cannot be reduced to mass tree planting. Remnant and spontaneous trees provide most ecological and agronomic benefits, while planted trees primarily fulfil economic and social functions. The real potential of cocoa agroforestry lies in their balanced combination: conserving legacy trees, harnessing natural regeneration and introducing useful species in a targeted way.

In short, our work challenges the dominant paradigm: it is not about "replanting the forest", but about managing more effectively the complementarity between remnant, spontaneous and planted trees in order to secure cocoa yields, resilience and long-term sustainability.

Table 1. Services provided and values attributed by cocoa farmers (*) to remnant, spontaneous and planted trees

	Remnant trees	*Spontaneous trees*	*Planted trees*
Agronomic services (*)	++	++	++
Biodiversity	++	+	-
Carbon inflows	?	++	-
Timber production (*)	++	++	-
Crafts / artisanal uses (*)	+	++	-
Carbon stock	++	+	-
Cultural functions	++	+	-
Traditional medicine	++	+	++
Social functions	+	+	++
Food security	-	+	++
Non-timber forest products trade	-	-	++

The three categories of trees provide essential agronomic services to cocoa by supplying shade, regulating microclimate and maintaining soil fertility, but differ markedly in their other contributions:

► ***Remnant trees** hold the largest standing carbon stocks and conserve biodiversity inherited from vanished forests, while also providing timber and cultural functions.*

► ***Spontaneous trees**, originating from natural regeneration, are distinguished by their rapid growth which generates significant carbon inflows and constitute the future of tree cover in cocoa farms. They ensure the renewal of tree services.*

► ***Planted trees**, chosen by cocoa farmers, provide fruit, income (non-timber forest products) and social functions.*

The efficiency and sustainability of agroforestry practices thus rely on the complementarity of tree origins.

RECOMMENDATIONS

The Ivorian cocoa model – first based on monoculture and more recently on mass tree seedling distributions - does not adequately address climatic, agronomic and ecological challenges. Our results open the way to an alternative pathway centred on the integrated management of remnant, spontaneous and planted trees within cocoa farms.

Preserve and value remnant trees

Often large and old, remnant trees hold the greatest carbon stocks and conserve biodiversity inherited from vanished forests. They also provide key agronomic services: shade regulation, favourable microclimate, and soil fertility maintenance. Their conservation requires systematic field inventories, legal recognition, and integration into public policies, certification schemes and incentive mechanisms.

Support natural regeneration

Spontaneous trees are central to tree dynamics in cocoa farms. Their abundance, diversity and rapid growth make them a major lever for renewing tree cover and sustaining carbon inflows. However, this resource remains largely dependent on regeneration from residual forest and remains vulnerable to plot-clearing practices. These findings advocate for the explicit integration of assisted natural regeneration (ANR) into agroforestry transition pathways, through early seedling identification, protection during farming operations, and adaptative management.

Introduce planted trees as a complement

Rather than relying on mass distributions of poorly diversified trees, planting strategies should focus on locally adapted fruit or utility species. When carefully selected and managed, planted trees can enhance food security, generate additional income through non-timber forest products (NTFPs), and strengthen social cohesion within local communities. Their role is not to replace existing biodiversity, but to complement the services provided by remnant and spontaneous trees.

Secure land tenure and strengthen capacity

Tree conservation and enrichment strongly depend on land tenure security and farmer knowledge. Cocoa farmers with secure land rights and botanical skills are far more likely to conserve remnant trees, protect natural regeneration, and introduce useful species. Coherent policies should therefore prioritise land tenure security and integrate silvicultural and botanical training into support programmes.

Aligning these levers is not simply a matter of adding practices, it demands a paradigm shift. Support to cocoa farming must move away from standardised replanting towards the adaptive, fine-scale management of trees already present in cocoa farms, based on observation, selection, and learning in the field. This transition is urgent, as the current natural regeneration dynamics inherited from past forests represent a limited window of opportunity. The ability to recognise, value, and transmit this knowledge will determine the future resilience of cocoa farms and their ability to meet production, biodiversity, and climate objectives simultaneously.

RECOMMENDATIONS IN BRIEF

► Conduct field diagnostics, including inventories of remnant trees and assessments of natural regeneration, to identify species present, their condition, growth potential, and guide management and planting decisions.

► Systematically preserve remnant trees, which safeguard the largest carbon stocks, inherited biodiversity, and essential agronomic services (shade, microclimate regulation, soil fertility).

► Support and promote spontaneous regeneration, a key of carbon inflows and of the future tree cover by training farmers to identify and manage young trees.

► Introduce planted trees in a targeted manner, in collaboration with farmers, to enhance food security, income and social functions while complementing ecological services.

► Reduce cocoa tree density to recommended standards to free space for trees, improve growth, and maintain a favourable agronomic balance for cocoa production.

► Secure land tenure and strengthen botanical training, essential levers to encourage farmers to conserve and enrich tree biodiversity.

► Strengthen alignment and coherence between certifications, public policies and farmers' practices around integrated agroforestry, based on tree complementarity.

CONCLUSION

The transition to sustainable cocoa farming in Côte d'Ivoire requires a reorientation of public priorities and investments. Our results show that the effectiveness of agroforestry policies depends less on multiplying tree-planting programmes than on recognising, protecting, and managing the trees already present in cocoa farms. This tree capital - inherited from past forests and sustained by natural regeneration – represents a time limited opportunity. Redirecting investments towards land tenure security, farmer technical support, and the integration of assisted natural regeneration into sustainability standards would deliver greater climatic, ecological and socio-economic benefits at controlled cost. For policymakers and donors, the challenge is now to move rapidly from a volume-driven approach to durable, landscape-level impact.

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https://www.cocoa4future.org/

References and other links

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