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GROWING THE FUTURE

HARVESTING LESSONS FROM CLIMATE-SMART AGRICULTURE

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GROWING THE FUTURE

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Solidaridad

More than 61,500 hectares of cocoa, coffee and livestock systems have been transformed to climate-smart agriculture (CSA) between 2016 and 2022

The adoption of CSA results in a carbon removal increase from 20% to 80% when compared to farms without CSA.

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EXECUTIVE SUMMARY

SOLIDARIDAD HAS BEEN IMPLEMENTING CLIMATE-SMART AGRICULTURE (CSA) INITIATIVES IN SOUTH AMERICA SINCE 2013, WITH THE AIM OF REDUCING THE ENVIRONMENTAL IMPACT OF COMMODITY PRODUCTION AND IMPROVING FARMERS' LIVELIHOODS. THE MAIN COMMODITIES OF FOCUS HAVE BEEN COFFEE, COCOA, LIVESTOCK AND SOY, AND THE PRIMARY OBJECTIVE IS TO REDUCE DEFORESTATION AND ENGAGE PUBLIC AND PRIVATE ACTORS IN ESTABLISHING CLIMATE-SMART PRODUCTION MODELS.

This learning case study uses data from a project that scaled up climate-smart agriculture in: (i) Colombia and Peru, where it focused on coffee, and (ii) in Brazil, where it involved cocoa, livestock and soy, mainly for the market uptake component. The environmental objectives were to achieve a positive carbon balance, increase productivity, reduce costs and improve producers' resilience. In coffee in Colombia and Peru, the intervention considered actions on three fronts in the coffee supply chain, including: collaboration between public and private actors, promoting private sector investment and encouraging farmers to adopt climate-smart agriculture practices. In Brazil, the initiative focused on promoting sustainable models of cocoa and livestock intensification and restoration, testing market mechanisms to advance sustainability with shareholders and developing public and private policies for soy, cocoa and livestock.

HOW CAN PRODUCERS ACHIEVE ENVIRONMENTAL AND FINANCIAL SUSTAINABILITY?

ADOPTION OF CLIMATE-SMART PRACTICES

Sustainable farming is crucial both for the conservation of the environment and for the financial well-being of producers. To drive this change, farmers must be provided with evidence-based methods. The adoption of sustainable practices was defined in two layers: (i) individual actions, such as compost management, and (ii) the adoption of a minimum set of activities that align with climate-smart agriculture. Although the expected level of adoption was not achieved by all participants, any adoption of individual practices was seen as progress.

In Peru and Colombia, more than 15,000 coffee producers adopted a comprehensive set of climate-smart practices, resulting in an average adoption rate that increased from 30 to 64%. Furthermore, by the end of the study, all producers were able to adopt at least one practice. In Brazil, 9,204 hectares were converted to climate-smart agriculture, with adoption rates of 73% and 89% for two groups that began the initiative in 2016 and 2018, respectively.

The successful adoption of sustainable practices requires a thorough understanding of the profile of users and how they learn and communicate. In this case, practical capacity-building sessions, group work and WhatsApp webinars proved to be effective strategies for promoting sustainable practices. These methods were particularly important during the COVID-19 pandemic, when mobility restrictions prevented in-person training sessions and visits from field staff. These methods allowed for innovation, knowledge sharing and community cohesion while providing producers with the practical skills necessary to implement sustainable practices on their farms.

ECONOMIC VIABILITY OF CLIMATE-SMART AGRICULTURE

The section on economic viability emphasizes the crucial role it plays in the successful adoption of climate-smart agriculture practices. The positive outcomes observed in this respect have been instrumental to the successful scaling of the model. The economic viability of climate-smart agriculture is determined by factors such as price, yield and production costs.

In Colombia and Peru, average yields increased by 10%, contributing to an increase in income of 70.5% along with higher commodity prices and premiums for quality and sustainability. The average yield at the baseline was 955 kg/ha and rose to 1,076 kg/ha by the end of the study. The farmers who adopted climate-smart agriculture practices achieved even higher production yields, averaging 1,169 kg/ha, 9% higher than the overall average and 22.4% higher than their initial production levels. *Data analysis reveals a positive correlation between the adoption of climate-smart agriculture practices and increased yields*, with yields reaching 1,704 kg/ha when producers implemented all five prioritised practices.

In Brazil, cocoa and livestock producers' incomes increased by an average of 52%. Incomes from cocoa production increased substantially by 87%, while those from livestock production rose by 11%. These improvements were driven by higher global commodity prices for cocoa and premiums in high-quality markets. The adoption of climate-smart agriculture practices enhanced cocoa quality, creating opportunities to access speciality markets where prices tripled. Despite the slight decrease in productivity among a group of farmers that joined the initiative at a later date, incomes still increased by 43%. *These results indicate that climate-smart agriculture practices can contribute to economic viability and income growth in the cocoa and livestock sectors in Brazil.*

ENVIRONMENTAL IMPACTS OF CLIMATE-SMART AGRICULTURE

REDUCING FOREST PRESSURE AS A PILLAR OF CSA

Deforestation rates were assessed through satellite imagery and GIS tools, comparing historical rates to the project period. Additionally, forest cover and land use were examined at the farm level to identify changes within properties.

Two competing theories—the Borlaug hypothesis and the Jevons paradox—offer conflicting views on the relationship between increased productivity and deforestation. Our findings tend to support the Borlaug hypothesis, namely that increasing productivity reduces pressure on forests. However, this does not entirely rule out the dynamics suggested by the Jevons paradox, which argues that increased productivity generates an incentive to increase deforestation.

Deforestation remains a critical environmental concern in agricultural landscapes, posing challenges both within and beyond farm boundaries. The results were mixed in each country. In Colombia, especially in Risaralda and Cauca, we observed limited deforestation within the coffee farms, and that which occurred predominantly took place more than five years before the study period. Although the forest cover within these farms is lean, there is concern that deforestation could shift to higher altitudes due to the impacts of climate change.

In **Peru**, climate-smart practices appear to have reduced deforestation. Average deforestation in the sample area of the project fell from 13.09 hectares per year before the project to 5.22 hectares per year during the 2018–2020 period (0.02176 hectares of deforestation avoided per farm during the project). When applied to the total number of farms involved in the project, the result is a total of 81.8 hectares of avoided deforestation. Furthermore, the productivity gains helped to reduce pressure on an additional 3,973 hectares of forests outside of the farms.

Finally, in **Brazil**, the project focused primarily on the municipality of Novo Repartimento in the state of Pará, where there was a significant 55% decline in deforestation within the farms. Although a slight increase was recorded in 2021, the overall trend confirms that climate-smart agriculture has the potential to reduce deforestation considerably.

In conclusion, our multi-country study highlights *the role of climate-smart agricultural practices in reducing deforestation, although several other factors also have an influence, such as economic incentives, policy frameworks and local ecological conditions*. The nuances in deforestation trends across countries demonstrate the need for localised strategies alongside broader policy measures.

IMPLEMENTING SUSTAINABLE PRACTICES MAY RESULT IN A TEMPORARY "CARBON COST", BUT THE LONG-TERM GAINS IN PRODUCTIVITY AND CARBON CAPTURE CANNOT BE OVERLOOKED.

CHANGES IN CARBON EMISSIONS AND REMOVALS IN CSA

We assessed the impact of CSA on changes in carbon emissions and removals in Peru, Colombia, and Brazil. In **Peru**, emissions from coffee production increased due to the adoption of climate-smart practices, resulting in an additional 4,982 tCO$_2$eq (tonnes of carbon dioxide equivalent) emitted during the project. The low yield and delayed gain in productivity were identified as the main reasons for the observed increase in emissions. In terms of emissions per hectare, farms without CSA showed a higher increase in emissions than farms with CSA due to their more extensive use of fertilisers. However, regarding emissions per kg of coffee, farms without CSA showed a better performance due to a higher productivity increase. Avoided deforestation on coffee farms in Peru led to 2.24 MtCO$_2$eq of emissions avoided. Carbon capture through shade trees and coffee plants resulted in a total removal of 15,895 tCO$_2$eq.

In **Colombia**, emissions decreased on farms with CSA, whereas farms without CSA showed the opposite trend. Reductions in fertiliser volumes and improvements in fertilisation management contributed to lower emissions on farms with CSA, while emissions on farms without CSA increased due to the absence of such practices, where wastewater was the main source of emissions. Agroforestry systems and shade trees resulted in a total carbon removal of 29,966 tCO$_2$eq.

In **Brazil**, emissions from livestock decreased from 1.24 tCO$_2$eq/ha to 0.83 tCO$_2$eq/ha, leading to avoided emissions of 7,497 tCO$_2$eq. In cocoa growing, carbon removals fell from 1.04 tCO$_2$eq/ha to 0.90 tCO$_2$eq/ha. Total removal from cocoa growing was 26,683 tCO$_2$eq. On project farms, forest areas sequestered an average of 0.5 tCO$_2$eq/ha per year, resulting in a total removal of 4,065 tCO$_2$eq.

These findings highlight the complex dynamics of carbon emissions and removals in CSA. The adoption of CSA can lead to temporary increases in emissions due to changes in production practices, but long-term improvements in productivity and carbon capture potential are expected. Implementing sustainable practices may result in a temporary "carbon cost", but the long-term gains in productivity and carbon capture—as evidenced by the 15,895 tCO$_2$eq removed through shade trees in Peru and the 29,966 tCO$_2$eq removed in Colombia—cannot be overlooked. Avoided deforestation and agroforestry systems play a crucial role in reducing emissions and increasing carbon removals. These findings emphasise the importance of implementing CSA practices and considering context-specific factors to mitigate climate change in agricultural systems.

ADAPTATION AND RESILIENCE

The aim of the CSA models implemented in the project was to strengthen the capacities of the agricultural systems to manage the impacts of climate change and reduce exposure to climate-related hazards. Climate-smart practices were introduced to enhance adaptation benefits and strengthen the resilience of agroecosystems while improving farmers' livelihoods and forest ecosystems in Colombia, Peru and Brazil.

The model applied in **Colombia** and **Peru** significantly improved the resilience of coffee agroecosystems. Climate-smart practices were introduced across 61,650 hectares, replacing vulnerable monocrop systems. The practices focused on agroforestry and shade-grown coffee, which offer numerous adaptation benefits such as improved soil moisture, microclimate buffering and reduced vulnerability to extreme weather conditions.

In **Brazil**, the model targeted cocoa and livestock production, promoting agroforestry systems that enhance soil health and water filtration while reducing risks associated with climate hazards. Forest conversion for livestock is a major issue in Brazil, so the initiative sought to promote soil analysis, shade tree cultivation and the management of stocking rates, all while avoiding the use of burning practices and thus reducing deforestation and carbon emissions.

Both initiatives also diversified income streams for farmers, further boosting their resilience. Deforestation-free production and forest restoration were key components, contributing to long-term environmental sustainability.

MARKET UPTAKE

The complexities of transitioning towards climate-smart agriculture and deforestation-free commodities are deeply entangled with market mechanisms and policies, which each present a unique set of challenges and opportunities across commodities and countries. In the coffee sector, Solidaridad's project in Colombia and Peru demonstrated that the concept of climate-smart coffee could indeed be integrated into existing sustainability sourcing frameworks, albeit with differences in scalability. Speciality markets in Colombia have been effective but face limitations in expanding their impact, whereas commodity markets in Peru show promise both in scalability and effectiveness. Regulatory changes, such as the European Union's introduction of rules for deforestation-free products, are increasing the urgency among coffee buyers to engage in climate-smart initiatives.

Brazil's cocoa sector, on the other hand, is a unique case where local market mechanisms, industry partnerships and access to premium markets have been leveraged to enhance both economic and environmental sustainability. Initiatives such as a barter system for fertilisers have proven to be both effective and scalable, while training in post-harvest practices has enabled small-scale producers to access speciality markets that offer substantially higher prices. In the livestock sector, sustainability is largely driven by local market demands, but efforts like the GIPS guidelines have shown that standardised tools can help farmers assess and improve their sustainability levels. However, more needs to be done to provide tangible benefits and incentives for farmers to actively participate in these initiatives.

When it comes to soy production, private efforts, such as those by Dunkin' Brands, Hershey's, Kellogg's and COFCO, are laudable but remain limited in their impact on deforestation. The Chinese market, given its size, has the potential to significantly influence sustainable sourcing practices; however, it will require concerted efforts by all stakeholders for implementation to be effective. Recent European and American regulations highlight the growing role of government policies in promoting sustainable practices across all these sectors. In summary, while clear advances are being made and promising mechanisms are in place for the transition to more sustainable agricultural practices across coffee, cocoa, livestock and soy commodities, the path forward necessitates a multi-pronged approach. This involves localised solutions informed by the unique commodity and market contexts coupled with broader regulatory frameworks and stakeholder collaboration to address both the scalability and effectiveness of these initiatives.

INTRO-DUCTION

IN SOUTH AMERICA, SOLIDARIDAD HAS BEEN ACTIVE IN CLIMATE-SMART AGRICULTURE SINCE 2013, WHEN WE BEGAN TESTING DIFFERENT MODELS OF LOW-CARBON AGRICULTURE INITIATIVES IN THE AMAZON AND CERRADO BIOMES IN BRAZIL, COLOMBIA AND PERU. OUR OBJECTIVE IN THE REGION IS TO REDUCE THE ENVIRONMENTAL IMPACT OF COMMODITY PRODUCTION AND MAXIMISE THE OPPORTUNITIES FOR NATURAL SOLUTIONS TO MITIGATE AND ADAPT TO CLIMATE CHANGE, WHILE IMPROVING THE LIVELIHOODS OF FARMERS.

Our strategy has been to test practices and analyse the results and impact of changing the way we produce coffee, cocoa, livestock and soy. Three interrelated variables on the production front are essential components in the solutions. First, the economic viability of the farm: if the interventions are not viable, they will not be adopted or maintained by the producers. Second, the environmental impact: the project should constantly assess whether the selected interventions are having the expected environmental results to ensure and communicate impact to stakeholders. This is connected to the third variable, which is the willingness of the market to place value on sustainability. The commitment of buyers to invest in climate-smart agriculture is key to generating additional incentives, whether it is through price premiums, the provision of services to the producer or other benefits that add value to producers (for instance, services such as technical assistance or access to finance, better contract terms, etc.).

Solidaridad's CSA model aims to scale the implementation of policies and practices that reduce deforestation through the engagement of public and private actors. The model builds on the experience and data of a previous project implemented with our partners Instituto Centro de Vida (ICV), Grupo de Trabalho da Pecuária Sustentável (GTPS) and Ceres, and funded by Norway's International Climate and Forest Initiative (NICFI). Focusing on four commodity value chains, this project promoted a set of practices that contributed to the model objectives (positive carbon balance, increase of productivity, cost reductions and resilience) with a group of target producers. The initiative focused on coffee in Colombia and Peru and on cocoa, livestock and soy in Brazil. Solidaridad provided producers with assistance, training and information using strategies tailored to each context. At the end of the project, the results were assessed in comparison to the baseline. The learning captured in this study comes from this analysis, updated to the current context and regulation changes. For the methodological details of the study, see Annex 1.

COFFEE IN PERU AND COLOMBIA

The coffee supply chain has a fundamental environmental and social influence in both countries. While global demand for coffee is increasing, production has been impacted in many geographies, resulting in low yields. This has increased price volatility, worsening the long-term stability – and sustainability – of the entire supply chain.

The end goals of this initiative were to test climate-smart coffee production models that could be replicated and to support public and private actors in the design and implementation of social and environmental policies related to production and commercialisation. In terms of production, the climate-smart model included mitigation and adaptation components. Mitigation components of the project aimed to decrease the pressure on forests through avoided deforestation and reduced carbon emissions from production. Adaptation components included improved water usage during processing, wastewater management and reduction of the risks that made farmers more vulnerable to landslides. In addition, the project sought to improve the livelihood of producers by introducing practices at the farm level that increase productivity and incomes in the context of a changing climate. These practices were promoted through several field strategies that included farmer leaders and support through technical assistance, training and digital tools. On the demand side, the project aimed to encourage the private sector to source climate-smart coffee that is recognised as such and to invest in the replication of these models in their supply chains, with a focus on the American and European coffee markets.

COCOA, LIVESTOCK AND SOY IN BRAZIL

Brazil is a crucial location where commodity-driven deforestation must be tackled. On the one hand, two fundamental biomes – the Amazon and Cerrado – are under its jurisdiction and, on the other, the country plays a key role in the global production of agricultural products. Our objectives were for private sector actors to implement social and environmental policies and practices that reduce pressure on forests and to engage them in global public-private partnerships to reduce deforestation.

The project focused on livestock and cocoa production. In livestock, together with Instituto Centro de Vida (ICV), the project scaled a previously tested livestock production model in the Amazon/Alta Floresta that increased productivity to reduce forest pressure. The model also promoted climate-smart livestock and cocoa systems with smallholder producers.

The demand strategy considered local and international markets. In the local market, we worked with the *Grupo de Trabalho da Pecuária Sustentável* (GTPS) to increase the adoption of their sustainable livestock guidelines (*Guia de Indicadores da Pecuária Sustentável*, GIPS) by companies and producers. In addition, we sought to engage cocoa traders in the sourcing of deforestation-free cocoa. In international markets, efforts have focused on China and the US and engaging demand to reduce agricultural expansion into forests and expand the use of degraded land. In China, the project sought to expand on existing initiatives and relationships to put Asian commitments to sustainable supply chains into operation. To do so, we focused on establishing multi-stakeholder platforms and implementing sourcing guidelines for soy. In the US, with the Ceres organisation, we worked to harness the power of its Investor Network on Climate Risk (INCR), which represents over $13 trillion in assets, to drive major US corporations to reduce deforestation in their supply chains. The strategy aimed to mobilise companies into making public commitments to sustainable soy sourcing.

1 HOW CAN PRODUCERS ACHIEVE ENVIRONMENTAL AND FINANCIAL SUSTAINABILITY?

Sustainability cannot be scaled without considering the economic viability of farms. This is the main incentive for producers to make changes, as the system currently lacks additional incentives that are directly tied to sustainability. We selected a set of practices based on their impacts on yield and on climate change adaptation and mitigation. The strategy was adapted to the producers of focus in each country. The strategies and results are presented in the following section.

ADOPTION OF PRACTICES

Farming systems change slowly over time. Practices are learned from past generations, the provision of technical assistance is scarce, and changes pose a high risk to annual income for the entire family. For these reasons, trying to influence a change in practices is an immense challenge that requires providing reliable evidence, managing the emotions and processes linked to change, and, above all, it requires a lot of trust in the field teams. Because of the different contexts involved the study, the model we tested addressed these challenges in different ways. To further complicate matters, the mobility restrictions imposed during the COVID-19 pandemic required changes to be made in how things were usually done. Despite all the above, the results were very positive in all cases.

In this context, the adoption of practices is seen in two layers: first, the adoption of a CSA practice, such as developing compost management, and second, the adoption of a set of practices that correspond to the minimum level expected to be considered a climate-smart producer. This minimum adoption of practices is defined by the technical team at the beginning of the project, so the goal for transformation is clear for everyone. Even if not all producers manage to achieve the expected level, the adoption of any practice should be celebrated as the beginning of a path to change that is hopefully gradual and incremental as the benefits become clear. Likewise, the adoption of practices beyond the expected minimum has shown to have excellent impacts on the production system (se chapters above).

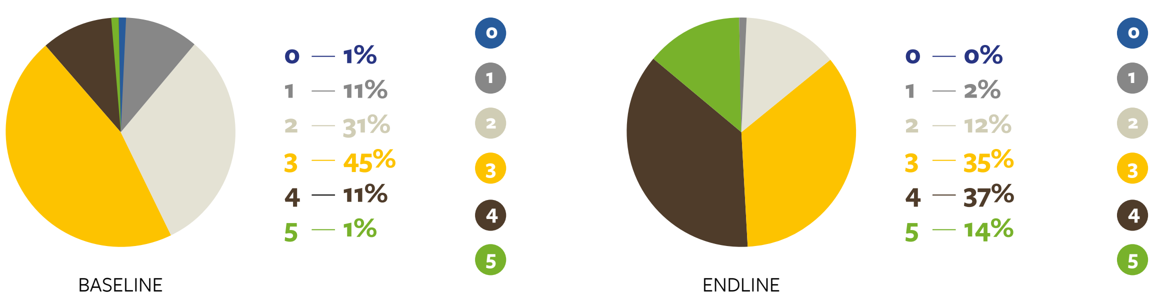
Success is linked to a deep understanding of user profiles and of how they learn and communicate. Taking the profile of the producers into consideration and understanding how adults learn has been a key part of the process.

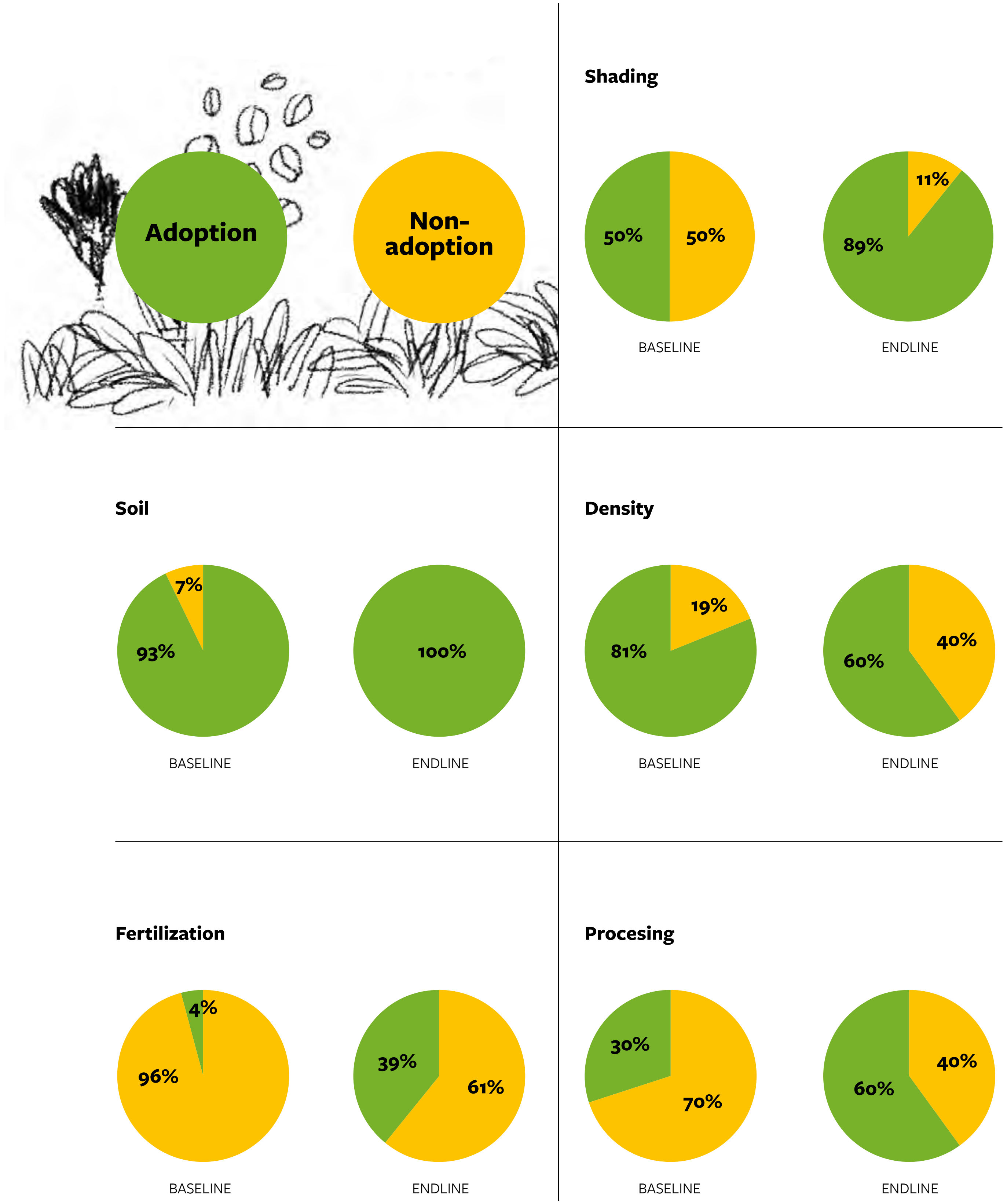
ADOPTING RESILIENT SYSTEMS IN COFFEE

The number of coffee producers implementing CSA practices doubled compared to the baseline, growing to **15,121** producers in Peru and Colombia. The rate of CSA producers rose from 30 to 64% on average. For coffee production to be considered climate-smart, it had to implement three out of the following five key practices: the implementation of agroforestry systems (shade management), conducting soil conservation, minimum tree density, appropriate fertilisation and good management of by-products. By the end of the project, all producers had adopted at least one practice (19,734).

In Colombia, the practices with the highest adoption rate were soil and shading, which aligns with the stated conservation and reforestation efforts of the implementation. The sample shows 14% of producers adopted all five practices, becoming best-in-class and capitalizing on productivity and environmental benefits. The laggards, who at the beginning of the project had adopted only one or two practices, were significantly reduced from 41 to 15% (see Figure 1 below).

FIGURE 1
Number of Climate Smart Practice Adopted in Colombia





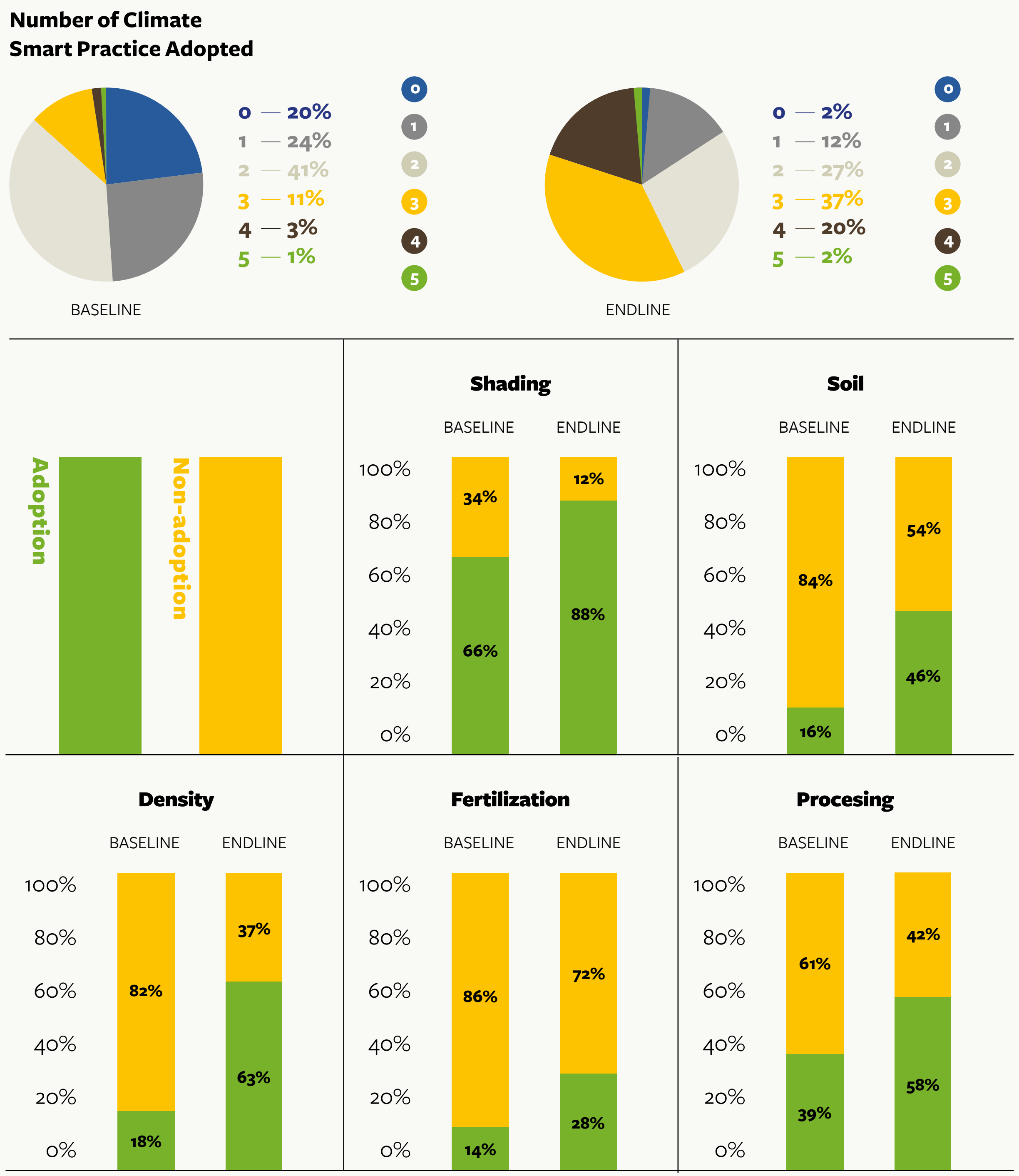
Solidaridad's team in Colombia highlights the following three key factors for success:

1. **Practical capacity-building sessions that completely discard written material.** The team found that practical sessions aligned better with the producers' learning style. Written materials that had been used in the past, such as guidelines, proved to have low effectiveness with producers in the area. During this project, no resources were devoted to designing or printing any materials.
2. **Group work.** The team promoted the creation of groups that required minimal logistical support and technical assistance from a local field staff officer to elicit concrete actions by producers that contribute to the project objectives. The groups met to conduct practical workshops on the farms of each member of the group, changing location periodically. This meant that, at each session, producers not only learned, but also received community labour to implement CSA practices on their farm. Group members provided constant motivation to other members. It was a great strategy to keep work running despite the mobility restrictions associated with the COVID-19 pandemic.
3. **Whatsapp webinars.** The majority of the project took place under mobility restrictions, which prevented in-person training sessions and visits from field staff. At the same time, the producers had limited access to the internet. The solution was to host WhatsApp webinars, since the app is widely used in the community. The webinars took place on a certain date and time through WhatsApp groups that were created with a specific learning purpose in mind. During the webinar, participants engaged in a conversation facilitated by the field officer using voice notes, videos and photos related to the subject. Participants considered the channel to be a success since the cost of logistics and use is relatively low and access to the technology is fairly easy. It also allowed for interaction and knowledge sharing. WhatsApp groups also strengthen community cohesion and reinforce a sense of belonging.

IN PERU, CSA TRANSFORMATION AT THE END OF THE PROJECT WAS THREE TIMES HIGHER THAN AT THE BASELINE. THE MOST WIDELY ADOPTED PRACTICES WERE SHADING AND PROCESSING, WHICH IMPACT CARBON SEQUESTRATION AND REDUCE WATER POLLUTION FROM BY-PRODUCTS.

In Peru, CSA transformation at the end of the project was three times higher than at the baseline. The most widely adopted practices were shading and processing, which impact carbon sequestration and reduce water pollution from by-products. At the beginning of the project, there was a significant group that had not implemented CSA practices (20%) or had adopted just one practice (24%). After the project, almost all producers had adopted at least one practice and, in addition, the group of best-in-class producers – those who implemented four practices – also grew from less than 3% at the baseline to 20% at the end.

FIGURE 2
Climate-smart practices adopted in Peru



Solidaridad's team in Peru highlights three keys for success:

1. **Producer leaders.** Observing the benefits of adopting a practice on the farm of a member of the community builds confidence in other producers to make changes. Selecting the leaders carefully has proven to be key to success, as they should inspire trust and be able to provide some advice to their peers.
2. **Expansion of the team of experts in the region.** The team saw they needed to increase the number of staff to be able to reach the ambitious target of the participants. However, there were relatively few field staff specialised in CSA in the region. As a response to this situation, the team engaged in different training initiatives – such as a short course for field staff officers – and also hired young and recently graduated professionals who received intensive training in CSA. This initiative not only helped the team of experts to reach more participants but also generated capacities in other entities that quickly absorbed the trained officers. The knowledge they acquired was decisive in being able to build trust and motivate producers to change their practices.
3. **Development of audiovisual content as a learning tool.** The team developed several videos, posters and radio programmes to reach producers when COVID-19 mobility restrictions were in place. The content was sent directly to some producers who were in the registry, while others accessed it through Facebook groups that had been created specifically for that purpose and which grew organically through word of mouth. Producers perceived this content as useful and a way to remain connected despite the heavy restrictions.

IMPACT ON WOMEN

The project aimed to increase the participation of women in training sessions as well as the technical assistance they receive since, traditionally, these programmes reach few women. The impact of the project was measured in a representative sample that consisted of 17-22% of women-led farms (see Methodology section), which is representative of their participation in farm management. It is difficult to fully understand the impact on women based on this small sample who are responsible for their farms. While the sample fails to provide information on women in other roles, such as in co-management or participating in one or several steps of the process, some interesting insights can be gleaned for future implementations.

The project in Colombia has been effective at supporting women-led farms in the transition to CSA. The gap between men- and women-led farms in terms of the adoption of practices narrowed from 15% in 2018 to 10% in 2020 (women-led farms having a lower rate of adoption compared to those led by men). However, since yield in the country was reduced due to different factors (see section on economic viability), women-led farms were particularly affected. The yield gap between men and women grew from 10 to 28% in the same period. Women-led farms that had not adopted climate-smart practices were hit the hardest, with yields reduced by 58%.

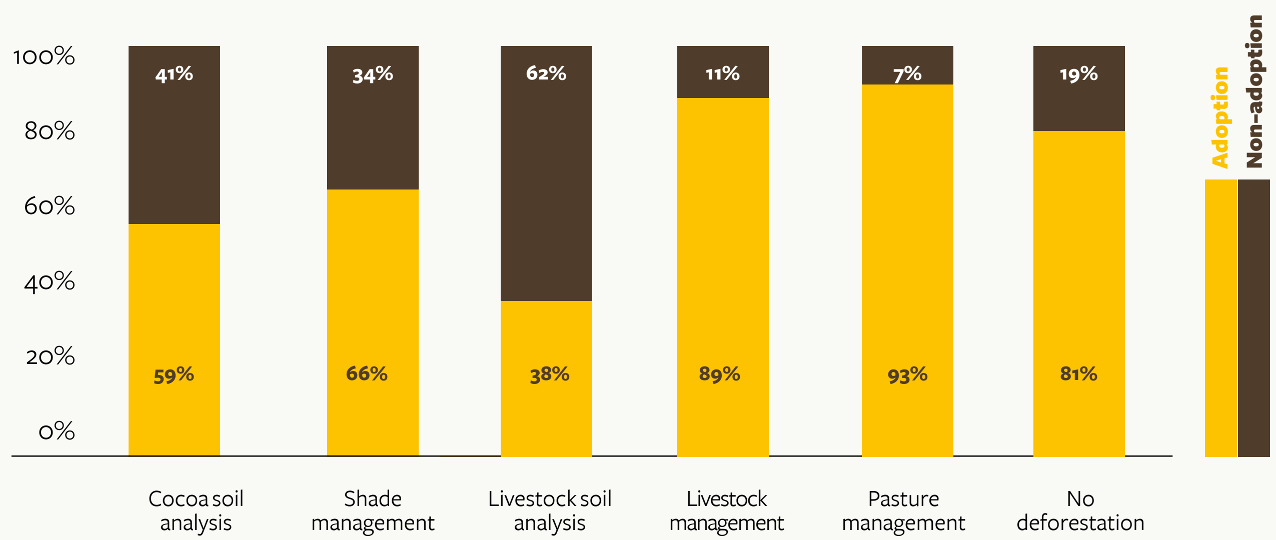
In Peru, the rate of producers that had adopted CSA was low on both women- and men-led farms in 2018 (13% and 16%, respectively). The adoption of CSA increased rapidly in Peru, at a higher rate for men. Adoption of CSA among men grew by 45%, while it increased only by 30% among women. Two years later, the gap widened to 19.4%. However, the yield for women-led farms increased substantially (113%). The largest increase in yield was seen among women who did not pass the bar of adopting three CSA practices. In 2018, women implemented 1.3 CSA practices on average and, in 2020, they implemented 1.75 practices. These farms doubled their productivity during the life of the project. However, because their starting point was particularly low (46% less than the country average), in 2020, despite the big increase, they produced 18% less than the country average. These reflections can inform future work, in which more attention should be paid to the different starting points of men- and women-led farms.

IMPLEMENTING COCOA AND LIVESTOCK AGROFORESTRY SYSTEMS IN THE BRAZILIAN AMAZON

The project worked to implement climate-smart agriculture practices on cocoa and livestock farms in Brazil. The project started working with some farms in the area in 2016 and others in 2018. By the end of the interventions, CSA practices had been implemented on 9,204 hectares. The set of practices promoted included conducting soil analysis for cocoa and pastures, growing cocoa under a shade system, managing stocking rates, and avoiding deforestation and burning of pastures. The analysis shows producers adopted CSA practices at a rate of 73% and 89% for two groups that started the project in 2016 and 2018, respectively. The most adopted practice was pasture management, which uses the resources of the farm more efficiently. The biggest challenges came from conducting soil analysis as the producers don´t necessarily have the habit or facilities to do it. Still, is a high-impact practice that can reduce costs of fertilization in the future and is fundamental for acidic soils like those of the Amazon.

THE RATE OF ADOPTION OF NO DEFORESTATION WAS 81%, WHICH IS A SIGNIFICANT IMPROVEMENT COMPARED TO THE LAST MEASUREMENT IN 2018 (47%).

FIGURE 3
Adoption rates of CSA practices for cocoa and livestock producers in Brazil



The team highlights the following three key strategies for their success:

1. **The technical assistance program.** Supporting producers in their assessment of applicable practices and providing constant technical guidance on the day-to-day practices is crucial in the transition towards CSA production. The technical assistance model consists of four pillars: (i) group training session, (ii) individual visits, (iii) demonstration plots on the leader producer's farms and (iv) digital tools to support and monitor the provision of assistance. This model was initially tested with Solidaridad staff and is gradually being transferred to local partners who can continue the service provision going forward.
2. **Connect producers to new markets that reward quality.** The opportunity to receive prices that reward quality is an optimal incentive for the adoption of CSA practices. Buyers of fine cocoa pay three times more for a kilogram of cocoa than the regular market, assuming the product meets a quality standard. Quality responds well to CSA practices, so, as the first producers gained access to this reward, the adoption of these practices was boosted. This has led to a commercial relationship between the fine cocoa buyers and the producers that has been maintained, and also to awards that recognise high-quality chocolate.
3. **Educational communication materials.** The constant production of educational content has kept producers informed and motivated to continue on their path of continuous improvement. The project produces short videos, podcasts, infographics and similar engaging content that are shared over social media with producers. The premise is to keep it short, constant and visually appealing so producers remain interested. During the mobility restrictions of the pandemic, a radio programme was developed with the local radio station, which worked well to keep people engaged despite the conditions.

USING DIGITAL TOOLS TO MONITOR PROGRESS AND PRACTICE ADOPTION

The adoption of deforestation-free production and CSA was supported by the use of the Extension Solution app, which supports the digitalisation of processes in rural extensions, with the aim of increasing the efficiency of monitoring and reporting while supporting data-driven decisions and learning. Extension Solution is a mobile app developed in-house by Solidaridad that enables field staff to collect farmers' data, record field visits, set improvement priorities, connect to a carbon calculator and track individual and group progress. The tool enables improved collection of farmers' information, while continuous monitoring and analysis also enable adaptive project management, farmer-informed planning, decision-making and learning. From a mitigation perspective, the tool supports the measurement of carbon emissions and capture. From an adaptation perspective, it supports the monitoring of livelihood incomes and CSA practices, as well as facilitating learning and implementation of practices that build resilience.

EXTENSION SOLUTION IS A MOBILE APP DEVELOPED IN-HOUSE BY SOLIDARIDAD THAT ENABLES FIELD STAFF TO COLLECT FARMERS' DATA, RECORD FIELD VISITS, SET IMPROVEMENT PRIORITIES, CONNECT TO A CARBON CALCULATOR AND TRACK INDIVIDUAL AND GROUP PROGRESS. THE TOOL ENABLES IMPROVED COLLECTION OF FARMERS' INFORMATION, WHILE CONTINUOUS MONITORING AND ANALYSIS ALSO ENABLE ADAPTIVE PROJECT MANAGEMENT, FARMER-INFORMED PLANNING, DECISION-MAKING AND LEARNING.

ECONOMIC VIABILITY OF CLIMATE-SMART AGRICULTURE

Economic viability plays a crucial role in the adoption of climate-smart agriculture. The positive results identified in this area have been key to the successful scaling of the model. Economic viability is determined by price, yield and costs of production. In commodities, prices are highly volatile, and therefore a component of low influence. During the project timeline, commodity prices increased significantly due to the COVID-19 pandemic. Improvements in product quality also led to better prices, although this effect is difficult to isolate in the results. Nevertheless, yield is a key variable that aims to be influenced. Still, yield can be sensitive to other external factors, such as crop cycles and rain. Climate-smart practices also had an impact on production costs, although this was not measured in detail.

The trajectory of yield and income vary depending on the level of production. The room for improvement on farms with already high production is more limited, especially in terms of adaptation and mitigation practices. Farms with low production tend to have a lot to gain in terms of yield and income, so they usually experience greater improvements.

RISING INCOMES IN COFFEE

INFOGRAPHIC 1
Key facts in sustainability practice adoption in coffee

Coffee in Peru and Colombia

YIELD INCREASE:	INCOME INCREASE:
10%	70.5%
15,121 producers adopted climate-smart practices (CSA)	**52,446** hectares transformed to CSA

Practice adoption increased from

30% → TO 64%

ON AVERAGE, YIELD IN COLOMBIA AND PERU INCREASED BY 10% AND INCOME INCREASED BY 70.5%. IN THE BASELINE, YIELD WAS 955 KGS/HA AND INCREASED TO 1,076 KGS/HA IN THE ENDLINE. FARMERS WHO INCREASED ADOPTION OF CSA HAVE A PRODUCTION OF 1,169 KGS PER HECTARE, WHICH IS 9% HIGHER THAN THE AVERAGE AND 22.4% HIGHER THAN THEIR INITIAL PRODUCTION.

It is expected that productivity will continue to increase over time as a result of the implementation of climate-smart practices, as several of the agronomic impacts are only seen after a longer period of analysis. Coffee is a perennial crop with variable yields (high/low) on a 3-4-year cycle. The sample shows that yields increase as CSA practices are adopted, reaching 1,704 kg/ha when a producer adopts the five prioritised practices (see Figures 4 and 5 below). The increase in income was due to changes in productivity, high international coffee prices and improvements in coffee quality.

Colombia started the project with high productivity of 1,426 kg/ha and finished with 1,217 kg/ha (a drop of 14.6%). This reduction was due in part to the productivity cycles, which were at a high point in 2018 (baseline year) and a low point in 2020. Annual income started at COP 16,172,830 (€4,638 [1]) and reached COP 35,059,356 (€9,511). Income increased by 105% after adjusting for inflation. The price received by the producers increased by 58% (from COP 5,762/kg to COP 9,161/kg).

Peru started the project with a production of 661 kg/ha and finished with a production of 890 kg/ha (an increase of 34%). Since the system started at a lower point, the increase is much higher than in Colombia. Baseline annual income was PEN 11,914 (€3,070) and increased by 36% at the end of the project, reaching PEN 16,865 (€4,177). The former does not include inflation either. The price received by the producers increased by 20% (from PEN 6/kg to PEN 7.23/kg).

FIGURE 4
# of practices adopted by % of farmers

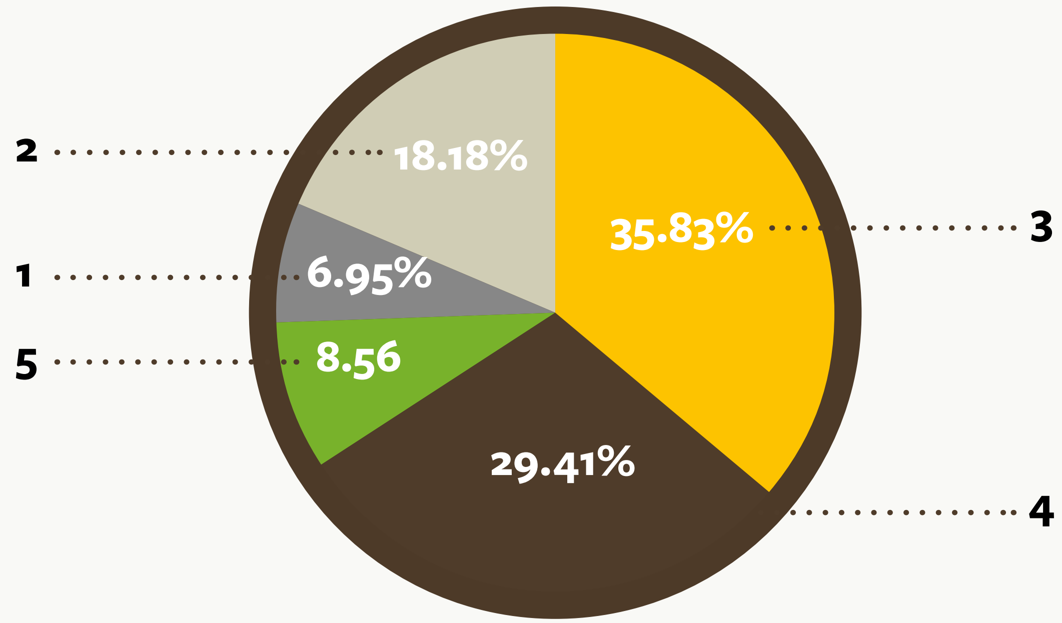
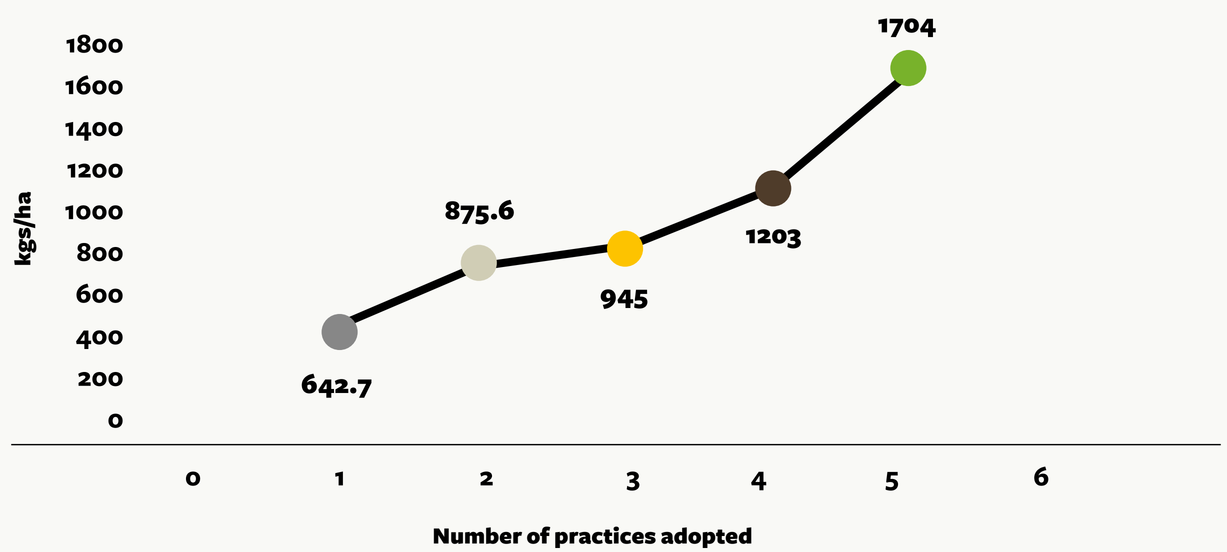


FIGURE 5
Yield per practice adoption



1. Due to currency fluctuations, an average annual exchange rate of 2018 has been used based on the rates determined by the Colombian National Bank. €1 = COP 3,486.8 (Banco de la República, 2019). Similarly, an average annual exchange rate of 2018 was used in Peru, determined by the Peruvian National Bank. €1 = PEN 3.88 (Banco Central de la Reserva del Perú, 2019). For comparison purposes, the same rate for both years was used.

INCREASING PRODUCTIVITY IN COCOA AND LIVESTOCK SYSTEMS

INFOGRAPHIC 2

Key facts in the adoption of sustainable practices in cocoa and livestock systems

INCOME INCREASE:
52%

9,204
hectares were transformed to climate-smart agriculture

230
producers adopted climate-smart practices

PRODUCTIVITY FROM LIVESTOCK DOUBLED FROM
1.06 ⟶ TO 2.13
ANIMALS PER HECTARE.

PRODUCTIVITY INCREASE IN COCOA FROM
857 ⟶ TO 862
KGS/HA.

Income from cocoa and livestock for producers in the project increased by 52% on average. Income from cocoa increased by 87%, while income from livestock increased by 11%. One of the reasons the rise in cocoa income was so significant is the higher global commodity price and the premiums achieved in high-quality markets. The adoption of climate-smart practices improved quality and therefore opened the door to opportunities to access speciality markets, in which prices increased threefold. Productivity also influenced the improvement in income. On average, productivity rose from 857 to 862 kg/ha. The project involved two groups that joined the initiative in different years (2016 and 2018), and closer analysis shows the productivity of the first group increased by 11%, whereas it fell by 12% for the second group. The group of producers that joined the project earlier also managed to maintain the increase in productivity, even during the pandemic and through the fluctuations in the market. On the other hand, the group that joined in 2018 was unable to maintain the same level. There are two potential explanations. First, the group that joined in 2016 had accumulated more knowledge to manage the plantation on their own and could maintain good management despite having less support. Second, the plantations of the older group were already stronger due to better management as well as shade and fertilization practices. Despite experiencing a fall in productivity, the second group started the project earning BRL 14,973/year and increased their income to BRL 21,496/year (43%), while the group with a longer trajectory earned BRL 20,845/year at the start and increased their income twofold to BRL 45,578/year (118%).

For livestock, productivity and income increased for both groups, but particularly for the group that began their participation at a later date. Their initial income was BRL 11,987/year and it increased to BRL 16,579/year by the end of the project (38%), while their productivity doubled from 1.06 to 2.13 animals per hectare. The group that joined at an earlier date (in 2016) had a higher initial income (BRL 18,000/year), which was slightly reduced (8%) by the end of the project, to BRL 16,643/year. Taking both groups together, the average income from livestock increased from BRL 14,994/year to BRL 16,611/year (a 10% increase).

Income from cocoa and livestock from producers in the project increased by

52%

Income from cocoa increased by

87%

While income from livestock increased by

11%

2 ENVIRONMENTAL IMPACTS OF CLIMATE-SMART AGRICULTURE

The environmental section of this report delves into three interconnected areas crucial to sustainable development: deforestation, carbon sequestration and adaptation to climate change. Focusing on coffee, cocoa and livestock ecosystems in Colombia, Peru and Brazil, the report highlights strategic interventions to curb deforestation and promote carbon-positive practices. It also outlines how the model fortifies agricultural systems against climate-related hazards through resilience-building measures.

DEFORESTATION: CAUSES, IMPACTS AND METHODOLOGIES USED TO ASSESS AND MONITOR DEFORESTATION

Commodity-driven deforestation in the Amazon and Cerrado can occur both **inside** and **outside** of farms. Farmers are the stewards of the forests in several areas, as large expanses of forests are found within farms and under the management of farmers. Forests are just one of the several resources on a farm that require management, whether this involves the use of resources, conservation efforts or conversion to other land uses. Historically, traditional management practices have involved some level of deforestation on farms to substitute degraded land for new arable land.

The farm management practices included in the model aim to improve degraded land and increase productivity and income while reducing deforestation and GHG emissions.

To assess the **reduction of deforestation within farms**, we analysed the average deforestation rate over the past 5 years (minimum) in the area of the farms included in the sample and projected this over the timeframe of the project in order to estimate the deforestation that would occur in a without-project scenario. At the end of the project, using satellite imagery and GIS tools, we analysed the deforestation within a sample of farms to identify the deforestation observed during the project timeframe (see Figure 6). The difference between the estimated and measured deforestation is considered to be the deforestation that has been avoided due to the actions of the project.

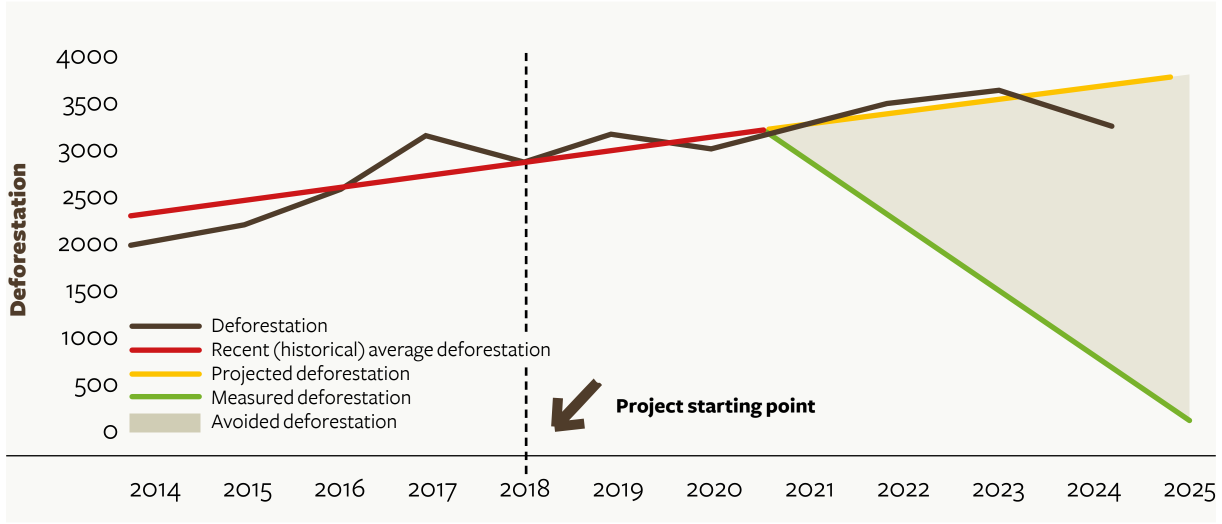
Commodity-driven deforestation outside of farms typically follows a pattern where farmers, seeking to expand their production, clear new areas of forest outside of their current farms. These new areas may be on protected or barren land, or even on new farms. Deforestation outside the farm is more complicated to measure because it is a response to an additional myriad of drivers and actors. In this case, we have assumed the main driver is to increase production. However, there are two different and conflicting hypotheses on the effects of increasing productivity of commodities on deforestation. On the one hand, there is the *Borlaug hypothesis* (Stevenson et al., 2013), which states that increasing productivity can help ecosystems since it enables more production in a given area of land and thus demands fewer resources or new arable land, alleviating pressure on forests and reducing deforestation. On the other hand, according to the *Jevons paradox*, increasing productivity results in higher profits and attractiveness of the activity which, in a scenario of increasing demand, may require more land and increase pressure over forests, leading to more deforestation.

Despite these two different perspectives and the uncertainty regarding the correlation between productivity and deforestation, we assumed a *ceteris paribus* condition, in which the demand is steady and the increase in productivity due to the project actions reduces pressure on forests and hence deforestation, aligned with the Borlaug hypothesis. Even so, one does not necessarily exclude the other, since the interaction between the producers and the land is highly dynamic and can be sensitive to the context.

In conclusion, we have explored the various causes and impacts of deforestation as well as the methodologies used to assess and monitor this phenomenon. However, it is also important to examine the specific environmental impacts of climate-smart agriculture on deforestation. In the next section, we will focus on three case studies that provide insights into the different ways in which deforestation is being addressed and reduced through climate-smart agriculture practices. The case studies include projects in Colombia, Peru and Brazil, and consider the deforestation dynamics both within and outside the farms, as applicable in each case. By examining these case studies, we can gain a deeper understanding of the environmental impacts of climate-smart agriculture and the strategies being implemented to reduce deforestation.

THE FARM MANAGEMENT PRACTICES INCLUDED IN THE MODEL AIM TO IMPROVE DEGRADED LAND AND INCREASE PRODUCTIVITY AND INCOME WHILE REDUCING DEFORESTATION AND GHG EMISSIONS.

FIGURE 6
Graphical representation of avoided deforestation

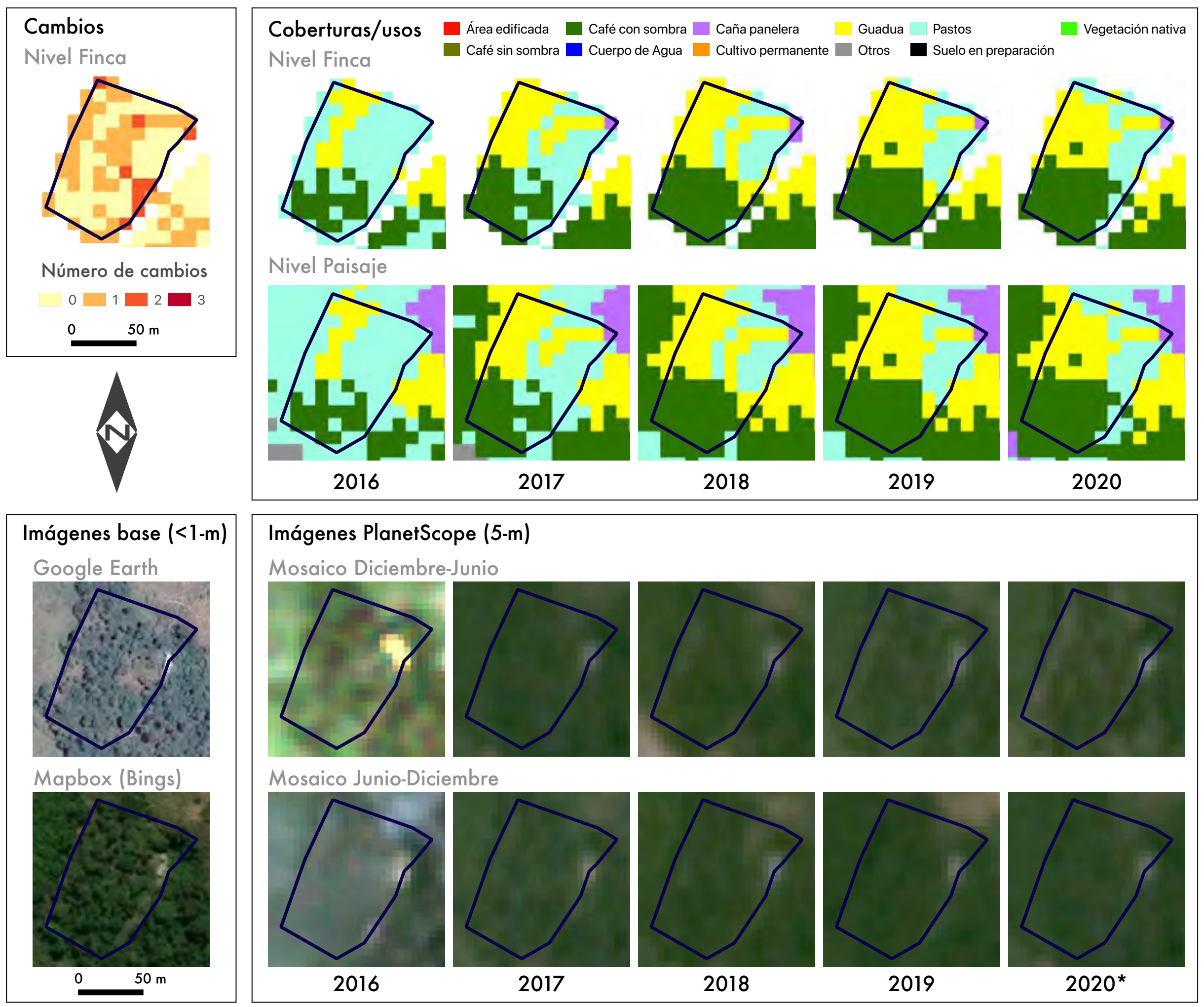


Source: Author's own elaboration

COLOMBIA: LIMITED DEFORESTATION IN COFFEE FARMS

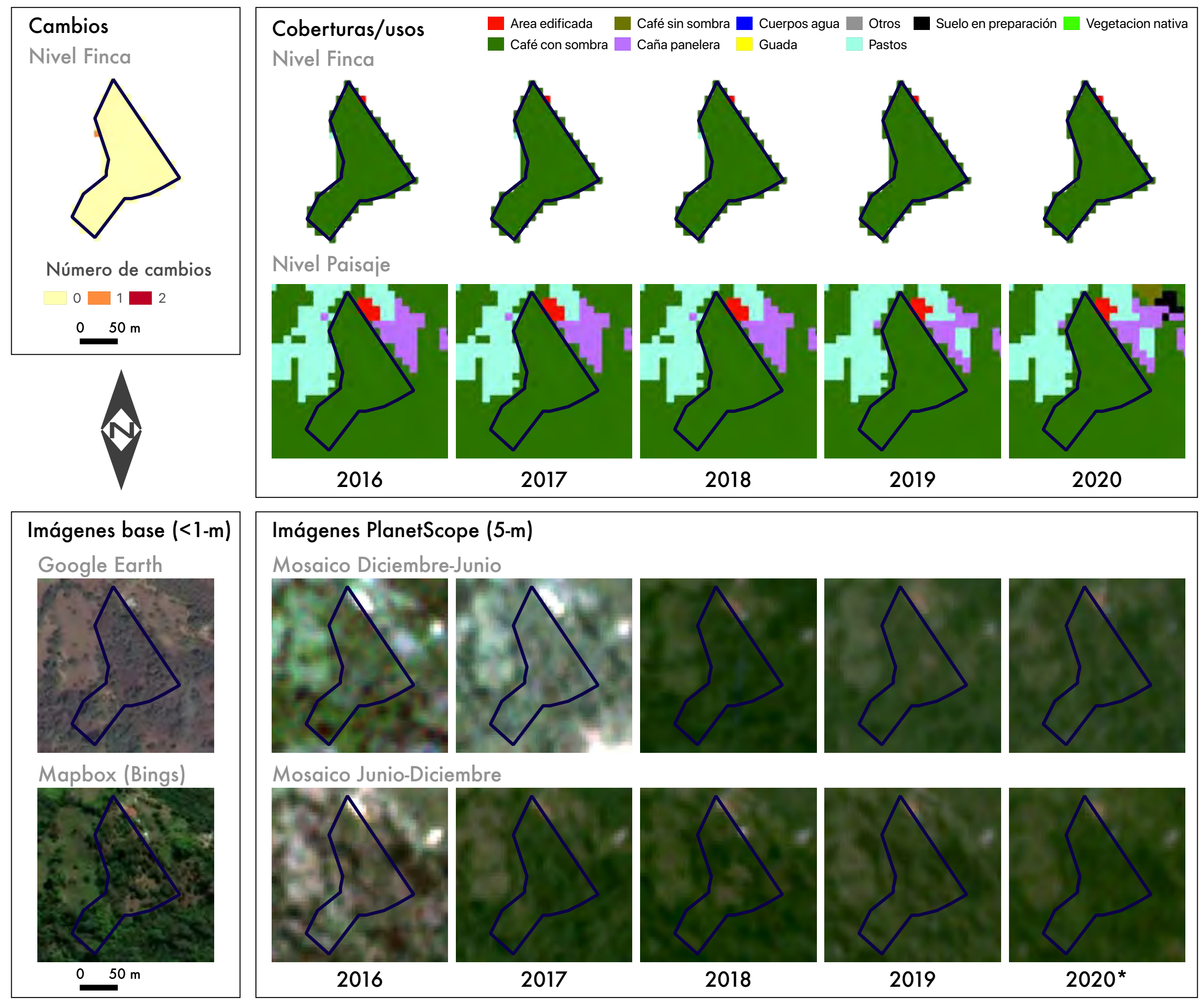
In Colombia, we analysed **deforestation within farms** for a representative sample in the two departments where the project was implemented. The sample includes 100 farms in Risaralda and 20 farms in Cauca, with a total area of 170.29 hectares and an average of 1.42 hectares per farm (1.37 ha/farm in Risaralda and 1.68 ha/farm in Cauca). Different categories of land use were identified in order to characterise the farms in the sample. The georeferenced perimeters of the farms were collected by Solidaridad's field team. This data was overlaid with satellite imagery from 2016 and 2020, enabling the identification of each land use class and any change, that is, whether a given land use class increased or decreased during the project. An example of a farm we assessed in Risaralda is presented in Figure 1.1 and a farm in Cauca is shown in Figure 8. As can be seen in Figure 7, this farm increased the shade coffee and bamboo areas over the pasture areas from the beginning to the end of the project. The example in Cauca (Figure 8) shows a farm that increased shade coffee on native vegetation (forest) areas.

FIGURE 7
Assessment of land use change on a farm in Risaralda



Source: GeoMagic labs, 2021

FIGURE 8
Assessment of land use change on a farm in Cauca



Source: GeoMagic labs, 2021

The study indicates that the native vegetation area within farms decreased from an average of 0.0008 hectares in 2016 to 0.0004 hectares in 2020 in Risaralda, and from 0.095 hectares to 0.061 hectares in Cauca. In Risaralda, the deforestation occurred before the beginning of the project (2018), while in Cauca it was after that date. According to the methodology adopted, this implies that deforestation in Cauca increased by 6.0% during the timeframe of the project compared to the baseline.

Despite using the latest technology and referencing a wide range of similar studies in the area, the methodology has an average margin of error of 36.5%, and can be as high as 109%, which is quite significant for such small areas and rates. The challenge of identifying land use changes on farms with an average area of less than 2 hectares and to distinguish native vegetation from coffee trees remains very high.

In conclusion, deforestation within farms in Risaralda is negligible, as the remaining forest within the farms is very small. Field work and other studies suggest that deforestation may be moving to areas outside of the farms, as they are located close to a natural area at higher altitudes. As climate change advances, the trend is for farms to move to higher altitudes due to increasing temperatures, thus putting the natural area at risk of deforestation. However, analysing deforestation outside the farms was beyond the scope of the project since it is linked to other factors such as land speculation, livestock production and other crops. The 6% increase in deforestation in Cauca should be explored further, since the sample was small and the margin of error high.

These findings led the team to focus on reducing carbon emissions and reforestation and carbon sequestration initiatives. Finally, we did not explore whether there were reductions in pressure on the forests outside the farm since productivity did not increase in this area (for more information on practices adoption and productivity, see Section 3).

PERU: REDUCING DEFORESTATION AND PRESSURE ON FORESTS

In Peru, the sample used to analyse deforestation within farms consisted of 125 farms in San Martín (87.2% of the total), Amazonas (7.2%) and Cajamarca (5.6%), with a total area of 828 hectares. During the project, 23 farms had an incidence of deforestation.

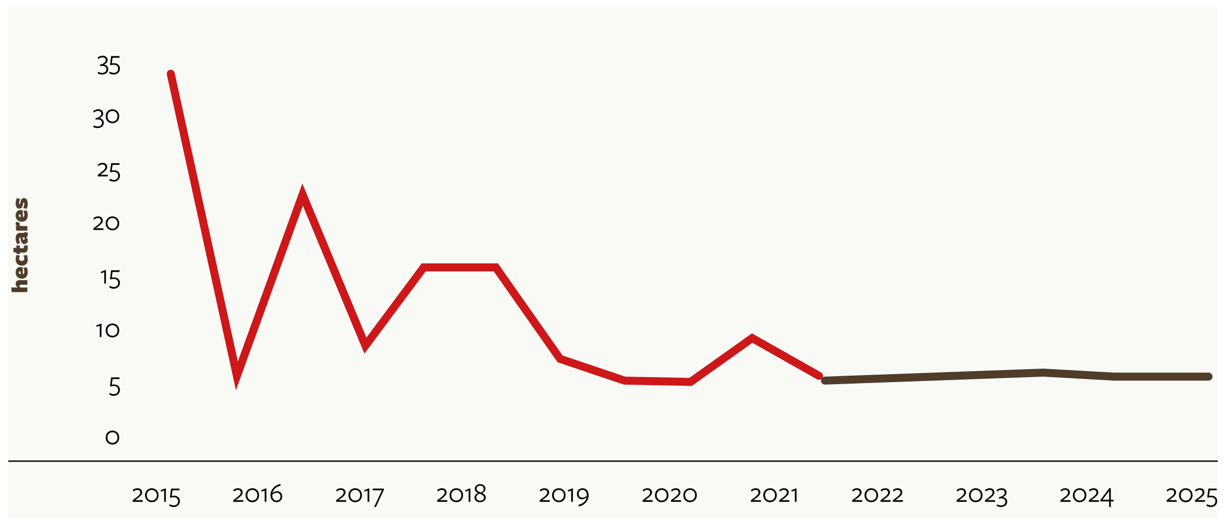
The georeferenced perimeter of these farms was collected by Solidaridad's field staff. Forest loss data from 2001 to 2020 (GEOBOSQUES, n.d.), made available by the Peruvian National Program for Forest Conservation (PNBC, in its Spanish acronym) through the GEOBOSQUES platform, was used to identify historical (past) deforestation.

Average annual deforestation between 2005 and 2014 was 13.09 hectares per year. Considering the trend of the previous decade, the projected average deforestation for the period 2015 to 2020 is 6.13 hectares per year (see Table 1).

TABLE 1
Deforestation from 2005 to 2014 in the sample of coffee farms in Peru

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Average
Deforestation (ha)	34.02	5.58	23.13	8.55	15.93	15.93	7.29	5.49	5.58	9.36	13.09

FIGURE 9
Historical and projected deforestation from 2005 to 2020 for the sample of 125 farms



Measuring deforestation using the satellite imagery and the georeferenced boundaries of the farms, we found that the actual average deforestation for the sample from the beginning to the end of the project (2018 to 2020) was 5.22 hectares per year, resulting in an average avoided deforestation of 0.91 hectares per year (Table 2), or 2.72 hectares for the project timeframe. Since the sample is 125 farms, this translates to 0.02176 hectares of avoided deforestation per farm during the period of the project. If we apply this number to the 3,759 farms enrolled in the project, the total avoided deforestation amounts to 81.8 hectares.

TABLE 2

Projected deforestation between 2015 and 2020, measured and avoided deforestation from 2018 to 2020 for the sample of coffee farms in Peru

	2015	2016	2017	2018	2019	2020	Average
Projected deforestation (ha)	5.96	6.12	6.3	6.53	5.77	6.08	6.13
Measured deforestation (ha)				10.8	0.81	4.05	5.22
Avoided deforestation (ha)				-4.27	4.96	2.03	0.91

On average, 37.4% of the land on coffee farms in Peru is covered by forest. In traditional coffee growing in the country, plantations are rotated as productivity decreases due to soil depletion, that is, producers eventually deforest part of their farms in order to substitute low-productivity land for new arable land. Therefore, the reduction of deforestation during the project is a relevant outcome that indicates a change in production patterns, in which efforts are made to recover soil productivity and maintain production in the same area.

In addition to deforestation within farms, the project also examined potential **deforestation outside the farms**, which results from the potential expansion of crops in order to produce more coffee. Reduced pressure on forests is achieved through gains in productivity, which implies greater farm output on the same or smaller land mass.

To understand the changes in productivity, we assessed the farms at the beginning (baseline) and the end of the project for two different groups: farms with climate-smart agriculture (CSA) practices and farms without CSA. A sample of 104 farms was analysed at the beginning and at the end of the project and the increased productivity and potentially reduced pressure on the forest were assessed for three different groups:

1. Farms with CSA at the beginning and the end of the project (14.4%)
2. Farms without CSA at the beginning and with CSA at the end of the project (44.6%)
3. Farms without CSA at the beginning and the end of the project (41.0%)

2. We consider farms with CSA practices to be those implementing at least three of the five practices recommended by Solidaridad (growing shade trees, fertilisation management, soil conservation practices, coffee density and crop residue management, including water management).

In the first group, productivity fell from 1,016 kg of dry parchment coffee per hectare to 973 kg of coffee per hectare due to a particularly low yield year across the region. The second group increased productivity from 604 kg to 973 kg of coffee per hectare by implementing CSA, and productivity increased in the third group throughout the project, rising from 604 kg to 776 kg of coffee per hectare (see Table 3). Even though the farms in the third group are categorised by Solidaridad as being farms without CSA (meaning they did not implement three of the five recommended practices), it is possible they implemented one or two of the good practices, which helped increase productivity. Furthermore, it is easier for the farms with low productivity (Groups 2 and 3) to achieve increased productivity than it is for those with higher productivity at the baseline (Group 1).

Given that the total area of the farms in the project is 10,061 hectares, total production at the baseline was 6,673 metric tonnes of coffee and rose to 8,977 tonnes at the end of the project (see Table 3). If the business-as-usual (BAU) production patterns were maintained, that is, if the percentages of farms with and without CSA and their respective productivities were to continue as at the baseline, in a without-project scenario, 13,998 hectares would be needed to produce the same 8,977 tonnes of coffee (Table 4). Therefore, an additional 3,937 hectares would be needed to produce the same amount of coffee as was produced at the end of the project. **Hence, we consider that the project reduced pressure on 3,973 hectares of forests.**

We consider that the project reduced pressure on

3,973 hectares of forests.

TABLE 3

Area, productivity, and production at the baseline and the end of the project

	Baseline				End of the project			
	% of total	Area (ha)	Productivity (kg/ha)	Production (kg)	% of total	Area (ha)	Productivity (kg/ha)	Production (kg)
Farms with CSA	14.40%	1,449	1,016	1,471,725	59.0%	5,936	973	5,777,591
Farms with no CSA	85.60%	8,612	604	5,200,815	41.0%	4,125	776	3,199,786
TOTAL	**100%**	**10,061**		**6,672,539**	**100%**	**10,061**		**8,977,377**

3. Throughout the report, in discussions of coffee production, yield measurements refer to dry parchment coffee.

TABLE 4
Area potentially required to increase production in a BAU scenario

	% of the total at baseline	Productivity at the baseline (a)	Production at end of the project (b)	Area potentially required (b/a)
Farms with CSA	14.40%	1,016	1,292,742	1,273
Farms with no CSA	85.60%	604	7,684,634	12,725
TOTAL	**100%**		**8,977,377**	**13,998**

Deforestation is a complex phenomenon involving several variables and stages. Though not all of the changes in deforestation can be attributed to the project, we can gain relevant insights from it. For instance, climate-smart practices did increase productivity in this group (see Section 3 for more about the adoption of practices), which can reduce the pressure to expand to new areas.
In summary, we assessed the regional deforestation within provincial political boundaries (San Martín, Amazonas and Cajamarca) and the measured deforestation in this area was 43% lower than the projected deforestation, confirming Borlaug's hypothesis presented above.

BRAZIL: REDUCING DEFORESTATION IN THE AMAZON

In Brazil, we analysed deforestation within farms using a sample of 67 small farms in the municipality of Novo Repartimento, in the state of Pará, with a total area of 4,209 hectares and an average of 63.78 hectares per farm.

The perimeter of the farms was identified using the geographic coordinates collected by Solidaridad's field team and, in some cases, with information obtained from the Rural Environmental Registry (CAR), and adjusted in the office using the Geographic Information System (GIS). These data were overlaid with Sentinel satellite imagery and land use was mapped into two classes, forest and non-forest, for the 2016 baseline year. For each of the subsequent years, deforestation was identified through the analysis of satellite imagery (Sentinel, from 2017 to 2021) within the area classified as forest the previous year. From the beginning (2018) to the end of the project (2021), the deforested area decreased by 55%. In all years monitored, there was a steady reduction of deforestation compared to the previous year, with the exception of 2021, when deforestation was 21% higher than in 2020 (Table 5).

The number of properties with deforestation decreased gradually year by year from 37 properties in 2017 to 12 properties in 2020, representing a decrease of 67.6% in 2020 compared to 2017. These results show a sharp decrease in deforestation in the properties that are part of the project. However, they also indicate that, in 2020, a few properties were responsible for large areas of deforestation since, in absolute terms, deforestation increased.

TABLE 5
Number of farms with deforestation, average deforestation area and total deforested area

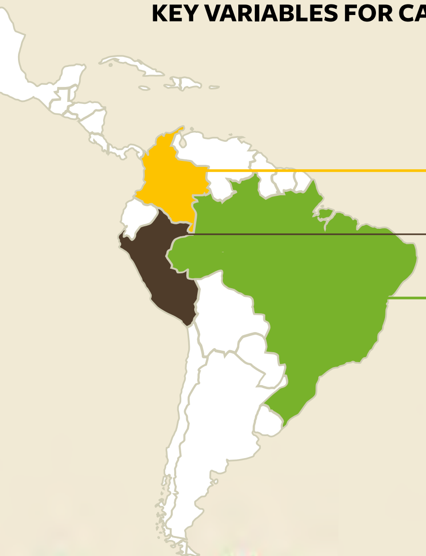
Year	2017	2018	2019	2020	Variation 2018 to 2021
Farms with deforestation in the sample (#)	37	29	21	12	-67.6%
Average deforested area in farms with deforestation in the sample (ha)	4.23	3.69	2.79	5.89	39.2%
Total deforested area in the whole project area (ha)	341.9	234.1	128.0	154.6	-54.8%

Based on the 2017 data, projected deforestation for the duration of the project period was 1,026 hectares (342 hectares per year). However, the actual deforestation monitored between 2018 and 2020 was 517 hectares (see Table 5), resulting in 509 hectares of avoided deforestation. Deforestation outside the farms was not monitored since the farms are well-established and there is a significant amount of forest within the farms.

CHANGES IN CARBON EMISSIONS AND REMOVALS IN CSA

INFOGRAPHIC 3

KEY VARIABLES FOR CARBON EMISSIONS AND REMOVALS IN CLIMATE-SMART AGRICULTURE



Total avoided emissions from production

COFFEE PERU
39,529
tons of carbon equivalent (CO2eq)

COFFEE COLOMBIA
21,942
tons of carbon equivalent (tons CO2eq)

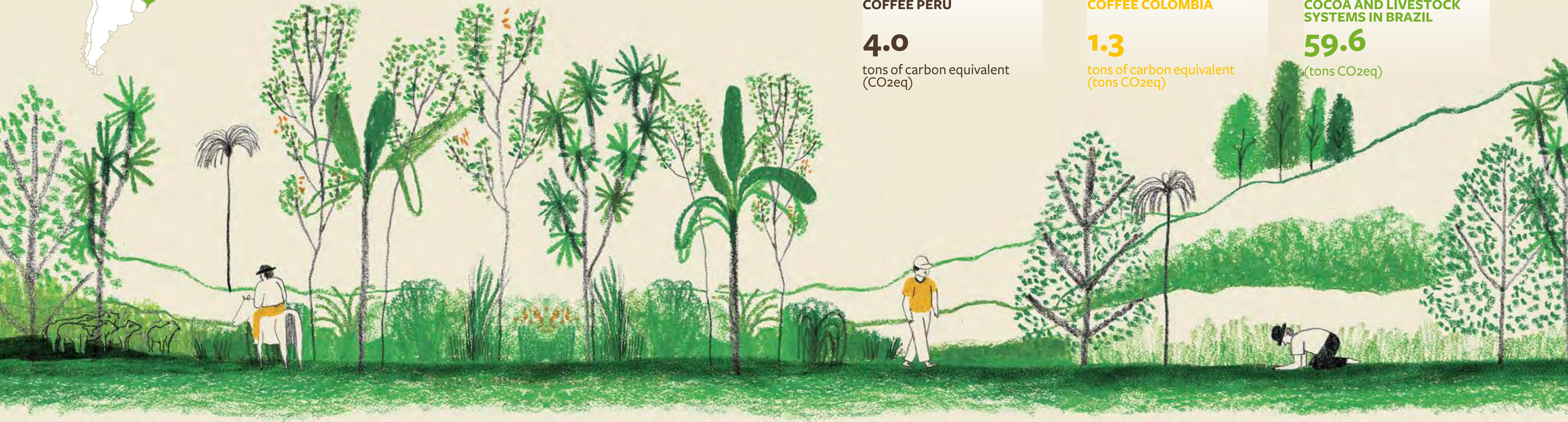
COCOA AND LIVESTOCK SYSTEMS IN BRAZIL
385,936
tons of carbon equivalent (tons CO2eq)

Avoided emissions per hectare

COFFEE PERU
4.0
tons of carbon equivalent (CO2eq)

COFFEE COLOMBIA
1.3
tons of carbon equivalent (tons CO2eq)

COCOA AND LIVESTOCK SYSTEMS IN BRAZIL
59.6
(tons CO2eq)



Carbon capture

COFFEE PERU
15,895
tons of carbon equivalent (tons CO2eq)

COFFEE COLOMBIA
29,966
tons of carbon equivalent (tons CO2eq)

COCOA AND LIVESTOCK SYSTEMS IN BRAZIL
39,529
(tons CO2eq)

Hectares of avoided deforestation

COFFEE PERU
82 has
within farm and 4,019 outside the farm

COFFEE COLOMBIA
NA

COCOA AND LIVESTOCK SYSTEMS IN BRAZIL
509 has
within farm

Changes in carbon emissions and removals were estimated for two main components: land use change (avoided deforestation and/or reforestation) and management practices. Avoided deforestation results in avoided GHG emissions, whilst restoration or shade tree planting results in carbon removals or sequestration. At the same time, the adoption of CSA through shifting production practices also results in changes in carbon emissions.

We estimated avoided deforestation using the methodologies discussed in the previous sections. Thus, the corresponding avoided emissions were estimated by multiplying the avoided deforestation of each country and commodity by the average biomass of that forest. The average biomass for each forest type and country/region was obtained from the literature and available public data.

With respect to production-based emissions, we used different carbon calculators to account for the carbon balances of farms before and after Solidaridad's intervention. The Cool Farm Tool was used for coffee production in Peru and Colombia[4]. For the cocoa/livestock component in Brazil, we used a bespoke calculator developed in conjunction with Imaflora because the component considers farms in an integrated way – forest, cocoa and cattle – and we were unable to find a suitable calculator to deal with this integrated approach. All the calculators present the CO_2 emissions in terms of area (emissions per hectare) and product (emissions per kg of product).

PERU: INCREASE OF EMISSIONS WHILE THE SYSTEM SETTLES

Increase of emissions from production practices

In terms of emissions from production practices, the Cool Farm Tool calculator, used at the baseline and the end of the project, shows that the farms with CSA experienced increased emissions both in terms of area and product (48.4% and 54.8%, respectively). In addition, the farms without CSA also increased their emissions in terms of area and product, by 60.9% and 25.0%, respectively. As a result, the coffee farms in Peru emitted an additional 4,982 tCO2eq during the project.

The increase in emissions per hectare was expected, since coffee growing in Peru is very low intensity with minimal use of fertilisers, and one of the practices of the model is to increase fertiliser management in order to enhance productivity. Nevertheless, productivity should increase more than fertiliser emissions and thus result in a decrease of emissions per kg of coffee, even as emissions per hectare would be expected to rise. However, this has not been observed and we have identified two primary reasons why this is the case. First, as has already been mentioned, the yield at the end of the project was low, as verified all over the region. Second, increased productivity is not observed immediately after the application of fertilisers, indeed, it may take a few years for results to come into evidence. Therefore, we expect there will be a steady volume of emissions per hectare and an important decrease in emissions per kg of coffee in the coming years.

A comparison of the farms with and without CSA reveals coherent results. For farms without CSA, emissions in terms of area increased more than for farms with CSA (see Figure 10). This is due to the higher use of fertilisers by farms with CSA at the baseline, albeit in low quantities. Thus, farms without CSA increased their use of fertilisers to a higher extent and thus their emissions increased more. On the other hand, emissions increased less per kg of coffee for farms without CSA (Figure 11) because it is relatively easier to increase productivity for farms with lower productivity at the baseline.

4. https://coolfarmtool.org/
5. https://www.imaflora.org/

FIGURE 10
Emissions per hectare in Peru (kgCO2eq/ha)

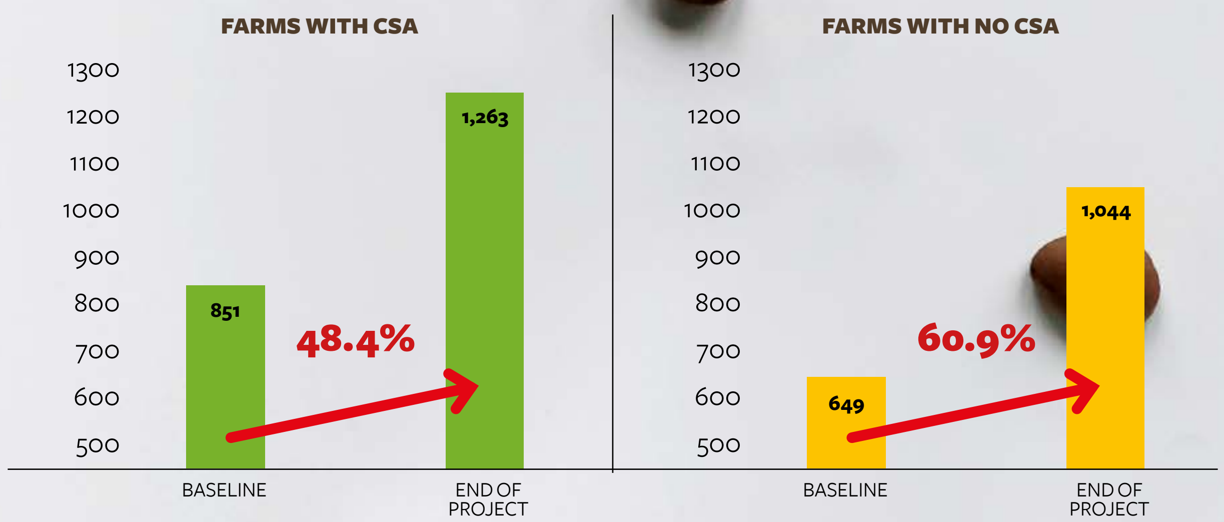
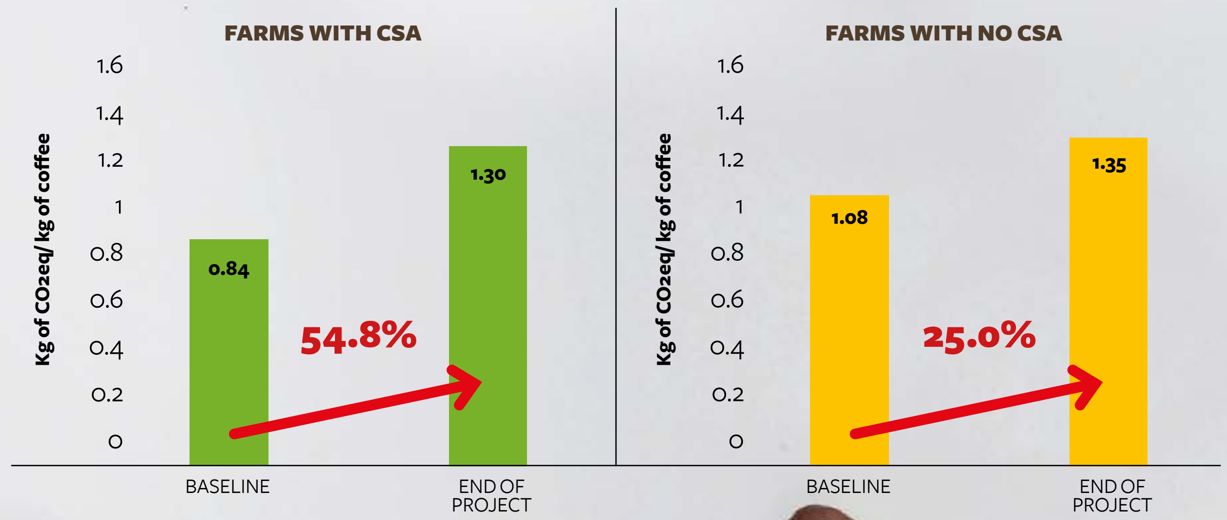


FIGURE 11
Emissions per kg of coffee (kgCO2eq/kg of coffee) in Peru



After fertilisers, wastewater and crop residues are the main source of emissions (see Figures 12 and 13). The higher increase in CO_2 emissions by farms without CSA are explained by their relatively higher increase in fertiliser emissions and significant increase in wastewater emissions.

FIGURE 12
Emissions per hectare (kgCO2eq/ha) for farms without CSA in Peru

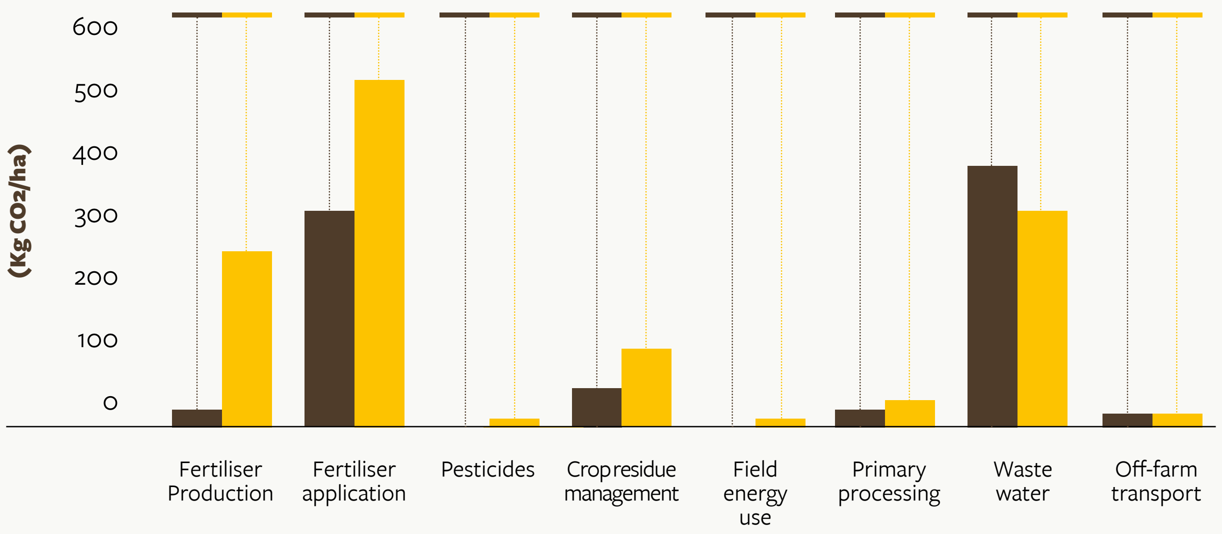
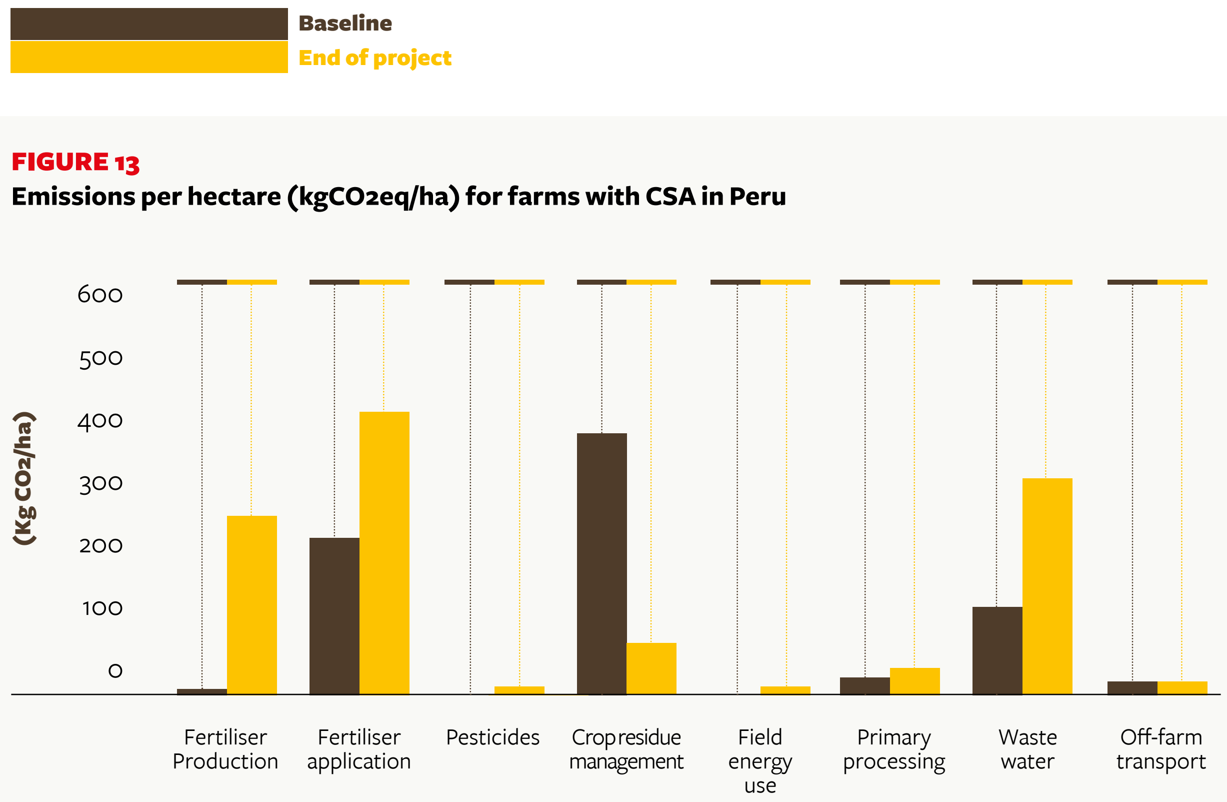


FIGURE 13
Emissions per hectare (kgCO2eq/ha) for farms with CSA in Peru



Reduced emissions from avoided deforestation

As shown above, 82 hectares of deforestation were avoided within coffee farms in Peru and 3,937 hectares of deforestation were avoided outside of the farm boundaries. We took the figure for the average biomass in the Alto Mayo protected forest of San Martín from the inventory produced by Aider, an NGO working with forestry and environmental conservation [6] (see Table 6).

TABLE 6

Carbon inventory for Alto Mayo protected forest, San Martín

Land cover	Carbon (ton/ha)	CO2eq (ton/ha)
Cloud forest	156.64	574.3
Pre montane forest	147.4	540.5
Dwarf forest	63.08	231.3
Secondary forest (purma)	61.8	226.6
Coffee	53.77	197.2
Pasture	10.42	38.2
Grass (pajonal)	5.1	18.7

Source: AIDER

Given that coffee farms in San Martín working with Solidaridad are in a transition area from pre-montane forest to cloud forest, we assumed an average biomass of 557.4 tCO2eq/ha. Since the avoided deforestation was 4,019 hectares, there were 2.24 MtCO2eq of avoided CO2 emissions due to avoided deforestation.

The avoided deforestation was

4,019 hectares

The avoided CO2 emission due to the avoided deforestation was

2.24 Mton CO2eq

82 HECTARES OF DEFORESTATION WERE AVOIDED WITHIN COFFEE FARMS IN PERU AND 3,937 HECTARES OF DEFORESTATION WERE AVOIDED OUTSIDE OF THE FARM BOUNDARIES.

6. https://aider.com.pe/

Increase in carbon capture from shade trees

Using the Cool Farm Tool calculator, we estimated the carbon captured by the project, mainly through biomass increase in shade trees and the coffee plants themselves. We used the same procedure as for estimating changes in emissions, looking at three different groups: (i) farmers with CSA at the beginning and the end of the project, (ii) farmers without CSA at the beginning and the end of the project and (iii) farmers without CSA at the baseline and with CSA at the end of the project.

The first group increased removals from 0.802 tCO2eq/ha to 2.272 tCO2eq/ha; the second group from 0.485 tCO2eq/ha to 1.882 tCO2eq/ha; and the third group from 0.485 tCO2eq/ha to 2.270 tCO2eq/ha (see Figure 14). This presents a total carbon removal of 15,895 tCO2eq/ha (see Table 7).

FIGURE 14

Removals per hectare (kgCO2eq/ha) for farms in Peru

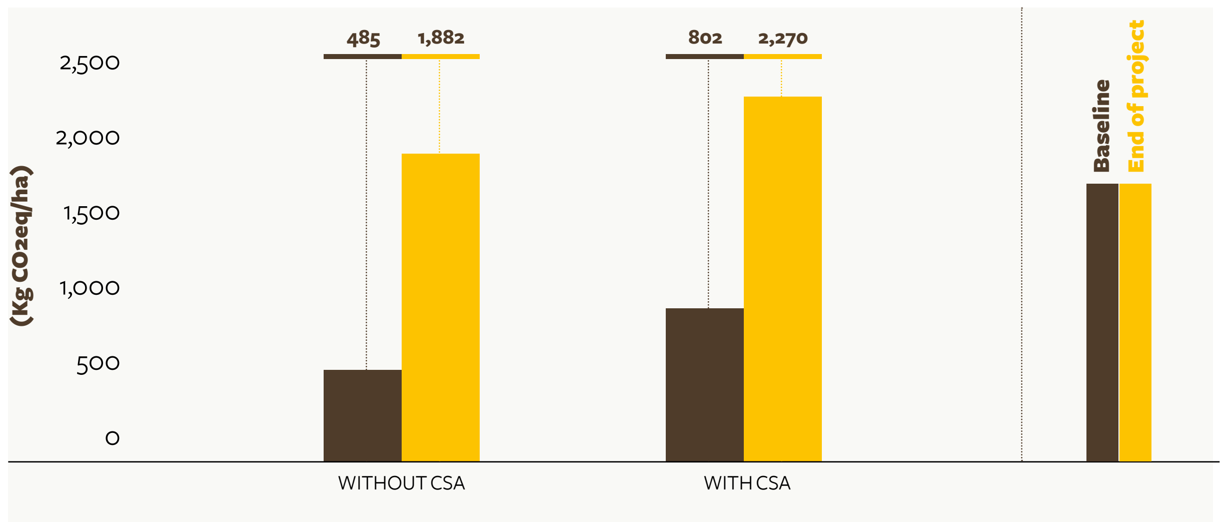


TABLE 7

Carbon removals in Peru

Changes from the baseline to the end of the project	Average sequestered carbon (tCO2eq/ha)	% of farms	Total area (ha)	Total sequestered carbon (tCO2eq)
With CSA --> with CSA	1,468	14.4%	1,451	2.13
Without CSA --> without CSA	1,396	41.0%	4,121	5.75
Without CSA --> with CSA	1,785	44.6%	4,489	8.01
TOTAL		100%	10,061	15.89

COLOMBIA: REDUCING EMISSIONS PER HECTARE

Reducing emissions from management practices

Contrary to Peru, emissions decreased in Colombia in terms of area and kg of product for farms with CSA and increased for farms without CSA (see Figures 15 and 16), resulting in total avoided emissions of 21,942 tCO2eq/ha during the project.

Unlike their counterparts in Peru, coffee farmers in Colombia are used to applying fertilisers on plantations. Since one of the practices promoted by the model is fertiliser management, which includes soil analysis and the use of adequate amounts of fertiliser, a reduction in fertiliser use and emissions is observed for the farms that implement CSA. However, the decrease in emissions in terms of area was relatively greater than that seen in terms of product. This is a result of the reduction in productivity from the baseline to the end of the project.

On the other hand, farmers without CSA show increased emissions, likely due to their higher use of fertilisers without applying the other good practices implemented by the project. Emissions increased more in terms of kg of coffee than area (hectare); once again this is due to the decline in productivity.

FIGURE 15
Emissions per hectare in Colombia (kg CO2eq/ha)

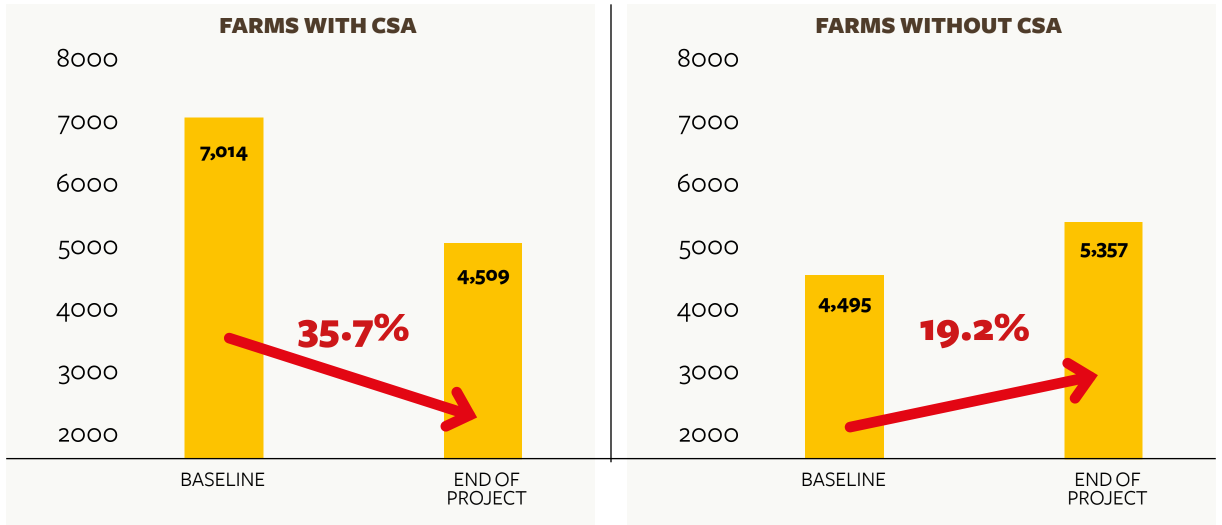


FIGURE 16
Emissions per kg of coffee (kgCO2eq/kg of coffee) in Colombia

As in Peru, the main sources of emissions are the use of fertilisers, wastewater and crop residue management. However, while fertilisers are the main source of emissions on farms with CSA, followed by crop residue management and wastewater (Figure 17), on farms without CSA, the main source of emissions is wastewater, followed by fertilisers and crop residue management (Figure 18). As can be seen below, a comparison of the two figures shows that the volume of emissions from crop residue management and from fertilisers are similar in the two groups (farms with and farms without CSA), while emissions from wastewater are higher for farms without CSA. Farms with CSA showed a significant 50% reduction in emissions from fertiliser application (Figure 17), likely as a result of the practices implemented by the project.

FIGURE 17
Emissions per hectare (kgCO2eq/ha) for farms with CSA in Colombia

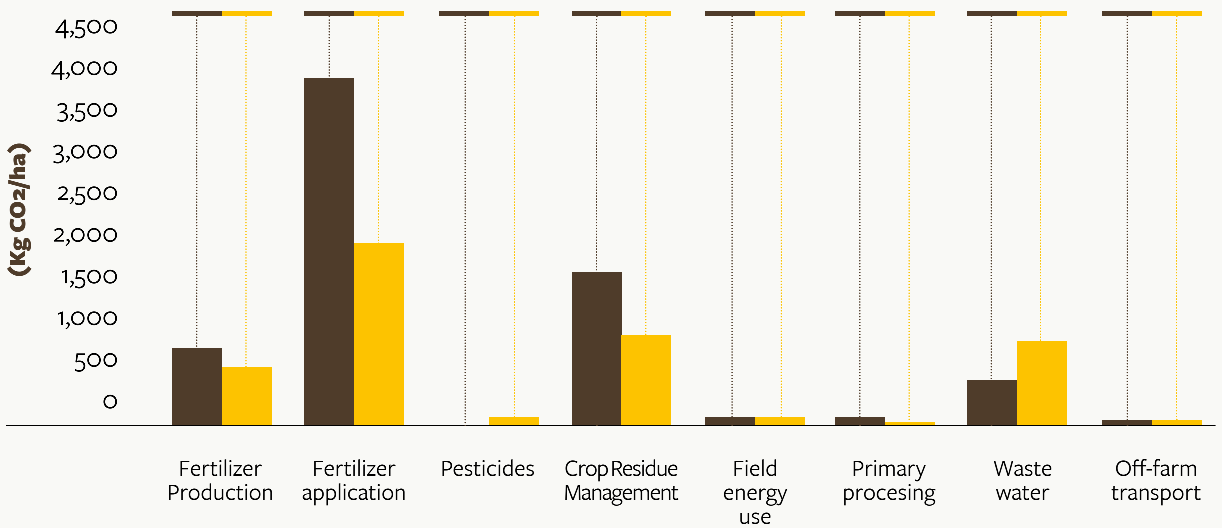
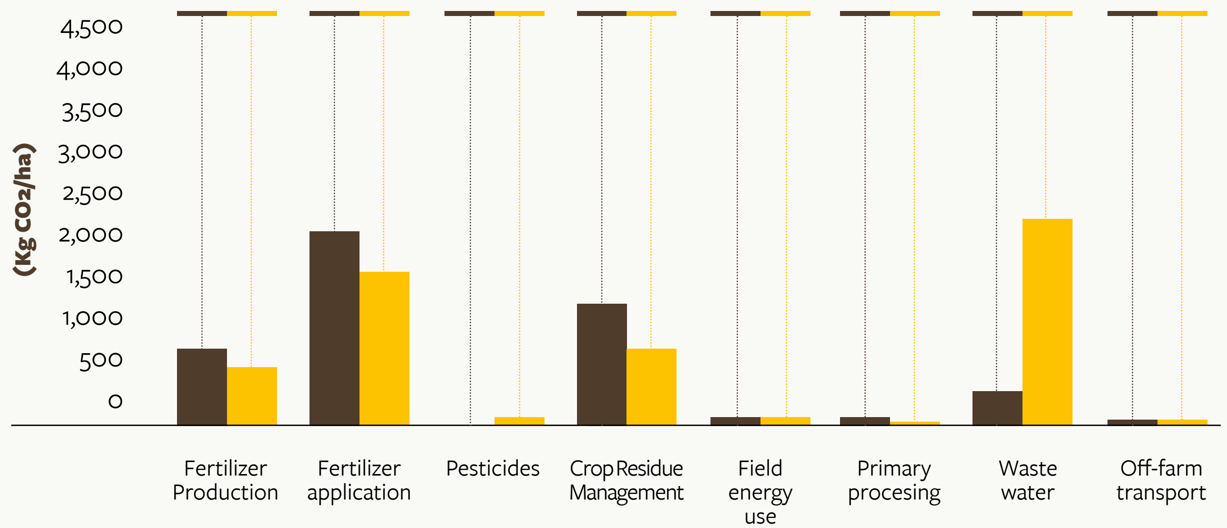


FIGURE 18
Emissions per hectare (kgCO2eq/ha) for farms without CSA in Colombia



Increasing carbon capture with agroforestry systems

As was the case for Peru, changes in carbon removals during the project in Colombia were analysed using the CFT calculator and the three groups of farms (farms with CSA; farms without CSA; and farms without CSA at the baseline and with CSA at the end of the project).

Farms with CSA at the beginning and the end of the project increased removals from 510 kgCO2eq/ha to 2,483 kgCO2eq/ha; farms without CSA at the beginning and the end of the project increased removals from 510 kgCO2eq/ha to 1,138 kgCO2eq/ha; and farms without CSA at the baseline and with CSA at the end of the project increased removals from 510 kgCO2eq/ha to 2,483 kgCO2eq/ha (see Figure 19), mainly through the seeding and growth of shade trees. These lead to a total carbon removal of 29,966 tCO2eq (see Table 8).

The volume of CO2 removed at the baseline per farm is equivalent for those with and without CSA. The higher increase of removals observed for farms with CSA is an outcome of the project, and of the use of shade tree seeding in particular, which is one of the management practices that was encouraged.

FIGURE 19
Removals by hectare (kg CO2eq/ha) for farms in Colombia

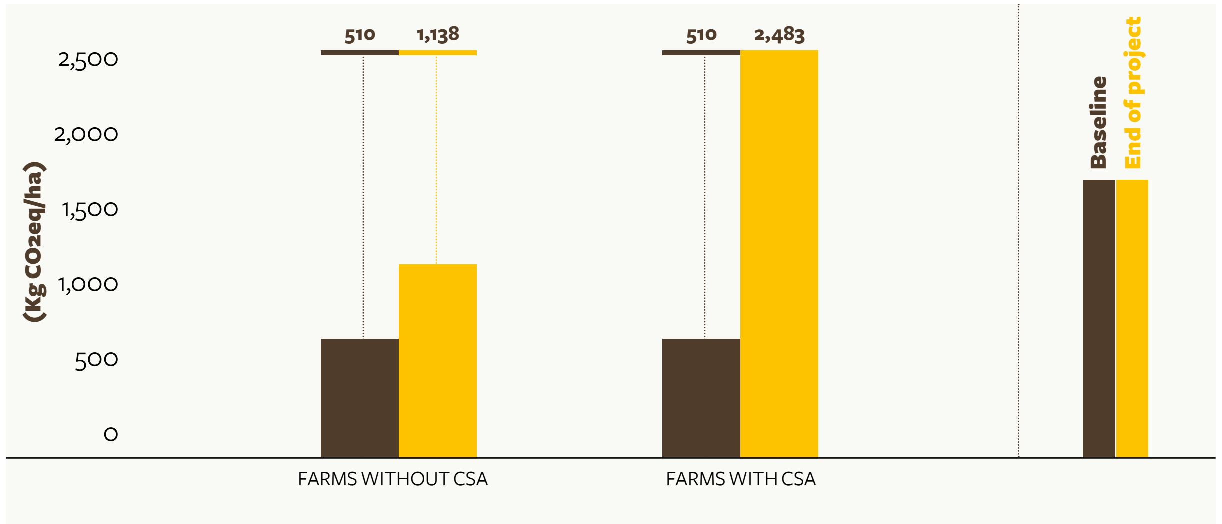


TABLE 8
Carbon removals in Colombia

Changes from the baseline to the end of the project	Increased sequestered carbon (tons of CO2/ha.)	% of farms	Total area (ha.)	Total sequestered carbon (tCO2eq)
With CSA --> with CSA	1,974	57.1%	9,623	18,993
Without CSA --> without CSA	628	14.4%	2,429	1,524
Without CSA --> with CSA	1,973	28.4%	4,788	9,448
TOTAL		**100%**	**16,840**	**29,966**

BRAZIL: REDUCING EMISSIONS AND INCREASING REMOVALS

Reducing emissions through climate-smart systems

In Brazil, farms are managed in an integrated way, with cocoa, livestock and forests. Emissions in this system come from livestock and deforestation.

Livestock emissions were measured with a customised calculator developed specifically for the project, which revealed a decrease from 1.24 tCO2eq/ha in 2018 to 0.83 tCO2eq/ha in 2021. For the total project area of 9,204 hectares, this translates into a reduction from 11,402 tCO2eq to 7,653 tCO2eq, leading to total avoided emissions of 7,497tCO2eq during the project, as shown in Table 9.

TABLE 9
Avoided emissions in Brazil - livestock (tCO2eq/ha)

	2017	2018	2019	2020	Total
Average emission per hectare in project area	1.24	1.10	0.97	0.83	-
Total emissions in the project area (a)	11,402	10,152	8,903	7,653	38,111
Emissions at BAU scenario (b)	11,402	11,402	11,402	11,402	45,608
Avoided emissions (c = b-a)	**0**	**1,250**	**2,499**	**3,749**	**7,497**

On the other hand, cocoa growing stores CO2, removing it from the atmosphere. According to the calculator, the removals derived from cocoa growing varied from 1.04 tCO2eq/ha in 2018 to 0.90 tCO2eq/ha in 2020, leading to a total removal of 26,683 tCO2eq in the 9,204 ha enrolled in the project (see Table 10).

TABLE 10
Carbon removal by cocoa growing

	2018	2019	2020	Total
Cocoa-growing CO2 removals/ha	1.04	0.97	0.90	
Total removals in the project area (9,204ha)	**9,534**	**8,894**	**8,255**	**26,683**

Increasing carbon capture in forests and agroforestry systems

While deforestation is an important source of CO2 emission, mature forests still remove some amount of carbon, even if in small quantities. For the forest present in the region (Novo Repartimento, Amazon biome), average carbon sequestration is estimated to amount to 0.5 tCO2eq/ha per year (Solidaridad Brasil, 2020). The forest area in the project farms is shown in Table 11 and the total removal is 4,065 tCO2eq.

In conclusion, the total carbon removals in Brazil through cocoa growing and forests amounted to 30,748 tCO2eq.

TABLE 11
Carbon removals from forest

	2018	2019	2020	Total
Total forest area	2,909	2,675	2,547	NA
Total removals	1,454	1,337	1,273	4,065

The total avoided emissions in Brazil is

337,234 tCo2eq

Avoided emissions associated with deforestation

To estimate the avoided emissions as a result of avoided deforestation, we multiplied the latter by the average biomass in the project area (Municipality of Novo Repartimento, Amazon biome). Since avoided deforestation for the project timeframe was 509 hectares and the biomass for the region is 648 tCO2eq/ha (Solidaridad Brasil, 2020), the avoided emissions resulting from avoided deforestation amount to 329,737 tCO2eq. Therefore, the total avoided emissions in Brazil, taking into account livestock and avoided deforestation, is 385,936 tCO2eq.

ADAPTATION AND RESILIENCE

Resilience building includes efforts to strengthen capacities to manage the impacts of climate change, while also reducing exposure in terms of the presence and relevance of exposed elements, as well as the direct impacts from climate-related hazards. Thus, resilience building needs to carefully consider business-as-usual (BAU) practices and how they can be affected by climate change or even exacerbate its impacts. Climate-smart practices are introduced into these systems in order to strengthen adaptation and other benefits. The main adaptation benefits of this model include strengthening the resilience of agroecosystems, improving farmers' livelihoods, and protecting forest ecosystems.

The greatest adaptation benefits of the model were attributed to agroforestry interventions in climate-smart and deforestation-free coffee in Colombia and Peru, and cocoa in Brazil. Overall, the project resulted in the implementation of climate-smart agriculture practices that strengthened the resilience of 61,650 hectares of coffee and cocoa agroecosystems. This includes 52,446 hectares (25,071 hectares directly and 27,375 hectares indirectly) of coffee agroforestry systems in Peru and Colombia. In cocoa supply chains in the state of Pará, Brazil, CSA practices were implemented in 9,204 hectares of diversified cocoa and livestock production systems.

The following sections will present in greater detail how adaptive capacity has been improved in coffee production in Peru and Colombia and in cocoa and livestock systems in Brazil.

BUILDING RESILIENCE AGAINST RISING TEMPERATURES IN COFFEE PRODUCTION IN COLOMBIA AND PERU

BAU coffee production in the target areas is typically characterised by monocrop production models with low biodiversity and higher vulnerability to extreme climate-related hazards (e.g., extreme heat, droughts, flooding). In Peru, coffee production systems show low productivity in the target area. As productivity declines, producers open new areas, often expanding agricultural lands into forest areas. Cleared land tends to provide a short-term boost in productivity before yields decline due to the application of unsustainable production practices (such as sowing against the slope or burning) that lead to soil degradation and nutrient depletion. The expansion of the agricultural frontier into forested areas results in the loss of vital ecosystem services in the Amazon rainforest.

The impact of climate change on these systems can increase the risk of losses and damages (e. g. reduced yields, mortality of trees) due to climate-related hazards (droughts, increasing temperatures, seasonal floods) (Hajek et al., 2021). Monoculture soils are particularly exposed to solar radiation, high temperatures, wind and water erosion, which contribute to accelerated soil and land degradation. In Colombia, a small survey by the Global Center on Adaptation in Risaralda found that 75% of the coffee farmers interviewed perceived droughts were getting worse (Eise & White, 2019). In Peru, coffee expansion came at the expense of forests in the San Martín region, where coffee production areas tripled between 1995 and 2010 (Marquardt et al., 2019). The expansion of the agricultural frontier leads to the loss of forests and, in turn, to the loss of ecosystem services, and increases the overall exposure and vulnerability of ecosystems to climate change.

The practices promoted by the model focused on the establishment or improvement of agroforestry systems on agricultural land (transitioning from monocultures to shade-grown systems, or improving degraded coffee production systems). The model also promoted deforestation-free production and raised awareness on the importance of conserving forests.

The specific CSA practices in the model are as follows:

- Implementation of agroforestry systems incorporating the growing of shade trees
- Fertilisation management
- Soil conservation practices
- Coffee density
- Crop residue management, including water management and pulp transformation

Implementing this CSA model results in important adaptation benefits. Agroforestry provides vegetative coverage that helps improve soil moisture (protecting against extreme heat and drought) and protects against soil erosion (from wind and rain). Shading also supports microclimate buffering, which strengthens resilience against extreme heat and droughts (Porro et al., 2012). Agroforestry also supports improved water filtration and cycling and reduces runoff speeds (Porro et al., 2012). This is further complemented by the CSA practices promoted by the model that focus on soil conservation.

In addition, the model provides diverse income streams and ecosystem services (e.g., provision of food, fuel, medicine) that strengthen producers' resilience in the case of loss or damages due to climate-related hazards (Solis et al., 2020). In addition, the application of CSA practices by coffee farmers in Peru and Colombia increased incomes by 71% on average, thus strengthening farmers' capacities to adapt to climate change.

Deforestation-free production is particularly beneficial in Peru, given the deforestation dynamics of the farms, which are mostly located in or near the buffer zones of protected areas. The practice reduces pressure on forests, helping to protect biodiversity and strengthening the resilience of forest ecosystems against climate change. This project helped avoid deforestation on 5,213 hectares (including areas inside and outside of the farms (see Section on deforestation).

The model also promoted deforestation-free production and raised awareness on the importance of conserving forests. The specific CSA practices in the model are as follows:

Implementation of agroforestry systems incorporating the growing of shade trees	Fertilisation management	Soil conservation practices	Coffee density	Crop residue management, including water management and pulp transformation

CONSERVING HEALTHY FORESTS SUPPORTS COCOA AND LIVESTOCK PRODUCTION IN BRAZIL

In Brazil, conventional cocoa production is characterised by monoculture production systems with low-biodiversity, low-carbon sequestration, low productivity and higher vulnerability to climate-related hazards (e.g., extreme heat), pests and diseases (Hernandes et al., 2022). Conventional livestock production practices involve extensive clearing of forests to convert to pastures, followed by low stocking rates (less than 1 head of cattle per hectare) and low productivity (some studies imply farms achieve only one-third of potential productivity) (Skidmore et al., 2022). The conversion of forests for livestock production is responsible for the majority of current deforestation in Brazil and, historically, is responsible for 80% of forest clearing in the Amazon (Tyukavina et al., 2017).

On farms in the project area, deforestation occurred on 7% of the land, which is usually converted to pastures for cattle and, to a lesser extent, to expand cocoa plantations. The expansion of the agricultural frontier into forested areas in Brazil results in the loss of vital ecosystem services in the Amazon rainforest.

Conventional systems are associated with an increased risk of losses and damages (e.g., reduced yields, mortality of trees) due to climate-related hazards (droughts, increasing temperatures, seasonal floods). Cleared pastures and monocultures are particularly exposed to solar radiation, high temperatures and wind and water erosion, which contribute to accelerated soil and land degradation. Fire, which is often used to clear pastures, can spread uncontrollably, increasing carbon emissions, causing impacts on ecosystems (especially due to the increasing frequency and intensity of fires, which limits recovery and adversely impacts the provision of many ecosystem services), the destruction of infrastructure and production systems and the loss of livelihoods (Pivello et al., 2021). Furthermore, it adversely impacts human health. Deforestation and forest degradation can drive the forest towards a tipping point in which it could become a net source of GHG emissions and could trigger forest dieback and mass transformation of ecosystems (Amigo, 2020). It further increases the vulnerability of ecosystems to drought, extreme heat and floods through reduced forest cover and reduced evapotranspiration (Staal et al., 2020). This results in a reinforcing feedback loop, which accelerates climate change, increases temperatures and dry conditions and ultimately also increases the risk and intensity of forest fires (De Faria et al., 2017).

The climate-smart model of the project promotes the establishment or improvement of more resilient agroforestry systems on farm land, degraded pasture and degraded forest (transitioning from monocultures to shade-grown systems, restoring degraded land or improving degraded cocoa production systems) (Jacobi et al., 2013). The project also promotes deforestation-free production, raises awareness of the importance of conserving forests and, through diverse measures (including working through multi-stakeholder entities), helps avoid deforestation. Education has proven to be fundamental in curbing deforestation.

The CSA practices promoted by the project are:

- No deforestation
- Soil analysis for cocoa crops and pastures
- Growing of shade trees in the cocoa area
- Management of the stocking rate in livestock areas
- Avoidance of the use of fire to clear pastures

Implementing the CSA model leads to several adaptation benefits. In a manner similar to that of coffee production, diversified cocoa agroforestry and sustainable livestock production systems increase vegetative coverage and help better maintain soil health (protecting against extreme heat, drought, floods), improve water filtration and cycling and protect against soil erosion (Porro et al., 2012). Shading through cocoa agroforestry supports microclimate buffering that strengthens resilience against extreme-heat and droughts (Niether et al., 2020). Agroforestry also provides vegetative coverage that helps improve soil moisture (Niether et al., 2020).

The model promotes CSA practices that provide diverse income streams and ecosystem services (e.g., provision of food, fuel, medicine) that strengthen the capacity of producers to cope with climate-related hazards and their impacts (e.g., droughts resulting in loss or damages to crops). The application of CSA practices by cocoa farmers in Brazil increased incomes by 52% on average, thus strengthening farmers' capacities to adapt to climate change.

Cocoa agroforestry supports forest restoration in Pará state, where it is an important activity for the recovery of degraded areas because they contain a native species and store 2.5 times more carbon than monoculture systems (Venturieri et al., 2022). Deforestation-free production helps reduce pressure on forest ecosystems, strengthening their resilience.

Managing stocking rates can improve livestock production without requiring additional clearing (which previously occurred at the expense of forests). Practices that promote the elimination of deforestation and the avoidance of the use of fire for clearing purposes also help protect forest ecosystems and the vital ecosystem services they provide. As climate change is projected to create increasingly dry conditions during the dry season, raising awareness and limiting the use of fires will help reduce the risk of forest fires (which are very likely to increase in intensity due to climate change).

Education has proven to be fundamental in curbing deforestation. The CSA practices promoted are:

- **No deforestation**
- **Soil analysis for cocoa crops and pastures**
- **Growing of shade trees in the cocoa area**
- **Management of the stocking rate in livestock areas**
- **Avoidance of the use of fire to clear pastures**

3 PROMOTING MARKET UPTAKE OF SUSTAINABLE PRODUCTION

Market uptake of climate-smart products is a fundamental component of the model. Sourcing climate-smart products would be unsustainable without mechanisms and policies embedded in companies to support this process. The characteristics and motivations of buyers vary significantly for each commodity, even though some actors participate in more than one market. What follows are some reflections on key commodities that play an important role in addressing the deforestation associated with agriculture, implementing climate-smart production models and maximising economic and social benefits in rural areas.

Various market mechanisms exhibit differing levels of effectiveness and scalability across key commodities. In the coffee sector, speciality markets in Colombia are highly effective in encouraging CSA but face scalability issues due to their niche focus. On the other hand, commodity markets in Peru show both high effectiveness and scalability, owing to the buying power of major purchasers. Revolving funds in Colombia also prove highly effective but their scalability is limited by the availability of competent local actors. For cocoa, barter schemes are both effective and scalable and well-aligned with producers' needs and sizeable sourcing volumes. Livestock mechanisms, such as the GIPS standard, offer high scalability but undetermined effectiveness. Shareholder lobbying in the soy sector currently shows little potential for both scalability and effectiveness, whereas China's sourcing standards are promising but require further evaluation. China's national soy regulations have a high potential for both effectiveness and scalability, given the size of the market. We carried out a detailed assessment of effectiveness and potential for scalability for all the mechanisms presented. The main results can be found in the table 12. Details are provided for each case.

TABLE 12
Effectiveness of market mechanisms tested

Product	Market mechanism	Case evaluated	Efectiveness*	Scalability**	Average efectiveness	Comment
Coffee	Sourcing CSA for speciality market	Finlays, RGC-Colombia	4	2	3	Effectiveness is high because the mechanisms provide good incentives for transformation. Scalability is low because the specialitymarket remains niche.
Coffee	Sourcing CSA for commodity market	ofi- Peru	4	4	4	Effectiveness is high as the scheme generates good incentives within their sourcing program. Scalability is high due as the company is one of the largest buyers of coffee nationally.
Coffee	Revolving funds	Finlays-Colombia	5	3	4	Effectiveness is high as it identifies beneficiaries well due to operations through local networks. It also covers the gap for finance, which is of high priority for producers. Scalability is limited as there is a limited number of local actors with capacity to manage revolving funds effectively.
Cocoa	Barter scheme of fertilizers and cocoa	Cargill and ofi	4	4	4	Effectiveness is high as it provides a scarce and relevant input in conditions that align with producer's needs. Scalability is high given the sourcing volumes of both traders and their ability to reach a high number of producers, even if specific conditions of exchange can vary for each context.
Livestock	Sourcing using GIPS standard	JBS, Minerva	TBD	4	2	This mechanism was tested but not yet adopted, hence effectiveness cannnot be assessed. Scalability would be high as proposes one standard for the whole sector.
Soy	Lobby from shareholders	Ceres	TBD	2	1	Commitments were recently adopted so their transformation capacity is yet to be determined. Scalability is low as this strategy requires intensive work, and resources, per company.
Soy	Adoption of sourcing standard (China Sustainable Soy Guidelines)	Cofco	3	3	3	Effectiveness can be partially assessed as the period of implementation is short. Yet, transformations in local production to attain the standard are already happening. Scale can be promising as the company has significant production and sourcing. Yet, this strategy requires intensive work per company.
Soy	National regulation	China SSP	TBD	4	2	Potential for effectiveness is high due to the market size. As the guidelines are in the process of development , these cannot be assessed yet. Scalability would be high as it has the potential to reach a wide base of producers with the same legislation.

*Effectiveness: Refers to the effectiveness to promote transformation from conventional/BAU to climate-smart and maintaining it. 0 represents the lowest effectiveness and 5 the highest.

**Scalability: Refers to the capacity to reach a critical mass of the sector to mainstream the mechanism. 0 represents the lowest capacity and 5 the highest.

THE GOAL OF MAINSTREAMING CLIMATE-SMART COFFEE

The market context for deforestation-free commodities was very different at the outset of the project than it is today. Deforestation-free commodities were only sourced on a voluntary basis. Solidaridad began work on this component by commissioning an external market assessment to gain an understanding of the appetite for climate-smart coffee. The market assessment presented the following key findings:

1

Despite the specific characteristics of the production model, this type of coffee will fall within the broader market segment for general sustainability volumes. By 2020, 55% of global coffee volumes were produced under sustainability verification and certification standards and 25% of global volumes were sold as sustainable on the market (Panhuysen & Pierrot, 2020). Therefore, climate-smart coffee is unlikely to expand this 25% share in the market. It would be more likely to be differentiated within the existing sustainability volumes.

2

Any market differentiation of climate-smart coffee would be likely to be channelled through premiums, which could be used to reward producers for their environmental performance.

3

The relevant marketing concepts for this segment are *climate-neutral coffee* and *deforestation-free coffee*. *Climate-neutral coffee* focuses on mitigation, allows for flexibility in achieving mitigation and does not require coffee-specific standards but still involves third-party verification, which fulfils the credibility objectives of commodity roasters. *Deforestation-free coffee* shows consumers there is climate action within their own supply chain. However, both at the time of the assessment and currently, there is the challenge that no widely-used system exists for defining and assessing good practices that allow for the specific claim that a product is "deforestation-free coffee."

4

The concept of *climate-neutral* or *deforestation-free coffee* was fairly new at the time of the assessment and was likely to only be piloted by frontrunners. This meant that it had limited market appetite, especially in the commercial segment. The speciality segment was better suited to sourcing of this type of coffee. Climate-neutral or deforestation-free coffee is better matched to sourcing programmes that integrate sustainability, which tend to be associated with the speciality segment.

The report's findings strongly suggested the market uptake of climate-smart coffee would likely remain a niche. Solidaridad has a long-standing history of introducing sustainable products to the market, beginning with the creation of Fairtrade in the 1980s, which introduced the first sustainable coffee produced by smallholders to the market. This was followed by the creation of UTZ (now Rainforest Alliance), which enabled volumes from large plantations to also achieve the sustainable label. Over the past few decades, we have learned that premium-based systems will remain niche; although they can influence the market, they are unlikely to transform it.

Since Solidaridad's ultimate goal is to transform sectors, we decided to test two market avenues for climate-smart coffee: *Commercial* and *Speciality*. Neither of these market avenues generated specific premiums per pound of coffee, but explored other market incentives that directly benefited producers.

The three main reasons for speciality traders or roasters to act on climate change are:

1. To ensure consistent quality (physical & sensorial),
2. To promote producers' livelihoods, and
3. To demonstrate climate actions to customers and consumers.

CLIMATE-SMART COFFEE IN THE SPECIALITY SEGMENT

Solidaridad partnered with two medium-sized traders in the United Kingdom and Canada, Finlays and RGC Coffee, to demonstrate that volumes from Colombian producers who were implementing three or more climate-smart practices on their farms could indeed be differentiated. This pilot did not connect Finlays or RGC to new suppliers but instead worked with their existing suppliers who were already buying coffee from climate-smart producers. Although Solidaridad works with many market players and promotes the uptake of sustainable volumes, we avoid being directly involved in competitive matters, such as contract negotiations.

SINCE SOLIDARIDAD'S ULTIMATE GOAL IS TO TRANSFORM SECTORS, WE DECIDED TO TEST TWO MARKET AVENUES FOR CLIMATE-SMART COFFEE: COMMERCIAL AND SPECIALITY. NEITHER OF THESE MARKET AVENUES GENERATED SPECIFIC PREMIUMS PER POUND OF COFFEE, BUT EXPLORED OTHER MARKET INCENTIVES THAT DIRECTLY BENEFITED PRODUCERS.

Nevertheless, Solidaridad facilitated the process by sharing our monitoring systems, which identify climate-smart producers, so they could be matched with the sourcing lists of cooperatives selling to these traders. As a result, by the end of the project four containers (114 Mt) of climate-smart coffee had been sold to RGC and Finlays. Finlays also invested USD 34,000 in a revolving fund for the cooperative, COOPCAFER, located in the Risaralda region. In total, 215 producers were able to access loans to invest in climate-smart practices. The funds revolved four times, amounting to a total of USD 138,000 in loans disbursed.

CLIMATE-SMART COFFEE IN THE COMMERCIAL SEGMENT

Influencing commercial supply chains can be more complex as margins are tighter and traceability is less comprehensive compared to speciality volumes. Therefore, we decided to influence the commercial volumes at their source and thus influence or feed the existing sustainability systems of supply chain managers. This market approach was piloted in Peru through a partnership with ofi (formerly Olam). At the outset of the project, 750 producers who supplied ofi were selected to participate in the climate-smart program. ofi subsequently linked the volumes it sourced from these producers to its digital B2B platform, AtSource, making the information on production practices and the levels of sustainability implemented by producers supplying ofi accessible to its customers. Our climate-smart project became ofi's first AtSource Infinity Project (the highest sustainability level attainable according to the AtSource criteria). Of the total of 4,071 Mt of climate-smart coffee produced by farmers involved in the initiative, 1,639 Mt were sourced by ofi. This mechanism underpins the crucial technical assistance service the company provides in the region, which is otherwise insufficient.

Today, the market for deforestation-free, climate- or carbon-neutral commodities has evolved considerably. The European Union regulation on deforestation-free products has now been approved by Parliament. The regulation will require that eight commodities, one of them being coffee, prove they have been produced without any links to deforestation and provides a cut-off date for reference. All coffee entering the European Union market will need to comply with this regulation. Europe is the second largest market for coffee from Peru and Colombia. Furthermore, companies around the world will be required to disclose their Scope 3 emissions[7] on a mandatory basis. This is particularly relevant to the primary coffee market for the origins of the project, which are Europe and the United States. There is certainly a sense of urgency for coffee buyers to engage with climate-smart initiatives, as the market moves from voluntary efforts to compulsory sustainability practices.

7. All indirect emissions that occurred in the supply chain.

ESTABLISHING MECHANISMS THAT WORK IN THE LOCAL COCOA MARKET

Brazil is currently the seventh largest cocoa producer in the world, with an approximate production of 200,000 tonnes per year. Today, the country imports cocoa, mainly from African countries, to meet the demand of its domestic industry. Brazil has approximately 70,000 producers who cultivate cocoa on nearly 700,000 hectares. At least 80% of these producers are classified as small- and medium-sized producers with less than 10 hectares of cocoa on average. Most of these producers lack the financial resources and technical support necessary to increase their productivity. Because cocoa is native to the Amazon biome, its production presents a good alternative to generate income for producing families and to restore degraded areas. The carbon sequestration capacity of cocoa plantations in agroforestry systems offers an opportunity for producing families to enter low-carbon agriculture markets. Market arrangements where producers have closer relationships with the cocoa industry or add more value to production through quality or sustainability are essential for improving incomes and consolidating cocoa production as one of the main chains of the Amazon bioeconomy.

ACCESS TO QUALITY COCOA MARKETS IS ANOTHER IMPORTANT STRATEGY TO IMPROVE THE INCOME OF PRODUCERS AND, CONSEQUENTLY, THEIR LIVELIHOODS. THROUGHOUT THE IMPLEMENTATION OF THE PROJECT, POST-HARVEST COCOA PROCESSING PRACTICES WERE IMPROVED AMONG PRODUCERS VIA TRAINING AND RECOMMENDATIONS PROVIDED THROUGH TECHNICAL ASSISTANCE.

PARTNERING WITH THE COCOA INDUSTRY AND STRENGTHENING COOPERATIVES

Through the project's actions and with the collaboration of the producer cooperative in the region as well as some of the cocoa processing companies, we were able to build a sustainable barter system in which inputs are exchanged for cocoa. The scheme operates with a private stakeholder that supplies fertilisers to the producers through a contract with the local cooperative. The fertilisers are paid back with cocoa at harvest time if the producer complies with the minimum labour and environmental production criteria. In this arrangement, fertilisers are offered at better prices than in the conventional market. The cocoa company is able to offer this benefit because it purchases large volumes of inputs. If a producer does not comply with the criteria, they cannot negotiate future contracts. However, they can return to the program after three years if they restore the area. These negotiations create a win-win situation, as these producers have never had access to inputs at a viable price and the industry guarantees that the cocoa purchased is tracked and produced under conditions of zero deforestation and without the use of child or degrading labour. Solidaridad conducts the monitoring of these practices on properties where the producers have committed to the barter contract. This is the first experience of its kind in the cocoa sector in Brazil. Since 2018, around 150 producers have signed these agreements, facilitated by Solidaridad, and 88% of the farmers who have signed the contracts have not incurred any deforestation. None of the producers involved in the project had any child labour violations over the three years.

ACCESSING PREMIUM MARKETS AND ADDING VALUE TO THE PRODUCT

Access to quality cocoa markets is another important strategy to improve the income of producers and, consequently, their livelihoods. Throughout the implementation of the project, post-harvest cocoa processing practices were improved among producers via training and recommendations provided through technical assistance. The adoption of these practices resulted in an improvement in the quality of cocoa in some production units, and these producers began to sell their cocoa to the speciality markets at prices four times higher than in the conventional market. Despite being a niche market, demand continues to grow, making it a promising alternative in the sector. In addition, cocoa from the project region has begun to appear in several national and international quality cocoa competitions. This has drawn the attention of premium cocoa buyers to the region and generated greater demand, encouraging producers to continue their pursuit of quality markets to improve their income.

THE CHALLENGES OF SCALING SUSTAINABLE LIVESTOCK

Most of the South American beef produced is consumed in local markets. This means the motivations for sustainability differ from other commodities such as coffee, where the transition towards sustainability is largely driven by a market pull from international buyers. In today's livestock market, only a few buyers require proof of any environmental or sustainability standards. Some local niche markets are beginning to demand deforestation-free production, but the volumes are not yet significant. Local regulations are not sufficiently developed so as to promote deforestation-free production or limit deforestation linked to livestock production. The former, tied to the lax enforcement of environmental offences, places more pressure on the market to demand and verify deforestation-free production.

LIMITED UPTAKE FROM THE NATIONAL MARKET

The Sustainable Beef Group received assistance to bolster the adoption of their guidelines, the GIPS (*Guia de Indicadores da Pecuária Sustentável*), by producers and buyers. The GIPS is a self-assessment tool for sustainability issues, developed by the GTPS. It aims to help farmers identify their level of sustainability and provides guidance on where and how they can improve. The GIPS covers 35 indicators, each of which is rated on a scale of five. It aims to provide the sector with minimum guidelines on what producers need to know about their level of sustainability and what buyers need to know about their suppliers.

WITH THE SUPPORT OF THE PROJECT, THE GTPS REACHED 1,033 PRODUCERS. GETTING PRODUCERS REGISTERED PRESENTED A CHALLENGE, SO GTPS MODIFIED THE ONLINE VERSION OF THE TOOL AND CONDUCTED SEVERAL WORKSHOPS TO ASSIST PRODUCERS IN COMPLETING THE INFORMATION IN SITU. ALTHOUGH ALMOST ONE THOUSAND SUPPLIERS APPLIED THE GIPS, IT WAS CHALLENGING TO ATTRACT THEM BECAUSE OF THE LACK OF INCENTIVES TO PARTICIPATE, OTHER THAN TO GATHER INFORMATION ON THEIR OWN FARMS

On the buyers' side, GTPS engaged two companies (Minerva and JBS) to promote GIPS as a tool to assess the sustainability of their suppliers. The companies informed their suppliers about the tool and encouraged them to use it. In addition, they shared the contacts of their suppliers with GTPS to provide information and support if needed. Staff from both companies received training on how to use the tool to support producers if requested (Vitalltech, 2021). JBS informed suppliers that the GIPS is not a conditioning criterion for sourcing, which suggests that the GIPS is likely not being used to its full potential. Ultimately, a comprehensive and integrated sustainability strategy is crucial if the GIPS or any other sustainability tool is to take off. At present, farmers do not see many real benefits to using the tool; instead, they often feel as if they are being used to extract information.

As the sector has evolved, the major meatpackers have been developing their own sustainability strategies and related systems[8]. This could be considered a duplication of efforts and certainly complicates the screening process. A unified system like GIPS would be advantageous, but the sector sorely lacks collective alignment. It is likely that producers would be more willing to change if the incentives were aligned.

In conclusion, at this time, there is no clear incentive from local markets to drive demand for sustainable products or to reward sustainable production. While exports to the European market may not represent the highest volume (it ranks as the fifth destination for beef in 2021), European regulations have been an important catalyser of sustainability initiatives. Within the country, the biggest challenge to achieving compliance with current regulations lies in the monitoring and traceability of indirect producers. This gap presents an opportunity to GTPS or other actors to make advances in sustainability in the coming months.

8. See JBS system as an example here: https://jbs.com.br/jbs-news/plataforma-com-tecnologia-blockchain-permitira-monitorar-todos-os-elos-da-cadeia-de-fornecedores-de-bovinos-ate-2025/

PRIVATE PILOTS SHOW THE NEED FOR A PUBLIC SOLUTION IN THE SOY SECTOR

Soy is a "hidden" commodity that is mostly used as animal feed. It is not highly recognised by consumers, as there is little awareness that products contain soy or that soy is used (for example, as feed), nor is there an understanding of the conditions in which it is produced. Furthermore, the soy supply chain is long and complicated, with huge volumes. These factors also change the drivers and pressures for sustainability.

OPTIMISED PRODUCTION MODELS TO TEST

Soy crops in Brazil have typically reached their peak productivity and, therefore, implementing CSA systems does not provide an incentive in that regard. However, deforestation remains a pressing and relevant issue that greatly affects the environmental impacts of soy production. In this context, there is a need to balance the development of new areas with deforestation, which is why the project proposed a model of growing on degraded areas. The project produced valuable studies on the potential and dynamics of soy expansion in the Cerrado, including information on pastures with potential for conversion (Solidaridad, 2021b). There is much to learn about how soy expansion is occurring, as it shows increasing changes. During the project, we conducted studies and explored alternatives together with AIBA, a producers' organisation in Western Bahia. In summary, production incentives can offer an attractive solution to avoid deforestation, though different mechanisms are still being tested.

PULL FROM THE PRIVATE SECTOR

On the market side, the private sector is taking steps towards sustainability. In this project, progress was seen both in engagement with shareholders and directly with companies.

Solidaridad worked with Ceres, which aims to accelerate the uptake of sustainability principles in the capital markets by educating and involving investors and companies. In the project, Ceres aimed to engage investors from six companies to make advances in their sustainability commitments and implementation. As a result, Dunkin' Brands, Hershey's, Kellogg's, Restaurant Brands International and Sysco have taken steps towards deforestation-free supply chains. Progress refers to commitments to engagement, especially with regard to establishing no-deforestation policies, whether at a general level or specific to soy. Policies also include disclosing the risk of deforestation and committing to sustainability at the board level. Detailed policies per company are shown in the box below. These commitments could have a great potential impact considering the size of the companies and their sourcing. Still, it remains to be seen when and how this progress will be achieved.

Public commitments made by companies with through Ceres' engagement

- Dunkin' Brands publicly announced the establishment of a board-level committee on sustainability risks;
- Hershey's signed a private investors agreement and publicly announced the creation of a new committee on sustainability in 2020. In 2021, a new cross-commodity no-deforestation policy was publicly announced;
- Kellogg's signed a private investors agreement in 2020 and, in 2021, it added soy to the list of priority ingredients for responsible sourcing;
- Kroger signed a private investors agreement involving the development of a no-deforestation policy (2019) and, in 2020, it released a public no-deforestation commitment;
- Restaurant Brands International committed publicly to eliminating deforestation for priority commodities by 2030, including beef, soy in poultry, coffee, packaging and palm oil; and
- Sysco: An investors' resolution was withdrawn after a private investment agreement was reached, and a document to disclose the risk of deforestation was publicly released.

There is also demand from the private sector for sustainable soy, mainly from large buyers focused on exports, especially to European markets. This is a niche market that typically uses certification such as the RTRS standard. However, after 10 years of working with the RTRS standard, the impacts on deforestation are still very limited since they extend to the best-in-class producers, who are likely to have a low risk of deforestation in the first place (Solidaridad, 2020, 9 April). The amount of certified soy is increasing, but, in 2020, the amount of soy in Brazil that achieved RTRS certification was 3.7 million tonnes, only around 3% of total Brazilian soy production.

Still, in a broader context, there is a huge and increasing demand for soy from markets that to date have not implemented sustainability requirements, such as China, other Asian countries and Africa. Certification standards do not extend this far and companies based in these regions do not have publicly traded shares, and thus engaging their management boards in schemes similar to that of Ceres is not possible.

However, in China, other companies have been engaged both directly and through multi-stakeholder platforms. COFCO has made the most progress, as it has committed itself to eliminating deforestation from its supply chain and adopted a Sustainable Soy Sourcing Policy in 2019, which focuses primarily on Brazil. The policy addresses issues such as compliance with environmental regulations (CAR registry) and with the Amazon Soy Moratorium, as well as demanding that production is free of child and slave labour, among other items. COFCO has begun screening producer areas and has purchased its first volumes of sustainable soy. COFCO's acquisition of new companies (Nidera and Noble), both of which had already implemented sustainability policies, further accelerated the progress in this area. COFCO is a major company that not only serves the Chinese market but also operates internationally, so, while pressure from markets outside of China may have influenced COFCO to take on its role as a frontrunner in the area, its zero-deforestation policy will impact global markets.

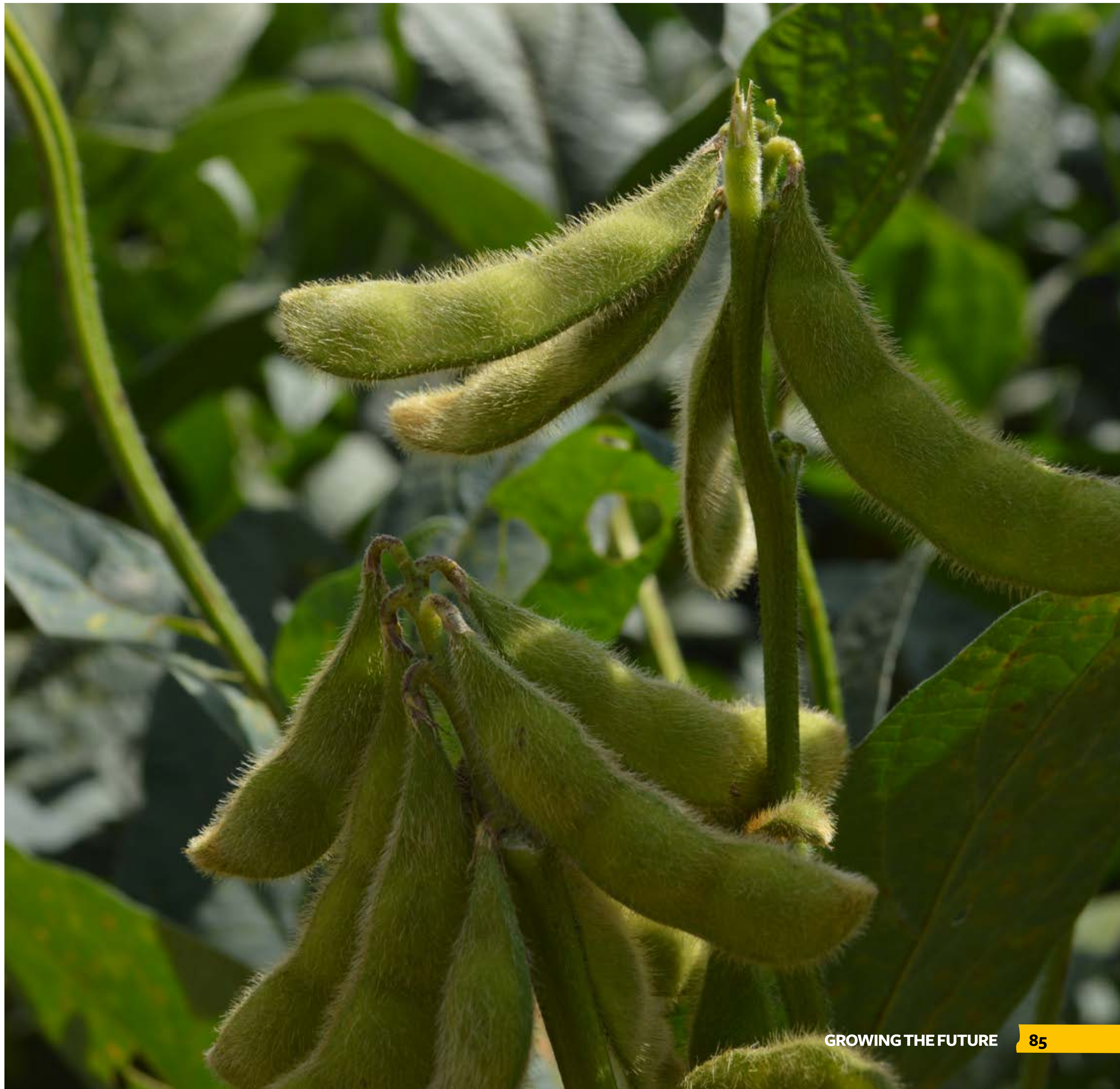
Other companies in China are also advancing on sustainability. Sinograin Oils' domestic production is now RTRS-certified and the company is currently developing, with the support of Solidaridad, a more comprehensive sustainability policy. In addition, the Jiusan Group released their first Corporate Social Responsibility Report in September 2018 and began a "Green Traceability" pilot project at the end of 2018.

THE NEED FOR REGULATION

Although important progress is being made in the private sector, the pace of change is still slower than desired, since deforestation continues to advance. Consequently, government policy has crucial role to play in this context. National legislative mandates are needed to promote the shift to deforestation-free production, even though it is a slow and long-term process. This project focused on mobilising sustainability regulations in China. In 2019, China was the world's largest soy importer, while Brazil was the largest exporter, with market shares of 58% and 47%, respectively. This suggests that the largest impact on sustainably produced soy can ultimately be achieved through the Chinese market.

The Sustainable Soy Platform, which is made up of key actors from China's public and private sectors, has officially launched the China Sustainable Soy Guidelines to help Chinese companies source sustainably produced soy, eliminate deforestation in the Amazon and Cerrado and promote the conversion of degraded pastures. The guidelines were developed with the support and endorsement of the Sustainable Soy Trade Platform (SSTP) Advisory Group, which is comprised of China's soy-related industry associations, companies and industry experts. Based on these principles and dialogues, Solidaridad has made progress with the companies mentioned above as well as with other traders that operate internationally.

Investing in China's sustainable soy guidelines is very important given the magnitude of the Chinese market, but it also requires long-term efforts, as was the case in Europe, the US and other markets. Chinese companies are gradually addressing sustainability and deforestation issues. It is never easy to involve all stakeholders in the process and ensure the government acts as a key player, and this is especially true in China given its very specific context. The processes in both Europe and the US have also been gradual and have taken years to mature. In the same way, it is very difficult to predict which concrete results can be achieved and at what pace.



INFOGRAPHIC 4

MARKET UPTAKE IN CLIMATE-SMART AGRICULTURE

COFFEE

3
mechanisms tested

AVERAGE EFFECTIVENESS:
3.6/5

3 companies sourced
1,753
metric tonnes of climate-smart coffee

2 partners invested
129,000 USD
in CSA transformation

COCOA

1
mechanisms tested

AVERAGE EFFECTIVENESS:
4/5

80%
of producers complied with the no-deforestation condition in the first year of implementation

LIVESTOCK

1
mechanisms tested

AVERAGE EFFECTIVENESS:
2/5

1,033
1,033 producers registered in the national guidelines of sustainability

2
companies promoting registration but not sourcing using the guidelines

SOY

2
mechanisms tested

AVERAGE EFFECTIVENESS:
2.5/5

1 company mapped the first
5,021 MT
of soy under sustainability criteria

4
companies adopting sustainability commitments in China and 6 in North America

CONCLUSIONS/ NEXT STEPS

1

Forest conservation and carbon sequestration: Dual pathways to sustainable agriculture

- The intricate relationship between deforestation and carbon capture mechanisms, such as agroforestry systems and shade trees, provides a comprehensive view of sustainable agriculture. In Peru and Brazil, avoiding deforestation played a pivotal role in reducing carbon emissions. Specifically, the implementation of CSA on coffee farms in Peru resulted in the prevention of 2.24 MtCO2eq emissions by avoiding the deforestation of 5,213 hectares. In Colombia, the inclusion of agroforestry systems and shade trees in CSA practices achieved a remarkable carbon removal of 29,966 tCO2eq in total. These examples underscore the dual benefits of forest conservation and carbon sequestration strategies in agricultural settings—each serving as a two-pronged approach that not only mitigates carbon emissions but also provides additional ecosystem services, such as biodiversity and soil conservation.
- The evidence supports that deforestation prevention and sustainable agricultural practices, such as agroforestry, can serve as robust strategies for both carbon mitigation and the preservation of essential ecosystem services. These are not isolated goals but interconnected outcomes of well-implemented CSA practices.
- Future efforts should prioritise these dual-benefit strategies and further investigate their combined impact on a variety of ecosystem metrics. In particular, additional research and stakeholder engagement should focus on how these practices can be better integrated into existing agricultural systems while taking into consideration the nuances in different climate and socio-economic settings.

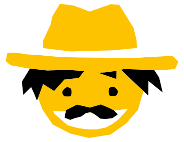
2

Temporal dynamics in sustainable agriculture: The interwoven paths of emissions, productivity, and deforestation

- The intricate relationship between carbon emissions, deforestation and the implementation of climate-smart practices reveals a complex yet instructive outlook for sustainable agriculture. For instance, the project's experience in Peru shows a short-term increase in carbon emissions by coffee farms adopting CSA practices – specifically, of an additional 4,982 tCO2eq. This uptick was largely due to the initial low yield and delayed productivity, but was counterbalanced over time by avoided deforestation, which resulted in 2.24 MtCO2eq of avoided emissions. Similarly, farms in Colombia that adopted CSA experienced reductions in emissions, which were largely due to improved fertilisation management, a strategy that the farms without CSA failed to implement, thereby increasing their emissions.
- This temporal dynamic between short-term increases and long-term reductions in emissions necessitates a nuanced approach to interpreting the impacts of CSA on both emissions and productivity. It is essential to understand that implementing sustainable practices may result in a temporary "carbon cost", but the long-term gains in productivity and carbon capture – as evidenced by the 15,895 tCO2eq removed through shade trees in Peru and the 29,966 tCO2eq removed in Colombia – cannot be overlooked.
- These findings indicate that a multi-faceted approach to climate action in agriculture is not just beneficial but necessary. It requires the careful planning, monitoring and adjustment of strategies that are tailored to specific agricultural contexts.
- Next steps should include further investigation into the short-term versus long-term emission impacts of CSA and, more importantly, the development of communication strategies to effectively convey these complexities to stakeholders, including donors, policymakers and farmers. Emphasis must be placed on long-term goals while navigating the short-term challenges to truly realise the potential of CSA in mitigating climate change.

3

The crucial nexus of technical assistance and climate-smart practices in sustainable agriculture



- Making a successful transition from conventional to sustainable practices is closely tied to the quality and adaptability of the technical assistance provided to farmers. Localised teams that offer contextualised solutions are more than simply support mechanisms; they are essential catalysts for the adoption of CSA, as is evident in the results in increased adoption rates among coffee producers in Peru, Brazil and Colombia.
- This multi-dimensional support includes not just prescriptive advice but also creative solutions that motivate producers to break from traditional norms. For instance, farmers found the use of digital platforms, such as WhatsApp, and multimedia resources, such as videos and podcasts, to be invaluable, especially during the restrictions imposed by the COVID-19 pandemic. Similarly, practical peer-led workshops and group work should be encouraged. These not only offer hands-on training but also reduce the high labour costs associated with implementing good practices, and thus serve as a motivational and practical catalyst for change.
- The project's focus on testing and sharing best practices is also a compelling feature, designed for replicability and scalability across different agricultural landscapes. These models, made adaptable for local organisations, can further facilitate the exchange of invaluable know-how, thus acting as another layer in fostering CSA.
- Next steps call for a focus on understanding the gender-specific impacts and dynamics of practice adoption to be considered within technical assistance schemes. The family-based nature of these agricultural systems offers a unique opportunity to tap into household dynamics to enhance each member's role and potential in the transformation to CSA.
- Another important next step is to make available some actionable insights from behavioural changes and adult learning theories to refine the technical assistance programmes and ensure they align with the motivations of farmers to adopt sustainable practices.

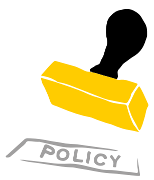
4

The economic cornerstone of climate-smart agriculture: viability, incentives, and market access

- Any conversation about the transition to CSA is incomplete without a thorough exploration of its economic impact. There is an indisputable correlation between CSA adoption and the economic viability of farming operations. In Colombia and Peru, adopting CSA resulted in an average yield increase of 10%, which translated into an income surge of 70.5% (also accounting for commodity price changes). In Brazil, the financial gains are equally compelling, with an average income rise of 52% in cocoa and livestock sectors. These are not mere statistics; they validate the economic underpinnings of sustainable agriculture.
- However, economic viability could be a double-edged sword. On the one hand, higher yields and quality gains, as evidenced in the Colombian and Peruvian coffee sectors and Brazil's cocoa and livestock industries, provide a strong business case for CSA. On the other hand, these changes often entail upfront costs and commitments that could deter farmers. For example, committing to carbon sequestration contracts may pose financial risks, making it imperative to introduce market incentives that tip the balance in favour of CSA. The project facilitated access to existing market mechanisms, such as Acorn, Cargill's barter scheme and speciality markets offering premiums for CSA-derived quality, ensuring farmers see tangible economic benefits to offset initial costs.
- In the future, a deeper understanding of payment for environmental services and economic viability is needed for scaling sustainable practices. Leveraging feedback from producers and service providers, along with further economic analysis, will inform the development of effective market incentives and identify profitable opportunities for CSA adoption.

5

Regulatory influence and market evolution in climate-smart initiatives



- Regulatory frameworks play a significant role in shaping market behaviour towards sustainable practices. In the coffee sector, the European Union's introduction of regulations for deforestation-free products and mandatory Scope 3 emissions reporting has heightened the urgency for buyers to engage with climate-smart initiatives. The livestock sector, largely driven by local market demands, also shows European regulations have been a catalyst in pushing sustainability initiatives forward, even if the export volumes to Europe are not the highest. Hopefully, this does not become a perverse incentive to divert to markets that have lower sustainability requirements.
- The soy sector underscores the crucial role of government in driving change. While private companies are taking steps towards sustainability, it is government regulations, as seen in Europe and the United States, that have the potential for broader impact. The nascent China Sustainable Soy Guidelines and national regulations in China are promising but require long-term commitment from all stakeholders, including the private sector and government, for significant and lasting impact.
- Thus, regulatory changes have a profound impact on the effectiveness and scalability of market mechanisms and serve as catalysts for sector-wide transformations. They can fill the gaps where market mechanisms fall short and set the stage for more integrated and impactful climate-smart initiatives. Not only can government policies push companies to act, they also provide a framework within which scalable and effective solutions can be implemented.
- In the future, robust mechanisms for monitoring and compliance should accompany new and existing regulations to enhance their effectiveness and provide a feedback loop for policy refinement. In addition, as the regulatory landscape evolves, there will be a pressing need for extensive education and training programs to help producers and other stakeholders adapt to new requirements; these can potentially be delivered through workshops, online courses, or partnerships with educational institutions.

6

Navigating the transition: From niche markets to mainstream adoption of sustainable practices

- The transition from niche to mainstream markets is a critical juncture in the scaling up of sustainable practices. For commodities such as coffee and cocoa, where sustainability practices have started to mature in niche markets, the challenge lies in translating this success to the broader commodity market. Factors such as higher pricing for sustainable products, the lack of awareness among general consumers and inconsistent regulations across markets can be barriers to mainstream adoption. However, changing regulatory landscapes, particularly in Europe, have initiated a shift, making sustainability not just a niche requirement but a mainstream demand.
- Going forward, the implementation of a balanced system of financial incentives and disincentives within the supply chains could serve as a powerful catalyst for encouraging producers and suppliers to adopt sustainable practices. This could manifest as tax benefits for those engaged in sustainable production, penalties for non-compliance, or even grants to assist in the transition to more sustainable methods.

METHODOLOGY OF THE STUDY

The study used a mixed methods approach that took into account the diversity of results of the project. The methods used are qualitative and quantitative depending on the information required. Baseline data was collected between February and May 2018, and end line data in the same period of 2021. Updated information on markets and regulation was introduced in 2023. Methods used to calculate each indicator were maintained to allow comparison.

QUALITATIVE
The qualitative methods for data collection include unstructured and semi-structured interviews with selected stakeholders from the government and private sector. Data analysis was conducted using a content analysis approach of the interviews to identify and structure relevant information for the research. Secondary sources were used for triangulation of the data collected.

QUANTITATIVE
Surveys of producers were conducted in representative samples by field staff from Solidaridad, as well as external enumerators. Questionnaires were developed by Solidaridad or partners, validated in the field with producers at the baseline, collected through in-person or phone interviews and, in most cases, consolidated using digital tools. Inferential statistics were used to draw conclusions of the total population based on a sample. Statistical details of the samples are in the table below. The samples were random and stratified to increase the validity of the information. The analysis of deforestation and land use change were obtained from three public studies conducted by Solidaridad[9]. The methodologies used to assess greenhouse gases emissions were selected based on the context and the practices implemented. The Cool Farm Tool was used for coffee in Peru and Colombia (Cool Farm Alliance, n.d). A specialised calculator was developed and used for diversified systems in the Amazon.

TABLE 13
Sampling details

Variable	Hectares directly under sustainable production			Hectares indirectly under sustainable production			Producers implementing CSA practices			Hectares under better management practices	Increase in income for smallholders through farm diversification
	Total	Colombia	Peru	Total	Colombia	Peru	Total	Colombia	Peru	Brazil	Brazil
Universe	35,040	17,011	17,697	36,453	32,315	4,138	6,980	3,797	3,183	11,500	230
Sample size	904	464	440	583	276	307	187	104	83	4,657	97
Confidence level	95%	95%	95%	95%	95%	95%	95%	90%	90%	95%	95%
Margin of error	3.22%	4.5%	4.6%	4%	5.8%	5.3%	7%	8%	8.9%	1.1%	7.6%

34. https://www.solidaridadsouthamerica.org/brasil/sites/solidaridadsouthamerica.org/files/publications/low-carbon_agriculture_in_the_brazilian_amazon_-_ghg_emissions_balance_in_family_agricultural_production_scenarios_and_opportunities_-_executive_summary.pdf

9. "Geoprocessing for deforestation monitoring in coffee farms in Peru", "Deforestation monitoring and land use change analysis in coffee farms in Colombia" and "Regional potential for the expansion of soy in Matopiba" from Brazil.

BIBLIOGRAPHY

- Amigo, I. 2020. When will the Amazon hit a tipping point? Nature, 578: 505-507. https://doi.org/10.1038/d41586-020-00508-4
- Cool Farm Alliance. (n.d.). The Tool. Retrieved from https://coolfarm.org/the-tool/
- De Faria, B.L., Brando, P.M., Macedo, M.N., Panday, P.K., Soares-Filho, B.S., Coe, M.T. 2017. Current and future patterns of fire-induced forest degradation in Amazonia. Environmental Research Letters, 12(9): 095
- Eise, J., White, N. 2019. Colombian coffee farmers are at severe risk from climate change. How can they adapt? https://gca.org/colombian-coffee-farmers-are-at-severe-risk-from-climate-change-how-can-they-adapt/
- GEOBOSQUES, (n.d.). Pérdida de Bosque_2001_2021 http://geobosques.minam.gob.pe/geobosque/view/descargas.php?122345gxxe345w34gg
- Hajek, F., Killeen, T.J., Ludena, C., Kiff, L., Barreiro, P., Gretzinger, S., Stronza, A., Mira, M., Gonzalez, J.C., Torres, D., Regal, F. 2021. Unlocking private capital by valuing bioeconomy products and services with climate mitigation and adaptation results in the Amazon: A feasibility study for Brazil, Colombia, Ecuador, Guyana, Peru and Suriname. Nature Services for the Inter-American Development Bank.
- Hernandes, G.M.C., Efraim, P., Silva, A.R.A., Queiroz, G.Z. 2022. Carbon footprint of Brazilian Cocoa produced in Pará state. Brazilian Journal of Food Technology, 25: https://doi.org/10.1590/1981-6723.26320
- Jacobi, J., Schneider, M., Bottazzi, P., Pilco, M., Calizaya, P., Rist, S. 2013. Agroecosystem resilience and farmers' perceptions of climate change impacts on cocoa farms in Alto Beni, Bolivia. Renewable Agriculture and Food Systems, 30 (2): 170 - 183. https://doi.org/10.1017/S174217051300029X
- Kennisgeving voor omleiding. (s. f.). https://www.google.com/url?q=https://jbs.com.br/jbs-news/plataforma-com-tecnologia-blockchain-permitira-monitorar-todos-os-elos-da-cadeia-de-fornecedores-de-bovinos-ate-2025/
- Marquardt K., Pain, A., Bartholdson, Ö., Rengifo, L.R. 2019. Forest dynamics in the Peruvian Amazon: understanding processes of change. Small-scale For, 18:81–104. https://doi.org/10.1007/s11842-018-9408-3
- Niether, W., Jacobi, J., Blaser, W.J., Andres, C. and Armengot, L. 2020. Cocoa Agroforestry Systems versus Monocultures: A Multi-Dimensional Meta-Analysis. Environmental Research Letters, 15, 13. https://doi.org/10.1088/1748-9326/abb053
- Panhuysen, S. and Pierrot, J. 2020: Coffee Barometer 2020.
- Pivello, V.R., Vieria, I., Christianini, A.V., Ribeiro, D.B., da Silva Menezes, L., Berlinck, C.N., Melo, F.P.L., Marengo, J.A., Tornquist, C.G., Moraes Tomas, W., Overbeck, G.E. 2021. Understanding Brazil's catastrophic fires: Causes, consequences and policy needed to prevent future tragedies. Perspectives in Ecology and Conservation, 19(3): 233-255.
- Porro, R., Miller, R.P., Tito, M.R., Donovan, J.A., Vivan, J.L., Trancoso, R., Van Kanetne, R.F., Grijalva, J.E., Ramirez, B., L., Goncalves, A.L. 2012. Agroforestry in the Amazon Region: A Pathway for Balancing Conservation and Development. Agroforestry - the Future of Global Land Use, Advances in Agroforestry, 9: 391-428;
- Skidmore, M.E., Sims, K.M., Rausch, L.L., Gibbs, H.K. 2022. Sustainable intensification in the Brazilian cattle industry: the role for reduced slaughter age. Environmental Research Letters, 17(6): DOI 10.1088/1748-9326/ac6f70;
- Solidaridad. (2021b). Regional Potential for the Expansion of Soy Crops in MATOPIBA: Solidaridad. https://www.solidaridadsouthamerica.org/brasil/sites/solidaridadsouthamerica.org/files/publications/regional_potential_for_the_expansion_of_soy_in_matopiba.pdf
- Solidaridad. (2021). Responsible soy - 10 years on. Solidaridad Network. https://www.solidaridadnetwork.org/news/responsible-soy-10-years-on/Solidaridad (2020).
- Solidaridad. (2020). Low-carbon agriculture in the Brazilian Amazon https://www.solidaridadsouthamerica.org/brasil/sites/solidaridadsouthamerica.org/files/publications/low-carbon_agriculture_in_the_brazilian_amazon_-_ghg_emissions_balance_in_family_agricultural_production_scenarios_and_opportunities_-_executive_summary.pdf
- Solidaridad. (2020, 9 April). Responsible Soy – 10 Years On. https://www.solidaridadnetwork.org/news/responsible-soy-10-years-on/
- Solidaridad Brasil. 2020. Agricultura de baixo carbono na Amazônia - Cenários e oportunidades no balanço de emissões de GEE na produção agrícola familiar: Solidaridad; Imaflora. 2a ed. São Paulo: 2020.
- Solis, R., Vallejos-Torres, G., Arévalo, L., Marín-Díaz, J., Ñique-Alvarez, M., Engedal, T., Bruun, T.B. 2020. Carbon stocks and the use of shade trees in different coffee growing systems in the Peruvian Amazon. The Journal of Agricultural Science, 158 (6): 450-460.
- Staal, A., Flores, B.M., Aguiar, A.P.D., Bosmans, J. H.C., Fetzer, I., Tuinenburg, O.A. 2020. Feedback between drought and deforestation in the Amazon. Environ. Res. Lett. 15. DOI 10.1088/1748-9326/ab738e
- Tyukavina, A., Hansen, M. C., Potapov, P. V., Stehman, S. V., Smith-Rodriguez, K., Okpa, C., Aguilar, R. 2017. Types and rates of forest disturbance in Brazilian Legal Amazon, 2000–2013. Science Advances, 3, 1–16.
- Venturieri, A., Souza de Oliveira, R.R., Koti Igawa, T., De Avila Fernandes, K., Adami, M., Cordeiro Mouraode Oliveira, M. Aparecido Almeida, C., Teixeira Silva, L.G., Cabral, A.I.R., Kneipp Cerqueira Pinto, J.F., Amorim Menezes, A.J., Neiva Sampaio, S.M. 2022. The Sustainable Expansion of the Cocoa Crop in the State of Pará and Its Contribution to Altered Areas Recovery and Fire Reduction. Journal of Geographic Information System, 14(3): https://doi.org/10.4236/jgis.2022.143016
- Verchot et al., 2007 and Mbow et al., 2014 in Vi Skogen. 2019. Agroforestry for Mitigation and Adaptation to Climate Change. Available online: https://www.siwi.org/wp-content/uploads/2020/02/Agroforestry-for-adapation-and-mitigation-to-climate-change_web.
- Vitalltech. (2021, 5 March). JBS cria programa para incentivar pecuaristas a elevar sustentabilidade em fazendas. https://vitalltechdobrasil.com.br/noticia/jbs-cria-programa-para-incentivar-pecuaristas-a-elevar-sustentabilidade-em-fazendas/
- Zu Ermgassen E K H J et al 2018 Results from on-the-ground efforts to promote sustainable cattle ranching in the Brazilian Amazon. Sustainability 2018, 10, no. 4: 1301.

GLOSSARY

- **Climate-smart Agriculture (CSA)**
  Solidaridad follows the Food and Agriculture Organization (FAO) definition of climate-smart agriculture (CSA): CSA is an approach that helps to guide the actions needed to transform and reorient agricultural systems to effectively support development and ensure food security in a changing climate. CSA aims to tackle three main objectives: sustainably increasing agricultural productivity and incomes; adapting and building resilience to climate change; and reducing and/or removing greenhouse gas emissions (e.g., through agriculture and land use change/deforestation, and by enhancing soil carbon sequestration). CSA is therefore inclusive of, but not limited to, deforestation-free production. It further generates additional benefits, including, among others: improving soil health through good practices, enhancing soil carbon and strengthening the resilience of agroecosystems to climate change.

- **GHG emissions:** GHG emissions, or Greenhouse Gas emissions, refer to the release of gases into the Earth's atmosphere that have the potential to trap heat and contribute to the greenhouse effect. The greenhouse effect is a natural phenomenon that helps regulate the Earth's temperature by trapping some of the heat from the sun, making the planet habitable. Greenhouse gases are generated by activities at all stages of agricultural value creation. Farm-based agricultural production (non-mechanical sources and sinks) may act as a carbon source (GHG emissions) or a sink (carbon sequestration in biomass and soils). The most common greenhouse gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gases. The accumulation of greenhouse gases is a major driver of global climate change and is responsible for the rising global temperatures, leading to phenomena like global warming, sea-level rise, and more frequent and severe weather events.

- **GHG mitigation:** Greenhouse gas mitigation is the amount of reduction or avoidance of GHG emissions and/or carbon sequestration (storage) achieved by a project/activity. A commodity-specific overview of the GHG mitigation potential is provided for a variety of interventions that can be part of a climate-smart package.

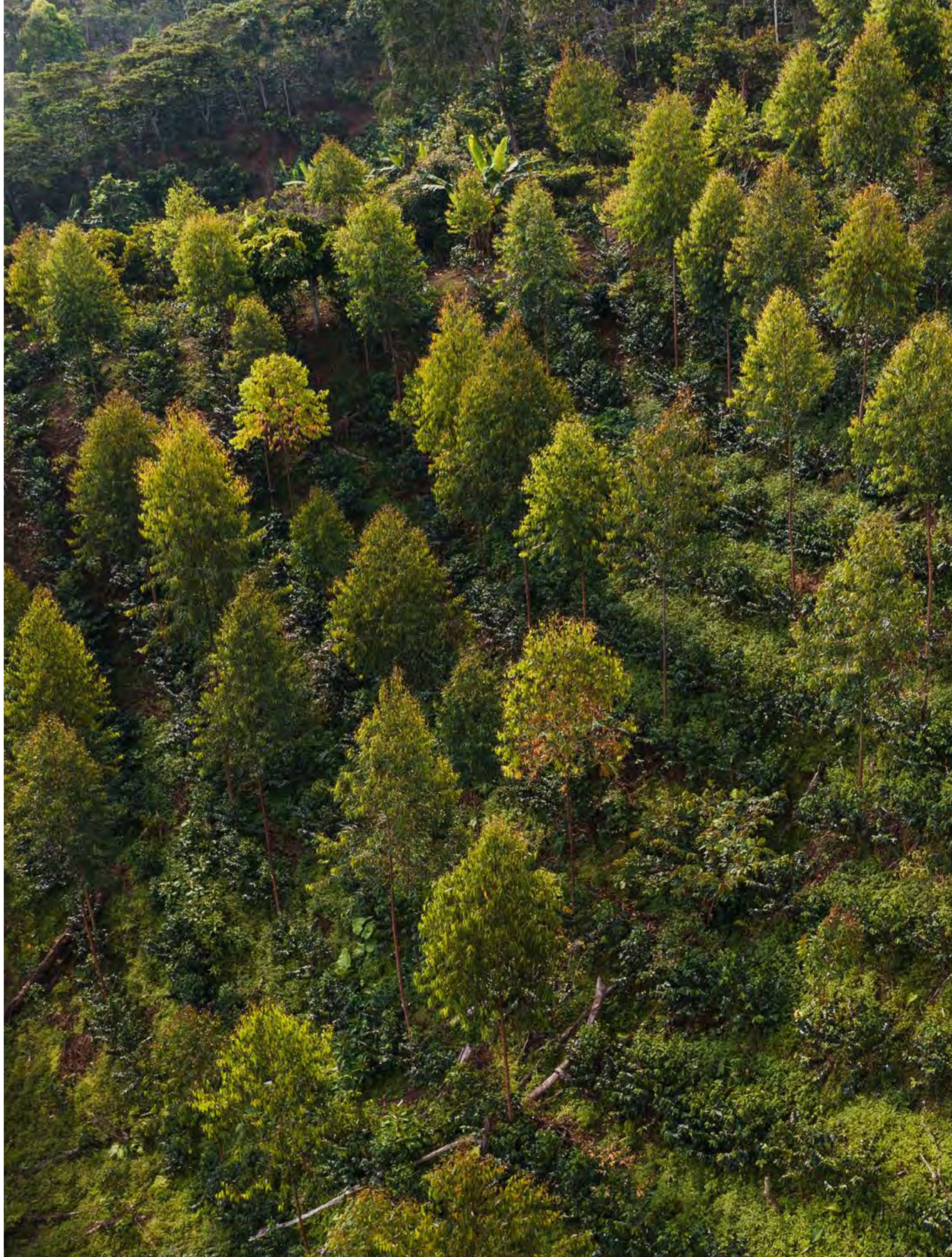
- **Biome:** Each of the large ecological communities in which a type of vegetation dominates; e.g., the Amazon rainforest, the tropical savannah of the Cerrado. efers to the production of commodities on farms that are no longer contributing to deforestation after an agreed cut-off date.

- **Deforestation-free production:** Refers to the production of commodities on farms that no longer contribute to deforestation after an agreed cut-off date.

- **Carbon balance:** The difference between the emission (release into the atmosphere) and sequestration (removal from the atmosphere) of greenhouse gasses (GHGs). A process with a positive balance emits more GHGs than it sequesters. A process with a negative balance sequesters more GHGs than it emits. A neutral balance indicates that emissions and sequestration are equal.

- **Carbon sequestration:** The process of capturing and storing the atmospheric carbon dioxide generated by activities at all stages of agricultural value creation. Farm-based agricultural production (non-mechanical sources and sinks) may act as a carbon source (GHG emissions) or a sink (carbon sequestration in biomass and soils).

- **Product traceability:** Every product has a set of characteristics that may be of interest to different actors in the chain. As chains continue to get longer, mechanisms and technologies are necessary to be able to communicate across all actors and steps involved, and to ensure that products are traceable or identifiable along the full extent of the chain.



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