



Book of Abstracts

Latest Research of Swiss Research Institutions

International Symposium on Cocoa Research

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Swiss Platform for
Sustainable Cocoa



International
Symposium on
Cocoa
Research

Foreword

The International Symposium on Cocoa Research is organized to provide a forum for the worldwide cocoa research community. At this event, experts from all over the world review and exchange on the latest research innovations to accelerate the development of the world cocoa economy.

Switzerland is home to many excellent research institutions that are leaders in the field of cocoa research. The Swiss Platform for Sustainable Cocoa (SWISSCO), as a multi-stakeholder initiative, is therefore pleased to present the latest research findings for our Sector E members (Research) in this Book of Abstracts.

There are still many challenges in the cocoa value chain as defined in the ICCO Global Cocoa Agenda and in our SWISSCO Roadmap 2030. To address these challenges effectively, the contributions of all member sectors represented in the SWISSCO are required in the sense of "shared responsibility". The research sector has a fundamental role to play. It contributes by exploring the complexities along the cocoa value chain, identifying innovative solutions and providing research resources for in-depth knowledge of the value chain. A vigorous research sector that provides robust data and sound analytics is therefore instrumental for an impact driven multistakeholder partnership.

This Book of Abstracts shows the variety of analytical inputs and solutions that have been developed by our research partners in recent years. It brings together issues from across the cocoa value chain, including socio-economics, gender, climate change adaptation and mitigation, production systems, governance, processing and sensory analysis. The multitude of topics highlights the importance to work on these most pressing challenges and close existing research gaps.

We would like to thank our members who submitted their abstracts and hope to contribute to the dialogue in the international research community. We look forward to future collective and collaborative action.



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Executive Director
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SOCIO-ECONOMICS



1. From Living Wage to Living Income: Economic Analysis of the Cocoa Value Chain in Ghana

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Abstract

What is the impact of living income concept implementation in Ghana on small-scale farmer's livelihood? How does productivity of farmers increase related to technic of farming improvement? And much more, what is the difference between farmers involved in this concept and those who are not? To answer these questions, we addressed a semi-structured questionnaire to 120 farmers in Kumasi region in Ghana. The data collection took place inside communities in Kumasi between October and November 2020. The analysis with R-studio helps to demonstrate 3 main categories of results. The first category, which is descriptive, is based on the socio-economic analysis of the group of people interviewed. It shown that there is no big difference between owners of farm. Most of the person living in each household depend on the income from cocoa production and other activities as trading and commerce. This is followed by the statistical analysis of the data on annual yield, income, certification and all the activities in which the producers are involved and that punctuate their lifestyle. To increase productivity, farmers use pesticides, followed by fertilisers, but also practice agroforestry. They are not benefiting from financial institution loans, but 50 % of them are certified through Cocoa life institution and assumed that they are not meeting living income expectations however there is a positive change of income. Finally, the third part is based on a comparative analysis of living standards over a period of time and the level of influence of financial institutions and cooperatives on production and recreation activities. Food, school fees and transportation are the most costing services to farmers. However, they are involved in majority in cooperative, they find credit from the cooperative and have a basic recreative activity. We assume that the proximity of schools in most of the case, could be one of reason of resilience of children in schools. The question on women leadership is nevertheless, mitigated. Women are strongly involved in the production activities but their encountering or segregation inside the community is mainly doubted.

Keywords: Cocoa, Living Income, Rural Development, Ghana

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2. Do Environmentally-Friendly Cocoa Farms Yield Social and Economic Co-benefits?

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Abstract

Downstream companies in chocolate supply chains are increasingly engaged in improving the sustainability of cocoa production, which requires a multidimensional understanding of cocoa farms' sustainability performance. However, prior research has insufficiently addressed the multiple sustainability dimensions of cocoa production or the interrelationships between dimensions. This study explores farm sustainability using our comprehensive data set of 395 cocoa farms in Ecuador and Uganda and identifies social and economic co-benefits and trade-offs of environmentally-friendly cocoa production. For this, farms were grouped according to their environmental performance followed by a comparison between subgroups regarding social and economic criteria. This approach revealed lowest sustainability performance in the social and governance dimension. We identified important social and economic co-benefits of environmentally-friendly cocoa production regarding human health benefits from reduced pesticide use and resource conservation for farms' long-term productivity, although at the expense of farm investments and profitability. Future interventions require approaches that target underrepresented sustainability issues and enable synergistic effects between environmental, social, and economic sustainability for cocoa farms.

Keywords: Cocoa, Sustainability, Global Value Chain, Co-Benefit, Trade-Off, SMART-Farm Tool

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3. A Natural Experiment on Cocoa Farm Management Under Increased Labour Availability During Covid

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Abstract

Cocoa is a predominantly smallholder crop with strong reliance on manual labour. Pest and disease management represents a major challenge and cocoa producers often resort to synthetic pesticides to secure their harvest. Due to pesticides' harmfulness and a growing demand for sustainable agricultural production and intensification, alternative pest and disease management practices are promoted among farmers. Yet these practices are more labour-intensive than synthetic pesticides, representing a limiting factor for their adoption. During the national Covid-19 lockdowns, Ugandan farming households experienced an increase in household labour from both school children not attending school and urban residents returning to their rural families. In a unique natural experiment setting comparing our own data from 2019 and 2021, we were able to test the relationship between household labour availability, pest and disease management practices, and pesticide use on Ugandan cocoa farms using qualitative and quantitative methods. Our results showed that household labour availability increased on average by 0.8 (± 2.5) household members and 22% of labour hours per hectare from 2019 to 2021. The share of farmers implementing alternative pest and disease management practices also increased significantly, yet pesticide quantities and expenditures remained roughly similar. Our results did not indicate a direct influence of increased household labour availability on pesticide use and expenditures. However, they showed that farms with increased household labour availability invested more time in alternative pest and disease management practices more often than farms without increased household labour availability. Farms implementing alternative practices like phytosanitary measures, in turn, had lower pesticide use and expenditures. These results indicate that increased household labour availability does not necessarily translate directly into more sustainable cocoa production. Alternative pest and disease management practices are an important pillar for pesticide-free cocoa production and their adoption should be further promoted and incentivised on cocoa farms.

Keywords: Cocoa, Uganda, Labour Availability, Sustainable Intensification, Pesticide Use

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4. Cacao Agroforestry Systems Have Higher Return on Labor Compared to Full-Sun Monocultures

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Abstract

The global demand for cacao has recently increased. To meet this demand, the cultivated area has been expanded in tropical forest areas and production has intensified by replacing traditional agroforestry systems with monocultures. This has led to a loss of biodiversity in cacao growing areas. More sustainable production systems such as agroforestry and organic managed systems are expected to yield less cacao, but by-crops and premium prices, respectively, might economically compensate for the lower yields. Here, we compared the productivity and the return on labor, that is the return per working day, of four different cacao production systems: agroforestry and monocultures under organic and conventional management. Cacao and by-crop yields, costs, revenues, and labor were registered during the first 5 years after establishment. Results show that cacao yields were, on average, 41% higher in monocultures, but the revenues derived from agroforestry by-crops economically overcompensated for this difference. Indeed, the return on labor across the years was roughly twice as high in the agroforestry systems compared to the monocultures. We found similar cacao yields and return on labor in conventional and organically managed agroforestry systems. However, in the monocultures, cacao yields were 48% lower under organic compared with conventional farming, but the return on labor was similar, mainly due to the higher costs associated to the conventional management. Overall, our findings show that cacao agroforestry systems have higher return on labor.

Keywords: Labour Demand, Long-Term Experiment, Organic Farming, Economic Analysis, Theobroma Cacao, Yield, Bolivia

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5. How Does Labour Availability Influence Pesticide Use on Cocoa Farms?

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Abstract

Pests and diseases represent a major challenge in cocoa production, which farmers commonly control using synthetic pesticides. Stricter residue regulations in cocoa importing countries and an increasing demand for sustainably produced cocoa generate pressure on chocolate manufacturers to source cocoa from production systems with little to no use of synthetic pesticides. Instead, alternative pest and disease management practices are promoted. The promoted practices, like manual weeding and phytosanitary measures, however, are often labour intensive. High prices for hired labour and an ageing cocoa farmer population due to youth migration to the cities limits labour availability on cocoa farms. So far, little knowledge exists about the relationship between labour availability and sustainable cocoa production. In this study, we thus aim to find answers to the question: How does an increase of labour availability contribute to reducing synthetic pesticide use among cocoa farmers? We hypothesise that the amount of available farm labour is positively associated with a reduction of pesticide use and an increase in alternative pest and disease management practices. We test our hypothesis using a natural experiment within a sample of Ugandan cocoa farmers. As a response to the COVID-19 pandemic, the Ugandan government imposed two national lockdowns, due to which urban workers and students returned to their rural homes, generating changes in available farm labour. We interviewed a sample of Ugandan cocoa farmers just before the outbreak of the COVID-19 pandemic and repeated farmer interviews in 2022. Comparing the 2019 and 2021 data, we will test the relationship between labour availability and pesticide use as well as alternative pest and disease management practices on farms as outcome variables. This is done using a difference-in-difference approach with entropy weights to estimate the causal effect of available labour on the outcome variables, controlling for multiple factors that could affect them like training participation and perceived pest and disease pressure. First insights into the data support our assumption that higher family labour availability increased time investments in both food and cash crop management including cocoa, however detailed data analysis is pending to confirm a consequent reduction in synthetic pesticides. Our results will contribute to the knowledge about the relevance of labour for sustainable cocoa production and thus inform the development of future private and public sustainability initiatives.

Keywords: Cocoa, Uganda, Labour Availability, Sustainable Production, Pesticide Use

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GENDER





6. A Gender Perspective on Direct Trade and Livelihoods of Cocoa Farming Households

A Case Study of Cocoa Farming Households in Bundibugyo, Uganda

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Abstract

Women play a significant role in cocoa cultivation. Nevertheless, women often have less access to important resources in cocoa farming, like land, finances, and training, in comparison to their male partners. Recently, direct trade relations between cocoa farmers and chocolate producers are promoted as a way to secure higher income for cocoa farmers. The question arises if direct trade positively affects cocoa farmers and their households in general and specifically, women in cocoa farming. Given these considerations, a case study in Bundibugyo with farmers selling their cocoa beans to a direct trading company was conducted. A household survey with 84 households involved in cocoa farming (25 = female-headed, 59 = male-headed) was conducted to compare livelihood endowments between these households. 15 semi-structured interviews had been carried out with male and female farmers and an employee of a direct trade company sourcing cocoa from Bundibugyo. The livelihood assessment showed that female-headed households were less well-endowed with livelihood capitals and women received lower education and annual income. In general, the farming households benefited from direct trade, however, as farmers were not organized e.g., in cooperatives dependencies on the trading company were quite strong. The women's position in cocoa farming could not be noticeably improved. In an environment where gender roles impede female farmers' possibilities, direct trading companies would have to define targeted measures to support the empowerment of women in cocoa cultivation.

Keywords: Cocoa Cultivation, Gender Differences, Women in Cocoa Farming, Direct Trade

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7. Gender Inequality in the Cocoa Supply Chain: Evidence from Smallholder Production in Ecuador and Uganda

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Abstract

Most cocoa is grown by smallholder farmers whose livelihoods depend largely on the income from cocoa. Today, cocoa production must increasingly comply with social and environmental requirements as the worldwide demand for sustainably produced cocoa is growing steadily. There is, however, insufficient information available on whether the sourced cocoa is produced under gender-equitable conditions. We address this by examining two cocoa supply chains using our own sex-disaggregated survey data from producing communities in Ecuador and Uganda that supply the Swiss market, using descriptive and inferential statistics. Our results show that women in Uganda were highly involved in cocoa production on both male and female managed farms, but their decision-making power was limited to female managed farms. In Ecuador, women were moderately engaged in decision-making yet participated less in cocoa production. Our log-linear regression analyses for both cases showed substantial differences in annual cocoa revenues of farms managed by women compared to those managed by men. Several socio-economic and agronomic factors for which women face structural inequalities largely explain the revenue gap, such as poorer access to productive resources. Indeed, our findings suggest that cocoa production is characterised by high levels of gender inequality, suggesting that private and public sustainability efforts do not sufficiently address gender discrimination. These findings can help design interventions for more gender-equitable rural development that address the complexity of disadvantages in the local context. Offering gender-specific trainings within private programs and promoting women's access to credit by the public sector represent first steps towards gender equality.

Keywords: Gender Roles, Food Systems, Revenue, Sustainable Supply Chains, Decision-Making, Women's Empowerment

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8. The Contribution of Inclusive Cocoa Value Chain Initiatives to Environmental Justice for Women in Peru

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Abstract

Inclusive value chain (IVC) initiatives are one of the most prominent approaches to promote the well-being of small-scale farmers, incl. in the cocoa sector. However, studies have shown that their effect on women is mixed. Given the current gender inequalities in Peruvian society and the cocoa sector, but also the potential of IVC initiatives to address those differences, this Master's thesis assessed a) the extent to which Peruvian cocoa cooperatives contribute to environmental justice (EJ) for their female stakeholders and b) how the cooperatives address gender inequalities. The analytical framework combined elements from EJ and IVC literature, as well as previous work regarding gender in both fields. Innovatively, EJ was used as an analytical lens to study environmental benefits rather than environmental burdens or conflicts. The explorative multiple case study research focused on five cocoa cooperatives and one all-women association producing cocoa derivatives. The analysis mainly relied on data collected through 41 semi-structured interviews with cooperative managers and employees, as well as with male and female members of affiliated households. The results show that women benefit less from cocoa cooperatives, have a lower participation, and tend to be misrecognized by themselves and others in terms of their contribution and capabilities. However, the study also demonstrates that cooperatives are addressing gender issues and have the potential to positively impact gender equality for their female stakeholders on a cooperative, household and community level. Concrete best practices include workshops, the generation of income opportunities for women, increasing the rights of partners of official members within the cooperatives, and the introduction of quotas for women in leadership positions. If such efforts are reinforced and gender strategies continuously implemented, IVC initiatives such as cocoa cooperatives have the potential to improve the EJ outcome for women within the organization, their families, and the community at large.

Keywords: Cocoa, Cooperative, Environmental Justice, Gender, Gender Equality, Inclusive Value Chain, Peru

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CLIMATE CHANGE



9. Fairtrade and Climate Change: Analyzing Impacts on Cocoa Producers in Ghana

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Abstract

Climate change is expected to severely impact agricultural production in the future. Identifying future climate change impacts on certified agricultural producers remains a challenging task. On the one side, there is numerous case-study evidence on past climate change impacts for different regions and crops. Such knowledge is however not always transferrable to other regions. On the other side, global studies on potential climate change impacts on main agricultural products present an overview of potential future impacts, while neglecting regional economic, cultural, and biophysical contexts. The aim of this study was to understand climate change *impacts* on farmers and cooperatives and how well climate change projects are *addressing* the farmers and the cooperative's needs. A combination of different methods including a systematic review of the documentation and a hotspot analysis was key to generate a deep understanding on the impacts of climate change on Fairtrade cocoa producers in Ghana. By synthesizing spatially explicit data from global climate change models for a world-wide analysis of climate change impacts on different crops, a pattern is observed, where most locations of current cocoa production will experience more days with extreme temperatures under a low emission scenario. Under a high-emission scenario, all cocoa producing locations will experience considerably more heat stress. Fairtrade production regions seem to be less affected by climate change indicators (consecutive dry days, warm spell duration index, extreme rainfall events) compared to other, non-Fairtrade production regions for the same crops. Results of interviews with Fairtrade Producers Organization Managers and a standardized producer survey indicate that farmers are aware of severe changes which demand a shift in their agricultural practices and livelihoods. In comparison to other crops in the identified hotspot areas, cocoa farmers reported the severest climate change impacts, particularly a negative effect on yields. Mitigation strategies include planting shade trees and implementing improved agricultural practices. Overall responses and the degree of changes in practices vary considerably between producers. Nevertheless, the need for further farmer-inclusive trials and further adaptations of agricultural practices come alongside economic needs intensified by the unstable context related to Covid-19, which fall disproportionately onto disadvantaged producers.

Keywords: Cocoa Production, Climate Change, Fairtrade, Adaptation, Mitigation, Ghana

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10. Estimation of Aerial Biomass and Carbon Capture in Cocoa (*Theobroma Cacao*) Plants of Different Ages in the Northeast of Antioquia, Colombia

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Abstract

Changes in land use, forest degradation, and unsustainable increase in agricultural production are some of the actions that carry out a higher greenhouse gases accumulation, especially of CO₂, which contributes to global warming. Faced with this problem, options have been sought for both; a reduction in CO₂ emissions and an increase of activities that do better at carbon sequestration. Cocoa agroforestry systems (AFS), have an important potential for carbon storage, making them one of the main alternatives as atmospheric CO₂ sinks since plants throughout the photosynthesis process are responsible for most of the carbon fixation. For this purpose, it is essential to calculate the existing biomass so it will be possible to calculate the storage capacity of the trees. The objective of this study was to calculate the aerial biomass of small cocoa plantations with or without agroforestry system at different age ranges: < 5 years; between 5 and 15 years; and > 15 years, implementing an indirect method using allometric equations. For gathering the required information, 13 small cocoa producers were selected and 115 circular plots of 500 m² were established in their productive units. To calculate the aerial biomass and subsequently estimate how much carbon these cocoa plantations captured, variables such as diameter, the height of the trees, vegetation coverage percentage, and slope gradient were taken, and each plot was georeferenced. A total of 4,744 trees were measured, of which 4,342 were cocoa trees and 402 were forest, fruit, and coffee trees. Significant differences in carbon sequestration were observed between cocoa plantations with and without AFS in the different age ranges, being higher in those plots with AFS. Specifically, a difference of 133,3 TCO₂e between monoculture of > 15 years vs AFS in the same age range. Even though the plant component reaches a point of equilibrium over time, slowing the rate of biomass production and carbon sequestration, it is given for granted that AFS could be an important part of the environmental and economic development of cocoa producers. This allows small producers throughout the scheme of payments for environmental services, generating economic incentives and in-kind benefits for their work in conservation and GHG reduction through a direct relationship between the producer and the entities interested in offsetting their emissions.

Keywords: Carbon Sequestration, Agroforestry Systems, Theobroma Cacao

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11. Cocoa and By-Crop Yields in Three Organic Production Systems Entering Mature Stage

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Abstract

Agroforestry systems for cocoa production are commonly promoted for biodiversity conservation, climate change mitigation and adaptation as well as for food security and risk mitigation. Generally, these systems include timber, legume or fruit trees. Successional or dynamic agroforestry systems represent a special type of design and management approach, using high densities and diversity of trees and crops occupying different strata and with varying life cycles. Here we present yields of three organic cocoa production systems entering the mature stage from a long-term trial in Bolivia: A complex successional dynamic agroforestry system (SAFS), a simpler but diversified agroforestry system (AF ORG) and a cocoa monoculture (MONO ORG). Average cocoa yields in the mature phase (9-11 years) were highest in MONO ORG (1520 kg/ha), followed by the AF ORG (910 kg/ha), and lowest in SAFS (790 kg/ha) (yields considering the 8 best yielding clones out of 12. Total system yields in both types of agroforestry systems (dry matter) were 3.5 to 4 times higher than in monocultures over the 11 years. This was mainly due to banana production in AF ORG and from a multitude of by-crops in SAFS. While in young SAFS (until 8 years) crops like cassava, and pineapple were contributing to total yields, peach palm was the most relevant by-crop in the mature phase with around 4 t/ha fresh yields. Additional interesting crops were ginger and curcuma, that growing under the cocoa in SAFS yielded around 1 kg of fresh tubers per m². The results demonstrate how different crops can be associated with cocoa while still reaching elevated cocoa yields. The potential of agroforestry systems to sustainably intensify production on one surface is high and could still be optimised with the use of improved and locally selected varieties of cocoa and by-crops. Different designs of agroforestry systems can contribute to diversification of diets and incomes of producing families and regions.

Keywords: Cacao Production, By-Crops, Associated Crops, Agroforestry Systems, Dynamic Agroforestry, Long-Term Experiment, Organic Farming, Theobroma Cacao, Yield, Productivity, Bolivia

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12. Carbon Sequestration Potential of Cocoa Agroforestry Systems in Caldas and Antioquia, Colombia

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Abstract

Agroforestry systems provide essential ecosystem services – enhanced carbon sequestration is one of them. The aim of this thesis was to assess the carbon stocks, sequestration potential and feasibility for carbon valuation on Hacienda La Tentación, a commercial cocoa agroforestry plantation in Caldas, and for 112 small-to-medium sized cocoa producers in Antioquia. In order to do so, the diameter and height of cocoa and shade trees on 45 sample plots on Hacienda La Tentación was measured and aboveground carbon stocks were estimated based on allometric models. In Antioquia, field surveys on variables relevant to carbon sequestration were conducted. Aboveground carbon stocks were estimated based on measurements of representative cocoa and shade trees. The sample plots on Hacienda La Tentación indicated a mean living aboveground carbon stock of 30.82 ± 22.23 t C ha⁻¹ of which 91 % was stored in shade trees. In Antioquia, the estimated mean living aboveground carbon stock was 12.41 ± 25.25 t C ha⁻¹ of which 68 % was stored in shade trees. There was a great variety in aboveground carbon stocks on Hacienda La Tentación (0.84 t C ha⁻¹ to 134.24 t C ha⁻¹) as well as with surveyed cocoa producers in Antioquia (1 t C ha⁻¹ to more than 80 t C ha⁻¹). Both the cocoa systems in Antioquia and on Hacienda La Tentación have not reached maturity and will therefore sequester more carbon during their rotation. However, there is potential to further increase carbon sequestration through the introduction of shade trees to non or only partially shaded systems, expansion of cocoa agroforests or forest plantations on pasture or through the replacement of unproductive cocoa lots with either new cocoa or timber trees. The largest potential for a carbon offset project lies with the 112 cocoa producers in Antioquia which have a total farm area of 1'778 ha including cocoa on 411.5 ha. The cocoa producers in Antioquia were questioned regarding their interest in carbon offset activities on their farms. 24 % of farmers have stated interest in restoring degraded forest ecosystems with native trees, 13 % were interested in expanding the area under cocoa cultivation and 6 % in introducing additional shade trees. In order to increase the feasibility of carbon offset projects, developers need to reduce transaction costs, understand their target market, diversify revenue sources and follow best practice principles.

Keywords: Cocoa Agroforestry, Carbon Offsetting, Colombia

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13. Climate Resilient Cocoa Landscapes in Madagascar: Monitoring Social Learning Towards a Functional Watershed Management Committee

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Abstract

Sustainable cocoa production in combination with biodiversity conservation can only be ensured if stakeholders from different sectors, representing civil society, private sector, and national and local authorities have one common strategy. Social learning is learning from each other through the collective sharing of experience, information, knowledge and collective decision-making. The goal of monitoring of the social learning among stakeholders during participative processes are ownership and acceptance of the project, the management approach and the documents generated for natural resource management. In the context of the climate resilient cocoa landscapes in Madagascar project, we monitored social learning via learning dimensions and factors throughout participative processes. We designed learning protocol and interviews that helped to observe and understand participants' learning as well as the factors encouraging (or not) social learnings. Preliminary results show that participants learn from each other via cognitive, normative, relational, and socio-emotional dimensions through time and repetitive participations. These learnings depend on different factors such diversification of participants, format of participation, access to information, facilitation, and the context. The process of social learning is fostering participation and appropriation of the project although power relation and unequal motivation among participants prevail. As social learning is currently seen as a key element in the transition to sustainability, monitoring and encouraging it is a way to overcome the difficulties of decision-making processes. Further, the implementation of an adequate planning instrument that considers the competing interests in multifunctional landscape and foster institutional anchorage.

Keywords: Cocoa Landscape, Climate Resilient, Social Learning, Watershed Management Committee, Sambirano, Madagascar

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14. Dynamic Agroforestry – A Tool for Successful Smallholder-Grown Cocoa in Times of Climate Uncertainty

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Abstract

More than half of the world's cocoa (*Theobroma cacao*) grows in monoculture-like systems in West Africa that are vulnerable to climate change. Dynamic agroforestry (DAF) –an approach developed in Brazil characterized by a high turnover of biomass due to high plant diversity and density, pruning intensity and systematic stratification –has the potential to restore soil fertility, mitigate and adapt to climate change, whilst improving the livelihoods of millions of smallholders. However, we need more knowledge about the acceptance of DAF by West African farmers and about the factors ensuring its socio-economic sustainability. We conducted bio-physical and socio-economic research in two DAF projects in the Eastern and Western Regions of Ghana from 2018 to 2021 and compared the results to traditional cocoa cultivation. We observed a significant improvement of soil fertility under DAF in the first four years after planting. Cocoa vigour and survival rate were significantly higher in DAF, which strongly correlated with lower air temperature amplitude, as well as lower temperature and higher moisture content in the topsoil. Significantly higher plant diversity of shade trees compared to traditional plots demonstrated the high ecological value of DAF. In the first year of establishment, DAF needed substantial investment and labour. Data from several years after planting is being put together to get a more comprehensive picture of the productivity and profitability of the systems. The results of several workshops and a survey with some 600 farmers on adoption constraints of DAF suggest that the main hindrances for large-scale adoption of DAF are financial and logistical challenges associated with the quantity and diversity of planting materials, stressing that cooperation among value chain actors and an effective incentive scheme are key for successful implementation of DAF on a large scale.

Keywords: Dynamic Agroforestry, Climate Change Mitigation and Adaptation, Socio-Economic Sustainability

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PRODUCTION SYSTEM



15. Cadmium in Cocoa: Assessment of Challenges and Mitigation Strategies to Support Smallholder Farmers in Colombia

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Abstract

Many Colombian smallholder farmers live in vulnerable contexts, affected by decades of conflict. Around 100'000 depend on cacao as main income. Many more farmers could benefit from cultivating cacao as legal alternative to illicit crops. However, cadmium, a heavy metal which in certain doses is highly toxic for humans presents a challenge. With recent research indicating even higher negative health impacts than assumed, new regulations regarding the cadmium content of food have emerged. Amongst others, the European Union introduced cadmium limits for cacao-based products in 2019. Consequently, farmers might lose their income when not being able to sell cacao due to elevated cadmium levels. Latin America is particularly affected, including Colombia. While the region is known for high-quality cacao, some of its cacao has shown relatively high cadmium values. To exploit the cacao's economic and social potential for thousands of smallholders, effective cadmium mitigation solutions are urgently needed. The investigation assessed challenges and prioritizes approaches of Colombian cacao stakeholders to mitigate cadmium levels of soils, cacao beans and final products. The research was conducted in cooperation with Swisscontact who leads the development of a national cadmium mitigation strategy. Based on a case study approach, qualitative data were collected in October and November 2019: 17 stakeholder interviews and two farm visits were conducted, and several workshops and roundtables attended. Data analysis followed the qualitative content analysis approach. An analysis of the Colombian cacao value chain and cadmium values in different regions points out the main challenges regarding cadmium. It is shown that the EU regulation has not yet directly impacted the sector economically. However, indirect economic impacts such as damage to the brand of Colombian cacao are felt. Future impacts are expected, including serious negative social impacts for farmers who would not have income alternatives. The assessment of mitigation approaches shows a remarkable scope of projects being conducted by national stakeholders. A prioritization matrix based on effectiveness, acceptability and implementation indicates several high potential mitigation measures, but also stresses the need for more research, particularly for field testing. A main recommendation is to integrate technical mitigation strategies into a holistic value chain approach, tackling challenges such as low productivity and quality. Such approach would include an increased focus on participatory research, improved extension services, more systematic communication, and continuing stakeholder coordination. The national cadmium strategy addresses most of these aspects, and is hence key in supporting farmers, industry, policy, and research.

Keywords: Cacao, Cadmium, Colombia, Smallholders, Value Chains

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16. The Role of Shade Tree Pruning in Cocoa Agroforestry Systems: Agronomic and Economic Benefits

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Abstract

Cocoa-based agroforests are promoted to replace monocultures for the provision of ecosystem services. However, shade tree pruning, an important tool to sustain cocoa yields, is not commonly implemented. This study investigates the effect of pruning on both agronomic and economic performance. In Bolivia, four farmers' sites were divided in half, and shade trees pruned in one of the two plots. Pruning resulted in a significant increase in cocoa yield, from an average of 430 to 710 kg ha⁻¹ by boosting flowering and pod production, but not reducing the proportion of damaged pods, and of those lost to cherville wilt. Additionally, scenario calculations using international and organic premium cocoa prices were conducted to evaluate the economic feasibility of pruning. The minimum, mean and maximum yield of 22 local cocoa-based agroforestry farms were used as reference for 25%, 50% and 75% yield increase scenarios. Offsetting the pruning costs highly depended on the initial yield levels. Using the minimum yield, all scenarios led to a lower net income compared with no pruning. For the mean yield level, the net income was equal to that obtained without pruning when the yield increase was above 51%. At the maximum yield level, all increase scenarios resulted in a higher net income. Our results prove the importance of pruning to increase cocoa yields, which is needed to meet the growing demand. However, farmers alone cannot cover the extra management costs. The cocoa sector should discuss different strategies to support pruning for a broader adoption of agroforests.

Keywords: Canopy Closure, Flowering, Yield, Pest and Disease, Income

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17. What Impact Does Centralised Fermentation Have on Smallholder Cocoa Farmers in Côte d'Ivoire

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Abstract

Within the frame of the Swiss Platform for Sustainable Cocoa, CABOZ AG, in collaboration with the Sustainable Agroecosystems Group (SAE) and the Transdisciplinarity Lab (TdLab) of ETH Zurich, launched the project “Village post-harvest processing and farmer support centres” in 2019, funded by the Swiss State Secretariat for Economic Affairs (SECO). The key element of the project is the provision of cocoa fermentation centres. The project has been implemented and managed by SCOPACI (cooperative of CABOZ AG) Côte d'Ivoire and evaluated by ETH Zurich. The objective of the monitoring and evaluation was to study the effects of the fermentation centres, considering social, economic and ecologic aspects. Qualitative and quantitative methods were used to compare farmers using the centres with those not using them. Data were collected over a three-year period through 286 interviews with farmers in 21 different villages, six focus group discussions in three villages, and six interviews with cocoa buyers, known as ‘pisteurs’. The results show that not fermenting one’s own cocoa is not for everyone and that it is difficult to change an age-old habit, despite the many advantages of fermentation centres. The interest of farmers is related to the amount of premiums they receive at the fermentation centre and how well the logistics are organized. After the three years of the project, no impact on farmers’ income, investments, or productivity was observed. However, the close collaboration of the cooperative staff with the cocoa farmers has increased their trust in and satisfaction with the cooperative. However, this satisfaction is not reflected in perceptions about the future of cocoa farming. The percentage of farmers who want their children to continue cocoa farming has steadily declined. In general, the project shows some positive impacts on farmers, however, for many outcomes it is still too early to draw conclusions.

Keywords: Monitoring, Evaluation, Cocoa, Post-Harvest, Centralised Fermentation

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18. Farm Resilience in Organic and Nonorganic Cocoa Farming Systems in Alto Beni, Bolivia

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Abstract

Cocoa production in Alto Beni, Bolivia, is a major source of income and is severely affected by climate change impacts and other stress factors. Resilient farming systems are, thus, important for local families. This study compares indicators for social–ecological resilience in 30 organic and 22 nonorganic cocoa farms of Alto Beni. Organic farms had a higher tree and crop diversity, higher yields and incomes, more social connectedness, and participated in more courses on cocoa cultivation. Resilience was enhanced by local farmers' organizations, providing organic certification and supporting diversified agroforestry with seedlings and extension, going beyond basic organic certification requirements.

Keywords: Farm Resilience, Adaptation to Climate Change, Agroforestry, Cocoa, Organic Agriculture, Bolivia

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19. Participatory Agroforestry Design – A Flexible Approach for Locally Adapted Systems: Experience from Alto Huayabamba, Peru

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Abstract

We present a method for participatory design of agroforestry systems, based on a process of sharing experiences, visiting inspiring models of agroforestry, definition of individual goals, assessment of resources and evaluation of the opportunities in each individual situation for diversifying production. In the design stage, species and crops to be combined with cocoa are evaluated in a participatory manner between farmers and technicians, based on different criteria like market possibilities, preferences for subsistence production, strata, life cycle, etc. The process can be supported by different visualization tools, especially if presence in the field is not possible. Feedback from technicians or consultants on the design is critical. Locally available data on yields, prices and labour time needed for different crops can further refine the species and their numbers to be planted. We have applied this approach for the design of demonstration plots in Peru, Alto Huayabamba, as well as a part of training of trainers, with high rate of engagement and adoption. Inspiration, peers' experience sharing and visual tools were extremely important in the process. The fact that the farmers design their agroforestry farm by themselves with just a guidance of technicians, make the system more approachable, holistic and sustainable compared to traditional agroforestry projects. The method does not limit itself only to cocoa but can also be applied to other crops suitable for agroforestry. Nevertheless, as each of the cases is individual, the time spent on such design makes it challenging to be applied on a large scale at the moment.

Keywords: Co-Design, Agroforestry Systems, Planning, Adoption, Methodology

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20. Selection of Different Cacao (*Theobroma Cacao*, *Malvaceae*) Production Systems by Birds in Alto Beni, Bolivia - A Cafeteria Experiment in the Field

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Abstract

The cacao (*Theobroma cacao*, *Malvaceae*) is a native species to South America, and its plantation is considered to play an important role in the conservation of biodiversity. We studied the birds' selection among five cacao production systems and fallow, using a cafeteria experiment in Alto Beni, Bolivia. The birds were quantified by a modified point count during the dry season. During the study we recorded 239 visits of 43 bird species belonging to 18 families. The number of species and the frequency of birds' visits were positively related to the complexity of vegetation structure and tree diversity, decreasing from fallow, successional agroforestry system (SAFS), agroforestry systems to monoculture plantations ($\beta_1 = -0.149$ \square 0.046 for the number of species, $\beta_1 = -0.167$ \square 0.078 for the frequency of visits). In the monocultures the number of species was reduced to the half of that found in the fallow plots. In conventional plots, the frequency of birds' visits decreased to 37-46% of that observed in the fallow plots. The bird composition was similar between the SAFS and the fallow, suggesting that the SAFS, having a diverse vegetation structure, provides resources similar to the fallow. It is important to encourage complex cacao agroforestry systems for the bird conservation in agricultural landscapes.

Keywords: Alto Beni, Birds' Habitat Selection, Cacao, Comparison of Agricultural Production Systems, Successional Agroforestry System

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21. Cacao Agroforestry Systems Do Not Increase Pest and Disease Incidence Compared with Monocultures under Good Cultural Management Practices

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Abstract

Pests and diseases threaten cacao production worldwide. Agroforestry systems are traditionally seen by farmers as one of the causes of increased pest and disease incidence, in contrast with full-sun monocultures. Cultural management practices—e.g. regular tree pruning, frequent pod harvest, regular removal of infested pods, weed management—have been reported to be crucial for pest and disease management. We performed two experiments for the purpose of assessing the effect of (i) different cacao production systems, and (ii) the frequency of harvest and removal of infested pods on the incidence of pests and diseases and on the cacao yield. The first experiment was performed in a long-term system comparison trial in Bolivia, where data on pest and disease incidence were recorded for three years in five production systems: two monocultures and two agroforestry system under organic and conventional farming, and one successional agroforestry system, i.e. a high tree density multi-strata system. Pest and disease management did not differ between systems and relied on cultural management practices. Overall, the incidence of pests and diseases did not differ between production systems, which indicated they were not the driver of yield differences between them. Across production systems, only 14% of the pods were affected by pests and diseases; 70% of these were affected by frosty pod rot. More than 80% of the pods infected by frosty pod rot were removed before the sporulation phase. In the second experiment, the effects of the frequency of harvest and removal of infected pods—every 15 days versus every 25 days—on pest and disease incidence and yield were tested in four farmers' fields. Fortnightly harvest and diseased pod removal significantly decreased disease incidence and increased cacao yield, by 25% and 46% respectively. Our results show that cacao agroforestry systems do not increase pest and disease incidence compared with monocultures when good cultural management practices are implemented, which, in turn, can increase the productivity of the cacao plantations.

Keywords: Labour Time, Long-Term System Comparison, Organic Farming, Frosty Pod Rot, Phytosanitary Inspection, Theobroma Cacao, Yield, On-Farm Trial

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22. Cocoa And Total System Yields of Organic and Conventional Agroforestry vs. Monoculture Systems in a Long-Term Field Trial in Bolivia

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Abstract

Cocoa (*Theobroma cacao* L.) is produced in systems of varying complexity ranging from monoculture with temporary shade to highly diverse agroforests. Producers have to weigh high cocoa yields in the short to medium term in monocultures against higher total system yields in the short term and sustainable production systems in the long term in conjunction with ecosystem services in agroforestry systems (AFs). More long-term data on the comparative agronomic, economic and ecological performance of differently managed cocoa production systems is required to make sound recommendations to farmers. This paper describes the only long-term field trial worldwide comparing different cocoa production systems under conventional and organic management. The factors (i) crop diversity (monoculture vs. agroforestry), (ii) management practice (conventional vs. organic) and (iii) cultivar are being tested in a full-factorial, randomized complete block design with four replications. First, results showed significantly faster development of trunk circumferences in monocultures (+21%) compared to AFs. Cocoa yields were 47% lower in the organic compared to the conventional monoculture. In the AFs, however, the organic-conventional yield gap was less pronounced (-16%) and statistically insignificant. The cumulative yields of all products harvested were significantly higher in the AFs (+161%) compared to the monocultures. The productivity of cocoa by-crops in AFs may contribute to local food security and risk distribution in smallholder contexts.

Keywords: Long Term Comparison, Theobroma Cacao, Agroforestry Systems, Production System

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23. Crop-Diversification and Organic Management Increase the Energy Efficiency of Cacao Plantations

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Abstract

The increasing global demand for chocolate and related products has intensified their production systems by both replacing traditional agroforestry systems with monocultures and increasing the use of synthetic external inputs and machinery. High dependence on non-renewable energy is a clear symptom of unsustainability in food production systems. Consequently, more sustainable agricultural practices should be promoted. With a special focus on non-renewable energy, this work compares: i) the cumulative energy demand (CED), ii) energy return on investment (EROI), and iii) energy return on labour of four different cacao production systems: two agroforestry systems and two monocultures under organic and conventional management. Cacao and subproduct yields and the use of labour and external inputs were recorded during the first five years after the establishment of the trial in Bolivia. Results show that CED per hectare was almost 2-fold higher in monocultures than in agroforestry systems. With regard to the kilograms of cacao produced, the higher number of inputs used in monocultures was compensated by a higher cacao output. However, when subproducts were also taken into account, non-renewable CED was 7.4 times higher in monocultures, and non-renewable EROI increased up to 4.8 times in agroforestry systems compared to monocultures. Under organic management, less than 10% of CED was from non-renewable sources, while it reached 75% in conventional systems. Non-renewable EROI was higher under organic management, both when only cacao was considered and when subproducts were also included. Productivity per hour worked and per energy unit of labour invested were both higher in agroforestry systems than in monocultures. In conclusion, diversification of production and organic management are crucial to increase EROI and diminish dependence on non-renewable energy sources of cacao plantations.

Keywords: Energy Analysis, EROI, Agroforestry Systems, Subproducts, Energy Return on Labour

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24. Will They Ever Emerge From the Shadow? An Analysis of Which Intrinsic and Extrinsic Factors Determine Shade Tree Incorporation into Cocoa Plantations in Soubré, Côte D'Ivoire

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Abstract

This master's thesis examined the intrinsic and extrinsic factors which determine the incorporation of shade trees into cocoa fields of CABOZ-affiliated farmers in Soubré, Côte d'Ivoire. Current research indicates that cocoa production under shade coverage has several ecological advantages, e.g., strengthened water retention, increased biodiversity, and pollination, as well as enhanced climate resilience. To capitalize on these advantages and to mitigate the detrimental climate effects of cocoa production, the cocoa industry has begun in recent years to (re-)introduce shade trees into today's prevalent monoculture cocoa fields in Côte d'Ivoire. One example is the small cocoa company CABOZ AG which distributes shade tree seedlings among its affiliated farmers. A recent evaluation conducted by CABOZ AG reveals that most of the distributed shade tree seedlings perished within the first 12 months after planting. Developing a better understanding of why shade tree seedlings perished was the core objective of this master's thesis. Based on a thorough literature review, the thesis tests the hypothesis that the farmers' negative attitude towards shade trees explains their low survival rates on cocoa fields. A robust test of this hypothesis required extensive data collection. To this end, 295 interviews with CABOZ-affiliated cocoa farmers around Soubré were conducted in July and August 2021. The interviews held with these 295 farmers indicate that cocoa farmers acknowledge the multiple benefits of shade trees and are willing to plant and maintain them in the immediate future. This strong positive attitude of farmers towards shade trees runs counter to the thesis' core hypothesis. The study discusses five potential explanations to account for this puzzle. Two of the rationales offered evolve around farmers' concerns about the disadvantages of incorporating shade trees and the lack of financial reward for doing so.

Keywords: Shade Trees, Agroforestry, Intrinsic Factors, Cocoa Farmers, Attitude

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25. A Short-Term Interdisciplinary Study on the Adoption and Diffusion of Dynamics Agroforestry for Cocoa Small-Scale Farmers in Ghana Western North Region

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Abstract

Ghana is the second largest cocoa (*Theobroma cacao* L.) producer in the world. Its economy heavily relies on this industry, since 800,000 households directly gain their income from cocoa production. The national production is assured by small-scale farmers with contrasting farming practices ranging from full-sun monoculture to complex agroforestry. On average, their productivity per hectare is low mainly due to soil mining, pest and disease and aging tree stock, which leads to forest conversion being employed as the main driver for growth at significant social and ecological costs. To remain a global leader, Ghana needs a profound structural change in its agricultural model. Dynamic agroforestry (DAF) – defined as a spatially and temporally well-planned system that mimics a high productive juvenile forest through key management practices – may an important element of this change, which may allow farmers to intensify cocoa productivity while restoring their degraded lands. Cocoa DAF is currently being tested by different interventions in Ghana, one of which is the SANKOFA project, which is implemented in collaboration with the Kuapa Kokoo Farmers Union (KKFU) on 400 farms in the Western North Region of Ghana. This master thesis aimed at evaluating the degree of adoption of DAF among participants of the project and its feasibility in the region. The DAF technology was split into practices and evaluated with quantitative (569 surveys) and qualitative (24 interviews) tools on a non-randomly sampled population. Our results suggest the most influential variables for adoption were “drought” as well as “pest and diseases” as perceived by the farmers. The study also revealed the following shortcomings of DAFS impairing its adoption at farmer, project and institutional levels, respectively: lack of appropriate integrated pest management strategies and subsidies for labour; poor distribution systems of planting materials, lack of weather forecasting systems and disregard of indigenous knowledge; insufficient coordination with COCOBOD and certification entities.

Keywords: Dynamic Agroforestry, Sustainable Cocoa Intensification, Roger Theory of Diffusion, Cocoa Smallholder Farm, Ghana, Transdisciplinary

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GOVERNANCE





26. Innovative Landscape Approaches as a Means to Co-Design and Manage Sustainable Agricultural Landscapes: A Focus on Private Sector-led Initiatives

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Abstract

Many agricultural landscapes in the Global South currently undergo an agrarian transition developing from diverse and small-scale traditional smallholder systems to industrialized systems that are optimized to produce efficiently at scales. Innovative landscape approaches are needed to balance the socio-economic development required to lift people out of poverty and to safeguard these landscapes in terms of securing long-term provision of ecosystem services, biodiversity and cultural values. Companies and other private sector actors increasingly initiate or engage in landscape initiatives within their sourcing regions. Cocoa production landscapes are thereby often used as pilot cases, to explore and test innovative landscape approaches. In this study, we attempt to bring together existing theoretical knowledge on landscape approaches with practice-related insights about private sector-led initiatives. We present an analysis of science-based design principles of integrated landscape approaches. We further review strategic documents of selected private sector-led initiatives in view of these design principles, pointing to potential learning opportunities for the (co-)design of innovative landscape approaches.

Keywords: Landscape Approaches, Private Sector, Sustainable Agriculture

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27. Beyond Certification: A Typology of Instruments of Private and Community-Based Sustainability Governance in Agri-Food Value Chains

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Abstract

Certification of voluntary sustainability standards have become a main strategy to enhance human well-being of producers, workers and communities involved in agri-food value chains. Accumulating evidence however points to the limited and sometimes even adverse effects of certification schemes. Partly in response to these mixed results, agri-food companies and producers have developed various alternative and complementary governance approaches to promoting sustainability in value chains. These include inclusive business, direct trade, and solidarity economy. This growing institutional diversity in approaches to sustainability governance creates an empirical and theoretical challenge of mapping the range of instruments applied in different strategies. Existing typologies in this field classify instruments at a broad level, without disentangling the precise institutional details regarding, e.g., ownership, voice, and the distribution of benefits, risks and costs. The proposed paper addresses this challenge by developing a typology of instruments of private and community-based sustainability governance based on data from an extensive survey of organizations based in Peru and Switzerland that are involved in the production, processing, trading, selling, and certification of coffee and cacao and derived products. The typology disentangles the precise similarities and differences of strategies in terms of governance instruments used and underlying theories of change. In the context of renewed demands to solve persistent sustainability issues in the agri-food sector, the presented typology sheds light on important dynamics of private and community-based governance. It may also become a useful tool for further analysis of sustainability governance strategies and instruments, and serve as a foundation for empirical studies tracing the effects of specific instruments and instrument portfolios on various sustainability outcomes.

Keywords: Sustainability Governance, Certifications, Inclusive Business, Solidarity Economy

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28. Can Sustainability Certification Enhance the Climate Resilience of Smallholder Farmers? The Case of Ghanaian Cocoa

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Abstract

Sustainability certification has been posited as a key governance mechanism to enhance the climate resilience of smallholder farmers. Whilst many certifications now include climate resilience in their standards, their ability to deliver this for smallholders remains untested. We take the case of the 2015–16 drought-shock to cocoa production in Ghana to examine whether certification can enhance smallholder climate resilience. We used a novel transdisciplinary methodology combining participatory outcome definition with household surveys, biophysical measurements, satellite data and counterfactual analysis. Utilising our climate resilience framework, we find that certification has a strong effect on the adoption of basic management, e.g. fertilization, but a weak influence on more complex resilience strategies, e.g. agroforest diversification. Beyond certification, we identify strong regional patterns in resilience. These findings suggest that certification has some potential to enhance climate resilience but greater focus on facilitating diversification and adapting to sub-national contexts is required for improved effectiveness.

Keywords: Sustainability Certification, Resilience, Smallholder, Food System Governance, Climate Change, Rural Livelihoods

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29. Trade-Related Policy Levers to Foster Biodiversity Abroad

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Abstract

International supply chains accelerate habitat degradation far from the place of consumption. Demand for palm oil in Germany, for example, is associated with tropical deforestation and biodiversity loss in Brazil. In most economic sectors, more than 50% of the biodiversity footprints is caused abroad and e.g. about 70% of Switzerland's ecological footprint originate from abroad. According to the WWF, the EU is the second biggest 'importer of deforestation; it accounted in 2017 for 16% of deforestation associated with the import of goods, for a total of 203,000 hectares and 116 million tonnes of CO₂. While research has shed light on the dynamics and impacts of trade-led biodiversity losses, further research is needed on how law should tackle the problem. The BIO-TRADE project analyses how the EU, its Member States and EFTA States can protect biodiversity outside Europe in a socially inclusive way through regulating trade relations, supply chains, and biodiversity no net loss policies. BIO-TRADE analysis combines insights from law and political science, assessing rules, norms and discourses. Further, we draw insights from socio-ecological systems research and feed them into the legal analysis of more sustainable trade, investment, and marketing systems. Bridging between the two, our research will innovate and promote legal techniques that enable flexible, context-sensitive solutions, but within the framework of general rules. The BIOTRADE project is implemented in collaboration between the Finnish Environment Institute (coordination), the Centre for Development and Environment (CDE), Switzerland, the Raoul Wallenberg Institute on Human Rights, Sweden, and the University of Copenhagen, Denmark. CDE leads the project's "trade" pillar, focusing on trade-related policy levers to foster biodiversity abroad. The analysis will generate new knowledge on how EU/EFTA states can differentiate between products based on their biodiversity footprint in a fair, proportionate, and context-sensitive manner. This must be consistent with the states' international obligations to incorporate biodiversity protection in their trade relations.

Part of the BIO-TRADE Project.

Keywords: Biodiversity, Deforestation, Trade, Investment, No Net Loss Policies, Supply Chains, Commodities

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30. Governing Spillovers of Agricultural Land Use through Voluntary Sustainability Standards: A Coverage Analysis of Sustainability Requirements

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Abstract

Voluntary Sustainability Standards (VSS) are prominent governance instruments that define and verify sustainable agricultural land use at farm and supply chain levels. However, agricultural production can prompt spillover dynamics with implications for sustainability that go beyond these scales, e.g., through runoff of chemical inputs or long-distance migrant worker flows. Scientific evidence on the governance of spillovers through VSS is, however, limited. This study investigates the extent to which VSS regulate a set of 21 environmental and socio-economic spillovers of agricultural land use. To this end, we assessed the spillover coverage in 100 sustainability standards. We find that VSS have a clear tendency to cover environmental spillovers more extensively than socio-economic spillovers. Further, we show how spillover coverage differs across varying types of standard-setting organizations and VSS verification mechanisms. Finally, we discuss the role and limitations that VSS can have in addressing the revealed gaps. Many of the 100 sustainability standards analysed in this study aim to promote sustainable cocoa production. We thus hope that the insights provided by this study trigger discussions within the cocoa research community about the presence of spillovers of cocoa production as well as need for addressing them through VSS and other governance instruments.

Keywords: Certification, Ecolabel, Externalities, Environmental Governance, Sustainable Agriculture, Telecoupling

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SUPPLY CHAIN



31. Transportation Inefficiencies in the Cocoa Value Chains in Ivory Coast: Is Sustainability Possible?

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Abstract

The purpose of this investigation is to examine transportation inefficiencies and the sustainability of cocoa value chains in Ivory Coast. Problems addressed include unidentified major actors, types of transportation and how it is measured, and lastly, improving efficiency in transportation with respect to society, costs and greenhouse gas emissions. A mixed method methodology is followed in which qualitative and quantitative data are gathered and analysed. Results show that the major actors are planters, cooperative management, exporters, ports, chocolatiers and supermarkets. The main forms of transportation are trucks and motorcycles and are measured using the United Nations criteria for sustainable transportation. The conclusion is that cocoa transportation in Ivory Coast is unsustainable. However, with the correct implementation of policy, financing and technological innovation, there is potential to improve the sustainability of cocoa transportation from farm gate to export harbour.

Keywords: Cocoa Value Chain, Ivory Coast, Sustainability, Transport

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32. Developing an Online Platform with Key Quality Metrics for Cocoa Beans to Enhance Direct Trade in Costa Rica

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Abstract

Heightened customer awareness and demand for sustainable chocolate has led to an increase in bean-to-bar chocolate producers and benefitted the market segment of fine flavour cocoa. However, although the sector is growing, the market remains a niche and is currently suffering from a massive oversupply of fine flavour cocoa. Costa Rica, a world leader in high-quality cocoa, is only one of many countries struggling with this issue. More innovative business solutions are necessary to help smallholders cultivating premium cocoa access markets and find buyers. The goal of this study was to establish a quality-based direct sourcing model in Costa Rica based on a multi-stakeholder approach. First, exploratory research was conducted in the form of interviews with cocoa producers, farm visits and written interviews with bean-to-bar chocolate manufacturers to help provide a more in-depth understanding of current challenges. To provide a set of key metrics to assess cocoa bean quality on a quantitative scale, data was collected by means of a literature review and protocols for chemical, physical and biochemical analyses were identified and summarized to create one standardized test protocol. 18 different cocoa bean samples were collected from lots of smallholders and processors in different regions throughout the country and analysed. Last, an online platform was established in the form of a direct sourcing map, linking interested cocoa farmers to potential buyers. Results showed high quality performances for all samples tested, indicating that biochemical aspects of cocoa bean quality could be assessed in a reliable manner with the methods provided and adapted. Flavour profiles of the beans could potentially be pre-assessed and identified by means of new promising technologies, such as GC/MS headspace or HPLC. Interview results showed that smallholders struggle to access markets and often lack the right knowledge on subjects such as the importance of quality control in post-harvesting practices. The study's results illustrate the often-neglected struggle of high-quality cocoa producers and the prevailing disconnect between different actors along the value chain. Furthermore, it highlights the need for more participatory and applied research. While research has made tremendous advance in optimizing and assessing cocoa bean quality and good flavour notes, the knowledge often cannot be accessed by producers. Digitization offers tools to connect stakeholders, consolidate the supply chain and increase transparency, traceability, and market access. By linking the efforts of research institutions, policy makers and actors from the industry, multi-stakeholder cooperation is enhanced.

Keywords: Cocoa, Fine Flavour, Online Platform, Costa Rica

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33. Environmental Justice Perspectives in the Context of Global Cocoa Value Chains – A Case Study in Piura, Peru

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Abstract

This research was conducted as a master thesis within the scope of the research project “Environmental justice for human well-being (COMPASS)” by the Centre for Development and Environment (University of Bern) in partnership with the Alliance Bioversity International and CIAT. The study aimed at an appropriate, inductive theorization of environmental justice (EJ) in the context of global cocoa value chains. Therefore, it explored and discussed the perspectives of actors involved in cocoa value chains regarding what justice in dealing with environmental issues of cocoa value chains means. The research was purposefully not grounded in a predefined EJ theory to prevent imposing preconceived notions on the results. However, it drew on the transdisciplinary research concept “three types of knowledge” to include problem-, goal-, and transformation-focused justice perspectives and thereby descriptive, normative, and practical knowledge. The Peruvian region Piura was chosen as a study case. The qualitative data analysis was based on 44 interviews with various stakeholders. Drawing on the findings, this study suggests that an appropriate, context-sensitive theorization of EJ in global cocoa value chains should build on (1) the three interrelated EJ dimensions distribution, recognition, and participation, incorporate the lenses of (2) the capabilities approach and of (3) politics of scale. Furthermore, it should be sensitive to (4) local contexts, (5) complexity, (6) marginality, (7) intersectionality, should (8) conceptualize “environment” in a broad sense and acknowledge (9) the plurality of justice conceptions.

Keywords: Environmental Justice, Cocoa Value Chains, Perspectives, Theoretical Foundation, Piura

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34. Implementation of Sustainable Farming Practices by Cocoa Farmers in Ecuador and Uganda: The Influence of Supply Chain Factors

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Abstract

Global demand for sustainable chocolate is rising, which has motivated several sustainability initiatives in the cocoa sector. A key strategy of these initiatives is the promotion of sustainable farming practices (SFP) among cocoa producers. A growing body of micro-economic literature has analysed factors influencing the adoption of such practices, yet broadly disregarded supply chain factors. Information on how factors within single supply chains increase the adoption of SFP can help direct chocolate companies' investments and increase return of investments in sustainability. The objective of this study was to understand: a) how important supply chain factors are, relative to farmer and farm factors for cocoa farmers' implementation of SFP and b) through which mechanisms supply chain factors influence SFP implementation. We collected data from 394 cocoa farmers in Ecuador and Uganda and analysed the determinants of implementation of 12 SFPs across three sustainability dimensions, testing quantitatively whether supply chain factors with variation within single supply chains are significantly associated with SFP implementation. We found that supply chain factors are comparable to farmer and farm factors in explaining the implementation of environmental practices, and exceeds them in the social and economic sustainability dimensions. In particular, both capacity building and stable, long-term relationships were significantly related to the implementation of SFP. Despite this, their potential was not fully exploited within our case study supply chains. Through their supply chain sustainability initiatives, chocolate companies should invest in capacity building beyond the agri-environmental dimension and align sustainability goals with all supply chain actors.

Keywords: Cocoa, Sustainability, Practice Adoption, Supply Chain, Uganda, Ecuador

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35. Pathways to Smallholder Resilience: A Model of Cocoa Farmers' General Resilience Tested During the Real-World Shock of the COVID-19 Pandemic

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Abstract

Changes in global food systems caused by disturbances like climate change, shifting consumption patterns, and political instability can create severe repercussions for involved actors. The global shock of the COVID-19 outbreak not only revealed the vulnerability of national and international health systems, but demonstrated how easily our globalised food systems and supply chains can be disrupted. The concept of resilience has been adopted to better understand farming systems' susceptibility to sudden shocks and disruptions. Nevertheless, there is a lack of consensus on how resilience is defined and measured in a comprehensive and meaningful way. Resilience concepts are often divided into general resilience capacities and specified resilience responses. General resilience aims to describe the capacities of a system to cope with uncertainty, while specified resilience requires a consequent definition of the shock threatening a system. We developed a model of general resilience capacities for smallholder cocoa farmers and validated it with data on actual impacts and countermeasures employed by the same farmers in response to the COVID-19 pandemic. The general resilience assessment consisted of a hierarchical multi-attribute decision-making model, using indicators from an extensive sustainability data set collected just prior to the COVID-19 outbreak from 395 smallholder cocoa farms in Ecuador and Uganda. For the specified resilience assessment, we collected data from the same cocoa farms on impacts and countermeasures implemented in response to the pandemic. Ugandan farms had a higher general resilience performance than Ecuadorian farms. Comparing actual impacts and responses between countries, Ugandan farmers were more severely affected and Ecuadorian farmers mobilised more effective responses. Correlating general resilience performance with an analysis of impact severity, we detected a significant relationship between the absorption capacity of our general resilience model, which considers the short-term robustness of the farming system to assimilate shocks, and specified resilience scores. Nevertheless, only weak relationships were found for the overall general resilience scores including mid- and long-term preparedness and the specified resilience scores, indicating limited practical use of indicator-based approaches to evaluate the preparedness of farming systems to deal with unforeseen shocks or disturbances. Rather than conceptualizing resilience as a defined property, it may be recommendable to shift away from simplistic understandings of resilience in order to acknowledge the ability of actors to engage in novel or culturally embedded solutions for unforeseen challenges and uncertainty.

Keywords: Resilience Capacities, Farming Systems, Shocks, Cocoa, Ecuador, Uganda

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36. Sustainable Sourcing Practices and Buyer-Supplier Relationships from a Cocoa Farmer Perspective

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Abstract

Chocolate companies increasingly implement new sustainable sourcing practices (SSP) to improve sustainability along cocoa supply chains, but these practices are usually designed without consulting farmers. Omitting the position of farmers in the design of SSP can potentially lead to the creation, or perpetuation, of power imbalances and prevent SSP from improving the wellbeing of the farmers who are intended to be among their main beneficiaries. SSP should improve sustainability along the entire cocoa supply chains, and research has shown that both environmental, economic and social sustainability improvement highly depend on the power relationships between actors including upstream supply chain actors. The aim of this study is to examine how cocoa farmers perceive these SSPs and to evaluate their relationships with downstream supply chain actors: in particular with their direct buyers. Semi-structured qualitative interviews were conducted with 395 farmers and 9 direct buyers in two case studies of cocoa supply chains to Swiss chocolate brands; an in-house sustainability program in Ecuador and an organic certifications scheme in Uganda. The responses were analysed according to their content and interpreted in light of a Buyer-Supplier Relationship (BSR) framework, which enables identification of both mediated and non-mediated power types within SSP and their influence on the BSR quality. The BSR framework was developed to integrate trust, commitment, dependency, and conflicts into the evaluation of SSP, and to illustrate BSR quality, from a cocoa producer's perspective. The results showed that farmers perceive both benefits and disadvantages from the SSP that have been implemented, with variation between high and low trust and commitment towards their direct buyers; depending on a range of factors including the duration of the professional relationship and the availability of competitors. Conflicts mainly arose related to prices, insufficient communication, and lack of support. The responding farmers collectively expressed a wish for training to be less theoretical, and be more practice-oriented and supportive for the farmers. Suggestions for improvement included practical measures, such as replacing in-kind premiums with transparent price premiums, and installing a system of correct pricing through fair weighting and quality rating, as well as advance payments. The lack of perceived benefits for farmers suggests that SSP could indeed be improved with enhanced participation by farmers in the design process, which would help farmers and intermediaries take the required actions to improve sustainability within cocoa cultivation and processing.

Keywords: Buyer-Supplier Relationship, Farmer Perspective, Power Relations, Supply Chain Sustainability, Sustainable Sourcing Practices, Ecuador, Uganda

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37. Cocoa in Numbers: From Data to Knowledge

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Abstract

Chocolate products are highly appreciated worldwide for its sensory properties. However, today's consumer not only ask for high-quality products that offer unique sensory experiences but also for products that are elaborated under fair ecological and social conditions. Various parameters within the value network impact, directly or indirectly, the different quality dimensions of cocoa and chocolate products. In this context, multi-stakeholder strategies are required that not only contribute to improved transparency but also enable a deeper understanding of the complex interrelationships between the various quality parameters. A step towards this overall goal was achieved with the development of a database that brings together the various data from different research areas within the cocoa value network. The application of a state-of-the-art non-relational graph database technique offered the possibility to model the value network all at once. The aim of the Cocoa in Numbers project was to develop such a database that allows insight into agronomical, ecological, economic, regulatory, and social aspects, as well as into food quality and safety markers within the cocoa and chocolate value network. For the set-up of the database, model experiments were conducted at the SysCom research station of Research Institute of Organic Agriculture (FiBL) in Sara Ana, Bolivia. For this purpose, cocoa beans deriving from defined cultivation systems, were fermented and dried under standardized conditions. Data were collected on agronomic factors, influencing factors of post-harvest processing, chemical constitution, sensory characteristics, environmental impact, social aspects, and regulatory requirements at all stages of the cocoa value chain. Based on the collected data, the structure of the graph database was developed and a first successful modelling of the relationship between different quality parameters was undertaken. In addition, an intuitive interface was developed that allows different stakeholders to easily explore and query the database.

Keywords: Cocoa, Quality, Database, Transparency, Sustainability, Value Network

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PROCESSING AND SENSORY ANALYSIS





38. Aroma-Kit Cocoa: An Olfactory Library for Cocoa and Chocolate

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Abstract

The consumption of cocoa and chocolate products offers a unique sensory experience, especially due to its wide variety of aroma and taste sensations. Today's consumers are more and more aware of high-quality chocolate products and its unique flavour profiles. The accurate naming of individual aroma impressions by trained judges is therefore an important prerequisite for the analysis of the sensory quality of cocoa and chocolate products. With the aim to support training and calibration processes of sensory panels and to foster communication between different actors in the cocoa and chocolate value network when talking about sensory quality of the corresponding products, an Aroma-Kit for cocoa and chocolate was developed. This tool includes 25 odour references with specific descriptors, which are the key odour compounds of cocoa and chocolate products. Key aroma compounds were identified using analytical techniques such as gas chromatography olfactometry (GC-O), sensory analyses with trained panels of cocoa and chocolate experts, and literature research. The classification of the aroma compounds into four groups was based on a systematic approach that reflects their generation along the cocoa and chocolate value chain, either by bio or thermal transformation: A) Molecules which are already present in freshly harvested, unfermented cocoa beans; B) Molecules which are mainly formed by the post-harvest processes; C) Molecules formed mainly by thermal processes; and D) Molecules which have a negative / undesirable influence on the sensory quality and can be considered as off-odorants. The Aroma-Kit Cocoa is already being applied successfully within different cocoa research institutions and chocolate companies, as well as by interested consumers. This tool not only supports training and communication processes between different actors in the cocoa value network but also builds a bridge between instrumental / molecular and human sensory analyses.

Keywords: Cocoa, Cocoa Aroma, Sensory, Quality

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39. Decoding the Fine Flavour Properties of Dark Chocolates

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Abstract

The demand of consumers for high quality chocolate, organic cocoa and bean-to-bar products is increasing. Bean-to-bar chocolates are made of cocoa beans of defined variety and origin, and differentiate themselves by its unique flavour properties in contrast to products from the mass market. In the past, a lot of research has been done in defining the flavour properties of cocoa and chocolate intermediates as well as their off-flavours. This research has been mostly conducted on products produced on high industrial scale, deriving from blends of cocoa beans from different origins to achieve a consistent standard quality. However, the specific fine flavour attributes of cocoa liquors or the dark chocolates produced thereof deriving from defined origins and varieties have been scarcely investigated on a molecular level. Therefore, the aim of this investigation was to decode the fine flavour properties of chocolates with specific flavour attributes produced of reference liquors of the Cocoa of Excellence Programme. For this reason, reference liquors with distinct fruity, floral or cocoa-like flavour profiles were selected, and the corresponding chocolates were analysed for their molecular flavour composition. After the screening for odour-active molecules by means of aroma extract dilution analysis (AEDA), selected key flavour compounds were quantified in the chocolates with the overall aim to decode the fine flavour properties on a molecular level. This way it could be observed that fruity and acidic flavour attributes were linked to high odour activity values (OAVs) of acetic acid and fruity smelling esters. Chocolates with intense cocoa-like and roasty flavour attributes showed high OAVs for the odorants 2- and 3-methylbutanal as well as for furaneol and dimethyl trisulfide. The flavour attributes floral and astringent were characterised by high dose over threshold values (DoTs) of epicatechin, procyanidin B2 and high OAV of 2-phenylethan-1-ol. The acquired knowledge of the molecular composition of selected cocoa fine flavour attributes provides a basis for future quality assessment of cocoa and chocolate as well as for the development of standardised training samples for sensory evaluation of cocoa products.

Keywords: Fine Flavour Cocoa, Sensory References, Dark Chocolates, Molecular Flavour Compositions

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40. Novel Time- and Location-Independent Postharvest Treatment of Cocoa Beans: “Moist Incubation” of Unfermented and Dried Cocoa Nibs

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Abstract

Post-harvest processing of cocoa beans is a crucial step for the formation of cocoa flavour. Spontaneous microbiological fermentation is not easy to control due to several variable factors such as weather conditions, ripeness of the fruits, as well as the batch-size, leading to quality variations of the resulting cocoa beans. In previous research on fermentation-like incubations of cocoa beans in aqueous solutions under controlled temperature regimes, it could be shown that not microorganisms themselves, but their metabolites are necessary for the flavour precursor formation and the desired biochemical changes within the bean. Therefore, it was concluded that an application of this technique in the cocoa growing area may permit standardisation and mechanisation of cocoa fermentation. However, implementing this process on a farm requires expensive infrastructure or transportation to locations with existing infrastructure. To overcome this challenge, an alternative time- and location-independent approach of post-harvest processing, the so-called “moist incubation” has been established. For this reason, unfermented and dried cocoa nibs, which are storable and easy to transport, were treated with a solution containing lactic acid and ethanol and incubated at 45 °C for 72 h under aerobic conditions to induce the desired changes within the cocoa material before drying. The resulting raw material of this process and the model chocolate produced thereof were analysed in comparison to the fermented and unfermented raw cocoa beans as well as their corresponding model chocolates by sensory evaluation, gas chromatography-olfactometry and the quantification of selected flavour-active compounds and their respective precursors by gas chromatography mass spectrometry and high-performance liquid chromatography mass spectrometry. The outcome of this investigation shows that moist-incubation constitutes an alternative post-harvest treatment for cocoa, resulting in chocolates of desired flavour properties.

Keywords: Cocoa Postharvest Treatment, Cocoa Incubation, Cocoa Aroma Formation, Sensory Evaluation

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41. Rapid Characterization of the Chemical Profiles of Cocoa Beans Fermented with Anti-fungal Co-cultures

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Abstract

Starter culture-induced fermentation of cocoa beans has been shown to enhance quality, often accompanied by elaborative screening approaches. The aim of this study was to facilitate the selection process of functional lactic acid bacteria (LAB)-yeast co-cultures with primarily anti-fungal properties. An innovative approach of microbial selection is offered by characterizing the metabolic profiles of cocoa beans using an untargeted rapid mass spectrometry method, REIMS (rapid evaporative ionization mass spectrometry). Controlled fermentations were conducted by inoculating cocoa beans with different co-cultures previously identified for their anti-fungal properties (Romanens et al., 2019 & 2020; Freimüller et al., in prep.). The chemical fingerprints of the beans were screened using the REIMS combined with multivariate data analysis. Statistical models were built based on the chemical fingerprints acquired by REIMS. Therefore, unsupervised component analyses were performed, followed by supervised linear discriminant analyses. These models allowed visualizing the differences and similarities between samples by clustering them according to the resemblances of their metabolite profiles. In our models, the cocoa beans fermented with co-cultures were gathered and separated from non-starter fermented, highlighting the similar metabolite profiles of beans fermented with co-culture. The models also permit the detection of the chemical compounds which differentiate the samples. The mass spectra of these key quality markers were obtained by supplementary REIMS analyses for further identification. Extensive screening of cocoa metabolite profiles will be conducted with additional anti-fungal LAB and yeast strains to strengthen the models and identify other quality markers. Thereby, these models aim to rapidly recognize cocoa beans fermented with anti-fungal co-cultures facilitating microbial strain selection. This selection approach could be extended by targeting other quality parameters which enhance cocoa bean quality, such as improving taste and aroma. Models could be built to discriminate beans with the targeted features. Then, unknown samples could rapidly characterize, determining whether they are conformed to expectations.

Keywords: Cocoa Bean Fermentation, Rapid Evaporative Ionization Mass Spectrometry, Anti-Fungal Microbial Co-Culture

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42. Monitoring of Cocoa Post-harvest Process Practices on a Small-Farm Level at Five Locations in Ecuador

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Abstract

Cocoa post-harvest practices on a small-farm level are multifaceted including varying fermentation devices and treating of the beans during processing. The aim of this study was to get deeper insight into the situation on site in Ecuador and to record the cocoa bean fermentation process. Therefore, cocoa post-harvest practices were monitored on a small-farm scale (ca. 50 kg fresh beans) at five intermediaries from four provinces in Ecuador: (A) in Manabí, (B) and (E) in Los Ríos, (C) in Cotopaxi, (D) in Guayas. Temperature, pH (pulp, cotyledon), cell counts (yeasts, lactic acid bacteria, acetic acid bacteria) were recorded daily, and cut-tests and sensory descriptive analysis were done to evaluate the end quality. As expected, an overall inconsistency and variability in processing were observed with different fermentation devices (jute/plastic bags, wooden boxes), pre-drying, turning during fermentation, fermentation duration, and different drying processes (temperatures, direct/indirect). Key parameters (maximum temperature, pH cotyledon development) revealed a significant impact of the fermentation device on the post-harvest process and, therefore, on the fermentation development. 67–74 h in jute bags without turning was sufficient to reach well-fermented cocoa beans without moldy off-flavors, whereas 133 h in plastic bags without turning resulted in $3 \pm 1\%$ moldy beans and cocoa liquor with moldy off-flavor. Drying at high temperatures (80 ± 10 °C) with direct heat contact resulted in beans roasted to burnt off-flavor. Conclusively, the whole post-harvest process was crucial for well-fermented beans without off-flavor. Plastic bags seemed unsuitable, while jute bags could be an alternative to wooden boxes.

Keywords: Cacao Nacional, Cocoa Bean Fermentation, Fermentation Techniques, Fermentation in Bags, Sensory Description

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43. Application of Functional Lactic Acid Bacteria-Yeast Co-cultures in Cocoa Bean Fermentations

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Abstract

Spontaneous cocoa bean fermentation is the first step in cocoa post-harvest processing and leads to the development of chocolate flavour and aroma precursors of cocoa beans. Depending on fermentation practice and environmental factors, mold development can be observed mainly towards the end of fermentation and during drying. Fungal presence in cocoa is generally undesirable and often related to the formation of off-flavors and a potential accumulation of mycotoxins, e.g. aflatoxin or ochratoxin. With the aim to suppress mycotoxin-forming molds in cocoa beans, an anti-fungal co-culture (AF) composed of *Limosilactobacillus fermentum* 223 and *Saccharomyces cerevisiae* H290 was recently developed (Romanens et al., 2019 & 2020). In a follow-up phase, a pectinolytic yeast (H403) was included into this co-culture (AF/Pec) aiming at a reduction of fermentation time (Freimüller et al., in prep). Since 2016, the AF and the AF/Pec co-cultures have been tested in Honduras (n=12), Bolivia (n=6), and Costa Rica (n=3). At the end of drying a cut-test, sensory analysis and a chemical fingerprint by Rapid Evaporative Ionisation Mass Spectrometry (REIMS) were carried out. The chemical fingerprint generated by REIMS showed a strong effect of the location and a clear effect of the applied co-culture on the chemical fingerprint of dried beans. In addition, a positive influence of co-cultures on the sensory profiles at lab-scale (lower bitterness, astringency, and off-flavours, more cocoa and fine flavours) and no to positive influence of co-cultures on the sensory profiles at industrial scale were detected. Further, a tendency to less violet beans with co-cultures (AF and AF/Pec) application was observed. Finally, a positive influence of co-cultures on the overall fermentation process and on the final bean quality was noticed, especially under adverse fermentation conditions.

Keywords: Cocoa Bean Fermentation, Starter Culture, Anti-Fungal, Pectinolytic

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