International Symposium on Cocoa Research

5, 6, 7 December 2022, LE CORUM, Montpellier, France

SESSIONS REPORT AND RECOMMENDATIONS

Introduction

ISCR organized by ICCO and CIRAD over 3 days- 5-7 December 2022

Theme: Innovations to support market development and promote the sustainability of cocoa farming for better farmer income

Objectives

- Present **advances in technology** and **innovations** in the cocoa sector
- Analyze the potential **impact of research results** for the cocoa sector and farmer income
- Provide **practical and relevant recommendations**
- Provide **a platform for the cocoa community** and scientists to exchange on the latest findings
- Proposed **dissemination channels** for the results
- **Agree on priorities for collective action**

THEMATIC AREAS AND ABSTRACTS

SESSION 1
COCOA CULTIVATION: INNOVATIVE APPROACHES AND PRACTICES FOR SUSTAINABLE PRODUCTION

1. Farmers Living Income
2. Cocoa Fertility and Fertilizers
3. Pest and Diseases
4. Good Agricultural Practices
5. Botany/Genetics and Breeding

SESSION 2
SUSTAINABLE COCOA AND CLIMATE CHANGE: THE WAY FORWARD THROUGH MITIGATION AND ADAPTATION

1. Overview and Intro
2. Physiology of cocoa and Climate
3. Climate Smart Cocoa
4. Social Ecological Interactions and Climate

SESSION 3
INNOVATIONS TO SUPPORT THE COCOA PROCESSING & MARKET DEVELOPMENT

1. Cocoa by-products
2. Origin, Genetics, Quality and flavour evaluation
3. Cadmium

Abstracts selection, presentations & E-proceedings

400 Abstract received

4 keynote presentations

75 oral presentations

137 poster presentations

Full papers to be submitted by 30th January 2023

Recommendations

SESSION 1
COCOA CULTIVATION: INNOVATIVE APPROACHES AND PRACTICES FOR SUSTAINABLE PRODUCTION

Challenges:

Link between yields-prices- markets and price formation – and farmer costs and revenues are not clear – with pathways to a LI not clear too.

Innovative methods/new findings	Potential impact for the sector and cocoa farmer income	Recommendations for their applicability
• **New scientific methods;** simpler Living income calculation (but missing cost data) & focus on sustainability in Value chain • **Collaborative big datasets** highlighted as influencing LI • **Service delivery models** which combine agronomic & social/health functions	• Sustainably could rely on **traceability** • **Price increases:** LI origin differential price can increase farmer price through market differentiation (eg organic, flavor). • **Role of government** can be stronger than certification in increasing revenues • **Knowing how world prices are calculated can** influence farmers voice/action • Farmers in West Africa who use **targeted specific service delivery models** can increase income	• **Collaboration** companies need to work with other stakeholders and research to harmonize methods and aggregate data. (yield and prices alone wont work) • **Change global governance** of cocoa value chain and increase competitiveness through market differentiation • A **smart mix of different service delivery models** should acknowledge the weaknesses and strengths of different models

Recommendations

SESSION 1

COCOA CULTIVATION: INNOVATIVE APPROACHES AND PRACTICES FOR SUSTAINABLE PRODUCTION

Soil fertility & fertilizers

Challenges:

- increased soil fertility and best agronomical pratices
- Increase knowledge
- Soil sustenability

Innovative methods/new findings	Potential impact for the sector and cocoa farmer income	Recommendations for their applicability
• The development of digital tools will help Knowledge Transfer • A network for big soil data from different datasets will allow recommendations on soil fertility management and a decision support system • Gap on fertilizers quantity and formulations for soil fertility in west Africa,	• Tools for decision support increase the efficiency of knowledge transfer • C sequestration in a cocoa farm can be an option to increase income • Cocoa nutrition in smallholder farms heavily depends on inherent soil fertility • Fertilizer adoption is dependable on knowledge and labour	• More surveys are needed to diagnose poor yielding and farmer sustainability • Development of decision-support tools and roadmaps to maintain and improve soil fertility; • Need to fully quantify the costs and returns of fertilizer user, especially at farm level • Most sustainable approach to achieve best

Recommendations

SESSION 1

COCOA CULTIVATION: INNOVATIVE APPROACHES AND PRACTICES FOR SUSTAINABLE PRODUCTION

Cocoa pest and disease

Challenges:

•Improvement of diseases knowledge about their diversity, genes involved, species involved, other species reservoir
• Detect and estimate diseases lost
• Control diseases
• Direct or prevented selection of resistant clones

Innovative methods/new findings	Potential impact for the sector and cocoa farmer income	Recommendations for their applicability
• Identification of genes involved in cocoa pathosystems. • Development of immunoassays to detect CSSV infection. • Use of barrier crops and compost associated to Trichoderma and Arbuscular mycorrhizal fungi (AMF). • Use of mathematical models to improve pest and disease control strategies. • Explore germplasm collection and make	• Better management of disease epidemics • Improvement of cocoa production by a better disease control • Diffusion of resistant clones to farmers	• Make the kits for CSSV detection available for any country • Apply studied strategies to control diseases and to validate the models recommended • Adopt the resistant selected clones

Recommendations

SESSION 1

COCOA CULTIVATION: INNOVATIVE APPROACHES AND PRACTICES FOR SUSTAINABLE PRODUCTION (suite)

Good Agricultural practices

Challenges:

- Lack of knowledge good agricultural pratices (**pruning, use of biostimulants)** to improve cocoa agroforestry systems (CAFs)
- Lack of **data sharing**.
- How to develop **cultivars** relevant for both quality, productivity and sustainability.

Innovative methods/new findings	**Potential impact for the sector and cocoa farmer income**	**Recommendations for their applicability**
• **Pruning** increased pods and beans per pod and reduced disease • **New methods (**DEXIcocoa, MOCCA)) allow forecasting and performance evaluations for sustainability. • **Biostimulants** is a good way to have resilient and sustainable cocoa production	• **Price gains from pruning-** increase yield and also reduce diseases losses and better bean quality • Potential to increase yield by increasing tree health using biostimulants (from trials in Colombia) and cultivar clones – but needs further research	- **Train farmers on pruning** - **Use of Tools which enable comparisons** of different systems and most performant can provide information for farmers - **Data sharing principles** that requires traceability but increases adoption. - **Biostimulants** appear useful to increase yield but **cost data and independent assessment needed**.

Recommendations

SESSION 1

COCOA CULTIVATION: INNOVATIVE APPROACHES AND PRACTICES FOR SUSTAINABLE PRODUCTION (suite)

Botany/Genetics, breeding

Challenges:

- Need to reduce the long breeding cycle by using relevant agronomic traits.
- Increase Pests and diseases and water-deficit stress tolerance.
- Increase selection efficiency for cocoa agronomic traits
- Identification of genetic basis for fine and flavour quality.
- The role of genomics (functional genomics, paleogenomics, etc…) for a better understanding of cocoa genome evolution.

Innovative methods/new findings	**Potential impact for the sector and cocoa farmer income**	**Recommendations for their applicability**
• Association between **Phenotypic-based** and **genome-based** cocoa selection through new approaches (Genomic selection- GWAS) • **Molecular tools** are able to detect disease-tolerant material (like CCSV-tolerant genotypes, water-deficit stress tolerance, etc,…) • Other innovative methods based on Functional Genomics, **Gene Atlas**, **Paleogenomics** and biochemistry (**Methylxantines**) analyses helps to trace the cocoa history.	• A better phenopyping to r**educe** the **breeding cycle and to improve the selection efficiency on agronomic traits.** • **Limitations of potential yield losses** due to the incidence of existing or emerging diseases in cocoa producing countries • Investigating the **history** (origins, domestication, geographical spread) and **diversity** of the cocoa species may generate **useful genetics information.**	• Current breeding programmes should **combine** both **conventional** and **molecular approaches** to **speed up** the selection. • Increase the collaboration between the Different **national** and **regional cocoa breeding programmes** tackling the **same cocoa challenges**. • A **relationship** should be built with **genetic/breeding information**, **genomic data** and **diversity studies**

SESSION 2 SUSTAINABLE COCOA AND CLIMATE CHANGE

Keynote Speaker Session 2

Rolando Cerda- Researcher and professor CATIE

Introduction and overview	Physiology of cocoa and climate	Climate Smart Cocoa	Social Ecological Interactions and Climate
Wiebke Niether	Sandrine Okayo Minakou	Ebagnerin Jerome Tondoh	Bonna Antoinette Tokou
Fiona Lahive	Benedicte Rhoné	Andrew James Daymond	Marieke Sassen
Alina Găinuşă-Bogdan	Julian Fernando Mateus-Rodriguez	Jean-Michel Harmand	Renee Brunelle
Maja Slingerland	Dominique Dessauw	Christian Andres	Dietmar Stoian
	Surja Chakrabarti	Johanna Rueegg	Sholahuddin Akbar
	Antonio Jesus Ariza Salamanca	Evelyne Marise Assi	
	Viviana Ceccarelli	Antoine Kouame Kouadio	

SESSION 2 SUSTAINABLE COCOA AND CLIMATE CHANGE

Key note, introduction and overview

Challenges:

- Climate action covers adaptation to changing conditions and mitigation of emissions.
- The climatic change mean long term changes, and changing climate variability.
- Cocoa production systems interact on different scales with these changes from plant to global level.

Innovative methods/new findings :	Potential impact for the sector & farmer income:	Recommendations for their applicability:
A lot of available solutions, priority on training materials, including digital tools, have been developed to help farmer decision making	***Solutions are available if ways can be found to help farmers adopt them***	Financial support and farmer training needed to ensure adoption
Agroforestry can have benefits compared to monocropping but has higher C stocks	Extension agents and farmers, even in remote areas, better informed on techniques and economic implications of introducing new cropping systems	***Value chain development needed to maximize income from non-cocoa products from agroforestry systems***
Higher CO2 levels and temperatures can increase photosynthetic rates. Cocoa can acclimate to higher temperature conditions.	CO2 fertilisation effects may help mitigate climate change, but water availability may still impact on productivity	Field validation of climate simulations
Timing of management is affected by climate and current calendars may not be optimal	***Dynamic decision-making based on real-time climate data can improve efficiency of interventions***	Deliver high quality real-time climate data to farmers, combined with management recommendations
Cool Farm and GHG tools based on existing and new field data developed to optimise yield/carbon sequestration balance.	New tools will help farmer make progress towards net zero C	Standardize data for carbon reporting for cocoa

SESSION 2 SUSTAINABLE COCOA AND CLIMATE CHANGE

Physiology of cocoa and climate

Challenges:

Climate interacts with cocoa physiology on multiple levels

- Genotype
- Phenotype
- Agroforestry system interactions
- Geographic distribution and climatic zones

Innovative methods/new findings :	**Potential impact for the sector & farmer income:**	**Recommendations for their applicability:**
New selection method for drought resistant cocoa trees for adult and juvenile stages ***Flowering time and pod development period are also indicators for the selection of drought resistant plant material*** An online tool (CacaoDiversity) can help cocoa farmers select shade trees. ***Shade trees more affected by CC than cocoa in ecological modelling*** GxExM - Clone is the most important factor Wild accessions and existing cultivars were screened for climate resilience	Drought-resistant cocoa trees can reduce tree mortality in the field ***New selection methods using phenotypical, geographical or genetic indicators will result improved choice of cultivars with improved tolerance of high temperatures and drought*** New clones improve productivity, triple yields Genetic variation of flowering time can be used to avoid climate impacts Reduce the mortality and ensure the persistence of shade trees under climate change	Train cocoa farmers to use variety selection methods, and provide access to select plants for transfer to the field The entire community needs to better characterize and preserve adaptive genetic diversity to cope with future environmental changes ***The scientific community must promote ex-situ (experimental stations) and in-situ (involving farmers, local communities...) conservation initiatives.*** More focus on shade tree planning as adaptive practice

SESSION 2 SUSTAINABLE COCOA AND CLIMATE CHANGE

Climate Smart Cocoa

Challenges:

- Cocoa production systems need to adapt to climate change and reduce emissions.
- How can varieties be chosen?
- What is the effect of shade tree management on the system?
- What are producers doing to adapt and diversify?

Innovative methods/new findings :	Potential impact for the sector & farmer income:	Recommendations for their applicability:
Crop models support the development of mitigation strategies Shade trees with environmental and economic functions were identified specifically for the Savannah zone. Dynamic agroforestry systems effectively regulate air and soil temperature, and loss of soil moisture. Adapted varieties are key to maintain good productivity. ***Farmers are very aware of climate change and impacts, but only very few take action.***	Diversified agroforestry system potentially provide income throughout the entire year. ***Agroforestry systems may double the income for producers, support the regeneration of soils, especially in the Savanna zone, and capture carbon.*** Agroforestry systems contribute to food security. Producers are interested in adaptation but lack the support to adopt practices. ***Fish production combines well with cocoa to improve income***	***Producers need improved knowledge about climate impacts.*** Nutrient cycling reduces the loss of soils fertility, which is an effect attributed to climate change. A better understanding of the physiological cost of each plant organ (leaves, fruits etc,) based on biochemical compositions is required. Models are key to support mitigation and adaptation but need to be better integrated with field experiments.

SESSION 2 SUSTAINABLE COCOA AND CLIMATE CHANGE

Social Ecological Interactions and Climate

Challenges:

- Adaptation to climate change and mitigation should benefit the livelihoods of farmers
- Agricultural production interacts with the ecological system
- How can we improve our understanding of the societal and ecological impacts of climate action in cocoa?

Innovative methods/new findings :	**Potential impact for the sector & farmer income:**	**Recommendations for their applicability:**
Empirical studies to quantify the economic effects of different agroforestry systems Spatial analysis shows that land use change is a concern both as a driver, and as a result of climate change. ***Preferences for shade trees differ by gender.*** Adapted agroforestry requires development of multiple value chains	***More diversification in cocoa production systems was empirically shown to be correlated with increased (global) revenue for farmers (twice higher) and improved farmer livelihoods*** Climate change makes it more difficult for cocoa to have a positive impact on ecosystems ***Women can be empowered to diversify incomes and practice resilient cocoa production***	***Context-specific responses to adapt to and mitigate the effects of climate change*** policies must be developed to implement climate-smart practices such as cocoa agroforestry systems gender-oriented strategies should be implemented to improve uptake of climate adaptation Level of management of the intercrop systems must be optimized to maximize income

SESSION 3 INNOVATIONS TO SUPPORT THE COCOA PROCESSING & MARKET DEVELOPMENT

Keynote Speaker Session 3: Andrea Doucet Donida - Cacao Barry Global Brand Leader

Cocoa by-products:	**Digital tools:**	**Origin, Genetics, Quality and Flavour Evaluation**	**Cadmium:**
Anna Laven - **Juicy beans: an integrated concept towards cocoa pulp use and living income.** Thomas Bickel Haase - **Influence of Origin and Thermal Processing on the Aroma Quality of Cocoa Fruit Pulp for it Use as a Food Ingredient.** Simeon Deo Hannes – **Human Consumer perceptions of the circular economy and the Ivorian cocoa value chain.**	Martin Notaro – **Characterisation of the digital divide and assessment of the impact of the use and non-use of digital tools in the Ivorian cocoa sector.** Neil Slettehaugh - **Applying computer vision to cocoa bean cut test images: towards an efficient and accessible tool for evaluating physical quality.**	Christina Rohsius - **Quality of traded raw cocoa: origin specific variation, correlations of quality determining factors and development of a "cocoa quality system.** Louis Ban Koffi - **Physical, aromatic and sensory evaluation of cocoa beans developed by agricultural research in Côte d'Ivoire and improvement of harvesting activities and quality of cocoa beans during primary processing activities.** Ariza Budi Tunjung Sari - **Virgin Cocoa Butter from Modified Cocoa Bean Processing.** Dolores Ixmucané Alvarado Rupflin - **Development of cocoa physical reference samples for training and calibration of sensory evaluation panels: perspectives from a range of food products.** Lisa Ullrich - **Decoding the fine flavour properties of dark chocolates.**	Gideon Ramtahal - **The effect of soil and foliar Zn and Mn application on the uptake of Cd levels in cacao grown on Cd-rich soils.** Erik Smolders - **Is chocolate consumption truly enhancing dietary cadmium intake in the general population? A Belgian consumption survey.** Carlos Alberto Adarme Duran - **Ureolytic bacteria that induce carbonate precipitation from cocoa farms in Santander, Colombia: cadmium distribution, isolation and application of rhizobacteria.** Francisco Miguel Menéndez-Burns - **Metal Transporters involved in Cd uptake and distribution in cacao: gene function, evolution, and expression.** Eduardo Francisco Chavez - **Agronomic countermeasures for reducing cadmium (Cd) uptake in cacao plantations in Ecuador.** Caleb Lewis - **Understanding cadmium accumulation in cacao and its implications for developing tools for mitigation of cadmium in cocoa beans.**

SESSION 3 INNOVATIONS TO SUPPORT THE COCOA PROCESSING & MARKET DEVELOPMENT

Cocoa by-products, Chair: Verina Ingram- Rapporteur Philippe Bastide

Challenges:

- Making the full use of all part of the cacao plant that is normally discarded
- Create markets and value addition at origin
- Understand the market development aspects

Innovative methods/new findings	Potential impact for the sector and cocoa farmer income	Recommendations for their applicability
• Use of the cacao pulp in the chocolate formulation – 100% cacao • Use of cacao pulp juice as product • Cacao resulting from pulp extraction may have a reduced fermentation time and maintain if not increase quality. • Circular economy increasing incomes and profitability. • Involvement of chefs in testing new products is key for adoption.	• Increase value of product often discarded. • Increase value at the local level. • Increase participation of youth and women in the value chain, at the farm or coop level. • Increase local investment capacities.	• Develop technologies for pulp extraction and storage. • Further testing of cacao quality from fermentation after pulp extraction. • Build capacity in marketing of new products and creating demand.

SESSION 3 INNOVATIONS TO SUPPORT THE COCOA PROCESSING & MARKET DEVELOPMENT

Digital tools – Chair: Philippe Bastide – Rapporteur: Verina Ingram

Challenges:

- Digital divide between north-south, urban-rural, and uses and impact on producer incomes not known
- Digitalising the cut test- most common quality assessment which cost, takes time and experience to do

Innovative methods/new findings :	Potential impact for the sector & farmer income:	Recommendations for their applicability:
• Correlation between farmer characteristics and use of phones – divide in terms of phone equipment and farmers sills. • Little income difference between effect of digital use and income and majority motivated • Under utilised resource and divide between farmers (usage capacities and use for banking and agriculture activities v low)	• Education literacy, reducing hardware internet and telephone costs and software could impact income • Reduce time and money of cut tests (analysis and cutting machine) – to help sector and farmers indirectly to understand and achieve quality	• Reduce connectivity costs, provide software, increase literacy – role of women to be more investigated • Model potentially interesting – needs additional images for learning, especially of defect beans (as CoEx data is biased towards high quality), protocols for taking images and making freely available app with cutting equipment that saves time

SESSION 3 INNOVATIONS TO SUPPORT THE COCOA PROCESSING & MARKET DEVELOPMENT

Origin, Genetics, Quality and Flavour Evaluation – Chair: Philippe Bastide – Rapporteur: Michelle End

Challenges:

- Understand and improve quality through good and accurate flavour descriptions
- Connecting desired market requirements to on-farm post-harvest practices

Innovative methods/new findings :	**Potential impact for the sector & farmer income:**	**Recommendations for their applicability:**
• Tools based on quality parameters analysed from traded samples to reveal important factors in identifying types of cocoa. • Laboratory facilities to improve capacity in Cote d'Ivoire to analyse local samples including from breeding programmes and producers and training. • Trials of different post-harvest treatments and cocoa butter pressing techniques can lead to diversity of cocoa butter products (virgin butter vs phenolic rich butters. good yields of high-quality cocoa butter from unfermented beans using expeller. • Review of physical reference sample development in other foods used as basis for developing reference samples for cocoa. Pilot project demonstrates value in improving repeatability and capacity to discriminate power. • Technologies to identify and quantify odour-active compounds. PCA analysis identifies chemical compounds associated with particular cocoa qualities.	• Cocoa Quality System in development can help identify where post-harvest practices need to be adjusted for better quality and to predict flavour quality, Improved access to high value markets. • Training shown to improve quality and help achieve better price. • Materials in breeding pipeline will meet quality requirements • Small holder farmers can produce cocoa suitable for cocoa butter even where fermentation is not possible. • Improved ability to consistently evaluate quality globally. Confidence in evaluation strengthen links producers/buyers and result in higher prices for farmers. • Tool for identifying flavour diversity, standardising and training.	• Reconsider current links between origin and quality, to improve market access for all producers of quality cocoa wherever their origin. • Continue to train at origin and build capacity of producers to target quality and flavour required by markets.

SESSION 3 INNOVATIONS TO SUPPORT THE COCOA PROCESSING & MARKET DEVELOPMENT

Cadmium – Chair: Michelle End – Rapporteur: Philippe Bastide

Challenges:

- Cd exposure assessment via consumption of all cacao containing products
- Reduce the uptake of cadmium in the beans of producing regions impacted by high cadmium levels
- Provide practical, economic solutions for cacao farmers to apply

Innovative methods/new findings :	**Potential impact for the sector & farmer income:**	**Recommendations for their applicability:**
• Reduction of biodisponibility of Cd at the plant level (Soil and Foliar Application: Zinc (Zn) & Manganese (Mn) and at the soli level by Microbially Induced Carbonate Precipitation MICP by ureolytic bacteria and/or Agronomic countermeasures – lime, gypsum, compost (biochar) and Foliar micronutrients - Zn, Mn and Fe. • Promising way in Genetics (and genotypes) to block or control of Cd Transportation into to the plant: protein Heavy metal ATPase 3 (HMA 3) with Cd transport capacity – • Better Understanding how partitioning of biomass and Cd affects Cd concentration to develop Tools for Mitigation. • Better understand Bioavailable dietary cadmium exposure	• Field soil applications of Mn and Zn may be more effective as a treatment to reduce Cd uptake and accumulation in cacao Leaves and stems, the main loading hubs for Cd in cacao and considering all the other Biomass compartments (pod husk, beans, ,….further studies needed in Genetics x Biomass interactions including Rootstock role. . • Cd intake from cacao consumption underestimated because of hidden cacao in non-chocolate food categories but overestimated true exposure because of lower bioavailability compared to main foodstuffs contributing to Cd exposure. • Understanding the physiology of Cd uptake could help inform amendment strategies on the farms. • Soil properties can be modified which lowers soil/plant Cd. • For acid pH soils, lime at a rate of 4 Mg ha-1 is most suitable. • For alkaline soils, application of compost at a high rate (50 Mg ha-1) or Zn, potentially lower bean-Cd. However, effect not as clear as liming. • Cadmium bio-accessibility decreases with increasing fat-free cacao solids content and up to factor 5 lower in cacao products.	• Zn & Mn soil and foliar application is an effective approach to reduce Cd levels in cacao leaf tissue- may offer an alternative approach to farmers. Rate/method of application should be optimized • Information about hotspots on farms can help farmers to decide where to plant/renovate based on both rhizosphere and non-rhizosphere soils sampling and better understanding of Cd location and mobilization. • Side effects of liming should be addressed such as decreased Zn availability and shallow penetration depth. • Consider biomass partitioning in breeding for low cadmium uptake genotypes (trees and rootstocks). • Cd levels in beans should also be evaluated for bioavailable dietary exposure.

Comments from the audience

Wrap up and Next steps

1) Dissemination of the results- ISCR Report online + e-proceedings
2) Full papers submission for e-Proceedings – 30 January 2023
3) Upload all oral and poster presentations PDF files on the ISCR website by 15 January
4) Post-ISCR evaluation survey – online 9-16 January

Thank you and see you at the next ISCR!