Sustainable Cocoa and Climate Change: The way forward through Mitigation and Adaptation

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CONTENT

- The climate change impacts in Lantin America/Caribbean, Africa and Asia
- What climate change mitigation and adaptation strategies/practices support a sustainable development of the cocoa sector and improve cocoa farmer income?
- In each section: What is needed (research), What we need in the field
- How can strategies/practices and research results be more accessible and applicable to cocoa stakeholders?
- Recommendations for the way forward

IMPACTS IN THE COCOA REGIONS

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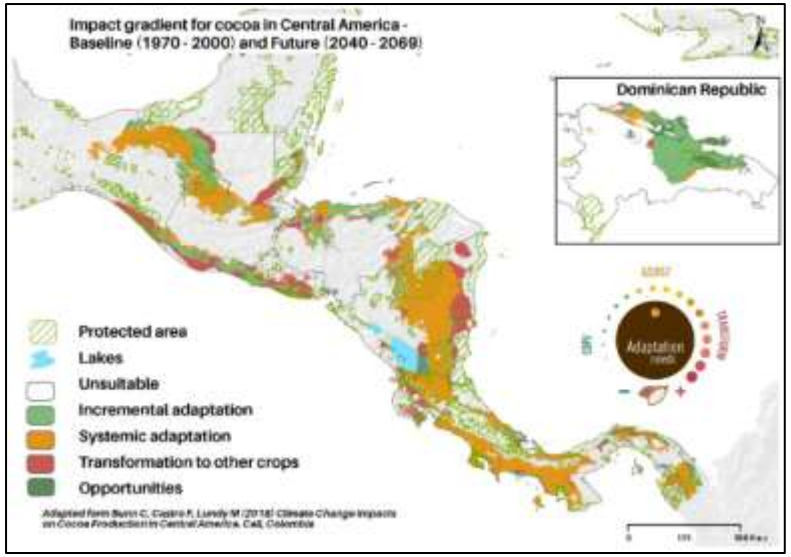
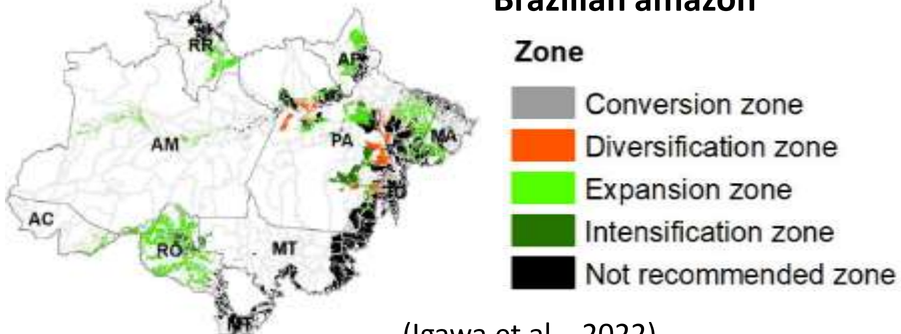
Central America



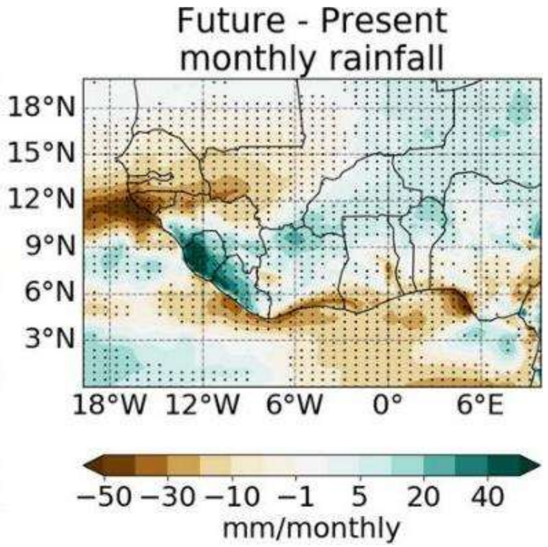
(Bunn et al., 2018; Bunn et al., 2019)

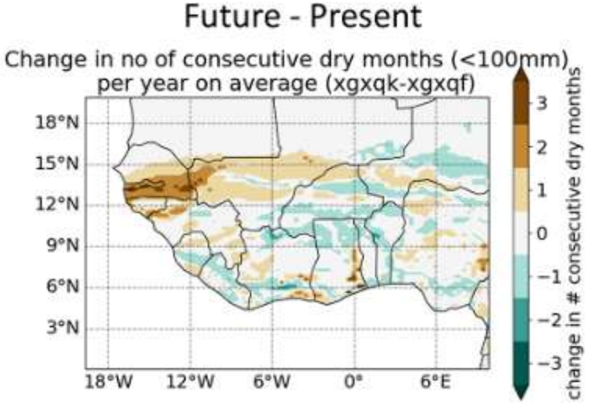
Brazilian amazon



(Igawa et al. , 2022)

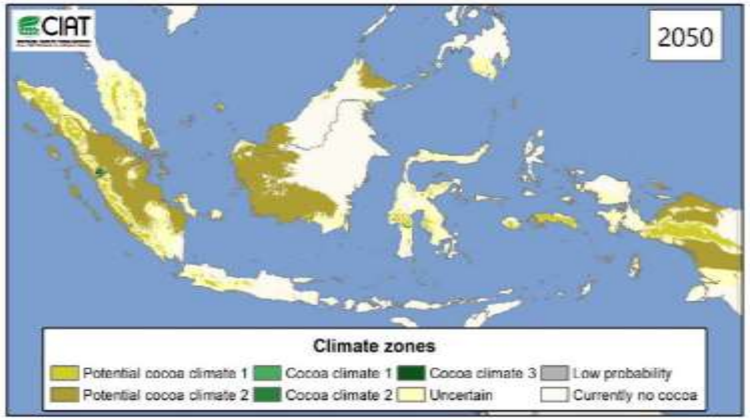
West Africa

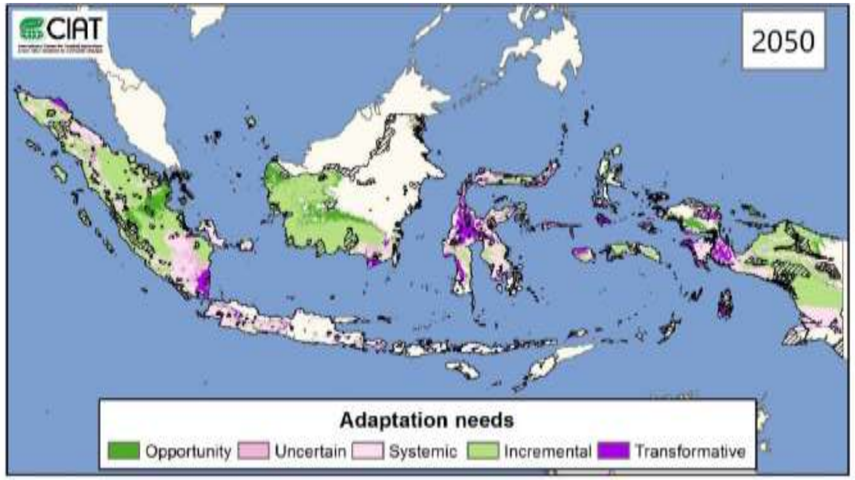




(Black et al. , 2021)

Asia





(Bunn et al., 2017)

INFLUENCES ON PESTS AND DISEASES (P&D)

- Influences on the life cycles and dispersion (Moraes et al., 2012; Hutchins et al., 2015; Asante et al., 2017; Leandro-Muñoz et al., 2017; Ortega Andrade et al., 2017; Cilas and Bastide, 2020; Ceccarelli et al., 2021)

Increase of Temperature
Changes in Rainfall
Strong winds (hurricanes)

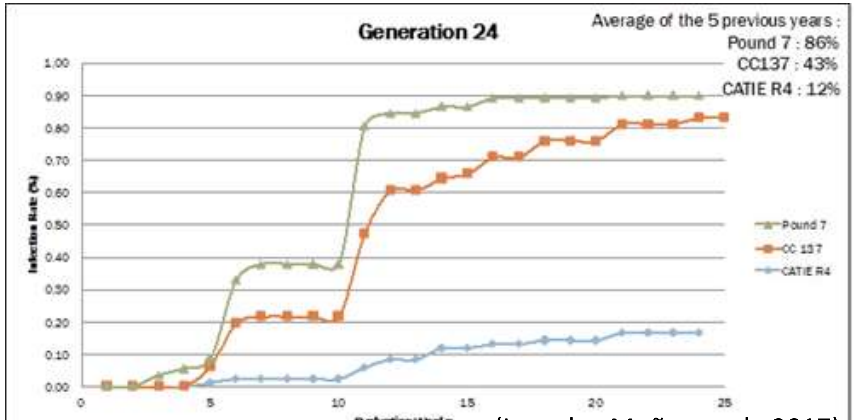
→ Shorter P&D life cycles
Shorter latency periods
Rise of secondary P&D

→ Implications for prevention and control measures

→ Probability of dispersion of pathogens to new areas

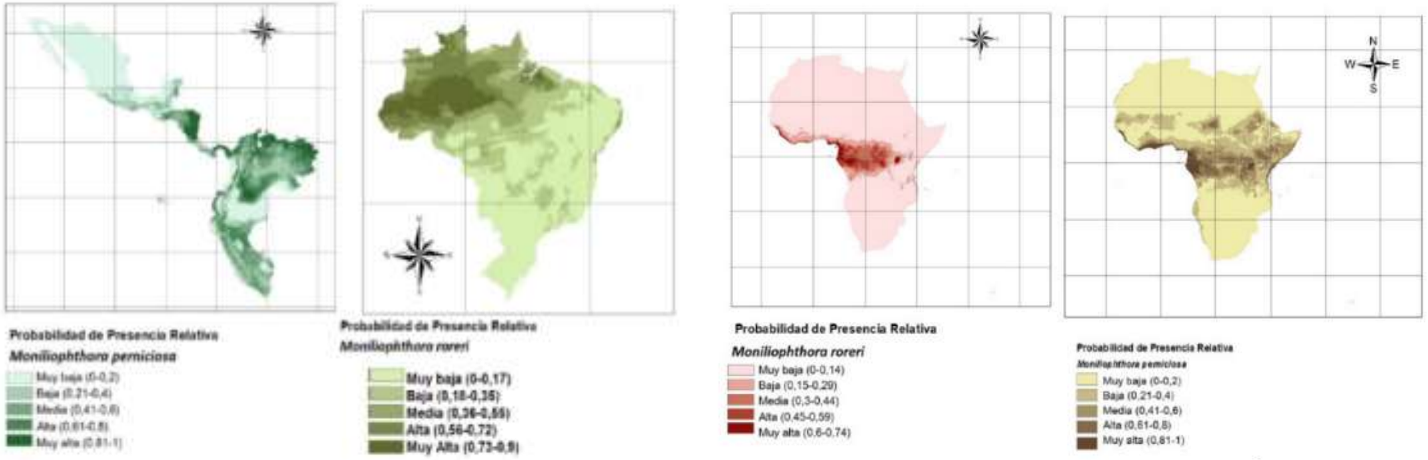
Climatic factors can reduce the tolerance of improved clones

(Codjoe et al., 2013; Leandro-Muñoz et al., 2017).



(Leandro-Muñoz et al., 2017)

Probability of presence of new diseases such as *Moniliasis*



(*Másmela-Mendoza*., 2019)

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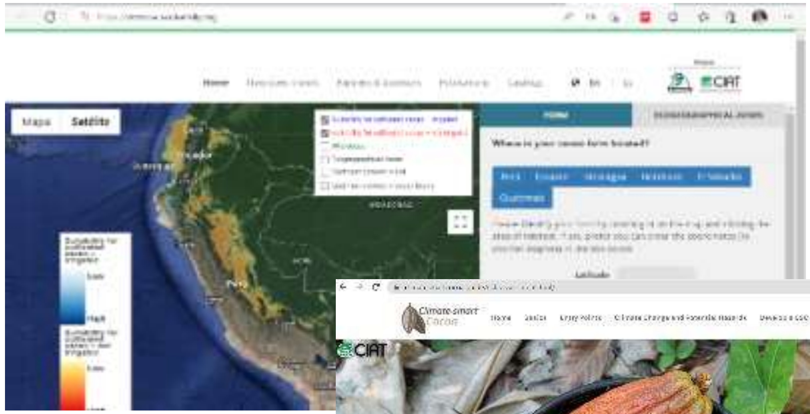
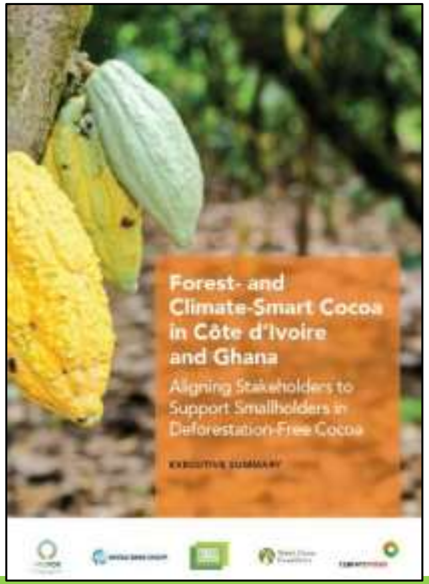
STRATEGIES/PRACTICES FOR ADAPTATION AND MITIGATION

- The sets of recommendations are based
  - Land suitability maps
  - Online platforms to visualize future climate scenarios
  - Climate risk assessment apps
  - Scientific papers, technical manuals

- Here we address the main best common practices suggested:

- Breeding for new varieties
- Irrigation; Fertilization; Pruning
- Agroforestry (including rehabilitation/renovation)





COCOA DIVERSITY AND BREEDING

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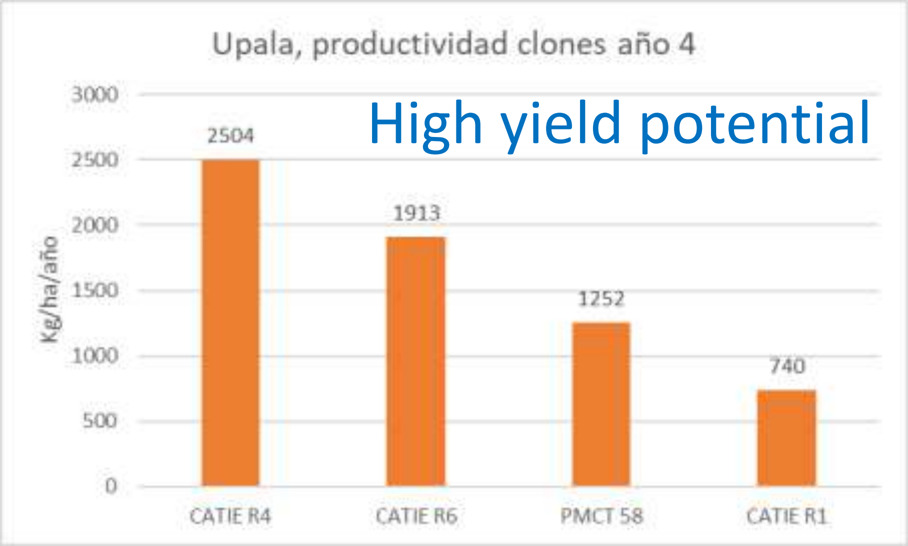

A traditional non-technified cocoa tree begins to produce barely in the 4th year. The national yield average is 271 kg/ha/year (In Costa Rica)

Project "Enhancement of cacao production through the use of improved germplasm and selected climate smart agricultural practices"

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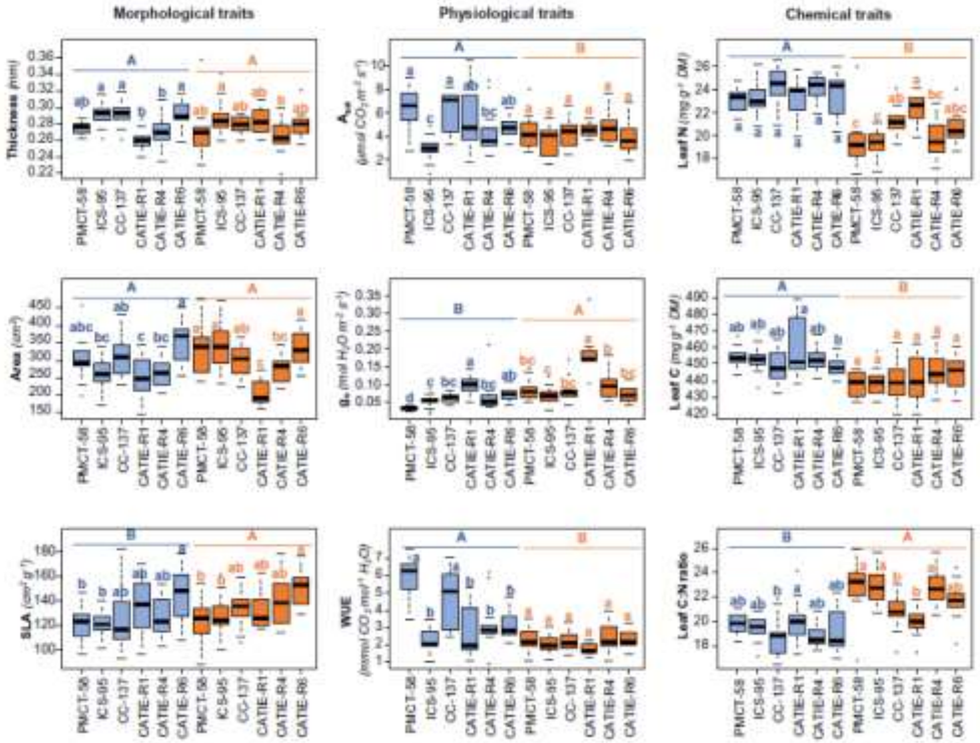
What is needed?

- **More new cocoa improved varieties**
  - In the past 20 years, only <100 cocoa varieties released (Farrel et al., 2018)
- Aim for productivity, resistance to pests, quality and add indicators to face climate change
- New indicators (traits):
  - Concentration of N, P, K, Ca and Mg in leaves
  - Total leaf area per plant
  - Stem dry weight
  - Leaf dry weight
  - Relative growth rate
  - Root dry weight
  - Root length
  - Root volume
  - Root diameter

  (Dos Santos et al., 2014, 2016; Lahive et al., 2019)

Different Traits in contrasting environments…assess Plasticity



(Sauvadet et al., 2021)

Studies on Genotype x Environment in Agroforestry Systems

(Daymond and Hadley, 2004, 2008; Lahive et al., 2019; Sauvadet et al., 2021)

What we need in the field?

- The bottleneck for farmers is to access the improved plant
    - Cost of plants in C.America: 2-5 USD/plant
    - Cocoa densities 800 – 2000 plants/ha
    - Represents >50% of the establishment/renovation
    - Limited access to vegetative materials
- Participatory selection of elite trees (FEDECACAO-Colombia/INIFAP-Mexico)

We need more:

Clonal gardens in the communities

Rural nurseries

Train young grafters

IRRIGATION

- In Ecuador: drip irrigation = 44qq/ha; micro-sprinkler irrigation = 37qq/ha CCN-51 (Romero and Proaño, 2018)
- In Brazil (semi arid): irrigation = early production at 1.5 years, >1700 kg/ha at the fourth year (Leite et al., 2012)
- In West Africa, irrigation + mulch = good early establishment and early cocoa yields (Acheampong et al. 2019)
- In Phillipines, irrigation + intercrops + shade = successful establishment (Valleser, et al. 2022)

	Irrigation + soft pruning	Irrigation + strong pruning	Irrigation + soft pruning	Irrigation + strong pruning
Cocoa Yield (kg/ha/year)	1052	626	576	410
Income (USD/ha/year)	2465	1467	1350	961

Cost of the irrigation system ≈ 1400 USD/ha
Recovery of the investment in the medium term

(Modified from Meneses-Buitrago et al., 2019)

What is needed?

- The search for drought tolerant trees in the very plantations of farmers in drier condition
- Nursery screening of drought tolerant cultivars
- Chamber experiments testing several provenances
- It is happening in Peru/Australia/Brasil

(Zavaleta et al., 2022)

What we need in the field?

- The bottleneck is the cost of installation
- Invest in water harvesting infrastructure
- In Colombia: proposal with gravity irrigation to reduce costs and energy use

Project "Enhancement of cacao production through the use of improved germplasm and selected climate smart agricultural practices"

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FERTILIZATION (chemical and organic, in agroforestry)

- In Ivory Coast: chemical fertilization = > 900 kg/ha the best treatments (Kotaix Acka Jacques Alain et al., 2021)
- In Colombia: lime + chemical fertilizers → 1000 to 4000 kg/ha depending on the clon (Rosas-Patiño et al., 2019)

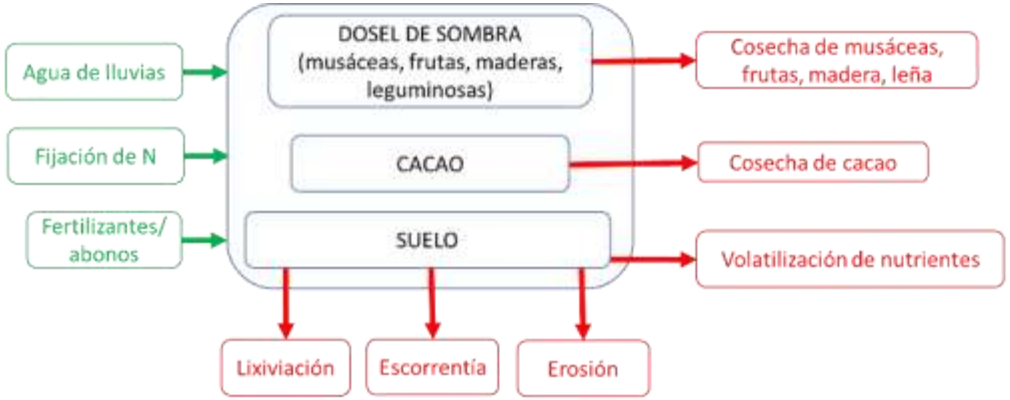
AGROECOLOGY APPROACHES

- In Colombia with CCN-51 and 30% shade cover, the yields:
  - Chemical = 1613 kg/ha
  - Organic = 1664 kg/ha
  - Mix = 2050 kg/ha
  - Control = 744 kg/ha 4
  - With a marginal net return 1:5

  (Ballesteros et al., 2022)

- The legume trees can contribute to N fixation (Nygren and Leblanc, 2015; Kaba et al., 2018, 2019; Bai et al., 2017)

What we need in the field?



Balance de nutrientes = Entradas – Salidas

Organic sources of nutrients

Ideal to combine mineral sources + organic sources + legume trees → reduce external inputs

Important: architecture of cocoa trees

It is also a key practice to prevent P&D

Benefits of pruning + fertilization

Variables	Groups of cocoa systems classified according to the level of yields				p-value
	C1	**C2**	**C3**	**C4**	
Cocoa yield (kg/ha/year)	270 d	830 c	1428 b	1770 a	<0,0001
Doses of fertilizers (g/tree/year)	0 c	0 c	206 b	400 a	<0.0001
Number of pruning/year	1 b	3 a*	3 a*	4 a*	0.0004
Net income (USD/ha/year)	-40b	1200b	2698a	374b	0.004

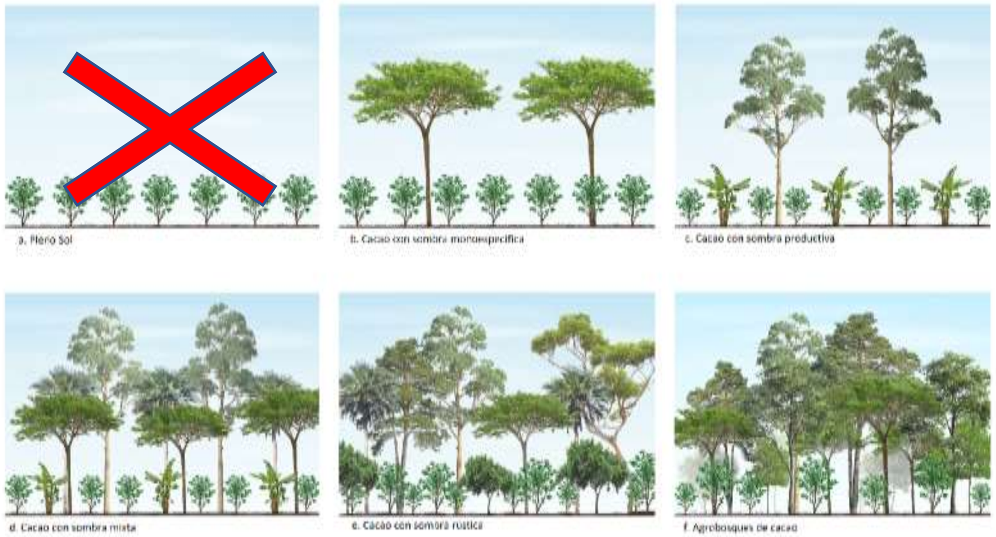
* One is a maintenance pruning, and the others are soft pruning

(Tarqui et al., 2020)

COCOA AGROFORESTRY (CAF)

Is widely recommended to cope with climate change (Sanial et al 2020)

Types of cocoa agroforestry



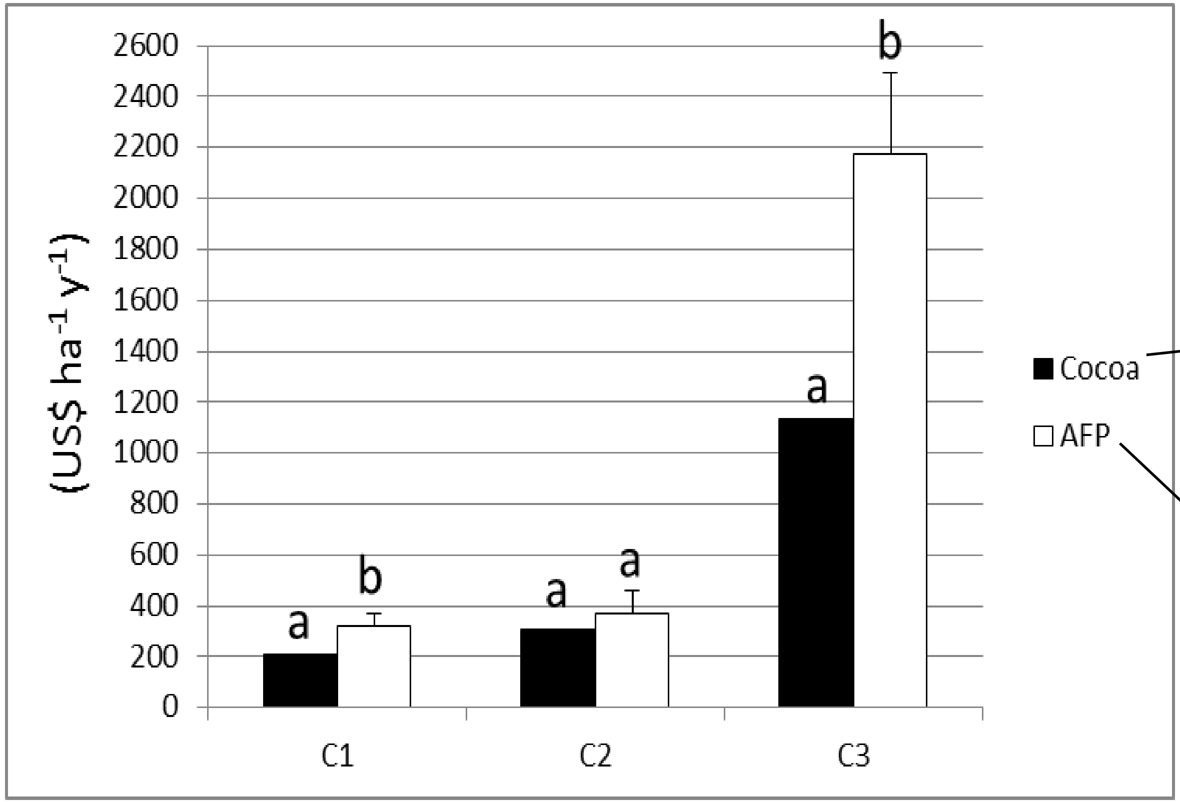
Main strategies for mitigation and adaptation

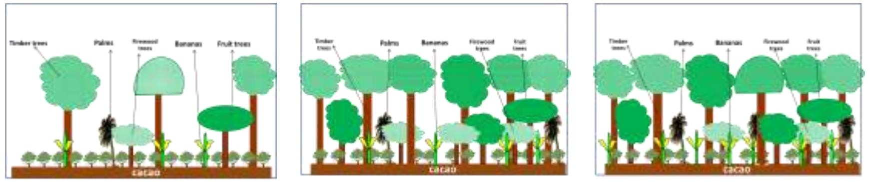
Mitigation: Store more carbon	Mitigation: Emit less carbon	Adaptation Strategies
●Select tree species with appropriate morphological and functional traits e.g. tall trees, small-leaved species and open crowns, inverse phenology, high wood density, etc. ●Increase litter and soil carbon ●Use cocoa agroforestry systems as replacement for degraded pastures and crop lands (Americas)	●Avoid deforestation (Africa) ●Optimize use fertilizers (Asia and Africa) ●Use leguminous, N-fixing trees as shade (in all cocoa producing regions)	●Increase production of high-quality fruits and timber to reduce financial vulnerability and increase incomes ●Select shade tree species with proper canopy characteristics to reduce heat stress, minimize competition for water ●Build-up a thick litter layer and increase soil organic matter to improve the retention and use of water and nutrients

Agroforestry for ecosystem services

Cash flow = Incomes – cash costs

Family Benefit = Cash Flow + value of domestic consumption



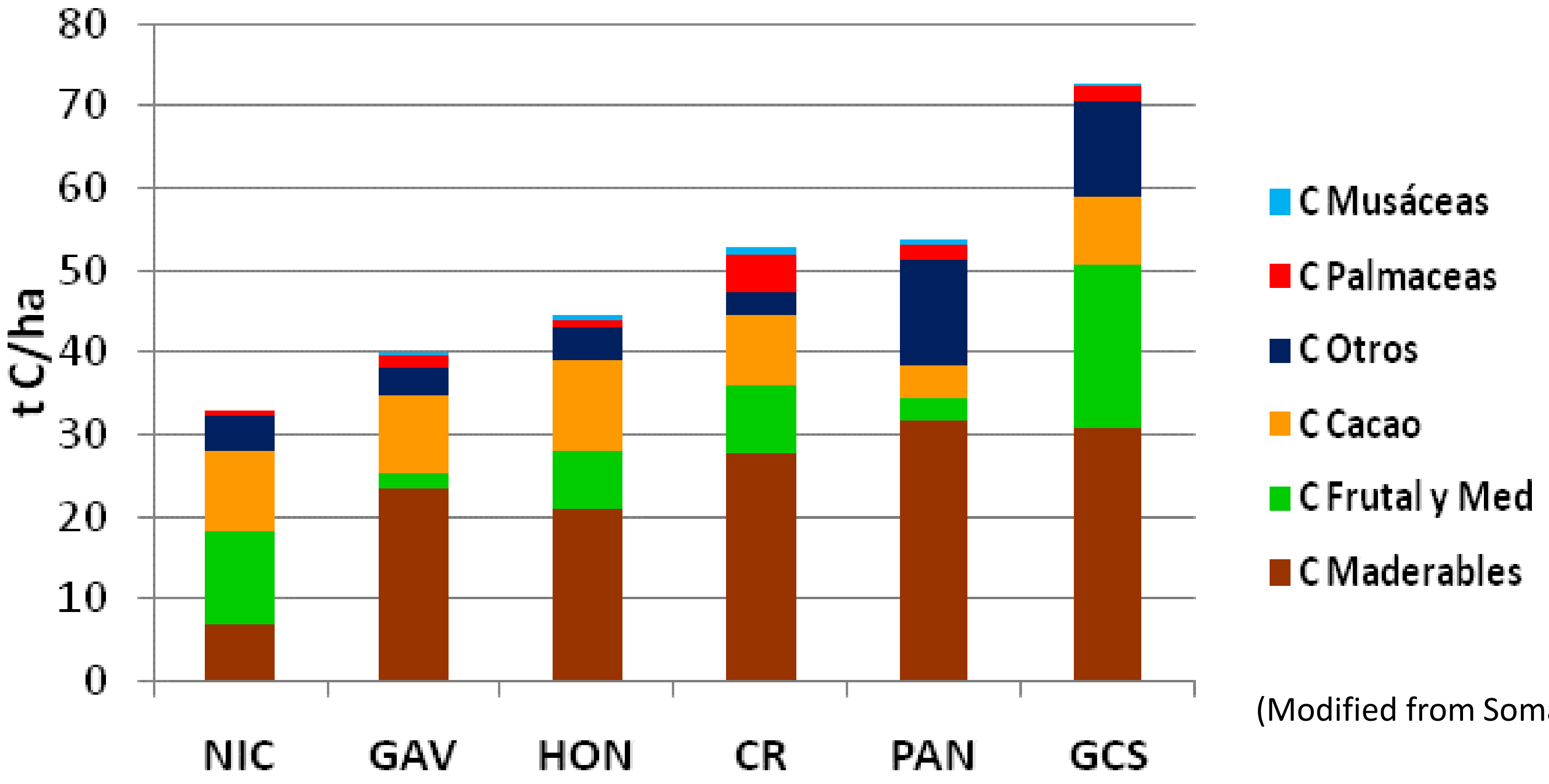


- Diversification and their benefits for the families

AFP: Agroforestry products

(Cerda et al., 2014)

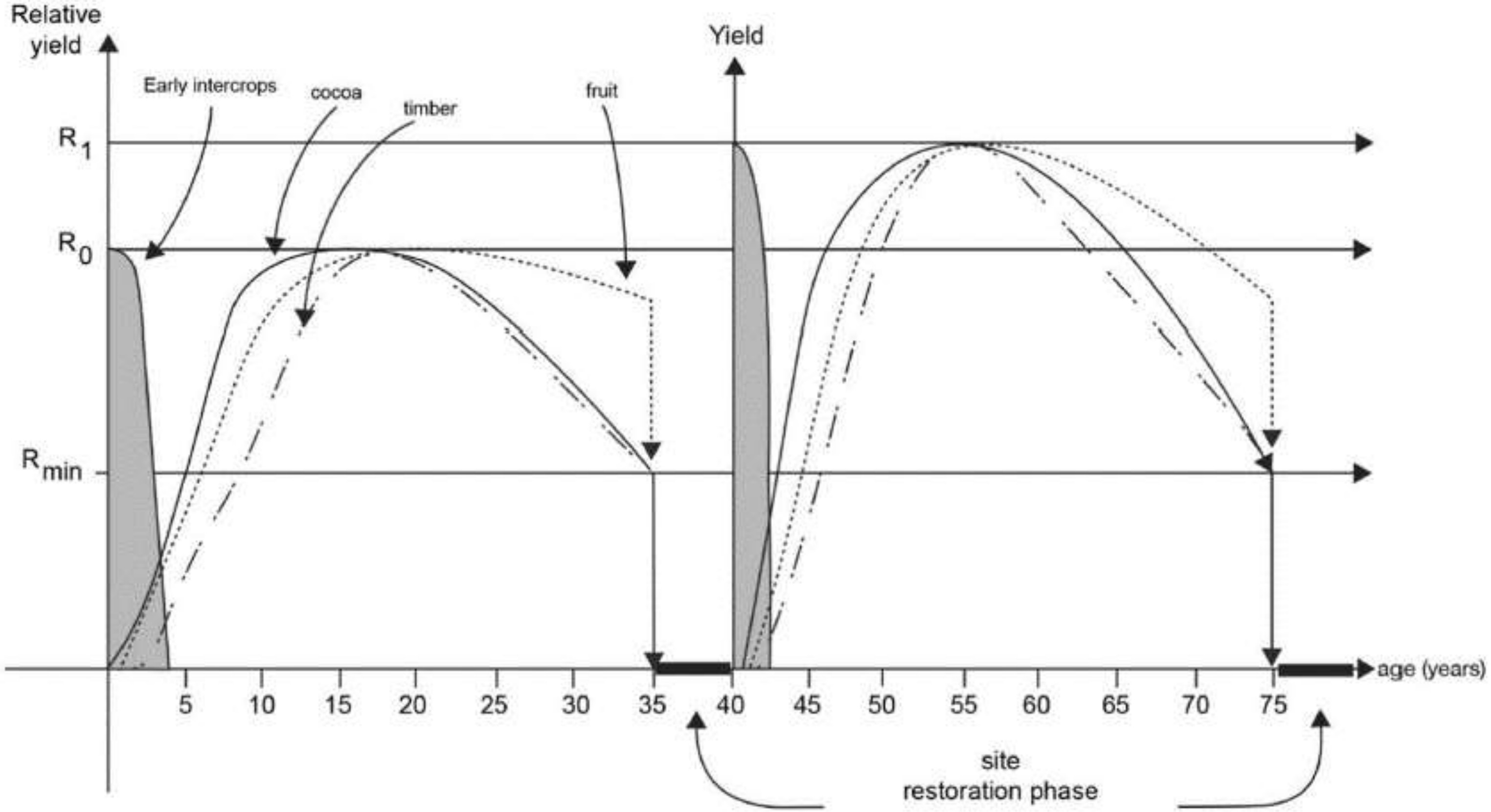
Above ground carbon stocks



(Modified from Somarriba et al. 2013)

Several other studies in America and Africa support the potential of agroforestry systems to store carbon and thus contribute to mitigation
(Duguma et al., 2001; Aristizábal et al., 2002; Concha et al., 2007; Cotta et al., 2008; Gama-Rodrigues et al., 2011; Gockowski and Sonwa, 2011; Wade et al., 2010)

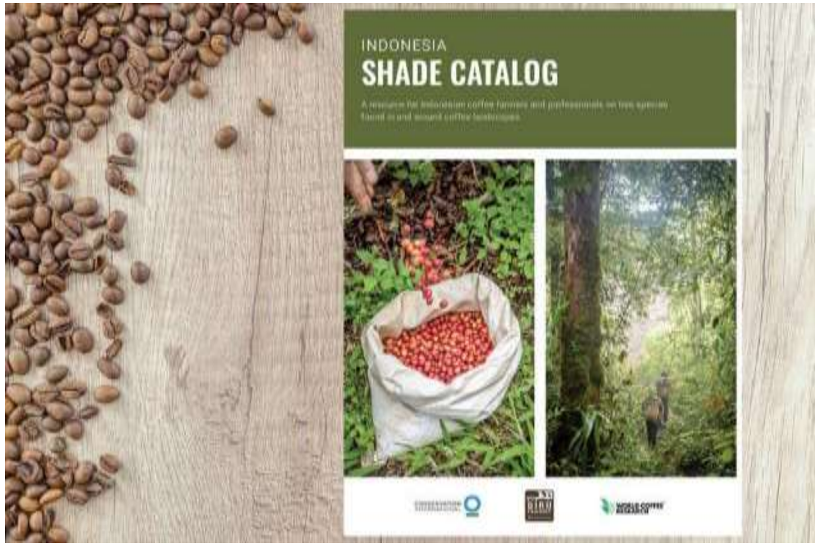
The Rehabilitation/Renovation Agroforestry (RRAF) approach



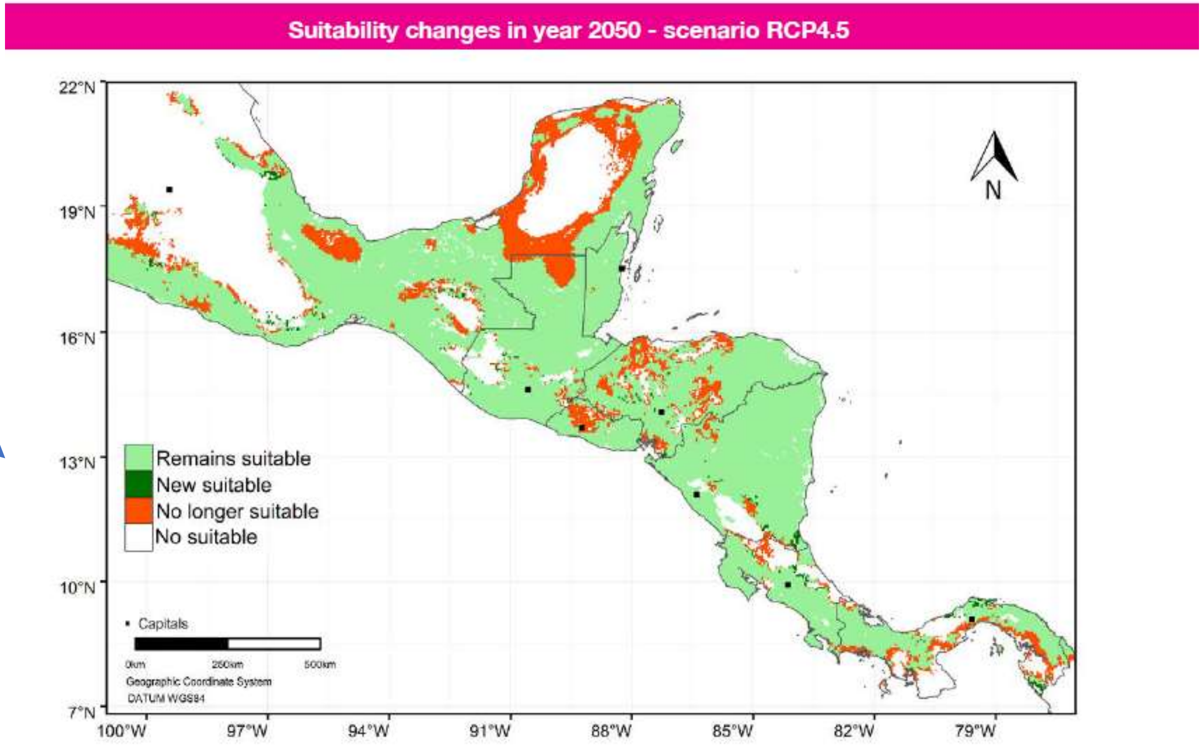
(Somarriba et al., 2021)

(Cerda et al., 2021)

Selection of adequate trees



Example: suitability for *Cordia alliodora*

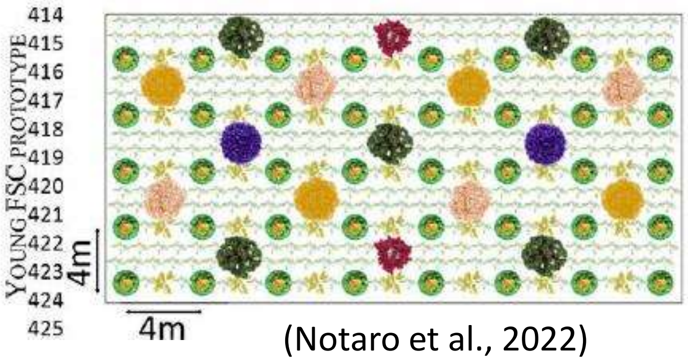


Zone	Current distribution per zone (km²)	Remains suitable	Potential new habitat	No longer suitable	Net change
Dry forest	68,071	79%	1%	21%	-20%
Rain forest	113,866	85%	1%	15%	-14%
Whole region	181,937	83%	1%	17%	-16%

(Sousa et al., 2017)

What is needed?

- Develop and put in place laws and policies promoting tree planting and use by farmers
- Support/develop value chains for timber and fruits produced in cocoa farms
- Educate extension agents and farmers on the use of agroforestry in cocoa cultivation
- Fund research on the optimization of synergies and trade-offs between shade trees and cocoa yields (Ecosystem services)
- Participatory design and evaluation of modern agroforestry systems according to the projections of climate change impacts (long term)



(Notaro et al., 2022)

Life cycle assessment (LCA) is important for mitigation

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- Based on this assessment we can know in which stages of the production chain are the main contaminations/emissions → measures to reduce impacts/footprints

ELSEVIER
Science of The Total Environment
Volume 849, 25 November 2022, 157795

Assessment of the environmental impact and economic performance of cacao agroforestry systems in the Ecuadorian Amazon region: An LCA approach

ELSEVIER
Journal of Cleaner Production
Volume 16, Issue 16, November 2008, Pages 1735-1740

Environmental impacts of cocoa production and processing in Ghana: life cycle assessment approach

Agroforest Syst (2022) 96:417–434
https://doi.org/10.1007/s10457-022-00729-8

Modelling greenhouse gas emissions of cacao production in the Republic of Côte d'Ivoire

W. Vervuurt · M. A. Slingerland · A. A. Pronk · L. G. J. Van Bussel

BRAZILIAN JOURNAL OF FOOD TECHNOLOGY
ISSN 1981-6723
Online version
ORIGINAL ARTICLE

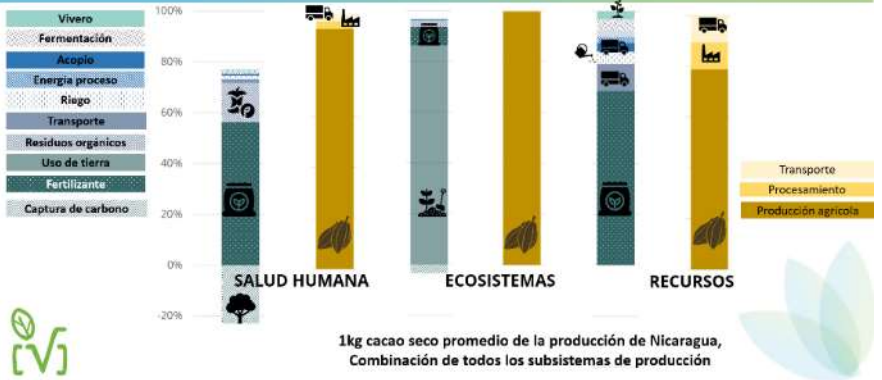
Carbon footprint of Brazilian cocoa produced in Pará state

Pegada de carbono do cacau brasileiro produzido no estado do Pará

ELSEVIER
Science of The Total Environment
Volumes 613–614, 1 February 2018, Pages 1013-1023

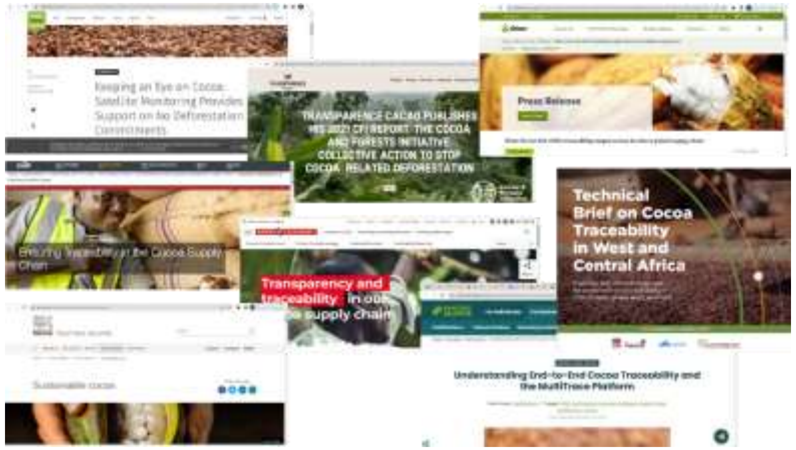
From beans to bar: A life cycle assessment towards sustainable chocolate supply chain

Resultados del análisis de contribución a los impactos ambientales-NIC-CIRAD-2022



INCENTIVES, PES AND REDD+ TO PROMOTE CAF

- Involvement of CAF in REDD+ and PES is a reality; however, only feasible in some countries with enabling conditions
- Investments in large-scale certification and tree distribution campaigns by industry players (Cocoa Forest Initiative)
- Commitments not fully monitored or implemented (Higonnet et. al.,2020)
- Little synergy between companies and landscapes users, resulting in low transformation and improvement of agroforestry (Sanial et. al., 2020)
- Farmers attitudes towards trees are often overlooked, low adoption (Somarriba and Lopez-Sampson, 2018)
- Forestry legal framework might limit the massification of Agroforestry benefits (Somarriba and Lopez-Sampson, 2018)



Lessons from PES in similar crops

- Transaction costs are high and time-consuming for local organizations.
- Lack of strong and reliable traceability systems across cacao cultivation landscapes.
- PES are often promoted by development projects and not factored into national/sectorial strategies; hence funds and sustainability are compromised.
- Involvement of non-cacao-related actors/industry are often neglected

https://www.solidaridadsouthamerica.org/news/22-familias-de-peque%C3%B1os-caficultores-reciben-incentivos-por-cuidar-el-medio-ambiente/

- Study cases of PES in cacao of ICCO (America, Africa, Asia)

https://www.icco.org/feasibility-of-payments-for-environmental-services-in-cocoa-farming/

Coffee farmers Colombia

DISSEMINATION OF PRACTICES AND RESEARCH OUTCOMES

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What training methods (farmers):

- Pilot plots/on field evidence
- Farmers fields schools
- Technicians and facilitators
- Cacao Doctors (Indonesia)
- Back to basics-on farm research (Alto Beni Bolivia-FiBL)
- Record keeping (12Tree)
- CacaoMobile (LWR-MOCCA)
- Journey of Knowledge (SICACAO)
- Radio Series (CATIE, FEDECACAO)

What dissemination ways (youth, technicians, students):

- Infographics + Vocabulary (LWR-MOCCA)
- Did you know series (LWR-MOCCA)
- Cacao homework-Google form (APPCACAO-Peru)
- Apps/Videos/WhatsApp groups (CEPLAC-Brasil)
- Young assistant teams: Juntas de Trabajo (NIC).
- Nursery enterprises led by women (MOCCA/Nestle)
- Cacao Diploma/Internships (CATIE)
- ShadeMotion for better technical assistance (CATIE)
- Policy brief for cacao boards (SICACAO)

Innovation in the way to train farmers

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Participatory sessions with farmers for better agroforestry design and re-design

Proyecto Chocolate4All Proyecto Heifer Internacional | BID LAB | HEIFER INTERNATIONAL HONDURAS | CATIE Solutions for environment and development Soluciones para el ambiente y desarrollo

Based on research results and successful experiences, we need to elaborate teaching materials for farmers

Digital animations, specially for youth

Video Fertilization
Español CATIE - Fertilizar un Cacaotal v8.mp4
Inglés CATIE Fertilizar un Cacaotal sub.mp4
Video Pruning
Español Video poda cacao VF.mp4
Inglés CATIE Poda del Cacao sub.mp4
Video IPM
Español Video MIP cacao VF.mp4
Inglés CATIE MIP sub.mp4

APPS

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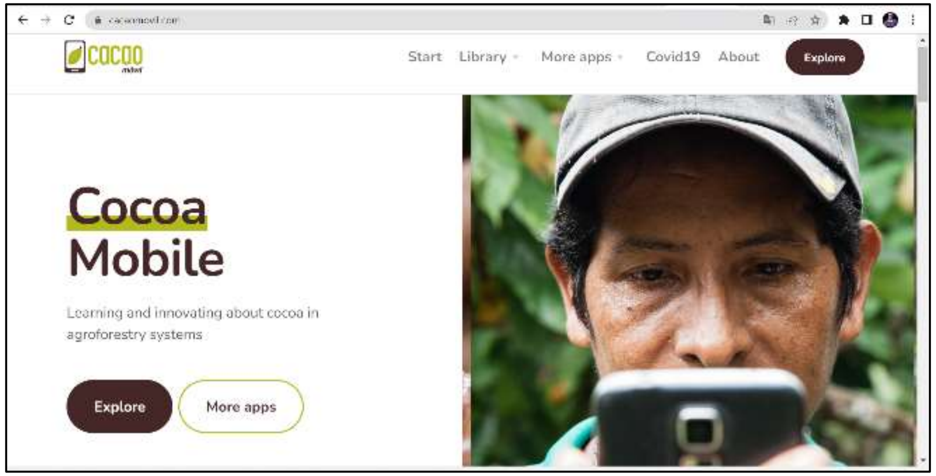
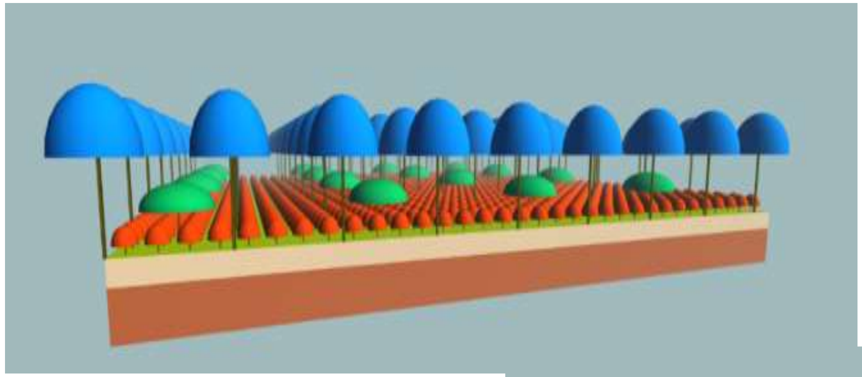
CocoaWise™

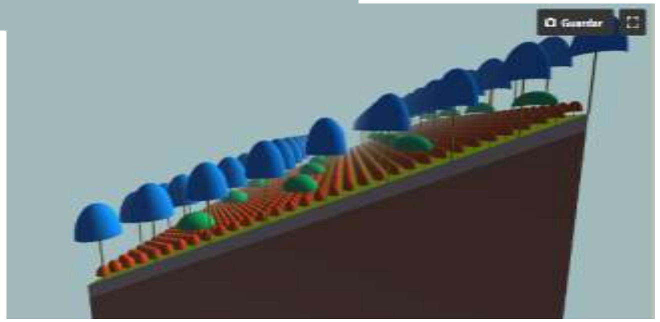
FarmGrow- Rain Forest Alliance

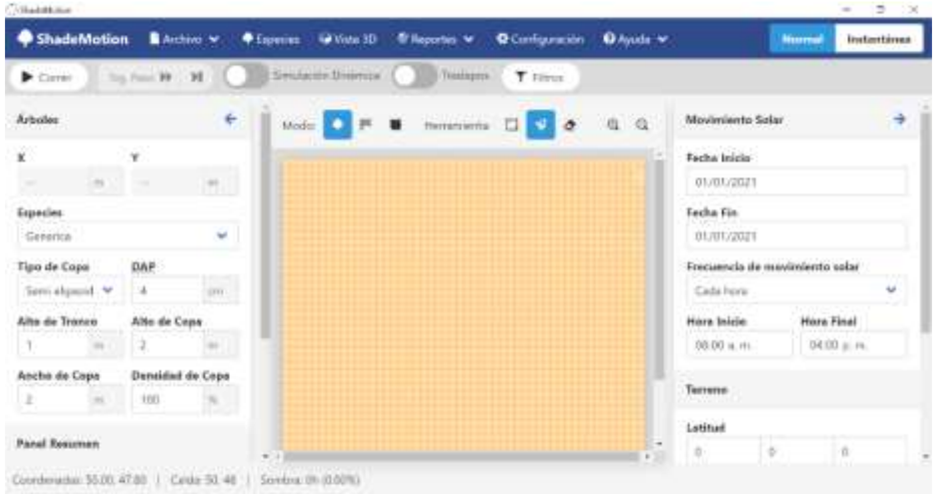
CIC-AGRO



www.shademotion.net







Paso	Intervalo	Especies	% Cobertura	Árboles/ha	Area Basal (m2/ha)
1	1	Total	55.64	130	7.15
1	1	Laurel	28.27	20	2.14
1	1	Naranja	19.91	22	0.69
1	1	Banano	7.46	88	4.32

RECOMMENDATIONS FOR THE WAY FORWARD

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- During the last five years → significant advances in land suitability and climate change Maps and Apps for decision making. Now, we need more attention and investment in:
  - Breeding and evaluation of climate-tolerant clones/varieties to face climate change (new indicators)
  - Fertilization and irrigation regimes to improve yields depending on the varieties
  - Improved protocols for integrated management of P&D
  - Long term essays on types of agroforestry systems → physiology of clones/varieties, yields, quality, soil, water, P&D
  - Develop more surveillance systems, early warning systems

- Knowledge sharing among research/experimental centers across regions is critical to better test new clones/varieties and adaptation/mitigation measures
- Research outputs need to be widely disseminated, take advantage of digital means (APPS) combined with on-farm interventions
- Support markets and value chains not only for cocoa, but for fruits and timber from CAF
- Take into account the enabling environment to achieve sustainable cacao farming and trading:
  Good Governance Policies + Good Purchasing Practices + Good Agricultural Practices (The Voice 2022)

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THANK YOU

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